ENGLISH HERITAGE

THE ARCHAEOLOGICAL POTENTIAL OF SECONDARY CONTEXTS

DR ROBERT HOSFIELD & JENNI CHAMBERS

FEBRUARY 2004

School of Humanities (Archaeology)

University of Southampton

The Archaeological Potential of Secondary Contexts

DR ROBERT HOSFIELD & JENNI CHAMBERS

The Archaeological Potential of Secondary Contexts project was undertaken in the School of Humanities (Archaeology), University of Southampton, between October 2002 and February 2004. The research project was funded by English Heritage (project no. 3661), through the Aggregates Levy Sustainability Fund, whose support is gratefully acknowledged.

Much of the work reported here was made possible by John Allen (Royal Albert Memorial Museum & Art Gallery, Exeter) and Dr Chris Green who permitted and provided easy access to, respectively, the museum's Broom artefact collection and the C.E. Bean artefact collection. Thanks to Mr & Mrs Lunt and Mr & Mrs Jennings for generously permitting access to the Broom pits between 2000 and 2003. Thanks also to Dr Phil Toms and Dr Rob Scaife for boldly sampling at Broom in all weathers and surviving treacherous conditions underfoot.

For access to various artefact collections in Hampshire, thanks to Kay Ainsworth (Hampshire Museums Service, Winchester), Robin Iles (Hyde Street Museum, Winchester), and Duncan Brown (God's House Tower Museum, Southampton). Thanks also to Dr Paul Tosswell for access to the Department of Civil Engineering's flume facilities at the University of Southampton.

We would particular like to thank our project officer Helen Keeley for all her support and assistance throughout the duration of the project. Thanks also to Professor Clive Gamble, Dr John McNabb, Dr Justin Dix, and Dr Francis Wenban-Smith for critical comments and general support throughout, to Dr David Bridgland and Dr Andy Howard for critical feedback on early drafts of Chapter 2, Dr Chris Green for our many discussions concerning Broom, Dr Danielle Schreve for her thoughts on bone transport (Chapter 6), and to Phil Harding, Terry Hardaker and Dr Keith Wilkinson for their thoughts on archaeological watching brief practices — naturally all of the final ideas expressed here represent our own views on all of these issues. Thanks also to all those who attended the many seminars and meetings held over the last two years and provided feedback to presentations and engaged in lengthy discussions in bars and pubs afterwards. And finally, thanks to Jenni for much good humour and patience during the many, long report writing sessions…

Dr Robert Hosfield & Jenni Chambers
School of Humanities (Archaeology)
University of Southampton
Avenue Campus
Highfield
Southampton
SO17 1BJ
E-mail: rth1@soton.ac.uk & j.c.chambers@soton.ac.uk
Telephone: +44 (0)23 8059 6864
Fax: +44 (0)23 8059 3032

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

This report is presented in two volumes. Volume I includes the executive summary and chapters 1–5 Volume II includes chapters 6–10 and the references. The table of contents, list of figures, and list of tables are included at the front of both volumes for ease of use.

Accompanying this report is a CD (2ndaryContexts). Included on the CD are:

- Microsoft Access 2002 (SP-2) database file 'Bean Collection Database_EHCopy.mdb'.
- Text file 'Readme.txt', to accompany the database file.
- Database image files (in the CD folder D:\Broom\Bean).
- Adobe Acrobat PDF files for each of the report chapters. The digital images from Chapter 3 (Figures 38–50, 89, 93–94 & Figure 116), Chapter 4 (Figures 144–145), and Chapter 5 (Figures 172, 174–185, 188–192, 195–199, 206–214 & 219–221) can be viewed in colour on the relevant PDF files.

EXECUTIVE SUMMARY

This report is concerned with Palaeolithic stone tool assemblages recovered from the flood deposits of Middle and Late Pleistocene (787–11,000 years BP) rivers in the UK. These are described here as *archaeological secondary contexts*. The stone tool assemblages are distributed across southern Britain, while Pleistocene flood deposits (referred to throughout as fluvial deposits) are distributed through the UK. The stone tool assemblages and their associated fluvial deposits vary in age from *at least* 500,000 years old (due to limitations in current geochronological understanding) to the end of the Palaeolithic period (*c.* 11,000 years BP). The importance of archaeological secondary contexts therefore stems from their widespread geographical distribution and extensive chronological coverage.

This report assesses the value of the archaeological secondary context resource in terms of the unique spatio-temporal structure of the data, assemblage taphonomy, appropriate analytical frameworks and the potential of the resource for current and future understanding of the Palaeolithic period.

The report is organised into ten chapters, discussing a series of key themes and case studies:

- Chapter 1: introduction to archaeological secondary contexts; a summary of current understanding; an overview of British Palaeolithic studies.
- Chapter 2: models of fluvial behaviour over the glacial/interglacial cycles of the Middle and Late Pleistocene; the duration of individual phases of fluvial activity (the erosion of floodplain sediments and the deposition of new materials). *The models indicate that fluvial activity phases were episodic and short-lived. Understanding the chronology of the Pleistocene fluvial sediments is critical as they are the context for the Palaeolithic stone tool assemblages.*
- Chapter 3: case study of fluvial sedimentation and erosion activity as represented by the sedimentary sequence at the Lower Palaeolithic locality of Broom, UK; the application of optically stimulated luminescence (OSL) dating to the Broom sediments. *The case study demonstrates the resolution on current OSL dating of Pleistocene fluvial sediments and provides support for the models presented in Chapter 2.*
- Chapter 4: case study of a stone tool assemblage from the Lower Palaeolithic locality of Broom, UK; models of the spatial derivation of stone tools in fluvial systems; models of technological patterning in stone tool production over time and space. *The case study develops important new methodologies and demonstrates that valuable behavioural data can be extracted from secondary context assemblages.*
- Chapter 5: models of the spatial derivation and modification of stone tools in fluvial systems; models of secondary context assemblage formation. *The models emphasise the complexity of artefact behaviour in fluvial environments and reinforce the value of the individual artefact-based models of spatial derivation developed and discussed in Chapter 4.*
- Chapter 6: models of the spatio-temporal data scales and resolutions associated with different categories of palaeoenvironmental evidence; mapping of palaeoenvironmental data against secondary context artefact assemblage data. *The models indicate that the contrasting data scales do not permit high resolution palaeoenvironmental evidence and derived artefact data to be directly equated. Reconstructed palaeoenvironments are therefore examples of some of the types of habitats that existed, but they cannot be explicitly populated with pre-modern human artefacts.*
- Chapter 7: models of the spatial resolution of the secondary context resource; models of the temporal resolution of the secondary context resource; presentation of new analytical frameworks for the interpretation of this resource; exploration of existing research themes using these secondary context interpretive frameworks. *The models evaluate the spatio-temporal structure of the secondary context resource and develop new methodologies. The interpretive frameworks originate from the evaluated spatio-temporal structure of the resource and demonstrate the potential applications of the data.*

- Chapter 8: reviews of current practice in the management, protection and recording of the secondary context archaeological resource; evaluation of priorities with respect to the recording of different data categories; recommendations for modifications in watching brief practice with respect to the future of the secondary context resource. *The review indicates that a wider range of data could be recovered from secondary contexts than currently results from standard watching brief practices. Recommendations are offered that highlight the shifting of data priorities and associated changes in working practice.*
- Chapter 9: case studies of regional secondary context data sets from the River Axe and River Test valleys; testing of secondary context data sets against extant research frameworks; presentation of new structures relating the secondary context resource to current research agendas. *The case studies highlight both the value and the validity of the secondary context resource, and demonstrate that these data can be used successfully to investigate current research questions and themes.*
- Chapter 10: summary of the project results; proposals for further research.

This project demonstrates that archaeological secondary contexts are a critical archaeological resource. It presents new methodologies for modelling the unique spatio-temporal scales associated with the resource. These permit the meaningful interpretation of the data contained within archaeological secondary contexts, expanding both the available analytical scales and the range of archaeological research questions that can be addressed. Proposed new frameworks provide mechanisms to integrate the primary and secondary context resources, and allow behavioural analysis to move from robust demographic signatures over 100,000 year glacial/interglacial cycles to subsistence practice over 100 years at the Boxgrove beach.

The case studies of secondary context assemblages from Broom (Devon/Dorset) and the Test valley (Hampshire) indicate both the value of the data-sets and their previously limited inclusion within archaeological dialogues. However, for their potential to be fully realised in future, there is a clear need for revised strategies with respect to data collection, research funding, and the perceived importance of the secondary context resource within the British Palaeolithic.

CHAPTER 1
INTRODUCTION

1. OVERVIEW

This research project is concerned with archaeological secondary contexts and their potential contributions to archaeological research. The importance of archaeological secondary contexts lies in their predominance within the archaeological records of specific regions and time periods (e.g. the British Lower and Middle Palaeolithic), and in their ability to offer unique analytical scales for archaeological analysis. These scales operate both in space and time, and have been the focus of extensive previous research (e.g. Bailey 1980; Stern 1993, 1994; Gamble 1996, 1999). However, relatively few explicit connections have been drawn between these scales and the available data-sets. The potential relationships between these analytical scales and the principle categories of evidence are therefore explored here, within a wider interpretative framework for the undertaking of secondary context archaeology. The archaeological record of the British Lower and Middle Palaeolithic forms the focus of the research, reflecting both the dominance of secondary context data-sets in the archaeological resource from this period, and the paucity of research directed towards them over the past two decades and more.

Archaeological secondary contexts are defined here as fluvial aggregate deposits situated on river terrace and river floodplain landforms, although it is recognised that this definition ignores other categories of deposits such as aeolian and glacial sediments. The fluvial aggregate deposits incorporate gravels, sands, silts and clays. With reference to their archaeological content, secondary contexts should be considered as artefactual materials that have been removed from their initial place of discard and subsequently re-deposited. This archaeological content is considered here to extend beyond humanly produced artefacts such as stone tools, and to also incorporate palaeoenvironmental evidence such as macro- and micro-fauna, and plant pollen.

An assessment of the archaeological potential of secondary contexts is especially timely in light of the current academic focus on models of colonisation, occupation and landscapes. These approaches have been particularly noticeable within recent research exploring the British Lower and Middle Palaeolithic (e.g. Gamble 1999; White & Schreve 2000; Ashton & Lewis 2002). Such models require testing against regional data-sets that incorporate macro-scales in time and space. The secondary context archaeological resource is the only data set that meets these criteria. However, the specific structure of the secondary context archaeological resource in time and space is currently unknown and must therefore be explicitly assessed.

2. BACKGROUND

The focus upon fluvial aggregate deposits reflects the extensive presence of these secondary contexts within the Lower and Middle Palaeolithic archaeological records of north-western Europe. With specific reference to Britain, Middle and Late Pleistocene fluvial aggregate deposits occur across the full extents of southern Britain (except in those areas where the Anglian and Devensian glaciations have destroyed the evidence of earlier river terrace aggradations (Figure 1)). These deposits have been the focus of extensive geological and geoarchaeological research (e.g. Gibbard 1985, 1994; Briggs *et al.* 1985; Ashton *et al.* 1992, 1998; Singer *et al.* 1993; Bridgland 1994, 1998, 2000, 2001, *et al.* 1995, & Allen 1996; Conway *et al.* 1996; Maddy 1997, & Bridgland 2000, *et al.* 2001; West *et al.* 1999; Thomas 2001; Schreve *et al.* 2002).

Yet despite a long recognition of the occurrence of Palaeolithic archaeology within secondary contexts (e.g. dating back to Evans (1872)), there has been very little explicit investigation of the potential of this resource. Approximately 3,000 findspots containing an absolute minimum of 90,000 artefacts (Roe 1968a) have been documented, yet they have been subjected to only limited interrogation. The absence of explicit investigations is argued to reflect the geoarchaeological context of the resource and the problems that it poses. The resource is best characterised as assemblages of artefacts and ecofacts, ranging in number from one to (in a few cases) several thousands, and occurring within fluvial sediments, most typically gravels and/or sands, but occasionally also including silts, clays and loams.

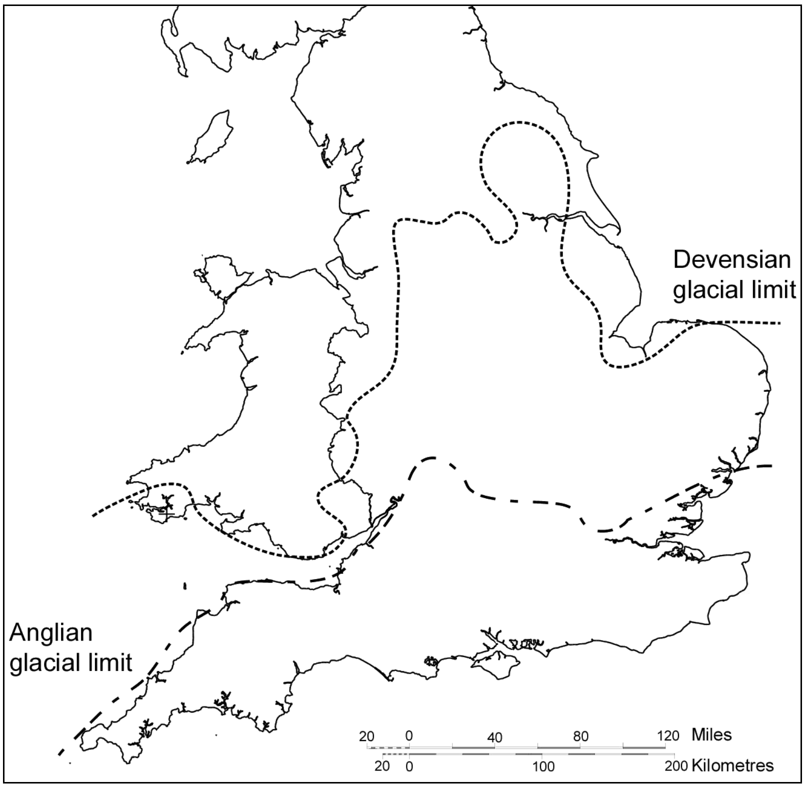

Figure 1: southerly extents of the Devensian and Anglian glaciations (after Wilkinson 2001: Figure 1)

While the early 19th century antiquarian collectors recognised that these artefacts frequently showed traces of fluvial transportation (descriptions of artefacts as 'waterworn' are common), there was no attempt to identify the source(s) of these stone tools. This was predominantly due to the goals of the day, as Palaeolithic archaeologists focused upon broad classificatory (typological) and chronological schemes. These approaches were to show a lengthy resilience in British archaeology. As late as the 1980's (Roe 1981), syntheses of river terrace, aggregate archaeology remained locked in typo-stratigraphic frameworks.

During the last twenty years however, absolute dates from key sites (e.g. High Lodge (Ashton *et al.* 1992), Boxgrove (Roberts & Parfitt 1998), Swanscombe (Conway *et al.* 1996) and Pontnewydd Cave (Green 1984) have upset those traditional frameworks. Moreover, the archaeological focus has shifted from the site-specific into the landscapes and regions of prehistory. This shift has emphasised the potential of the secondary context archaeological resource at both a national scale (providing broad spatial coverage) and over the duration of the British Palaeolithic (full temporal coverage). The significance of these macro spatio-temporal scales is further highlighted when one considers the extremely limited coverage (in time and space) provided by the handful of primary context Palaeolithic sites that have been excavated over the last 150 years (e.g. Boxgrove (Roberts & Parfitt 1998), High Lodge (Ashton *et al.* 1992), Hoxne (Singer *et al.* 1993), Caddington (Sampson 1978), Swanscombe (Conway *et al.* 1996), Barnham (Ashton *et al.* 1998), and Pontnewydd Cave (Green 1984). While these sites provide outstanding, high resolution data, they represent only a tiny fraction of this period. The regional, secondary context archaeological resource provides the lower resolution, regional backdrop that is vital for a complete understanding of the British Palaeolithic.

Yet the employment of the secondary context archaeological resource in the reconstructions of early prehistoric behaviour requires the understanding of its unique geoarchaeological context. The occurrence of Palaeolithic stone tools within secondary context fluvial deposits poses two fundamental problems:

1. What are the spatial origins of the artefacts?

2. What is the duration of the deposition of the secondary context sediments?

These two questions raise a host of sub-issues, all of which are concerned with the degree of behavioural integrity associated with the archaeological assemblages. For example, does an assemblage represent a single behavioural episode with the artefacts re-deposited during a single flood event, or 20 separate behavioural episodes? If the latter, how widely separated were those episodes in space and time? These questions must be addressed if we are to meaningfully interrogate the secondary context archaeological resource as part of our understanding of the earliest prehistoric periods. This project therefore highlights key research questions and approaches, and suggests potential interpretive frameworks for the future interrogation of the secondary context archaeological resource within British Palaeolithic research.

3. CURRENT UNDERSTANDING

There has been relatively little study of the archaeological potential of secondary context fluvial aggregate deposits in terms of:

1. The spatial origins of the stone tools.

2. The age of the archaeology.

3. The potential value of the archaeology for the reconstruction of early human behaviour.

With regard to the spatial origins of stone tools, work on artefact wear (abrasion) during fluvial transportation (Wymer 1968; Clark 1974; Shackley 1974, 1975; Isaac 1989; Schick (in Bunn *et al.* 1980; Murray 1985; Harding *et al.* 1987; Hosfield 1999; Hosfield & Chambers 2002a) has merely identified the scale of the problem and the need for considerable further desktop and field research. In the meantime, the prevalent view remains that where dense concentrations of stone tools occur within river gravels, it can be assumed that they have not travelled far from their place of discard (Wessex Archaeology 1993a: 12). This view glosses over the variable physical states that occur amongst artefacts within a single deposit (demonstrated by Hosfield 1999) and the range of potential mechanisms by which concentrations of stone tools may occur (Hosfield 1999; 2001). There is therefore a clear need to understand the processes by which artefacts are abraded, transported and re-deposited.

Attempts to assess the age of secondary context assemblages face four problems:

1. The stone tools cannot be directly dated and may be considerably older than the deposit.

2. The integrity of the assemblages is unclear (e.g. were the artefacts all re-deposited in the secondary context deposit at the same time and from the same source)?

3. Middle Pleistocene terrace deposits are outside the range of radiocarbon dating.

4. There is currently no clear consensus as to the amount of time represented by a single terrace deposit (e.g. does x metres of sands and gravels represent 40,000 years or 4 years of deposition?).

Fortunately, the dating of fluvial river terrace sequences has been considerably aided by the development of the marine oxygen isotope record. During the 1990's, new geo-chronological models have linked terrace formation with the glacial/interglacial cycles of the Pleistocene and isostatic uplift (Bridgland 1994, 1995, 1996, 1998, 2000, 2001, & Allen 1996; Maddy 1997, & Bridgland 2000; Maddy *et al.* 2001). However, these geo-chronological models operate at the level of macro-scale processes. Terrace landforms and their overlying deposits are associated with individual glacial/interglacial cycles of 70,000–100,000 years duration. Research examining fluvial systems at shorter time-scales (e.g. van Huissteden *et al.* 2001; Vandenberghe 2002; Starkel 2002) has tended to argue that brief climatic oscillations often cannot be traced in the fluvial record, reflecting both the insensitivity of the river systems to these short fluctuations and the subsequent erosion of small-scale sedimentary features. Nonetheless, the work of Gibbard (1985, 1994) and others (e.g. Maddy *et al.* 2001) has indicated that it is possible to identify and date changes in the depositional environment within a single terrace deposit.

There has been very little consideration until recently of the archaeological potential of secondary context materials beyond their role for typological stratigraphy (e.g. as at Swanscombe (Conway *et al.* 1996) and geo-chronology (e.g. White 1998a; & Jacobi 2002). Ashton & Lewis' (2002) recent investigation of late Middle Pleistocene population patterns utilised the secondary context aggregate archaeology from the River Thames, examining variation in the quantity of artefacts between individual terrace aggradations. Hosfield (1999) attempted to explore population patterns in the Solent River system from the secondary context aggregate archaeology, while also trying to discern land-use strategies through an analysis of the temporal and spatial origins of the derived artefact assemblages. While these studies have been partially successful, their scope has been limited by the absence of suitable frameworks for understanding the depositional contexts. Until such frameworks are developed, secondary context aggregate archaeology will remain an under-utilised resource.

4. AIMS AND OBJECTIVES

Current studies in the early prehistory of Britain are typically restricted to primary context, high resolution data sets. This focus upon high resolution data sets reflects the widespread perception that the secondary context archaeological resource is of extremely limited value. This report takes as its starting place the argument that this perception is the product of assumption and not explicit investigation. The project will document the geoarchaeological realities of the British resource and from this base, assess its potential for identifying and answering relevant archaeological questions above and beyond the traditional typo-chronological concerns.

The report is divided into nine further chapters, organised as follows:

- Chapter 2: reviews extant models of fluvial activity across the glacial/interglacial cycles of the Middle Pleistocene; applies Late Glacial and Holocene research to assess the duration of the temporal intervals associated with fluvial sedimentation and incision events; applies Late Glacial and Holocene models to assess the duration of the temporal intervals occurring between episodes of fluvial activity (sedimentation and incision).
- Chapter 3: presents a case study geochronological framework for the Lower Palaeolithic locality of Broom, Devon/Dorset, UK.
- Chapter 4: presents a case study analysis of the secondary context stone tool assemblage from the Lower Palaeolithic locality of Broom, with particular emphasis upon the spatio-temporal component of the data-set.
- Chapter 5: presents new models for the interpretation of spatially-derived secondary context artefact assemblages.
- Chapter 6: assesses the potential of the secondary context resource for the reconstruction of early prehistoric, fluvial palaeoenvironments.
- Chapter 7: evaluates the overall potential of the secondary context archaeological resource for the reconstruction of early human behaviour and early prehistoric landscapes.
- Chapter 8: proposes generic recommendations for the future management, protection and recording of the terrestrial aggregate resource and its archaeological content.
- Chapter 9: presents new interpretative frameworks for the modelling and interpretation of landscape archaeology in the early prehistoric period, as explored from the secondary context archaeological resource.
- Chapter 10: conclusions.

CHAPTER 2

THE TEMPORAL STRUCTURE OF SECONDARY CONTEXT, FLUVIAL SEDIMENTARY SEQUENCES

1. INTRODUCTION

This chapter is concerned with the time periods represented in river terrace sedimentary sequences. Understanding both the time periods associated with the deposition of a gravel unit, and the subsequent interval until the next phase of fluvial activity is critical to understanding and interpreting the archaeological content of these fluvial sediments. If a distribution of derived artefacts throughout the vertical stratigraphy of a secondary context gravel deposit that accumulated over 70,000 years is suggestive of low density, continuous occupation in a river valley landscape, then a restricted distribution of bifaces within a gravel deposit that accumulated over just 2,000 years at the end of a glacial/interglacial cycle may be suggestive of a high density, but short-lived occupation.

The initial goals of this component of the project (module 1 in the project design) were therefore to identify sedimentary structures that might be employed as potential temporal markers, to indicate the time-depth of fluvial sequences and the duration of the depositional and erosive events associated with those sequences. Three themes were therefore addressed:

- The preservation of sand, gravel, clay and silt sediments, and the duration of the fluvial episodes associated with their deposition.
- The proportion of glacial/interglacial cycles preserved within river terrace fluvial aggregates sequences, either as sedimentary units or incised channel features.
- The preservation and duration of depositional hiatus and/or erosive events within fluvial sedimentary sequences.

However, it rapidly became apparent that sedimentary structures could not be used as precise temporal markers, and the three themes highlighted above were subsequently addressed through an exploration of extant models of fluvial activity across the glacial/interglacial cycles of the Middle Pleistocene, and during the MIS-2/1 transition. Although much of the discussion concerns theoretical models and field data associated with Late Glacial and Holocene river systems (due to the high resolution radiocarbon chronologies associated with those systems), the overall focus is upon Middle Pleistocene fluvial deposits, preservation, and the levels of geo-chronological resolution that may be applied to those deposits. This chapter is therefore concerned with both cold-climate (e.g. Rose *et al.* 1980; Vandenberghe 1993, 2001; Collins *et al.* 1996; Lewis & Maddy 1999; van Huissteden 1990; & *et al.* 2001) and interglacial (e.g. Rose *et al.* 1980; Collins *et al.* 1996; Gibbard and Lewin 2002) river systems. Given the breadth of fluvial settings discussed, the considerable variations in fluvial evolution between upland, piedmont, lowland and estuarine river zones are explored with respect to the resulting sedimentary signatures and their potential impact upon the preservation of archaeological material (e.g. Harvey *et al.* 1981; Harvey and Renwick 1987; Meinke 1995; Howard & Macklin 1999).

While attention is paid to variabilities in floodplain types and channel forms under different climatic regimes and within different river zones (e.g. Nanson & Croke 1992; Howard & Macklin 1999), the chapter's primary focus is the temporal resolution of the preserved sedimentary sequences (whether cold or warm, upland or lowland). Fundamentally, this report is written by an archaeologist for other archaeologists, and this chapter seeks to exploit models of fluvial geomorphology to address fundamental *archaeological* problems. While the following statement may sound like heresy to the geography community, our interest does not lie in the subtle variations of river behaviour in their different reaches. The concern is how gross patterns influence the preservation and temporal resolution of the archaeological record.

Themes one (the duration of sedimentation events) and three (the duration of depositional hiatus) are therefore principally addressed with reference to high geochronological resolution studies from the last glacial phase and the Lateglacial/Holocene transition (e.g. Rose *et al.* 1980; Cleveringa *et al.* 1988; Schirmer 1988, 1995; Meinke 1995; Collins *et al.* 1996; Starkel 1988; Maddy *et al.* 2001; van Huissteden *et al.* 2001). These studies are drawn from a wide European catchment including the UK (Rose *et al.* 1980, Collins *et al.* 1996), the Netherlands (van Huissteden *et al.* 2001), Germany (Schirmer 1988, 1995; Meinke 1995), and Poland (Starkel 1988), and the implications of comparing these studies are highlighted.

By contrast, with reference to the second theme (the proportion of the glacial/interglacial cycle preserved within fluvial terrace sedimentary sequences), emphasis is placed upon macro-scale models of river development (e.g. Bridgland 1994, 1995, 1996, 2000, 2001; Vandenberghe 1995; Maddy *et al.* 2001; Gibbard & Lewin 2002). This chapter begins therefore with a brief review of the principle models for fluvial activity over glacial and interglacial stages and glacial/interglacial cycles during the Middle Pleistocene. All of these models are grounded in the marine isotope geochronology of this period (Figure 2), with eccentricity-driven 100,000 year cycles of glacial/interglacial conditions, the so-called Milankovitch cycles (Lowe & Walker 1997: 12–13).

2. MODELS OF FLUVIAL EVOLUTION

An assessment of the timescales of fluvial activity and the geochronologies of the resultant sedimentary sequences must begin with a review of the extant models of fluvial activity across the glacial/interglacial cycles of the Middle and Late Pleistocene. Current models are grounded in a long history of research (e.g. Zeuner 1958; Wymer 1968; Clayton 1977; Rose 1979; Green & McGregor 1980, 1987; Gibbard 1985; Vandenberghe 1993, 1995, 2002, 2003; Bridgland 1994, 1995, 1996, 2001; Maddy *et al.* 2001; Gibbard & Lewin 2002) and all have sought to explain the fluvial sedimentary sequences of northern Europe. These are most classically represented by *terrace landforms* (abandoned floodplains, typically lying above the current river floodplain), below whose surface lie ancient flood deposits, typically consisting of gravels, sands, silts, clays, and small quantities of other sediments (e.g. loams). In many cases, series' of altitudinally-distinct terrace landforms form terrace flights or staircases, best represented in Britain by the lower, middle and upper valleys of the river Thames (Figure 3).

The earliest models emphasised a direct link between climate and fluvial system evolution (e.g. Sörgel 1921; Büdel 1977; Bryant 1983; Gibbard 1985), with fluvial *sedimentation* (the deposition of sand and gravel sediments upon the river channel(s) and floodplain) occurring during glacial periods and river *incision* (the cutting of a new floodplain at a lower elevation) between successive *terraces* (abandoning the old terrace and leaving it lying above the new contemporary floodplain) taking place during the interglacials. However, a number of observations have since contradicted this notion of a direct link (see Vandenberghe 2003 for a complete discussion):

- The presence of interglacial sediments within cold-climate terrace sediments (e.g. Green & McGregor 1980; Bridgland 1994).
- The relatively thin deposits of river terraces in comparison to the duration of the glacial period in which they were formed.
- The absence of river incision during the Holocene (prior to anthropogenic deforestation), in favour of a state of equilibrium between erosion and deposition.
- River incision during cold periods (e.g. van Huissteden 1990, *et al.* 2001), although typically in association with climatic transitions during these cold phases (Vandenberghe 1993).
- The presence of braided (multi-channel), anastomosing (single-channel) and meandering (single-channel) rivers in both cold and warm stages, as opposed to the traditional notion of braided/cold-climate and meandering-anastomosing/warm-climate associations.

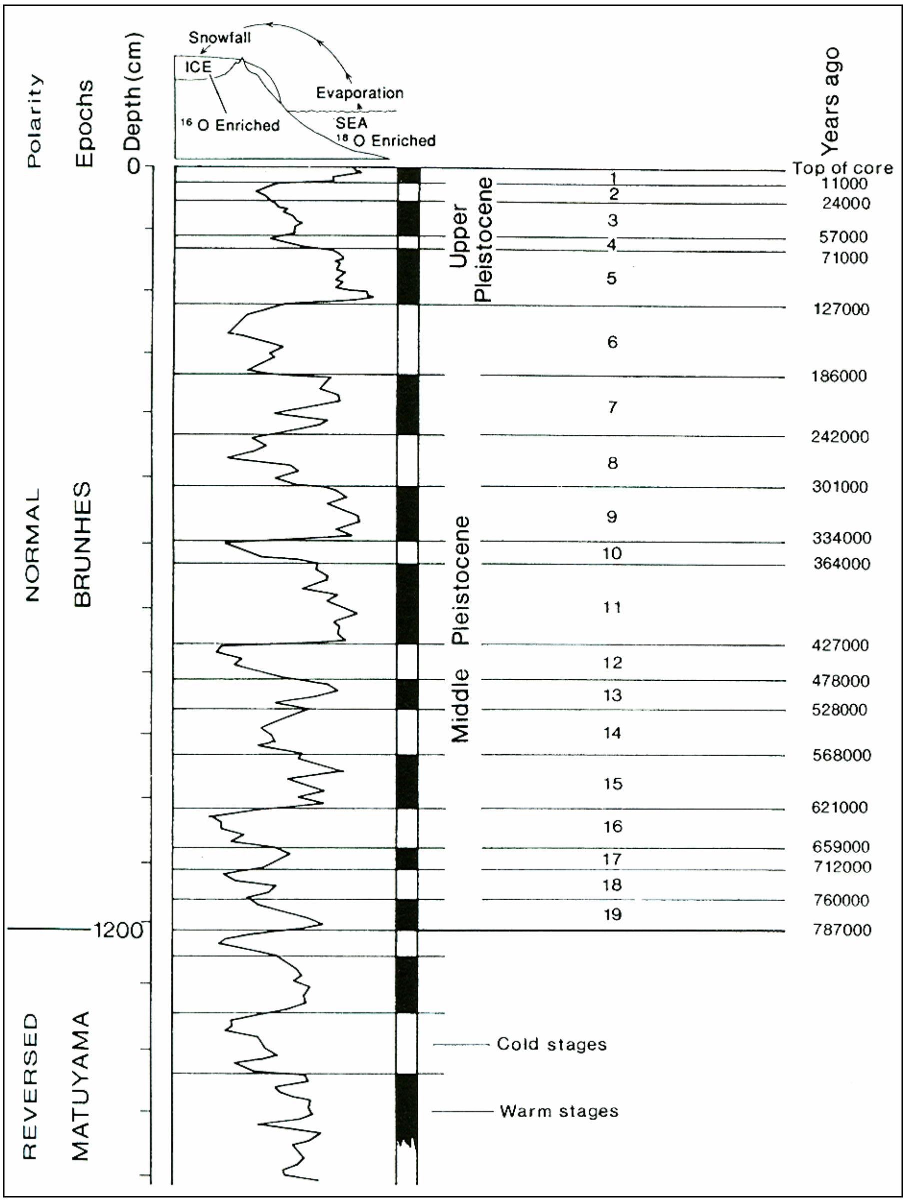

Figure 2: marine isotope record (core V28–238) of the glacial/interglacial cycles of the Middle Pleistocene (Gamble 1999: Figure 4.2)

This research adopts as a starting point the cyclical models of river terrace formation proposed and modified by Bridgland (1994, 1995, 1996, 2000, 2001), which broadly link channel incision and fine- and coarse-grained sedimentation to the glacial/interglacial climatic cycles of the Pleistocene. These models emphasise the impact of climate change upon fluvial activity, through variables such as flood frequency and magnitude, sediment supply, vegetation cover, and soil cohesion, and relate the key phases of aggradation and erosion with periods of climatic transition and instability (Figure 4). In this respect, these models draw considerable parallels with the work of Vandenberghe (1995), and at the broadest level suggest that the preserved component of fluvial sedimentary sequences may represent relatively small proportions of the glacial/interglacial cycle.

However, it is acknowledged that higher frequency climatic changes (at the sub-MIS scale) also play a key role in fluvial activity and river evolution (e.g. Vandenberghe 1995, 2002, 2003; Maddy *et al.* 2001), and to consider these processes, emphasis is therefore placed on higher resolution models of fluvial development within cold and warm-climate regimes and, most importantly, at the transitions between these climatic regimes.

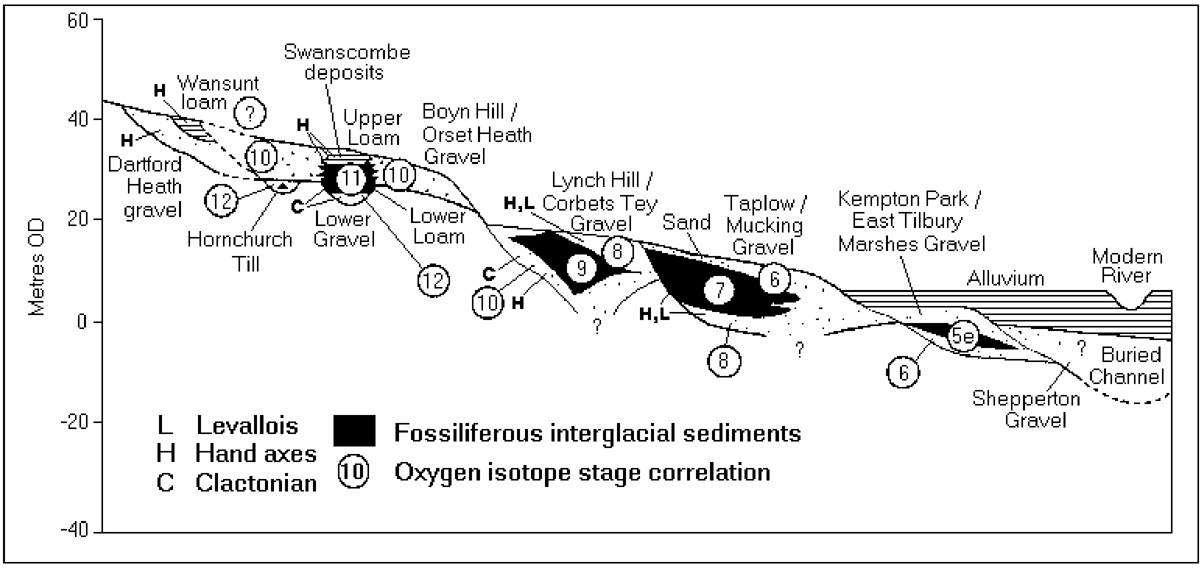

Figure 3: idealised transverse section through the terrace sequence in the Lower Thames valley (Bridgland 1996: Figure 3.4)

2.1 Fluvial activity under glacial conditions

Bridgland (1994, 1995, 1996, 2000, 2001) has argued that during full glacial conditions, river systems are broadly stable. Bridgland relates this to the rivers being adjusted to Arctic Nival type discharge regimes (annual snow-melt discharge), with these flooding events simply redistributing the existing sediments stored upon the floodplain. Maddy *et al.* (2001) expands upon this theme, highlighting the eventual shutdown of thermohaline circulation during the cold-stage and associated movements of the polar front, resulting in depressions tracking further south, the reduced frequency of high magnitude rainfall events, and a reduction in flood frequency to the nival-type presented above. Vandenberghe (1995: Figure 5 & 633) highlights similar factors, arguing for general stability under glacial conditions, with braided river system sedimentation (reflecting irregular discharge regimes and considerable sediment availability) during the earlier part of the cold phase, gradually being replaced by decreased fluvial activity, a relative erosion/aggradation balance, and increasing aeolian activity.

Notably, all of these models contrast with that of Gibbard & Lewin (2002: 194), which suggests that a 'typical' lowland British extra-glacial river actively accumulated sediment during the Devensian cold stages. It is suggested that this sediment accumulation was dominated by gravel deposition, with the rivers adopting braided or wandering modes, and sediment supplied by bank and channel floor erosion (we propose that this is equivalent to Bridgland's sediment redistribution process) and by slope processes (e.g. solifluction). Moreover, Gibbard & Lewin (2002: Table 2) suggest that this braidplain deposition of gravel and sand is characteristic of the full-late glacial stages of the climatic cycle, rather than the early-full glacial phase of the cycle, with which they associated sediment and substrate erosion, resulting in incision.

Yet while the models of Bridgland (1994, 1995, 1996, 2000, 20001), Maddy *et al.* (2001), Vandenberghe (1995) and Gibbard & Lewin (2002) vary in their specific interpretation of fluvial activity under glacial conditions, they do share a number of key observations with respect to the nature of fluvial activity during glacial phases:

- Coarse-grained (gravel and sand) sedimentation occurs within braided river systems.
- Sediment is redistributed from the existing floodplain and new material is introduced onto the floodplain from the adjacent slopes.
- Sedimentation events occur in response to annual snow-melt events.
- The system is broadly stable.

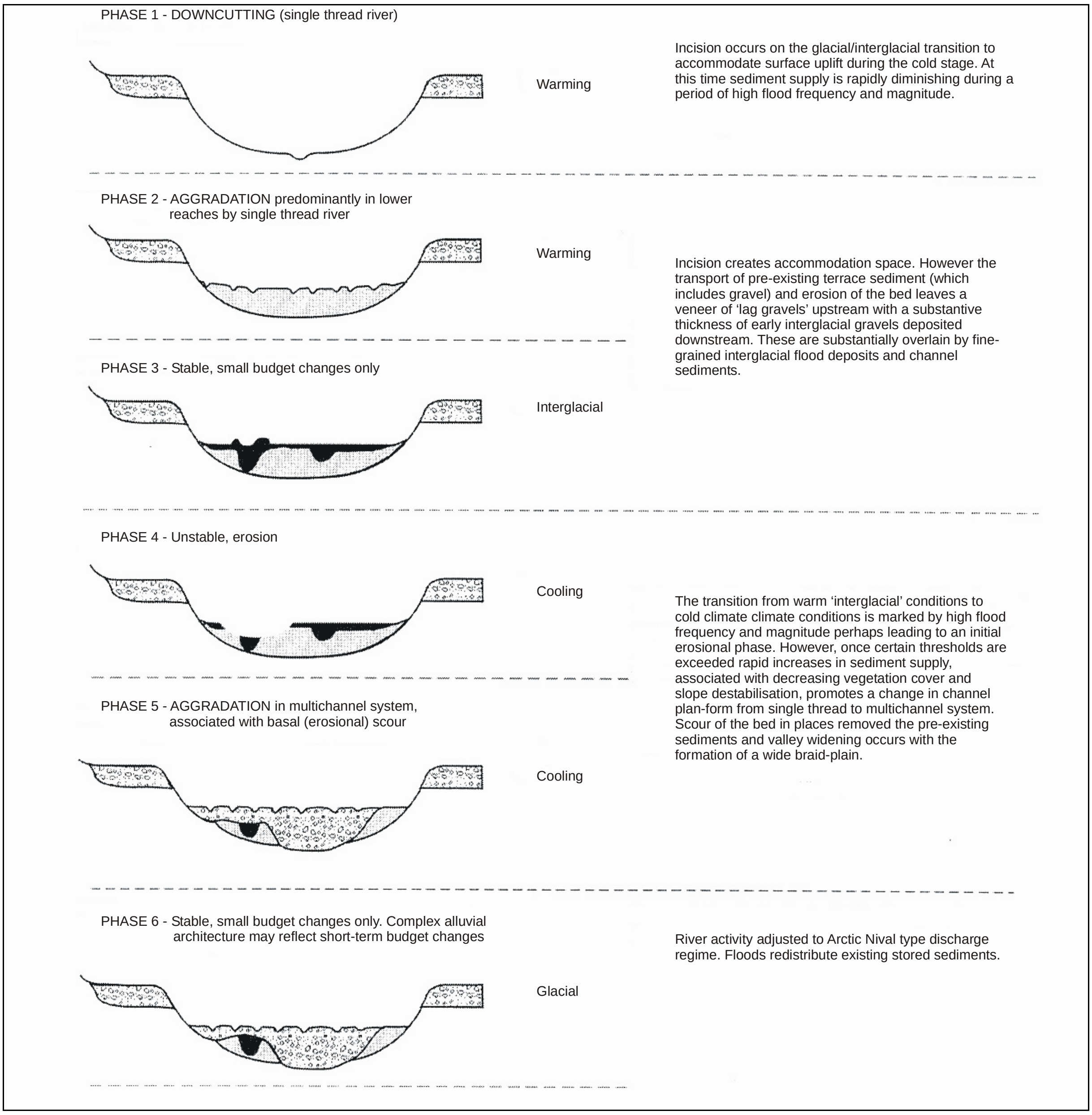

Figure 4: climate-driven fluvial terrace development (after Maddy et al. 2001: Figure 3)

Alongside the nature of fluvial activity during the glacial phase, a key concern from an archaeological perspective relates to the potential for the long-term preservation of the sediments. In this instance, it is suggested that only the terminal phase of braided river sedimentation activity will be preserved. This is based on modern analogues for active braided river systems, which suggest that the process of lateral channel shift by bank erosion is both rapid and spatially extensive (Gibbard & Lewin 2002: 194). It has even been suggested that the surface layer of entire alluvial valley floors may be reworked in a matter of decades (Best & Bristow 1993). Under such conditions, it is clear that while the processes of nival-regime sediment redistribution and reworking activity during the glacial period will generate a succession of sedimentary features and arrangements of fluvial architecture, only the sedimentary features that were created during the final decades or centuries of the specific cold-climate phase will be preserved. This has clear implications for the re-working of archaeological material, and is returned to in chapter 6.

2.2 Fluvial activity during transitional conditions

Vandenberghe (1995), Maddy *et al.* (2001), and Bridgland (1994, 1995, 1996, 2000, 2001) have all argued that fluvial incision and aggradation is a widespread characteristic of phases of climatic transition, both from warm to cold and vice-versa. In all cases the importance of non-climatic factors are stressed, with emphasis placed upon soil and sub-soil cohesion. Nonetheless, there are marked contrasts between the glacial/interglacial and interglacial/glacial transitions, and the associated sequences of events.

2.2.1 The interglacial/glacial transition

Vandenberghe (1995: 633) noted that incision occurs when runoff and soil cohesion are high, with a subsequent aggradation phase occurring when either cohesion or runoff drops substantially. With specific reference to the warm to cold transition (Vandenberghe 1993: 21–22):

- The drop in temperature causes lower evapotranspiration and a higher amount of overland flow (nb — the model assumes that precipitation is broadly constant).
- Vegetation cover persists for a short time, resulting in continued soil and river bank stability.
- The ratio of river discharge: sediment supply increases, resulting in fluvial incision.
- Subsequently, the deteriorating climate disrupts vegetation cover, resulting in soil destabilization, increased sediment supply and fluvial aggradation within the newly formed accommodation space.

Bridgland (2000: Figure 1) and Maddy (Maddy *et al.* 2001: 26–27) provided a related explanation which emphasises incision at the interglacial/glacial transition, as a result of changes in sediment and water supply. The model emphasises initial climatic instability during the cooling phase, potentially resulting in enhanced flood frequencies magnitudes which may have promoted an initial erosion phase. As with Vandenberghe (1993, 1995), the model also highlights subsequent aggradation during the cooling phase. This is linked to increased sediment supply (through mass movement, freeze-thaw activity and vegetation loss) and high water supply (due to high-frequency and high magnitude rainfall events, associated with instabilities in the North Atlantic atmospheric and oceanic circulation during the adjustment to global climatic change).

2.2.2 The glacial/interglacial transition

Erosion, followed by aggradation, is also a key component of the models developed for the glacial/ interglacial transition by Vandenberghe (1993, 1995) and Maddy *et al.* (2001). Vandenberghe again highlights vegetation development as a key factor (1993: 24–25):

- Vegetation development occurs gradually in response to climatic amelioration.
- Evapotranspiration initially remains low, resulting in high river discharges at the outset.
- Although vegetation restoration is retarded relative to increasing temperature, it is still sufficient to stabilise soils and consolidate channel banks.
- The combination of high run-off, bank stability and reduced sediment load results in incision and meandering.
- Subsequently, erosion is replaced by aggradation, in response to decreasing discharges due to increasing evapotranspiration.

Maddy *et al.* (2001: 26–27) also highlighted changes in sediment and water supply, although they introduced different specific mechanisms:

- During climatic warming, colonising vegetation stabilises slopes, reducing mass-movement processes and sediment supply.
- The global climatic adjustment causes instabilities in the North Atlantic atmospheric and oceanic circulation, that probably lead to increasing frequencies of deep depressions tracking across the UK, resulting in higher frequency and higher magnitude rainfall events.

- Considerable quantities of water are also released from frozen ground storage, and aquifers (layers of soil and/rock able to hold or transmit water) are re-established.
- The combination of high discharges and low sediment supply results in fluvial incision.
- The completion of the global climatic adjustment brings atmospheric and ocean-circulation to a broadly stable condition, reducing rainfall event frequency and magnitude, which results in falling discharge levels and the replacement of erosion with aggradation.

These models are notably disputed by Gibbard & Lewin (2002: 198), who argue against the occurrence of incision in British lowland rivers during the glacial/interglacial transition (although they recognise that does occur on the continent as documented by Vandenberghe (1993, 1995)). In contrast, they propose a model of channel pattern inheritance occurring during the glacial/interglacial transition (Gibbard & Lewin 2002: 198):

- Increasing mean annual temperatures.
- After a lag delay (estimated to be around 500 years in the earliest Holocene), seasonal flow variability is likely to decline, with permafrost melt, declining winter severity, precipitation, and infiltration providing groundwater sources for all year round flow.
- Stabilisation of gravelly channels inherited from the preceding cold phase occurs, with rivers lacking sufficient energy to transport gravel and alter gross channel form and distribution.

This model highlights issues of archaeological interest with respect to patterns of channel inheritance, in particular in terms of the potential for reduced sediments and artefact re-working under a model of channel inheritance rather than incision. However, it is significant that Maddy *et al.* (2001: 27) have argued for clear evidence of downcutting during the Lateglacial/Holocene transition, as demonstrated by the deep incision of Early Holocene valleys in many unglaciated river basins in southern England, including the Upper Thames. This evidence seems to noticeably contradict the claims of Gibbard & Lewin (2002: 198).

Overall there are marked contrasts between the models presented by Vandenberghe (1993, 1995), Bridgland (1994, 1995, 1996, 2000, 2001), and Maddy *et al.* (2001) with respect to fluvial activity during major climatic transitions. The incision/aggradation models are adopted here, not least because of their apparently widespread relevance to the river systems of northwest Europe (as demonstrated by the studies of Rose *et al.* (1980) and Collins *et al.* (1996)). However, the contrasts of these models with the work of Gibbard & Lewin (2002) is informative, not least because they stress the importance of regional variations (e.g. the apparent absence of incision in British lowland rivers at the Lateglacial/Holocene transition, unlike the rivers of continental Europe), and the variability between upland and lowland river zones (e.g. incision during the early Holocene has been demonstrated for upland British rivers (Harvey and Renwick 1987).

2.3 Fluvial sedimentation under interglacial conditions

The predominance of gravels and sands within Quaternary fluvial sequences, and the widely held belief that they accumulated under cold Pleistocene climates, has resulted in relatively little focus upon documented Pleistocene interglacial sediments (Gibbard and Lewin 2002: 187). Maddy *et al.* (2001: 27) observe only that climatic conditions in the full interglacials resulted in subdued fluvial system activity, with relatively low-energy facies being deposited across the inherited floodplain. Similarly, Vandenberghe (1995) highlights valley bottom stability, with lateral migration of the river across the alluvial plain and soil formation. Yet recent work has highlighted the potential complexity of these sediments, with Gibbard & Lewin (2002: Table 2 & 205) proposing a multi-stage model of lowland river behaviour in response to an interglacial climatic cycle. Given the contrasts of this model with existing views of interglacial sequences, it is reviewed in detail here:

- Late glacial/early interglacial transition: river flow adjusts to decreased seasonal contrasts, permafrost melting and the introduction of year-round precipitation and infiltration. Stabilisation of the inherited channels results, due to insufficient energy for gravel transport or channel form modification. The initial loss of the nival flood-peak causes a reduction in mean flow velocities and water depth, under which large areas of the emergent braidplain/floodplain surface become free from flood incursions for long periods. A complex of surfaces for plant colonisation and soil development is provided, while vertical accretion of fine-grained, organic, fossiliferous sediments begins in braidplain depressions and abandoned channels. Increased plant productivity and vegetation of floodplain surfaces also encourages fine-grained sedimentation, through the stabilisation of floodplain surfaces and the restriction of streams to the courses inherited from the preceding cold stage (*ibid*: 198).

- Full interglacial (early phases): the establishment of forest vegetation further diminishes variations in river flow (the soil-vegetation system stabilises ground surfaces and delays flood responses) and severely reduces inorganic sediment supply to alluvial systems. Stream flow is relatively slow throughout the year (except following exceptionally severe storms), channels stabilise, and minor, fine-grained, organic deposition is predominant in the minor, open channels. Vertical accretion leads to the infilling of the remaining, inherited depressions and pools with detrital, marsh, and peat sediments (*ibid*: 200–201).

- Full interglacial (late phases): continued infilling of floodplain depressions and channels leads to a decrease in the number of channelised flow routes. This restriction of streams to relatively few channels leads to increased periodic flooding and widespread vertical accretion across the majority of the floodplain surfaces. The overall pattern is of stable meandering and/or anastomosing river behaviour, and appears to have been widespread throughout lowland Britain during interglacials. This pattern has a notable consequence in that the flowing channels remain relatively fixed in the positions inherited from the previous late glacial, although the channels are not necessarily in contact with the cold-stage sediments. Marsh and peat sediments continued to accumulate on the floodplain areas beyond the channels, while surface wetness was augmented by spring activity at the break of valley slopes (*ibid*: 201).

- Late interglacial: although there are as yet no Holocene analogues for the late interglacial climatic deterioration, the extant geological record suggests that sedimentation initially continued during the late temperate phase. However, as the climate deteriorated it is assumed that the mean annual temperature declined, discharges became more seasonally variable, while extreme events (may) have become more frequent. Specifically, the opening up of the woodland (e.g. the replacement of mixed deciduous-coniferous woodland with coniferous woodland) would have increased infiltration, while vegetation retreat and thinning may have progressively increased run-off to the extent that storm-induced flow peaks were raised and water velocities increased. These processes may also have been accompanied by increased winter storage of snow on the ground, in response to dropping winter temperatures. The consequent increase in gullying (e.g. on valley-side slopes, in stream headwater areas, and locally upon the floodplain) would deliver increasing quantities of fine sediment to the river. Overall, increased overbank flooding would be expected, delivering thick accumulations of sands and fines across the floodplain surface, and this flooding would also be accentuated by the restriction of the river to single, deeper flow channels (*ibid*: 202).

- Early glacial: the return to predominantly treeless conditions (regional, herb-dominated early-glacial grassland) is associated with typical cold-climate regimes, with highly peaked flow discharges. Energy is therefore provided for stream rejuvenation, channel enlargement, remobilization of coarse debris, rapid removal of fines and substantial incision into the accumulated floodplain deposits (into which pollen and spore fossils are also reworked). The redevelopment of permafrost and inhibition of infiltration ensures rapid surface water flow, which combined with slope erosion and solifluction provides a source of coarse sediment. The initial absence of coarse sediments results in fluvial incision, the removal of fine alluvium, and the planing off of the upper parts of floodplain and channel deposits by laterally mobile, incising rivers, during the early period of the interglacial/glacial transition. It is not currently clear when the gravel transport was re-activated, and it is suggested that this may have varied between different interglacial episodes (*ibid*: 202).

This model of fluvial activity across the span of an interglacial episode adds considerable detail to the models of Vandenberghe (1995) and Maddy *et al.* (2001). It also has several fundamental implications for the three issues highlighted at the beginning of this chapter:

1. Sedimentation styles appear to have changed during the progression of an interglacial stage.
2. Preservation of sediments from different parts of interglacial stages appears to be highly unequal, with sediments laid down early within a warm stage being far more common in the geological record than those from later in the same stage (Gibbard & Lewin *ibid*: 188 & 205). This is due to the widespread 'accommodation space' mosaic that is available for sedimentation during the early interglacial period (this mosaic consists of surface irregularities and channels in the wide braidplain surface inherited from the preceding cold stage river). By contrast, accommodation space and sedimentation is of a restricted nature during the later interglacial, and the sediments are also extremely vulnerable to the subsequent high energy rivers of the succeeding glacial phase.
3. Fragmentation and reworking of the interglacial sediments varies according to the nature of the valley (e.g. narrow valleys with steep slopes compared to wide, unrestricted valleys with non-cohesive or unresistant substrates).
4. The contact between the subsequent cold-climate gravels and sands and the underlying interglacial fine-sediments has often been demonstrated to be erosional, implying the removal of pre-existing sediments and an unknown time interval (Gibbard & Lewin 2002: 204).

Drawing upon all of the models summarised above, it is possible to present a provisional model of fluvial activity across a generic glacial/interglacial, in terms of episodes of fluvial incision, erosion, sedimentation and preserved sedimentation (i.e. the fluvial architecture that can be observed and recorded today):

- Glacial phase: relatively stable systems, but with frequent, small-scale braidplain sedimentation of coarse-grained materials in response to nival-regime flooding. Re-working of braidplain sediments results in the favourable preservation of fluvial architecture dating to the end of the phase.
- Glacial/interglacial transition phase: unstable systems, with high frequency and high magnitude flooding. An initial phase of major incision (resulting in the cutting of a new floodplain) is followed by extensive aggradation of coarse-grained deposits. Preservation of both the incision events (the new floodplain landform) and the sedimentary deposits.
- Interglacial: stable system, with fine-grained sedimentation. Favourable preservation of sediments dating to the early stages of the interglacial.
- Interglacial/glacial transition: unstable systems, with high frequency and high magnitude flooding. An initial phase of minor erosion (removing existing fine- and coarse-grained sediments) is followed by extensive aggradation of coarse-grained deposits. Preservation of the sediments is likely, and preservation of erosion surfaces may also be documented.

The model is summarised schematically (Figure 5), and would appear to suggest that relatively short spans of the glacial/interglacial system are preserved and represented in the resultant fluvial architecture. However, it is stressed that two additional themes require consideration with respect to fluvial activity across the glacial/interglacial cycle and its potential for preservation: i) the evidence for high frequency (sub-Milankovitch) climatic change (i.e. rapid climatic variations, sometimes of large magnitude, occurring over centuries and millennia and superimposed onto the 100,000 year orbitally-driven glacial/interglacial cycles (Lowe & Walker 1997: 15)); and ii) the nature of fluvial responses to it; and the impacts of non-climatic factors, including basin properties (e.g. topography, valley width, subsoil lithology) and system response times (linked to catchment size).

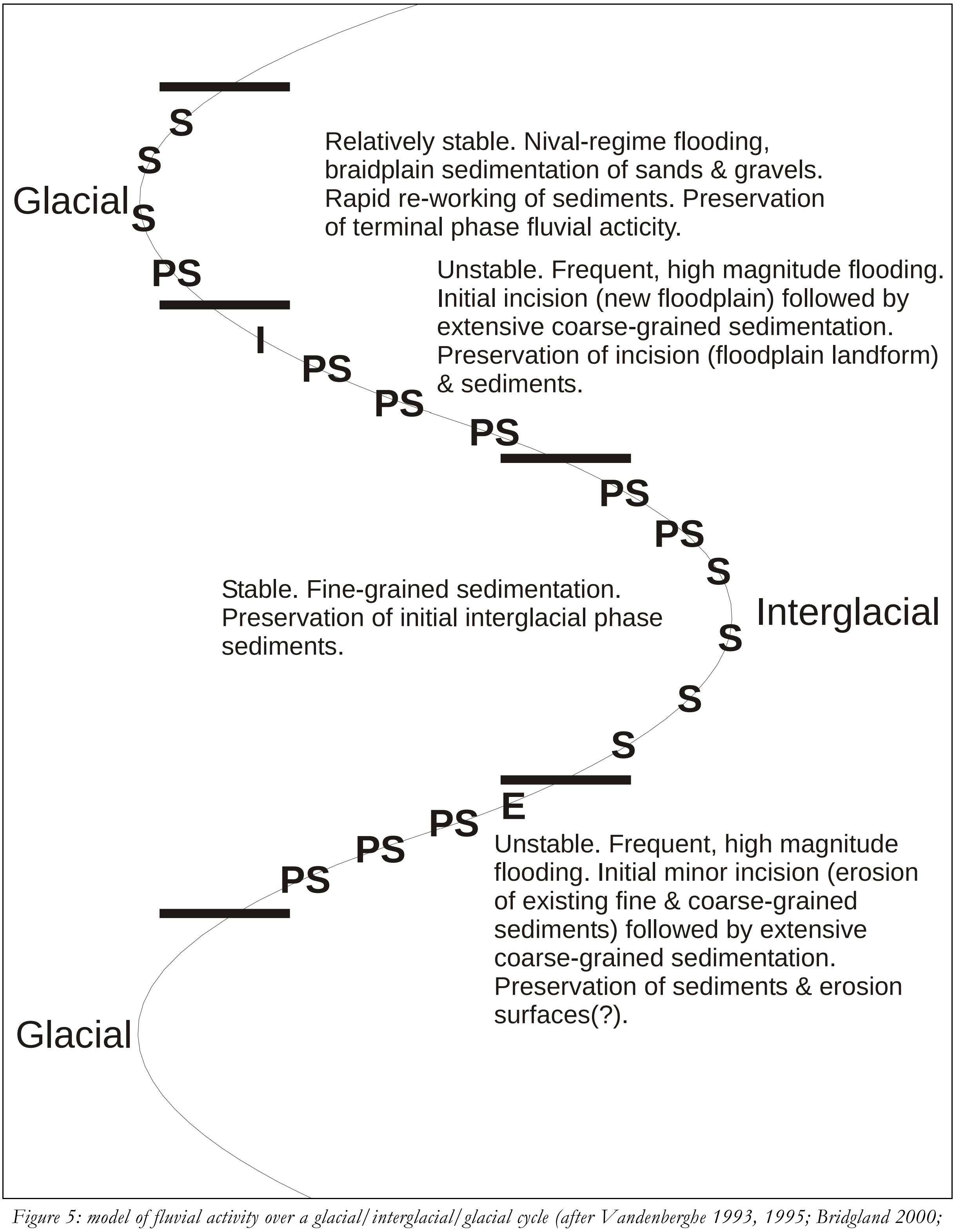

Figure 5: model of fluvial activity over a glacial/interglacial/glacial cycle (after Vandenberghe 1993, 1995; Bridgland 2000; Maddy et al. 2001; Gibbard & Lewin 2002). S = sedimentation; PS = preserved sedimentation; I = incision (floodplain downcutting); E = erosion.

2.4 High frequency climatic changes

A key framework for the understanding and interpretation of high frequency, sub-Milankovitch scale climatic changes was provided by Vandenberghe (1995):

- 100,000's of years (glacial/interglacial sequences). At these scales, fluvial evolution is broadly climatically dependent, within its tectonic framework, in accordance with Bridgland (1994, 1995, 1996, 2000, 2001) and Maddy *et al.* (2001).
- 10,000's of years (a single glacial/interglacial cycle). Fluvial activity and response is now determined by the derived impacts of climate: vegetation, soil cohesion and run-off (discussed above in Sections 2.1–2.3). Short unstable phases alternate with long periods of inactivity, with the unstable phases occurring at the major climatic transitions, as emphasised for Middle Pleistocene sequences by Bridgland (2000), Maddy & Bridgland (2000), and Maddy *et al.* (2001).
- 1,000's years (single phases of instability). The fluvial response is governed by the intrinsic evolution occurring within the system, as recently demonstrated by Howard & Macklin (1999).
- 100's of years (lower order climatic changes). The well-pronounced effects of local thresholds are the most striking at this scale, including climatic thresholds (e.g. the duration and intensity of climatic change) and landform and sedimentary thresholds (e.g. valley gradient, and the diameter and quantity of sediment to be transported).

Within this framework, the 1,000 and 100 year scales are of key interest in terms of high frequency climatic change. At these scales, while climate remains an important factor, the response of fluvial landforms and sediments to climatic change is a complex one, since: (1) fluvial processes are not only dependent upon the climate, but also upon physical parameters such as subsoil cohesion and evapotranspiration; (2) those factors are largely determined by vegetation, which responds in turn to climate; and (3) rivers adapt their pattern and gradient to the new conditions over time. This can be illustrated with a cyclical model of fluvial development (Figure 6), based upon observations of river activity in the Maas and Dinkel systems (Vandenberghe 1995):

- The cycle begins with a temperature drop, causing lower evapotranspiration and higher quantities of surface run-off. Vegetation cover persists for a period, ensuring that the soils and river banks remain stable. The increased ratio of discharge to sediment yield leads to river incision: "at the start of cold periods erosion is induced by a delay in the disappearance of the vegetation cover in comparison to the temperature decline" (Vandenberghe 1993: 26).
- Gradually vegetation is disturbed by the persistence of periglacial conditions (Vandenberghe 2001), resulting in increased sediment supply to the rivers, particularly through the process of run-off. Aggradation to previous levels occurs by the infilling of former channels. Sedimentation takes place largely by braided river systems as a result of the irregular discharge regimes and the availability of large amounts of sediment.
- During the later part of the cold period there is a relative balance between erosion and aggradation. At times fluvial activity decreases dramatically and aeolian activity may become dominant.
- As the climate ameliorates, vegetation development is initially retarded, with herbaceous vegetation remaining dominant. This results in evapotranspiration rates remaining low and discharges becoming relatively high at the beginning of the warm period. Soils are stabilized by the existing vegetation, reducing the sediment load in the channels, and the rivers tend to incise and adopt a meandering pattern: "at the very beginnings of warm periods, erosion is induced by a delay in the full development of forests in comparison to temperature rise" (Vandenberghe 1993: 26).
- Vegetation development and increases in evapotranspiration rates result in reduced discharges, leading to a change of channel activity to infilling.
- During the following interglacial, valley bottom stability is expressed through the lateral migration of the river across its alluvial plain and by soil formation.

Summarising the cyclical model, Vandenberghe (1995) concluded that;

"Incision took place at climatic transitions (from cold to warm and from warm to cold). The incision phases are of relatively short duration and are followed by almost equally rapid aggradation. Between these short phases of instability long periods of stability prevailed characterized by approximately balanced lateral sediment accretion and erosion…This sequence of events and sedimentation cannot be explained only by climatic factors, but must especially be due to cohesion of the basin subsoil in

relation to run-off. Incision occurs when both cohesion and run-off are high, while the succeeding aggradation takes place when either the previous cohesion or run-off drop substantially…Finally, delay effects with respect to climate play a crucial role in the origin of the instability phases: the delay in vegetation disappearance at the beginning of a cold period, the delay in forest development at the beginning of a warm period."

(Vandenberghe 1995: 633–635)

Of critical archaeological interest is the claim that the phases of incision and aggradation were of relatively short duration. How long were these phases? This issue is returned to in Section 3. Of equal interest is the question of the magnitude and frequency of the climatic transitions to which Vandenberghe (*ibid.*) refers. If the climatic transitions are associated with the glacial/interglacial cycles (i.e. two transitions per 100,000 year, eccentricity-driven cycle), then Vandenberghe's model would suggest very long periods of fluvial inactivity. However, it is clear from recent ice core research (e.g. Anklin *et al.* 1993; Petit *et al.* 1999; van Andel 2003) that climatic shifts are not restricted to the major glacial/interglacial transitions. The recognition of the Dansgaard/Oeschger oscillations (brief, high frequency climatic oscillations of varying amplitude) indicates that periods of fluvial inactivity (as defined above by Vandenberghe (1995) were relatively short, and that even within interglacial and glacial stages, there was considerable potential for fluvial activity in response to these sub-Milankovitch climatic oscillations.

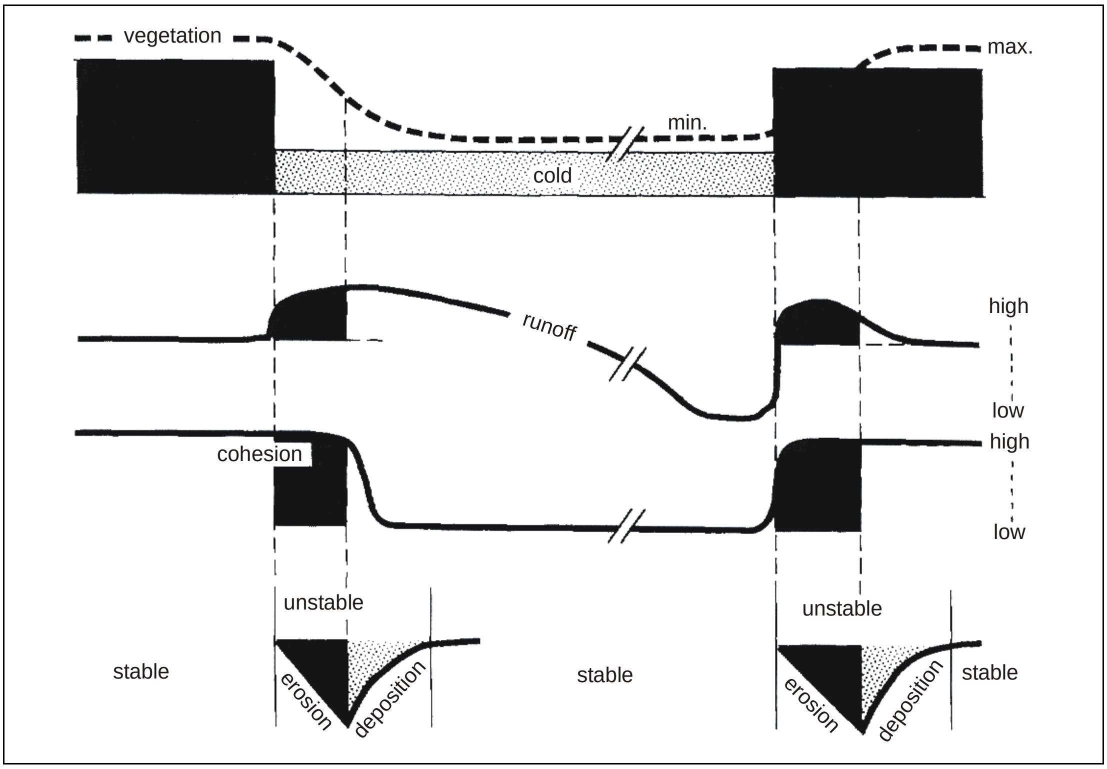

Figure 6: model of fluvial stability-instability alternations in relation to climate and climate-induced parameter (Vandenberghe 1995: Figure 5)

Recent evidence for such fluvial responses to high frequency climatic oscillations has been provided for the last glacial/interglacial cycle by Maddy *et al.* (2001). Complex fluvial architecture in the Northmoor terrace in the Upper Thames valley indicates high resolution responses to climatic shifts (Figure 7). Although the model presented by Maddy *et al.* (*ibid*: Fig. 5; reproduced here as Figure 7) is conceptual, it highlights the importance of climatic control, exerted through its influence upon sediment and water budgets:

- Warm climate shifts within cold stages may result in temporary reductions in sediment loading and changes in the discharge regime. This can promote low energy sedimentation across the former braidplain and a tendency for incision within confined channel zones (phase 6a in Figure 7). During substantial warm climate shifts (e.g. the Devensian Late Glacial interstadial), thresholds in channel planform may be triggered. Substantial reductions in sediment supply and the stabilisation of channel banks by vegetation may be sufficient to promote meandering single thread channels. Scour in meander pools may remove pre-existing sediments while abandoned channels fill with fine-grained sediment (phase 6c in Figure 7).

- Cold climate shifts (e.g. the Younger Dryas event) are likely to result in increased slope instability, increased sediment supply and high sediment loads, and a change to high energy, multi-channel systems, occupying large parts of the floodplain. Scour at the base of the channels can lead to the removal of pre-existing sediments (phases 6b and 6d in Figure 7).

However, while Maddy *et al.* (2001: 33–34) highlight the potential for high resolution fluvial response to high frequency climatic oscillations, they also emphasise the problems inherent in this type of fluvial architecture: the magnitude of high frequency climatic changes results in relatively small-scale sedimentary features that may or may not be fortuitously preserved; while geochronological tool-kits do not always permit the resolution of these features. It is therefore apparent that any discussion of patterns of fluvial activity needs to consider not only the relationships between fluvial activity and low and high frequency climatic changes, but also the potential for the products of the fluvial activity to be preserved over geological timespans and to be detectable to modern geochronological methods and techniques. Moreover, it is increasingly apparent that the same climatic switch will not result in identical fluvial activity in different river systems, or even within different reaches of a single system.

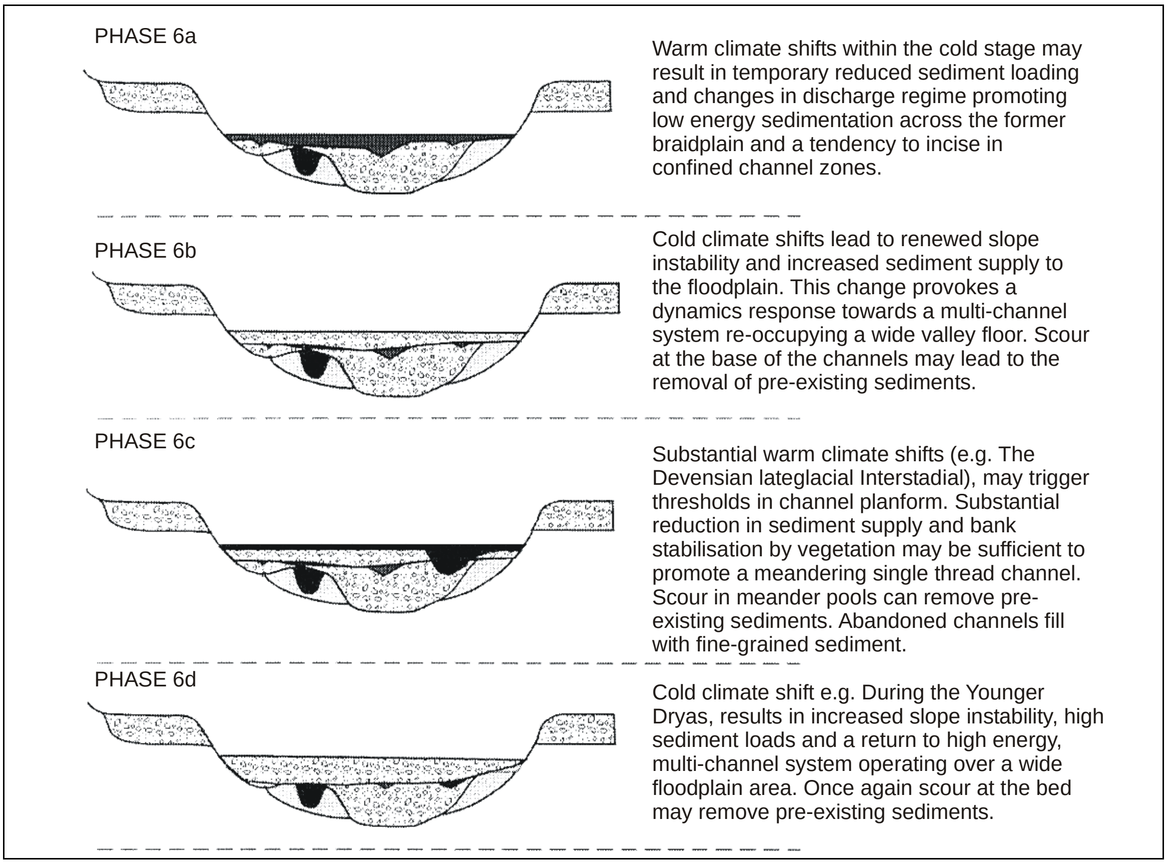

Figure 7: conceptual model of climate-driven sedimentary architecture of the Northmoor Gravel of the Upper Thames valley (Maddy et al. 2001: Figure 5)

2.5 Variability in fluvial response

Variability in fluvial system response has been documented by a number of researchers, in wide range of geographical settings. Cleveringa *et al.* (1988) noted in their study of 16 small river basins in Belgium and the Netherlands that river adjustments had occurred episodically over the last 15,000 years, associated with five periods: end of the Pleniglacial/early Late Glacial; Alleröd; Late Dryas; Boreal; and the Subboreal/Subatlantic. Yet it was clear that not all of these periods were documented in all of the river basins, with fluvial activity associated with the Alleröd and terminal Pleniglacial/early Late Glacial being the most commonly represented (in 13 of the 16 basins). The study region was characterised by low relief, relatively homogenous climatic conditions (both in the past and the present), and unconsolidated geology of Pleistocene or Tertiary age. Cleveringa *et al.* (*ibid*: 125) concluded that variations in river system response to changing climatic conditions were grounded in differences in local-scale parameters controlling discharge, including: the intensity and duration of precipitation; the type of vegetation and litter-layer (interception); the infiltration capacity of soils; and the density of the substrate. However, they also stressed that the stratigraphic sequences of the drainage basins were incomplete as a result of the local dominance of erosional discontinuities. Finally, it was proposed that sedimentation in the lower parts of basins can be chronologically associated with erosional factures in the upper part of the basin, illustrating differences in fluvial response in two stretches of the same river system.

This theme was explored by Houben *et al.* (2001; Houben 2003), in an investigation of the small and mid-scale rivers in the Hessian Depression (Hessische Senke) in Central Germany. The Amoeneburger Becken and the Wetterau are neighbouring, small river basins, located north of Frankfurt am Main in the Hessian Depression. The depression forms a zone of subsidence, the northern continuation of the Upper Rhine Graben, and is bordered by the Rhenish Slate Mountains (Rheinisches Schiefergebirge) in the west and the basalt Vogelsberg upland in the east. The basins themselves are filled with Tertiary sediments, which are covered with Pleistocene loess. The river landscapes lie in the non-glaciated zone between the Scandinavian inland ice sheet and the alpine glaciations, and therefore formed in response to periglacial processes during the Pleistocene glaciations (Houben *et al.* 2001: 249). Analysis and radiocarbon dating of Younger Dryas deposits from the upland and lowland reaches of the Wetter valley revealed apparent discrepancies in the system's responses during this climatic period. Although widely considered to be a phase of colder climate, pollen evidence from the northern Wetterau did not indicate considerable deforestation, while sedimentary evidence from the upstream Wetter near Lich did not indicate a sudden change in fluvial style during the Younger Dryas (*ibid*: 254–255). Yet the majority of the floodplains in the studied basins were affected by increased fluvial activity during this period, with the re-working and deposition of coarse-grained sediments suggesting a climatically-driven change to a braided river system (*ibid*: 260). How can this discrepancy be explained? Houben *et al.* (*ibid*: 260) emphasised the contrasting spatial scales of the palaeo-environmental evidence provided from sedimentological and pollen data, and the differential behaviour of fluvial systems in contrasting parts of the catchment. For example, the upland reaches were influenced by markedly deteriorating climatic conditions, increasing proportions of precipitation stored as snow, high magnitude snowmelt discharges that were capable of entraining and transporting coarse materials, and the minor role of vegetation cover in upland areas. By contrast, the low gradients of the downstream basins resulted in the sedimentation of the coarse-grained sediments, although these lower reaches may have been little affected by the Younger Dryas cooling, hence the absence of major deforestation.

The question of variability in system response has also been highlighted by Vandenberghe (2003), with respect to the role of non-climatic factors in fluvial system development, particularly catchment size, threshold values, and system lag or response times to changes in external conditions. Fluvial evidence from the Netherlands indicated that in contrast to the climatic changes of the Late Glacial, the rapid climatic oscillations that are present in the marine and ice core records of the preceding Pleniglacial are not easily detected in terrestrial environments and it is even more difficult to identify their potential effects upon fluvial systems. For example, a fluvial adaptation to the pronounced Hasselo-Hengelo stadial/interstadial event has scarcely been found in the rivers of the Netherlands (e.g. van Huissteden *et al.* 2001). This may be due to the similarities in duration between the climatic oscillations (centennial or millennial) and the response times of the river to distinct climate change (the Maas and the Warta rivers took several hundred years to respond to the Weichselian Pleniglacial/Late Glacial transition). Given such similarities in timescales, it is not surprising that fluvial systems do not always react to climatic changes of limited duration (Vandenberghe 2002: 19). A further factors behind such variable response concerns the observation that the duration of a climatic oscillation must be long enough to enable a particular system to react to the forcing process. Given that climatic events need to last longer to affect large catchments in comparison to small ones, it is clear that small systems could *theoretically* provide more comprehensive archives of both large and small magnitude climatic events. Unfortunately, such small systems are also extremely vulnerable to subsequent erosion, while the larger systems, although perhaps only documenting the more major climatic events, are more likely to preserve the resultant major sedimentary structures. Finally, Vandenberghe (2003) has noted that the critical threshold values that must be crossed also vary on a regional basis in absolute and relative values. For example, the energy available for sediment removal and transport is determined by river gradient as well as discharge, while the energy required is expressed by the amount and grain size of the river's sediment load. Catchment size will also influence river responses, due to the differential increase in small catchments in the catchment area that is only occupied by surface runoff under permafrost conditions. This trend results in river responses to permafrost development or degradation being more pronounced in smaller rather than larger catchments.

Fluvial environment	**River type**	**Evolution**	**Archaeological preservation**
Upland	> High-energy > Non-cohesive channel banks	> Episodic incision & aggradation. > Dominance of coarse-grained sedimentation in braided & meandering systems. > Limited fine-grained sedimentation.	> Narrow valley floors may prevent long-term terrace preservation. > High magnitude flooding may flush sediment fills from valleys. > Incision results in re-working of archaeological materials.
Upland margins (piedmont)	> Medium energy > Non-cohesive channel banks	> Vertical & lateral instability. > Episodic incision & aggradation. > Dominance of coarse-grained sedimentation in braided, anastomising & meandering systems. > Fine-grained accretion on coarse sedimentary units during overbank 'flood' events.	> Wider valley floors may allow for long-term preservation of terrace units. > Incision results in re-working of archaeological materials.
Lowland	> Low energy > Cohesive channel banks	> From glacial braided to interglacial meandering/ anastomosing systems. > Dominance of vertical accretion through time. > Fine-grained units of sand, silt, clay & peat.	> River system stability & dominance of vertical accretion = burial & preservation on in situ archaeology. > High preservation potential for organic materials.
Perimarine	> Low energy > Cohesive banks	> Sea-level fluctuations results in flooding, peat development & overbank sedimentation in anastomosing & meandering channels. > Cyclical sequences of silt/clay and peat.	> River system stability & dominance of vertical accretion = burial & preservation on in situ archaeology. > High preservation potential for organic materials.

Table 1: examples of fluvial systems, geomorphological evolution and issues of archaeological preservation (summarised from Howard & Macklin 1999: Tables 1–3)

These short examples indicate the potential for variation both in fluvial system response to specific changes in climatic conditions, and the implications for long-term preservation of the fluvial archive. These themes were explored specifically by Howard & Macklin (1999) with respect to the considerable complexity associated with fluvial processes and the archaeological record (Table 1). They focused upon the differential behaviour of upland, piedmont, lowland and perimarine systems (defined for the UK on the basis of physiography and basin relief):

- Upland fluvial environments (high energy river systems with non-cohesive channel banks): high river channel gradients (> 10m km^{-1}), high bedload sediment transport rates, steep valley side slopes (which often merge into the channel without an intervening floodplain), and flow regimes dominated by large, infrequent flooding.
- Piedmont fluvial environments (medium energy river systems with non-cohesive channel banks): river channel gradients between 2 and 10m km^{-1}, steep valley side slopes (but with floodplain development between the valley side and river channel), and the transport of gravel bedload and deposition of fine-grained overbank sediments during flooding.
- Lowland and perimarine fluvial environments (low energy river systems with cohesive channel banks): low channel gradients (< 2m km^{-1}), low angle valley side slopes, well developed floodplains, and the transport of predominantly fine-grained sediment.

There are clear marked contrasts between the different systems in terms of system energy, channel stability, sedimentation type and incision activity, and preservation patterns (Table 1). The last of these has clear implications for the interpretation of archaeological assemblages occurring within fluvial secondary contexts, and is returned to in chapter 7. However with respect to the other aspects of system variability, we reiterate the observation made at the beginning of this chapter: *our interest does not lie in the subtle variations of river behaviour in their different reaches, but rather we are concerned with the gross temporal patterns of fluvial activity and the relative preservation of large and small-scale sedimentary features*. This is not because the variations identified by, amongst others, Howard & Macklin (1999), Houben *et al.* (2001) and Cleveringa *et al.* (1988) are not important for the understanding and interpretation of archaeological data. In an ideal world, these variables could be documented and incorporated. However, the partial and highly fragmentary preservation of Middle Pleistocene fluvial sediments, alongside the extensive modification (e.g. through aerial and sub-aerial erosion) of the surrounding landscapes, and the cyclical restructuring of the UK landscape in response to the high and low-sea level fluctuations severely limits our ability to assess local and regional factors. We propose that Middle Pleistocene data currently make it impractical to confidently distinguish for example between upland, piedmont, lowland, and perimarine fluvial environments (Howard & Macklin 1999), reconstruct catchment sizes and local soil lithologies (Vandenberghe 1993), or model upstream/downstream gradients (Houben *et al.* 2001).

By contrast what is possible is an investigation of the temporal magnitude of fluvial activity phases, whether those magnitudes vary in accordance with the type of fluvial activity (e.g. fine- or coarse-grained sedimentation), and the implications of this temporality for the formation and interpretation of archaeological assemblages.

3. THE DURATION OF FLUVIAL EVENTS

From an archaeological perspective the most important element of Vandenberghe's (1995) timescales concerns the observation that *short unstable phases alternate with long periods of inactivity*. The key question concerns the issue of how short the short unstable phases are? Vandenberghe (1995) suggests that these single phases of instability are *c.* 1,000's of years in duration, although it is emphasised that these phases are not characterised by constant fluvial activity. This is illustrated with respect to precipitation, where the intensity of precipitation and its seasonal distribution are more important than annual values in determining the processes of erosion and deposition. Thus, extreme events at a recurrence interval of years or tens of years leave the largest imprints in the production of sediment (Vandenberghe 2003: 2055). This however still leaves the question of the duration of these short, unstable phases, during which a combination of factors (climatic, climate-derived, climate-dependent, and non-climatic) influence fluvial development (*ibid*). This issue is explored below through reference to examples from the Last Glacial and the Holocene. This approach has been adopted as a result of:

- The limited resolution of geochronological tools suitable for the investigation of Middle Pleistocene fluvial sediments. Thermoluminescence, optically stimulated luminescence, amino-acid racemization, and electron-spin resonance all carry an error range of several millennia (Renfrew & Bahn 1996), limiting the possibilities for using multiple dates to model the depositional history of a fluvial sequence.
- Middle Pleistocene fluvial sequences have typically been subjected to extensive post-depositional erosion and modification, resulting in highly partial and fragmentary records of Pleistocene floodplains.

3.1 Fluvial Event Chronology: Case Studies

Two specific case studies are presented as examples of the geochronologies associated with the short-term phases of fluvial activity highlighted by Vandenberghe (1995). They represent a wide geographical catchment, different river types, and cover the Late Glacial and Holocene periods. These variations are acknowledged, and it is again stressed that this review is seeking to test whether overarching relationships between fluvial activity and specific timescales (e.g. seasonal, annual, decadal, centennial, and millennial) exist within the geoarchaeological record. We therefore feel that the inclusive character of the selected case studies is justified. The implications of this approach for the use of the case studies as analogues for Middle Pleistocene sedimentary sequences are considered below.

3.1.1 Cleveringa et al. (1988)

The processes of river activity and spatial and temporal scales were explored for 16 small river basins in Belgium and the Netherlands (Figure 8). The overall area is characterised by low relief, and generally homogeneous climatic conditions, both in the past and at the present. The drainage basins are all situated in unconsolidated rocks of Pleistocene and/or Tertiary age (Cleveringa *et al*. 1988: 123). Long distance and long-term factors were not considered in the analysis of fluvial adjustment (encompassing both aggradation and incision activities within the study), reflecting the small size of the rivers under study. The potential causes of river adjustment were instead restricted to those parameters controlling discharge, including: the intensity and duration of precipitation; the type of vegetation and litter-layer (interception); the infiltration capacity of soils; and the density of the substrate (*ibid*: 127). The amount of precipitation and the degree of evapotranspiration were also highlighted as key factors impacting upon the total amount of water available for river discharge.

It was clear that river adjustments had occurred episodically over the last 15,000 years, associated with five periods: the Subboreal/Subatlantic; Boreal; Late Dryas; Alleröd; and the end of the Pleniglacial/early Late Glacial. Adjustments associated with each of these periods were not evident in all of the river basins, with the Alleröd and terminal Pleniglacial/early Late Glacial adjustments being most commonly represented (in 13 of the 16 basins; *ibid*: 125).

Based on external models of vegetation cover and climatic development over the last 15,000 years (*ibid*: 125–127; summarised here as Figure 9), and cut and fill sequences, pollen analyses, and radiocarbon chronologies for the river basins, a model of river adjustments and climatic parameters was proposed:

- Pleniglacial/early Late Glacial adjustment: *increased water discharge*. Improvements in climate and the presence of non-adapted vegetation (due to delays in tree migration) influenced run-off (sediment yield) and infiltration capacity. Delayed tree migration also resulted in a low evapotranspiration rate. Alongside the retardation of vegetation development and the temperature rise, increased precipitation and the absence of a closed vegetation cover were also key factors behind the increased discharge. Evidence for a considerable precipitation increase include: evidence that the last phase of the Pleniglacial was dry; the widespread presence of organic deposits in shallow depressions of early Late Glacial and Alleröd age, indicating a high ground water level immediately after the Pleniglacial; and the early onset of the deglaciation in Scandinavia and the Alps at 14,000 BP, resulting in a considerable increase in maritime conditions in the Low Countries since the Late Glacial.

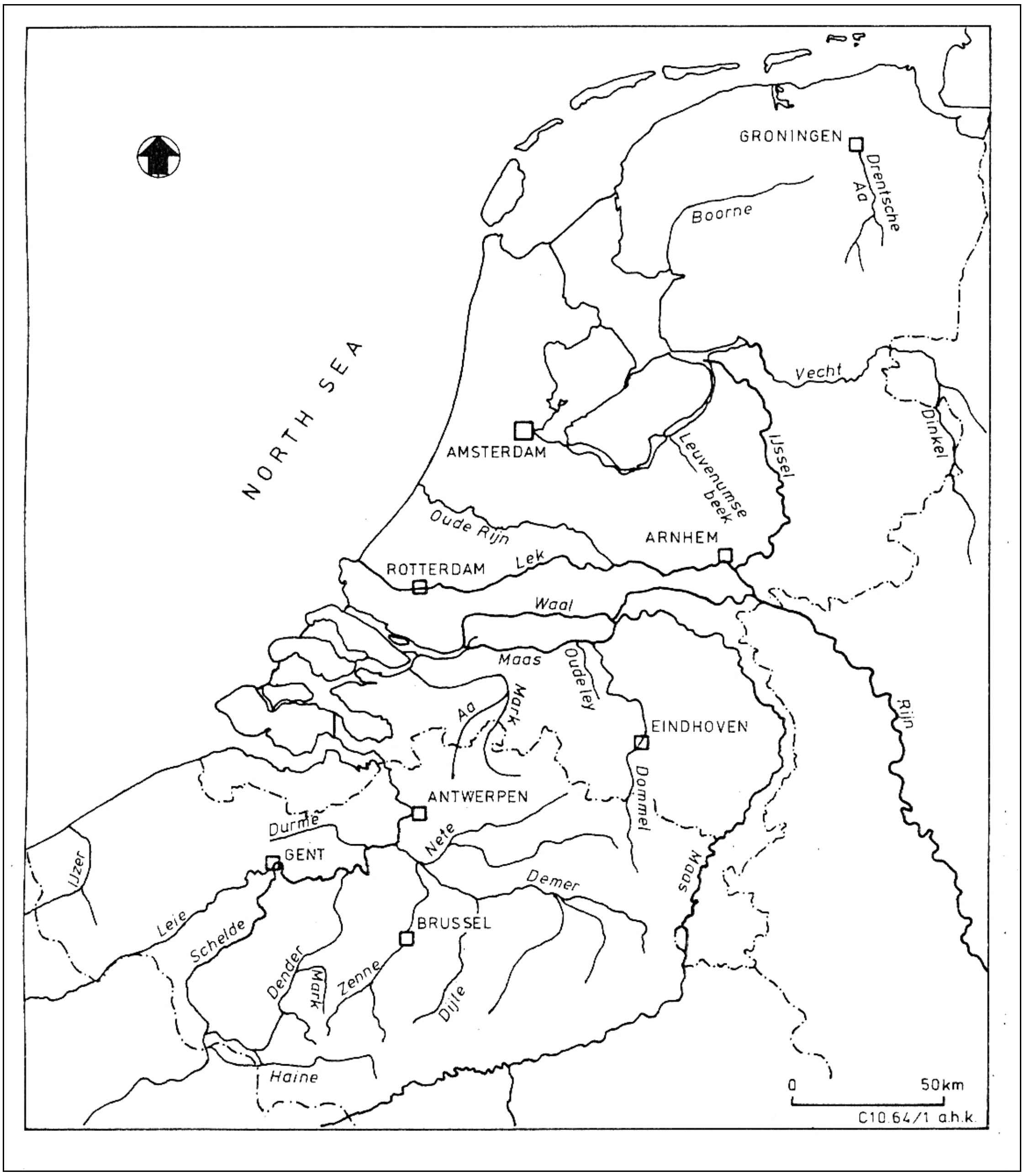

Figure 8: location of the investigated lowland river basins in Belgium and the Netherlands (Cleveringa et al. 1988: Figure 1)

- Late Dryas adjustment: *increased water discharge*. A decrease of evapotranspiration rates occurred due to a substantial temperature drop followed by vegetation regression.
- Boreal adjustment: *minor increase in fluvial discharge* (a possible base level incision). A direct relationship with climatic factors is not clearly indicated, although the ecological shift from pine to deciduous forest may have lead to reduced evapotranspiration. It is possible that the slight increase in water discharge, combined with low sediment yield (due to the dense plant cover and soil forming processes) may have lead to river adjustment.
- Subboreal/Subatlantic adjustment: *slow increase in water discharge.* A slight drop in temperature combined with a minor enhancement of precipitation is indicated, while the increasing effects of anthropogenic activity (on a local and limited scale) must be considered. Overall, the impacts of human activity and

climate change led to increased water discharge, but the gradual nature of the changes resulted in a sporadic crossing of the thresholds for major adjustment in many of the river basins.

Overall therefore, Cleveringa *et al.* (1988: 130) emphasise increased precipitation and decreased evapotranspiration as the main causes behind increased water discharge (and therefore fluvial activity). This is a similar (albeit simpler) conclusion to that drawn by Vandenberghe (1993, 1995) and Maddy *et al.* (2001), summarised above. What is critical from an archaeological perspective however is the relatively short duration of the phases of river adjustment, with those associated with the Late Pleniglacial, the Late Dryas and the Boreal suggested on the basis pollen and radiocarbon data to be *c.* 1,000 years in length (Figure 9).

Cleveringa *et al.* (1988) noted that all four of the river adjustments were only documented in the Leuvenumse Beek valley, with three adjustments recorded in the Dinkel, Dijle and Mark valley, and fewer than three in the remaining basins. This prompted the highlighting of issues of relevance in the potential application of geomorphological models to the understanding of varied archaeological sequences. These are returned to below, but summarised here:

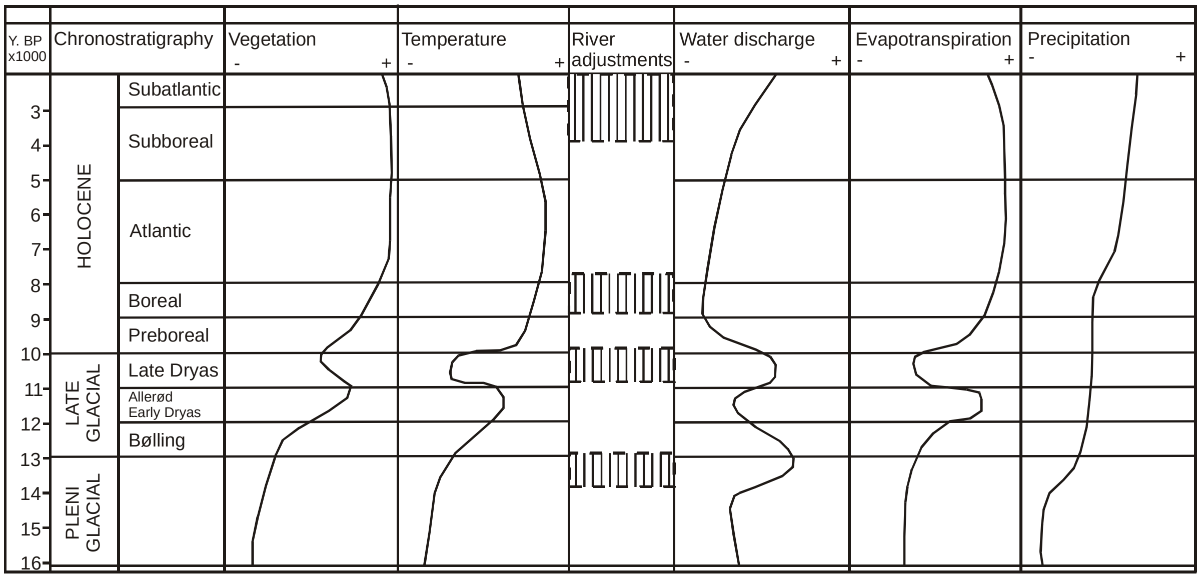

Figure 9: tentative relative curves of climatic parameters related to river adjustments since the Upper Pleniglacial (Cleveringa et al. 1988: Figure 5)

1. Not all river systems react with the same intensity, for the same length of time and to the same degree, to changing conditions (climate and/or vegetational).
2. The number of river adjustments detected is dependent upon research methods and objectives.
3. The stratigraphic sequences of drainage basins are incomplete as a result of the local dominance of erosional discontinuities, while sedimentation in the lower parts of basins can be chronologically associated with erosional factures in the upper part of the basin.

3.1.2 Houben et al. (2001; Houben 2003)

The interplay between climatic factors and local acting controls was explored for small and mid-scale rivers in the Hessian Depression (Hessische Senke) in Central Germany (Houben *et al.* 2001; Houben 2003). The Amoeneburger Becken and the Wetterau are neighbouring, small river basins, located north of Frankfurt am Main in the Hessian Depression (Figure 10). The depression forms a zone of subsidence, the northern continuation of the Upper Rhine Graben, and is bordered by the Rhenish Slate Mountains (Rheinisches Schiefergebirge) in the west and the basalt Vogelsberg upland in the east. The basins themselves are filled with Tertiary sediments, which are covered with Pleistocene loess. The river landscapes lie in the non-glaciated zone between the Scandinavian inland ice sheet and the alpine glaciations, and therefore formed in response to periglacial process during the Pleistocene glaciations

(Houben *et al.* 2001: 249).

Unlike trunk stream deposits, the floodplain sediments of the small to mid-scale rivers in the Depression provided a reflection of landscape processes and change on a local and regional scale, and provide evidence for the environmental changes that have occurred since the Late Glacial. The responses of the fluvial systems to variable climatic conditions during the Late Glacial/Holocene transition are reflected in deposits of different facies. Section excavations and coring at four study sites revealed a mixture of sedimentary units, including coarse-grained sands and gravels, fine-grained overbank deposits (including the Black Floodplain Soil (BFS) of the early to mid-Holocene), and tephritic sediments (*ibid*: 251).

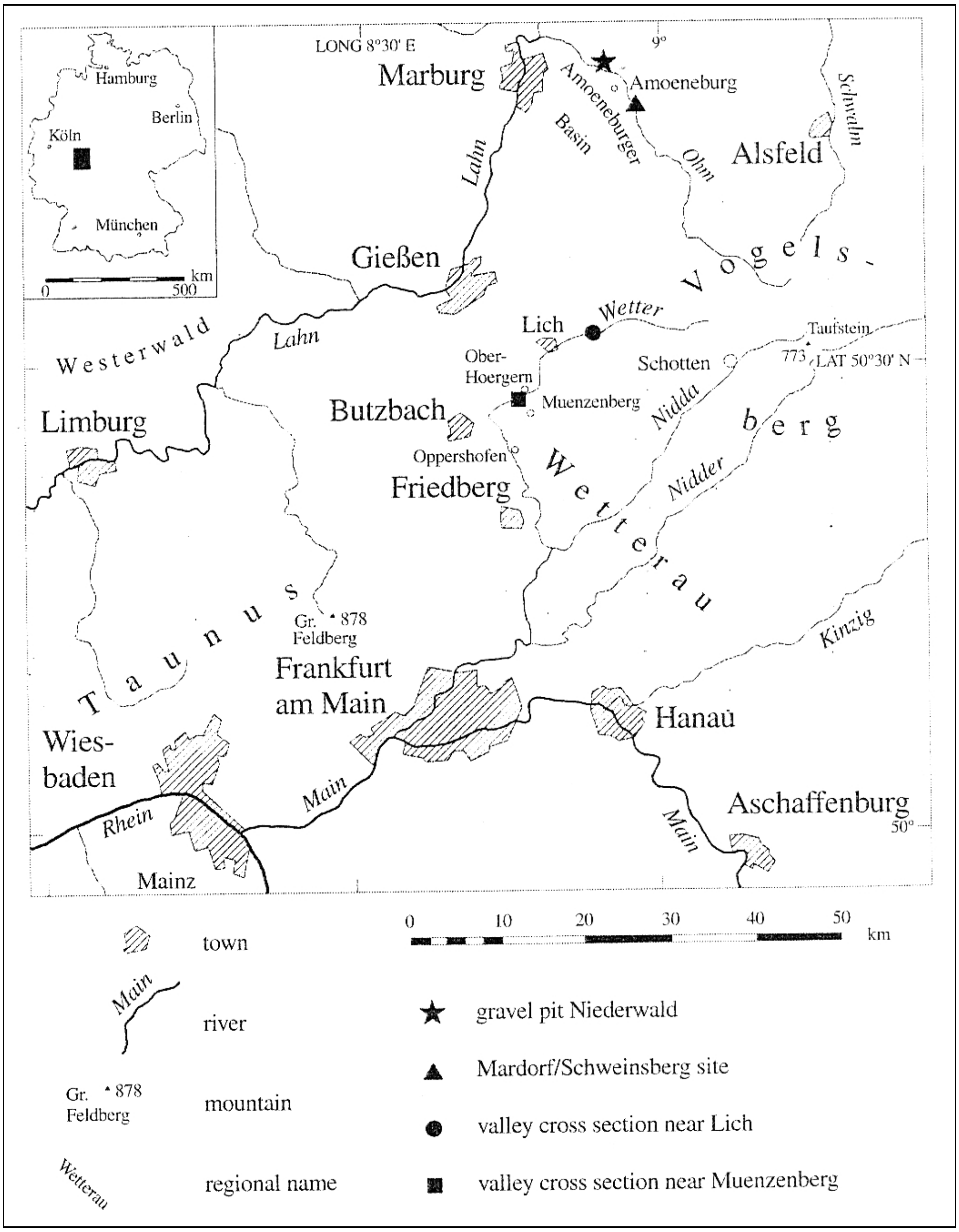

Figure 10: location of the Amoeneburger Becken and Wetterau basins (Houben et al. 2001: Figure 1)

Radiocarbon dating, pollen and macro-fossil analysis, tephrochronological investigations, and magnetic volume susceptibility measurements provided a high resolution record for the Late Glacial to Holocene period, and supported an interpretation of the responses of the fluvial system to varying climatic and other factors:

- Late Glacial period: in the upper Wetter valley, two or more layers of fine-grained overbank deposits overlie Pleniglacial gravelly deposits and sands. The lowermost of these overbank fines appear to relate to abandoned channels, with the pollen and macro remains of the peat and clay fills suggesting a shallowing channel. Radiocarbon dates from the macro fossils of three channel fills indicate that the channel filling occurred between 15,745–15,105 cal BP and 14,485–14,135 cal BP (Houben *et al*. 2001: 252). The change in sedimentation style indicates a shift in fluvial style at the end of the Pleniglacial, from a braidplain to a system dominated by very few stable channels. This change to a pattern of vertically accreting fines and a single thread course is linked to more continuous run-off, due to the decreasing magnitude of seasonal snowmelt events. The dominance of suspended load indicates increased soil erosion during this cold climate phase of the Late Glacial (*ibid*: 259).
- Alleröd period: this period is characterised by the increasing expansion of woodland cover (demonstrated for the Amoeneburger Becken), while the local formation of a well-developed soil horizon is also indicative of a more stable (as well as warmer) environment (*ibid*: 259).
- Younger Dryas period: floodplain deposits of this age are dominated by sands and gravels, up to 3m in thickness in the central Wetter valley near Ober-Hoergern, where these sediments are covered by fine-grained overbank sediments (Figure 11). The radiocarbon sequences highlight the rapidity of fluvial sedimentation events, which occur at a scale of hundreds (10^2) rather than thousands (10^3) of years. Pollen analysis and radiocarbon dating also indicate the presence of older sediments that were re-worked and redeposited during the Younger Dryas. Although this period is widely considered to be a phase of colder climate, pollen evidence from the northern Wetterau does not indicate considerable deforestation, while sedimentary evidence from the upstream Wetter near Lich does not indicate a sudden change in fluvial style during the Younger Dryas (*ibid*: 254–255). Yet the majority of the floodplains were affected by increased fluvial activity during this period, with the re-working and deposition of coarse-grained sediments suggesting a climatically-driven change to a braided river system (*ibid*: 260). How can this discrepancy be explained? Houben *et al*. (*ibid*: 260) emphasise the contrasting spatial scales of the palaeo-environmental provided from sedimentological and pollen data, and the differential behaviour of fluvial systems in contrasting parts of the catchment. For example, the upland reaches were influenced by markedly deteriorating climatic conditions, increasing proportions of precipitation stored as snow, high magnitude snowmelt discharges that were capable of entraining and transporting coarse materials, and the minor role of vegetation cover in upland areas. By contrast, the low gradients of the downstream basins resulted in the sedimentation of the coarse-grained sediments, although these lower reaches may have been little affected by the Younger Dryas cooling, hence the absence of major deforestation.
- Preboreal to mid-Holocene: climatic amelioration is indicated during these periods by vegetation development, particularly the widespread expansion of pine forests, and a lithological shift toward the deposition of organic and fine-grained sediments. This is indicated by an undisturbed laminated sequence of thin peat and clay layers at the Niederwald site. This period is also characterised by the widespread development of the Black Floodplain Soil (BFS; a dark brown to black clayey horizon), between 9,800–6,300 cal BP (the Boreal to Atlantic periods). The BFS is interpreted as indicating a geomorphologically stable floodplain, unique during the Holocene. The very high clay content of the BFS is only explainable by its formation under dense vegetation covering the floodplain. The soil therefore developed by a combination of pedogenesis and the slow accretion of overbank fines. The BFS also marks the last phase of natural floodplain development, since all overlying may carry information relating to anthropogenic impacts upon the landscape (*ibid*: 261).

Overall, Houben *et al*. (*ibid*: 261–262) highlighted three issues of relevance in the potential application of geomorphological models to the understanding of varied archaeological sequences:

1. Changes in fluvial sedimentation in the Hessian Depression during the Late Glacial and early–mid Holocene generally correspond to know, overall climatic stages.

2. However, locally different environment conditions can develop in different physiographic settings.
3. Radiocarbon dated channel fills indicate that fluvial events, principally the deposition of sedimentary units, occur relatively rapidly, with a time-scale of hundreds of years associated with the Late Glacial channel filling. Although a 3–4,000 year span is quoted in association with the development of the BFS, the intervals between radiocarbon dates from different sedimentary units in the Wetter valley near Muenzenberg again support timescales for fluvial events with a magnitude of hundreds rather than thousands of years (Figure 11).

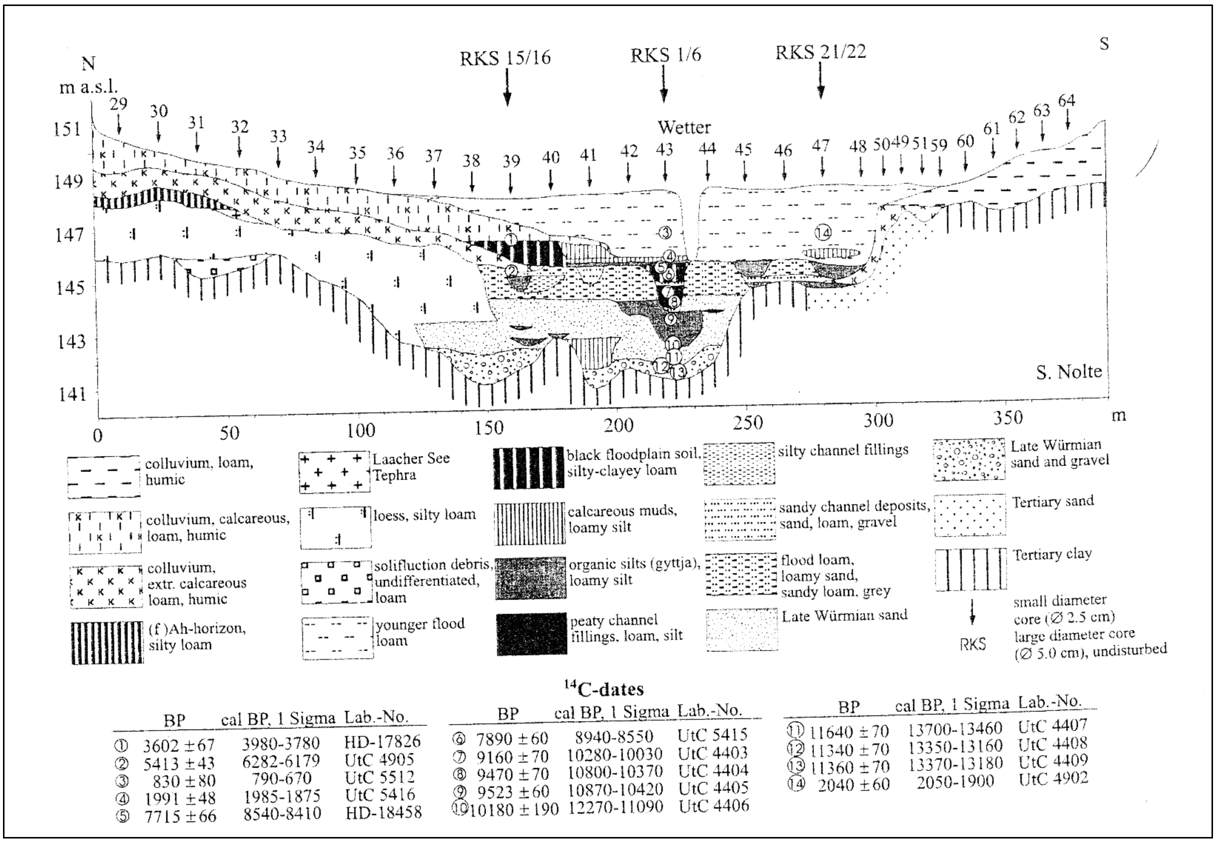

Figure 11: valley cross section near Muenzenberg (Houben et al. 2001: Figure 3)

These case studies therefore suggest a potential common duration for fluvial events of the magnitude of a few hundred years. These observations are also supported by a wide range of other examples of rapid fluvial activity in the extant literature, associated with the river systems from a wide geographical and chronological range:

1. Schirmer (1988, 1995) provides broad chronological frameworks for a series of Middle European rivers (the Amper and Mittel-Isar, Unter-Isar, Donau, Oberrhein, Mittelrhein and Niederrhein, Main, Regnitz, Oberweser and the Mittelweser) over the Upper Würm and Holocene periods. The frameworks indicate the relatively short durations associated with the deposition of both fine and coarse-grained sediments. Examples include the deposition of fine, floodplain sediments over the Schönbrunn terrace during the early Late Würmian, between 13,000 and 11,800 BP; and gravel deposition on the Ebensfeld terrace between 5860 and 4300 BC. Although other chronologies are available suggesting rapid fine-grained sedimentation (e.g. between 5700 and 5300 BP), these events post-date the Neolithic occupation and are therefore likely to at least partially reflect anthropogenic influences such as slope clearance (Schirmer 1995: 45).

2. The Warta river in north-western Poland provides a long chronology of fluvial evolution from the Bølling to the Subatlantic period, punctuated by short periods of rapid fluvial activity (Kozarski *et*

al. 1988). The floor of the Warta valley consists of low bifurcation and transitional terraces, and the floodplain. Radiocarbon dating of organic deposits in the bifurcation terrace at the Zabinko exposure indicates a period of *c.* 600 years during which the palaeochannel was filled (a minimum age of 12,110±140 years BP and maximum age of 12,770±190 BP).

3. Vandenberghe (1993, 1995) documented rapid phases of fluvial activity for the Dinkel and Maas rivers (Netherlands) and the Warta valley (Poland). Up to 8–9m of incision has been recorded in the Dinkel river valley in the eastern Netherlands, between *c.* 13,000 BP (the Weichselian Pleniglacial/Late Glacial transition) and *c.* 11,800 years BP. This phase of fluvial erosion was followed by relatively rapid aggrading of the gullies, which was almost completed by the end of the Late Glacial (*c.* 10,000 BP). Vandenberghe (1993: 23) notes that the phase of fluvial erosion occurred widely in Europe, although it is not clear whether it occurred as or less rapidly in other regions. Radiocarbon dating of organic fills and pollen stratigraphy from the Warta and Maas rivers also highlights rapid fluvial activity in association with the climate change at the Pleniglacial/Late Glacial boundary (Table 2).

	River system		
	Warta		***Maas***
Fluvial styles	*Single meandering channel*	*Fluvial styles*	*Single meandering channel*
Chronological Shift	*c.* 11.6 ka BP	Chronological Shift	*c.* 11.8 ka BP
Fluvial styles	*Multi-channel meandering or anastomising type*		
Chronological Shift	*c.* 11.9 ka BP		
Fluvial styles	*Lateral migration*	*Fluvial styles*	*Multi-channel transitional type*
Chronological Shift	*c.* 12.3 ka BP		
Fluvial styles	*Multi-channel type, with narrow, curved gullies*		
Chronological Shift	*c.* 12.7 ka BP	Chronological Shift	*c.* 12.7 ka BP
Fluvial styles	*Braided type*	*Fluvial styles*	*Braided type*

Table 2: chronology of fluvial events for the Warta (Poland) and Maas (Netherlands) rivers during the Late Glacial (Vandenberghe 1995: 635–636). Chronology in non-calibrated radiocarbon ages.

4. Rose *et al.* (1980) documented fluctuating phases of channel stability and instability for the River Gipping at Sproughton, Suffolk in the UK. Although the channel was stable during the early and middle phases of the Windermere Interstadial and throughout the Flandrian (with limited bedload transport and cohesive banks), it was markedly unstable during the latter part of the Windermere Interstadial and throughout the whole of the Younger Dryas. These phases were characterised by dominant bedload transport, and a channel pattern ranging from deep, large-scale discontinuous gullies, and then to braids. Radiocarbon dates and ages inferred from a coleopteran assemblage (*ibid*: Table 12.1) documented the erosion of discontinuous gully channels between 11,300 and 11,000 years BP, followed by braided and meandering river sedimentation of sands and gravels between 11,000 and 9,500 years BP. Rose *et al.* (*ibid.*) attributed the channel instability to a period of short-lived, high magnitude discharges, with the changes from erosion to deposition and meandering to braiding related to the relative magnitudes of the peak discharges and the quantities of available sediment supplied to the channel from the hill-slopes. Most importantly, it is suggested that the changes indicates the importance of short-lived, climatically induced changes of fluvial energy.

5. Collins *et al.* (1996) also documented changing fluvial activity for the River Kennet, in central southern England. Evidence from the site at Woolhampton highlighted a series of major changes in fluvial activity, linked by pollen and macrofossil data to broad climatic fluctuations: Last Glacial Maximum to the pre-Late Glacial (nival, braided regime, erosion); Late Glacial Interstadial (lower energy flows, incision that increased channel stability, deposition of fines, some erosion at the end of the interglacial); and the Younger Dryas Stadial (increased energy flows, channel deposition of sands and gravels, lateral channel migration, and some channelisation at the end of the stadial).

Radiocarbon dates for the Heales Lock Member of the Woolhampton Formation suggest that deposition of the upper gravels did begin until 11,500–11,000 yr BP at the earliest, and did not persist long after the end of the Loch Lomond Stadial.

6. Maddy *et al.* (2001: 32–33) highlighted the archiving of higher resolution signals of climatic change within individual terrace aggradations, with specific reference to the Northmoor terrace of the Upper Thames valley of the UK. It is emphasised that the sedimentary architecture produced during each aggradation comprises complex cut-and-fill sequences. These sequences reflect short-term changes in sediments, which *may* be triggered by short-term climatic changes (Figure 7). The durations of these climatic changes are proposed to be in the order of one to several millennia (Vandenberghe's (1995) 3rd timescale), although few specific examples are presented (reference is made to cold- and warm-climate shifts within a glacial, such as the Devensian Late Glacial interstadial and the Younger Dryas).

7. There are also a wide range of other studies supporting a model of fluvial activity at the sub-millennial scale, including Bibus & Wesler's (1995)) study of Holocene morphodynamics in the Neckar, Main, Regnitz, Lower Isar, Danube and Upper Rhine; Macklin & Lewin's (1993) identification of relatively brief periods of major Holocene alluviation in UK river systems; and Starkel's (2002) documentation of short, sub-millennial phases of higher flood frequencies and resultant fluvial activity during the central European Holocene (e.g. 8.5–7.8 and 6.6–6.0 ka BP).

Despite the geographical variability and diversity of river systems discussed in the above examples, it is apparent that in all cases, individual episodes of fluvial activity occur relatively rapidly. This appears to hold true whether that activity is channel incision or erosion, sedimentation of coarse-grained sands and gravels, or fine-grained overbank flooding. Thus while the nature of the fluvial activity may vary, in most cases it appears that episodes of fluvial incision/erosion and aggradation (both coarse-grained and fine-grained) occur over a time-spans stretching between a few hundred, or (at the very most) a few thousand years. It is of course emphasised that this fluvial activity (channel migration, incision, erosion and aggradation) was not occurring *constantly* during these periods of decades and centuries, but rather episodically in response to major events (e.g. nival spring floods), such as the 100 year interval flood documented by Schmidt (1994). They key point is that during the periods of fluvial activity these extreme flood events were occurring at a higher frequency (Starkel 2002) than during other periods. Therefore fluvial processes of incision and sedimentation were dominant during these decadal and centennial phases of climatic change and fluvial activity. These chronologies have clear implications for the archaeological interpretation of the European Palaeolithic stone tool assemblages occurring in association with the fluvial sedimentary units of the Middle and Late Pleistocene. In combination with the generic models of fluvial activity across the glacial/interglacial cycle outlined above (Section 2), it can be proposed that:

1. The increasing ice core evidence for multiple, short-term climatic fluctuations at the sub-MIS scale (e.g. Anklin *et al.* 1993; Petit *et al.* 1999) indicates that fluvial activity (erosion and aggradation) will occur both during the major glacial/interglacial transitions, and within the individual glacial and interglacial phases.
2. River system response to minor climatic fluctuations (e.g. within glacial and interglacial cycles) will be sporadic, reflecting catchment size, threshold conditions and other local and regional factors.
3. River system response to major climatic fluctuations (e.g. at the glacial/interglacial and interglacial/glacial transitions) will tend to be more uniform, reflecting the greater magnitude of these events
4. River system response (fluvial incision, sedimentation) will occur relatively rapidly, typically over several hundred rather than several thousand years. It is stressed that these durations are probably over-estimates, since the geochronological sequences on which they are based do not provide estimates for the duration of the 'invisible' breaks in deposition between the superimposed sedimentary units (see below).
5. The fluvial activity associated with the major climatic transitions will be preferentially *preserved* within the fluvial archives over the long-term (compared to the fluvial architecture resulting from

minor climatic oscillations), reflecting threshold factors and the favourable preservation of large-scale sedimentary features.

This modified framework highlights key issues with respect to the interpretation of secondary context assemblages, principally in terms of the duration of the sedimentary events and the differential preservation of large and small-scale sedimentary features. These are fundamental for interpreting the issues of assemblage homogeneity/heterogeneity, and the degree of potential artefact re-working that may have occurred after the *initial* depositional event. However, a key problem still requires investigation: what was the duration of the phases of fluvial inactivity in-between the periods of incision and sedimentation?

4. THE DURATION OF FLUVIAL ACTIVITY HIATUS

Identifying the duration of periods of fluvial inactivity presents a number of considerable problems, reflecting the resolution of currently available geochronological tools, and the highly fragmentary preservation of fluvial sedimentary sequences. Frustratingly, these problems are at odds with the relative ease of identification of breaks in fluvial activity. Commonly recorded features include ice wedge cracks (Figure 12) and other cold-climate indicators, buried soils, weathering horizons, and erosional surfaces within fluvial sedimentary sequences:

1. Conway *et al.* (1996: 119–122) provides a detailed example of a Middle Pleistocene sequence with the documentation of the succession of erosional surfaces in the Barnfield Pit sequence:
    - Erosion surface E1: the base of the channel, cut into Thanet Sand and Chalk (in the northern part of the pit). The surface is marked by some cryoturbation disturbance of the top of the Thanet Sand, on which rests a lag deposit and solifluction material.
    - Erosion surface E2: the irregular top of the basal gravel, marked by a lag deposit resting upon it. The lithology changes from unsorted gravel in clay/silt matrix to well sorted, horizontally-bedded sandy gravel.
    - Erosion surface E3: the irregular surface of the Lower Gravel, with truncated bedding and partial decalcification. The lithology of the overlying beds shows a change to a much lower energy regime of deposition.
    - Erosion surface E4: the surface layer of the Lower Loam is weathered to a depth of *c.* 50 cm and shows decalcification and the development of a soil. The surface is irregular with truncated bedding and the presence of animal footprints. A lag deposit rests upon the surface.
    - Erosion surface E5: the surface of the Lower Middle Gravel shows considerable topography and marks a lithological change from a high energy environment (horizontally-bedded sandy gravels) to a lower energy environment (cross-bedded sands). The bedding of the Lower Middle Gravel is truncated.
    - Erosion surface E6: the upper part of the Upper Middle Gravel shows cryoturbation disturbance and in places a solifluction deposit rests on the surface. The environmental change is from cool fluvial to cold, partially terrestrial conditions.
    - Erosion surface E7: the upper part of the Upper Loam shows marked cryoturbation disturbance together with ice-wedge casts, with a solifluction deposit resting upon the surface.

2. Bridgland (1994) documented extensive evidence for hiatus in fluvial activity, within the Middle Pleistocene sequences within the Thames Valley:
    - Buried soils, including the Barham and Valley Farm soils and the Swanscombe Lower Loam soil, indicating the development of stable landsurfaces (and by inference a temporary cessation in fluvial activity).
    - Gravel deposits showing evidence of cryoturbation and weathering, typified by the 'Silchester' gravel at Hampstead Marshall and the deposits at Martells Quarry, Ardleigh.
    - Weathering horizons, such as that at the Baker's Hole complex where intense rubification indicates both soil development and an interglacial climate.

- Cold-climate indicators, principally ice-crack casts and solifluction deposits, are indicative both of cold climate conditions and exposed landsurfaces.

Figure 12: Ice wedge cast in fluvial sediments, Linch Hill Pit, Oxfordshire

3. Miall (1996) provides a hierarchy of bounding surfaces or unconformities, modified by Jones *et al.* (1999), which highlights the status of the bounding surfaces between the sedimentary units as physical discontinuities within a fluvial depositional sequence. The hierarchy (Table 3) highlights the wide range of scales at which erosional surfaces occur, from scour in the trough of a dune bedform, through channel erosion surfaces to palaeovalleys. These surfaces are associated with contrasting scales of primary processes, in this case bedform migration, channel migration and incision (Bristow 1996: 360–361). Unfortunately, bounding surfaces of the 0^{th}–3^{rd} order occur within the timescales for fluvial activity episodes (100's of years) identified previously and are

therefore of relatively little application here (although they serve as a useful reminder that even during 'periods' of fluvial activity, sedimentation/incision does not occur constantly). The 6th order refers to the 100,000 year Milankovitch cycles of fluvial activity (i.e. terrace development over the glacial/interglacial cycle), which can be observed through the robust evidence of fluvial terrace sequences. The 4th and 5th order surfaces are potentially the most useful, but their timescales essentially refer to the associated processes (e.g. bar or channel development) and not to the interval phases.

The key problem is therefore that the features which document phases of fluvial inactivity or stability cannot be directly dated to provide a measure of the length of the hiatus. For example, while Bryant (1983) has observed that growth rates for ice-wedge casts in modern Arctic stream environments are 0.5 mm $year^{-1}$, their use as a measure of the duration of stable landscape conditions and continuous permafrost would be fraught with assumptions about comparable climatic conditions. Similarly, the cyroturbated and weathered deposits at Ardleigh could have been produced by either frequent lateral shifting of a network of braided channels or by a long period of deposition in an essentially stable fluvial environment. These two interpretations have strikingly different implications for the chronology of the sequence (and for any archaeology occurring within the deposits), yet distinguishing between them is an extremely difficult task. Finally, although soils indicating stable landsurfaces may be utilised as temporal markers, it is impossible to accurately assess how much time is represented by the soils.

Rank	**Character of bounding surface**	**Depositional unit**	**Examples process**	**Timescale of process**
0th order	Lamination surface	Lamina	Burst-sweep cycle	10^{-6}
1st order	Set bounding surface	Ripple (microform)	Bedform migration	10^{-5}–10^{-6}
2nd order	Co-set bounding surface	Dune (mesoform)	Bedform migration	10^{-2}–10^{-1}
3rd order	Reactivation surface	Macroform growth increment	Seasonal events (10 year flood)	10^{0}–10^{1}
4th order	Convex-up macroform top	Macroform (e.g. point bar)	100 year flood, bar migration	10^{2}–10^{3}
5th order	Flat to concave-up channel base	Channel	Long term geomorphic process	10^{3}–10^{4}
6th order	Flat, regionally extensive	Channel belt sequence	Milankovitch cycles	10^{4}–10^{5}

Table 3: hierarchy of bounding surfaces identifiable in fluvial sequences (Lewis and Maddy 1999: Table 5.2)

The problems of directly dating episodes of fluvial stability are of course removed where high resolution dating of sediments above and below the erosive surface or ice crack can provide an indirect estimate. This has been demonstrated by Vandenberghe (1993: Figure 4) at Belvedere, Maastricht in the southern Netherlands, where there is evidence of cryoturbation and frost-cracking in association with the early and late Pleniglacial. However, when dealing with sedimentary sequences from the Middle Pleistocene, the problems of fragmentary preservation and low resolution geochronological tools do not permit this approach.

However, it is possible to approach this issue from the high resolution ice core records now available for the last glacial/interglacial cycle (e.g. van Andel 2003), and rapidly being extended back into the Middle Pleistocene (e.g.; Anklin *et al.* 1993; Petit *et al.* 1999). The ice core records for the last 80,000 years document 21 interstadial events occurring during stages 5a, 4, 3 and 2 (Watts *et al.* 1996). The duration of these events is uncertain (Vandenberghe (2002) dates the Hengelo Interstadial between 41–38.5 ka BP)), reflecting current geochronological toolkits, but whatever their duration, the average interval between an interstadial event in the period 80–10 kya BP is just *c.* 3,300 years. Assuming that the last glacial/interglacial cycle is a sound analogue for earlier periods (see Section 5), it is proposed that an average duration for periods of relative fluvial inactivity is approximately 3,000 years. This estimate is of considerable importance to the interpretation of secondary context artefact assemblages, since it provides an indicator of the periods over which floodplain landscapes remained relatively stable, and therefore artefacts could *potentially* accumulate upon the time-averaged land surface. It is emphasised that these periods may be considerably longer in systems which for various reasons (e.g. catchment size, threshold conditions) do not respond to each of the high frequency, low magnitude climatic oscillations. Nonetheless, the high resolution ice core record would seem to provide the most useful gauge for currently estimating the intervals between the critical phases of pronounced fluvial activity.

5. ANALOGUE ISSUES

A critical issue concerns whether high resolution Late Glacial and Holocene models of fluvial system development are applicable to the interpretation of Middle Pleistocene sequences. Resolution of this issue focuses upon two points: are the climatic and environmental conditions comparable?; and was fluvial development overtly influenced by anthropogenic activity during the Holocene period?

The question of anthropogenic influence is certainly pertinent for many studies of fluvial systems (e.g. Schirmer 1988, 1995; Macklin & Lewin 1993; Bibus & Wesler 1995; Brown *et al.* 2001). For example, Bibus & Wesler (1995) observed that the younger meander systems of the Neckar floodplain show evidence of human influence in the form of heavy soil erosion in the drainage basin; meander system development in rapid succession; and the rapid accumulation of thick, high-water loam layers. Similarly, Schirmer (1995: 45–46) emphasised a series of human impacts upon the development of central European fluvial systems during the mid and late-Holocene, including augmentation of flood sediment in loess-rich areas (e.g. the thicker flood sediments of the Ebensfeld Terrace on the Oberrhein) and the input of soil materials into fluvial deposits; changes in the type of sedimentation (e.g. the increase in suspension load on the Main river), although river activity rhythms and cycles do not appear to be influenced; and the widening, branching and flattening of the river bed, combined with the augmentation of flood sediment and the elevation of flood levels, promoting a braiding pattern.

In light of these factors, the use of analogue models for fluvial system activity and development should be restricted to the Late Glacial and early Holocene periods. Fluvial development in these periods shows no apparent evidence of anthropogenic impacts, but continues to provide a relatively high resolution radiocarbon chronological record. This however leads directly to the second key issue — whether the climatic and environmental conditions of the Late Glacial and early Holocene periods are applicable to the Middle Pleistocene?

Throughout the last 12 MI stages, climate change has been dominated low-frequency (100 ka) eccentricity-driven cycles (Lowe & Walker 1997: 12–13; Maddy *et al.* 2001), suggesting that the overall pattern of glacial/interglacial cycles over the Middle and Late Pleistocene has remained relatively consistent. However, while the Late Glacial and early Holocene periods essentially document a glacial/interglacial transition, from MIS-2 (the Devensian/Pleniglacial) into MIS-1 (the Flandrian/Holocene), this transition is complicated by the presence of brief climatic oscillations. The UK's Devensian Late Glacial divided into the Windermere Interstadial and the Loch Lomond Stadial, and continental north-west Europe's Weichselian Late Glacial further splits into the Bølling Interstadial, Older Dryas Stadial, Allerød Interstadial, and Younger Dryas Stadial (Lowe & Walker 1997: 9–13). It is clear from the previous case studies that these short-lived climatic oscillations played an importance in the documented phases of fluvial development and rapid activity in northern European rivers during this period. Were such oscillations therefore common during the Middle Pleistocene? This is difficult to currently assess, but available ice core evidence (e.g. Anklin *et al.* 1993; Petit *et al.* 1999) is supportive of parallels between the Late Glacial and the early Late Pleistocene and the Middle Pleistocene. Specifically, the GRIP core (Anklin *et al.* 1993) indicates a series of shifts during the Eemian (MIS-5e) from warm interglacial to mid-glacial period conditions. These changes appear to be both transient (lasting decades or centuries and analogous to the climatic mode switches that have been identified in the late glacial period) or can last up to 5,000 years. The core data indicates 3 warm sub-stages of MIS-5e (5e1, 5e3, and 5e5) and two cool sub-stages (5e2 and 5e4), and it is notable that many features of the Eemian cool events appear to be parallel the changes in the Younger Dryas. Overall however, the most striking feature of this period is the series of high-amplitude, high frequency oscillations, which appear to be evidence of rapid climate change, with cold/warm mode switching completing in as little as 1–2 decades but may also become latched for between 70 and 5,000 years. Over longer timescales the Vostok core (Petit *et al.* 1999) records a comparable sequence for all four of the climatic cycles since 420,000 years BP, with a warm interglacial stage (MIS 11.3, 9.3, 7.5 and 5.5) followed by increasingly colder interstadial events, and ending with a rapid return towards the following interglacial. Finally, the recent stage 3 project (van Andel & Davies 2004) has provided high resolution data from one part of the late glacial/interglacial cycle, and it is notable that van Huissteden *et al.* (2001: 75) have argued that stage 3 can be considered to represent 'average' glacial conditions, despite its strong climatic variability characterised by rapid climatic oscillations (as discussed above with respect to the Late Glacial). They suggest that the variability may be an intrinsic property of such average glacial conditions, with only glacial and extreme glacial conditions characterised by far less variable climates.

Overall therefore, while the situation is not yet certain, the available evidence appears to suggest that the climatic and environmental patterns of the Late Glacial (short-lived climatic oscillations) do appear to be replicated throughout the Middle Pleistocene, in association with glacial, interglacial and transitional phases. Given the apparent link between rapid climatic oscillations and relatively short phases of fluvial activity during the Late Glacial it is proposed here that similar relationships would have been prevalent during the Middle Pleistocene and that therefore the use of Late Glacial and early Holocene analogues is a valid approach.

6. SUMMARY

This chapter began to highlighting three issues that are critical to the understanding and interpretation of archaeological assemblages occurring within fluvial secondary contexts:

- What are the patterns of deposition and preservation of sand, gravel, clay and silt sediments, and what is the approximate duration of the fluvial episodes associated with their deposition?
- What is the approximate proportion of the Middle Pleistocene glacial/interglacial cycles preserved within river terrace fluvial aggregates sequences, either as sedimentary units or erosional features?
- What is the duration of the depositional hiatus and/or erosive events within fluvial sedimentary sequences?

These issues were explored through an examination of extant models of fluvial activity across the glacial/interglacial cycle, studies of Late Glacial and Holocene fluvial activity, and the latest ice core-derived models of climatic fluctuation during the Middle and Late Pleistocene. The results are summarised below:

1. Fluvial activity (including both sedimentation of fine and coarse-grained deposits and erosion/incision of floodplain and channel features) is associated with climatic change, although the relationship is not linear, but rather highly complex. Evidence from the last glacial/interglacial cycle and the Holocene indicates that these periods of dynamic climatic change were relatively brief, and that the resultant phases of fluvial activity were also relatively short-lived, typically lasting hundreds rather than thousands of years. It is stressed that fluvial activity was not occurring constantly during these phases simply that those activities were the dominant system processes (e.g. reflecting increased frequency of high magnitude spring floods). These periods of dynamic climate change are associated both the major glacial/interglacial climatic transitions (occurring approximately every 50,000 years during the 100,000 years eccentricity-driven cycles of the Middle Pleistocene) and also with the minor climatic oscillations (stadial and interstadial events) that occurred within the glacial and interglacial parts of the cycle. It is likely that all fluvial systems responded to the major climatic transitions, reflecting both their overall duration and the magnitude of the events. However, system response to minor climatic oscillations would have been far more variable, reflecting both climatic factors (e.g. the length and magnitude of the event) and non-climatic system variables (e.g. catchment size, threshold values, and local and regional palaeogeography). Preservation of sedimentary units would have been favourably weighted towards large-scale features created in response to high magnitude events, while the small-scale products of minor climatic oscillations would have been highly vulnerable to

subsequent erosion.

2. Fluvial activity across the interglacial/glacial cycle is characterised in terms of major events at the glacial/interglacial and interglacial/glacial transitions, and a series of sporadically represented minor climatic oscillations throughout the cycle:

   - Late glacial/early interglacial and late interglacial/early glacial transitions: relatively rapid phases of incision, followed by coarse-sediment, all in response to changes in sediment and water supply. Vegetation development, evapotranspiration rates and related factors (e.g. run-off rates, bank stability) are key factors in this phase. The duration of these phases are unclear, but current MIS and ice core data would *suggest* periods of less than *c.* 5,000 years.
   - Interglacial: relative quiescence, with small-scale fluvial activity (e.g. channel migration and fine-grained sedimentation) in response to minor climatic oscillations (e.g. stadial and interstadial events). Evidence from the last glacial/interglacial cycle suggests that minor climatic oscillations (e.g. interstadial events) may occur *on average* every 3–4,000 years.
   - Glacial: general stability, with minor fluvial activity (e.g. channel migration and sediment deposition) in response to minor climatic oscillations.

   It is extremely difficult to estimate the proportion of the glacial/interglacial cycle represented within fluvial sedimentary sequences, primarily because the response of individual systems to climatic events is highly variable, whilst the sedimentary products of any responses are often vulnerable to subsequent erosion during the cycle (especially where the features are small-scale). We would cautiously suggest that as a general rule of thumb, less than 10% of the glacial/interglacial cycle is represented within sequences, with the majority of preserved sedimentary features associated with the major climatic transitions. This applies both to large-scale systems (which are less likely to respond to minor climatic oscillations, and also to small-scale systems, where the sedimentary products of minor events are vulnerable to subsequent erosion).

3. The time intervals between episodes of active fluvial activity (incision, erosion and deposition) are difficult (if not impossible) to estimate from sedimentary sequences. Evidence from ice core records suggests an average interval between minor climatic oscillations of approximately 3–4,000 years. However, it is critical to recall that not all of these events will lead to fluvial system response (see above) and that even where fluvial activity does occur, the physical evidence may be subsequently eroded. There is therefore a contrast between the time intervals between climatic events, fluvial activity and preserved fluvial activity.

6.1 A Floating Geochronology

The issues discussed above highlight the considerable problems facing the construction of a geochronological framework for Middle Pleistocene fluvial sedimentary sequences (and their archaeological content). Ultimately these are all grounded in the resolution of currently available geochronological tools. The major currently available dating technique for fluvial sedimentary sequences is optically stimulated luminescence (e.g. Lewis & Maddy 1999; Hosfield & Chambers 2002b), and it is clear that the error ranges associated with sample ages do not allow for the correlation of sedimentary architecture with individual climatic oscillations identified in the ice core records. Nor does the technique support the correlation of sedimentary units recorded in different sites or different exposures of a single site. However, OSL ages do permit the identification of the age of sedimentary features at the MIS scale (e.g. Hosfield & Chambers 2002b) and these estimates can be correlated against other sources of geochronological evidence such as amino-acid ratios (e.g. Lewis & Maddy 1999). This relatively coarse degree of geochronological resolution supports the preliminary framework of fluvial activity over the interglacial-glacial cycles (point 2 above). In regions with significant rates of uplift (e.g. southern England), these cycles of fluvial activity are preserved as fluvial deposits in association with discrete terrace features (Maddy *et al.* 2001).

Within this framework, fluvial activity is associated with climatic change, including both the high magnitude, low frequency climatic shifts associated with the glacial/interglacial transitions (and vice-versa) and the minor, low magnitude, higher frequency climatic oscillations association with all phases of the cycle. As discussed above, it is highly probable that not all of these climatic events will be represented within the sedimentary archive of a river terrace deposit. This is due both to the differential response of river basins to high/low magnitude climatic events (fluvial systems may simply not respond to very low magnitude, high frequency climatic oscillations), and the vulnerability of sedimentary features (especially those of a relatively small-scale) to subsequent erosion and removal from the archive. It is therefore argued here (following Bridgland 1994, 2000, 2001) that the majority of preserved coarse-grained sediments and fluvial architecture *probably* relate to the major phases of interglacial/glacial and glacial/interglacial transition, although it is stressed that the current resolution of geochronological dating tools rarely enables this to be unequivocally demonstrated.

These problems of low resolution geochronological tools, incomplete representation of climate shifting events within the fluvial archive, and incomplete preservation of sedimentary features in the archive therefore hugely complicate any attempts to define a sub-MIS geochronology. Even where there is a clear sequence of distinct terrace features relating to glacial/interglacial cycles (e.g. as with the Middle and Lower Thames), the individual sedimentary units and features within the terrace deposits cannot be precisely aged, and only sometimes can they be relatively dated with the cycle. This is typically dependent upon the presence of unequivocal interglacial sediments within the terrace deposits, since these can indicate the approximate ages of the sediments lying stratigraphically above and below them. For example, the presence of MIS-7 interglacial sediments in a terrace deposit (securely dated on the basis of fauna, amino-acid ratios and OSL) would *suggest* ages of the MIS-8/7 transition and the MIS-7/6 transition for the coarse-grained sedimentary units above and below them. Yet it cannot be assumed that such sedimentary features (especially those that are small scale) represent the major climatic transitions, rather than being a fortuitously preserved relic of a short-lived climatic oscillation during an interglacial or glacial phase. Moreover, the stratigraphic sequence and position of sedimentary units can also be misleading, given the potential for extensive erosion and differential preservation in local parts of the deposit.

Yet at the same time what is clear is that these sedimentary units represent sporadic but high magnitude fluvial activity (e.g. nival spring flood events) over relatively short periods of time, perhaps as little as 1 or 2 decades, and rarely more than a few hundred years in duration. We are therefore left with an unusual scenario, in which the chronology of the individual sedimentary features is relatively well understood in terms of its magnitude (primarily 10^1 and 10^2 years — based on Late Glacial analogues), although the exact age of the features remains unknown. These features cannot be related to the climatic oscillations and switches evident in the high resolution ice-core record, both because of the lack of high resolution dating techniques for the deposits (preventing direct correlation) and the complexities of system response and sporadic preservation (preventing indirect correlation between the number of sedimentary features and the number of climatic oscillations and switches). The broader age of the features can be estimated, based on:

- Geochronological dating tools (e.g. OSL, AAR, faunal and pollen assemblages).
- Geochronological models of terrace sequences, based on Bridgland's (1994, 1995, 1996, 2000, 2001; Maddy *et al.* 2001) framework of terrace formation and fluvial activity across the glacial/interglacial cycle.
- The spatial scale of the sedimentary features, which is *indicative* (but no more) of the magnitude of the climatic transition/oscillation with which it was associated.

The geochronology is therefore absolute at the scale of MIS cycles, but is a relative one at the sub-MIS scale, although the duration magnitude associated with individual sedimentary features and fluvial events can be estimated on the basis of Late Glacial analogues. We refer to this as a semi-floating geochronology. What does this mean for the interpretation of archaeological debris (typically stone tool assemblages) occurring in secondary context within fluvial sedimentary units?

6.2 Implications for archaeological material

The implications of the proposed geochronological framework for archaeological interpretation operate in two scales: firstly, with respect to the analysis of temporal trends in archaeological data, for example the similarities and contrasts between two assemblages occurring in sediments of different ages; and secondly, with respect to the interpretation of the archaeological assemblages' temporal homogeneity/heterogeneity, in terms of the processes involved in the incorporation of the cultural debris (e.g. stone artefacts) within the fluvial sediments.

In terms of the analysis of temporal trends, the cyclical terrace forming frameworks of Bridgland (1994, 1995, 2000, 2001) have provided a mechanism for the analysis and comparison of secondary context archaeological data at the MIS scale for over ten years (e.g. White 1998a; Wymer 1999; Ashton & Lewis 2002). However, it is clear from the discussion above, that it is currently not possible to analyse and compare secondary context data at the sub-MIS scale in terms of an absolute geochronological framework. This is a desirable goal, since it would support the investigation of high resolution research questions, for example whether there is evidence for changing behavioural strategies (e.g. in terms of stone tool manufacture) in response to short-term climatic shifts and limited phases of warm and/or cold climate. Unfortunately, current geochronological tools and methodologies do not provide absolute ages for sub-MIS events and cannot tie specific sedimentary features to particular events. However, even if these tools and methodologies were available, it would still be necessary to consider the second issue: the process of artefact and assemblage incorporation within sedimentary bodies and their temporal dimension.

6.2.1 Duration of fluvial depositional events

Studies of fluvial system development during the Late Glacial and early Holocene suggest that fluvial events such as channel erosion or floodplain sedimentation occur relatively rapidly, over a few hundred or a few thousand years. These time-scales are likely to be over-estimates, and reflect the limitations of both the Late Glacial radiocarbon chronologies and the stratigraphic resolution of the sedimentary records. The key issue from an archaeological perspective is therefore that the archaeological content of a single sedimentary context can be bracketed within a timescale of (at most) several hundred years rather than several thousand or tens of thousand of years. It should be noted that this approach highlights the need for high resolution recording of fluvial sedimentary sequences with respect to their archaeological content, in particular the sub-division of sediments on the basis of cut and fill features and erosion surfaces. Most important however, is the point that this temporal bracketing of the archaeological content refers only to the process of the incorporation (entrainment) of the artefacts within the fluvial system and subsequent deposition as part of the sedimentary body. It does not therefore permit the immediate asking of research questions that operate at the decadal or centennial scale (e.g. is there evidence in the stone tool assemblage for localised traditions in tool-making that lasted for a handful of generations). The reason for this is that the artefacts could have lain on the floodplain or valley slopes for millennia prior to their incorporation, and that the artefacts could be a variety of markedly different ages.

6.2.2 Dormancy in the fluvial record

Late Glacial and Holocene studies suggest that river systems respond to short-lived, low magnitude and high frequency climatic oscillations, albeit not inevitably and in a complex fashion. The duration of these oscillation events is uncertain, reflecting current geochronological toolkits, but whatever their duration, the average interval between an interstadial event in the period 80–10 kya BP is just *c.* 3,300 years. Although the nature of fluvial system response to these climatic oscillations is variable, this would suggest that the potential for heterogeneous artefact 'assemblages' to accumulate, undisturbed, upon floodplains through repetitive artefact discard over several millennia or tens of millennia is slight. It is proposed that artefact accumulations would be re-worked into fluvial sediments every few thousand years, as a result of fluvial activity in response to minor climatic oscillations. It is stressed that these assemblages are temporal palimpsests (they might of course actually represent single occupation phases but this cannot be demonstrated), but of the order of a few thousand, rather than a few tens of thousand, of years. It is also noted that the time-depth of these temporal palimpsests will vary, most obviously between small river systems, which tend to be most sensitive and responsive to the high frequency, low magnitude climatic oscillations (Vandenberghe 2003), and the larger systems, in which there is greater potential for undisturbed artefact discard and accumulation over longer time-spans. Unfortunately however, this assessment of the temporal palimpsest scale also does not permit the asking of research questions that operate at the millennial scale (e.g. is there evidence in the stone tool assemblage for either 'standardisation' or variability in tool-making over thousands of years). The reason for this is the most awkward of archaeological problems when dealing with secondary contexts — namely that the artefacts may have been re-eroded out of older sedimentary units.

6.2.3 The glacial/interglacial cycle

The considerable evidence for localised erosion of fluvial architecture within Late Glacial and Holocene sequences (e.g. Rose *et al.* 1980; Vandenberghe 1993; Collins *et al.* 1996) is augmented by the fragmentary records for the Middle Pleistocene (e.g. Bridgland 1994; Maddy *et al.* 2001) and highlights the potential problem of artefact erosion and re-working. Adopting Bridgland's (1994) model of terrace formation it should be clear that artefacts re-worked from the oldest sediments on a terrace feature into the youngest sediments may be spanning two or even three MI stages. There is no simple solution to this problem, although we propose in chapters 4, 5 and 7 that the physical condition of artefacts can be a useful indicator of the degree of re-working (both vertical and horizontal) that artefacts have undergone (see also Hosfield & Chambers in prep.). Nonetheless, it is clear that when dealing with secondary contexts the starting assumption must be that the assemblage is a mixed collection of re-worked artefacts of different ages, and that one is dealing with a time-averaged palimpsest of the order of tens of thousands of years. It should be clear that this has fundamental implications both the types of questions that may be asked and for the interpretation of the data.

Overall therefore, an episodic model is proposed, with periods of major fluvial activity during phases of climatic transition, separated by longer periods of *relative* system dormancy, interspersed with minor climatic oscillations. The proportion of glacial/interglacial cycles represented within river terrace sequences is difficult to estimate, due to the low resolution geochronological tools, the variability of individual system response to sub-MIS low magnitude climatic oscillations, and unfavourable preservation of small-scale sedimentary features. As a preliminary estimation it is suggested that no more than 10% of the cycle is represented within a terrace sedimentary sequence, based on current ice core and MIS chronologies. Overall therefore, the sedimentary and archaeological materials occurring in river terrace sequences were as probably deposited during a series of episodic intervals within the glacial/interglacial cycle, associated with the formation of the terrace landforms at the major climatic transitions. The second key to understanding the archaeological material however, stems from the recognition that; (1) materials may have been eroded from older sediments prior to their terminal deposition; and (2) the age of the material's manufacture, use and discard may be considerably older than the age of the deposits from which it is ultimately recovered. Addressing these issues forms the core of chapters 5 and 8.

7. CONCLUSIONS

It is clear that at the current time the most robust geochronological framework for the analysis of archaeological assemblages in secondary context (fluvial sedimentary units) operates at the MIS scale. This reflects both the current limitations of geochronological tools and extant models of cyclical terrace development and large-scale fluvial activity across the glacial/interglacial cycle. Absolute chronologies at the sub-MIS scale are currently impractical, but the evidence for fluvial activity during the Late Glacial and early Holocene periods has highlighted some important issues with respect to the potential future interpretation of secondary context data:

- Individual fluvial events (e.g. gully erosion, coarse-grained braidplain sedimentation, fine-grained overbank flooding) occur relatively rapidly, with time-scales of an identifiable magnitude of 10^2 and 10^3 years, in partial response to short-term climatic oscillation and change.
- The relatively rapid duration of these individual events is a widespread, shared phenomena, although the specific response of individual river systems (and individual reaches within those systems) to the same climatic events can vary markedly.

- The ice core record indicates a high frequency of low magnitude climatic oscillations during the Middle and Late Pleistocene, occurring within the broader 100,000 year framework of glacial/interglacial cycles and the major phases of climatic change.

These observations and data both highlight the climatic instability of the period, and indicate that there is *potential* for secondary context assemblages that both accumulated (through discard in the fluvial landscapes) and were incorporated within fluvial sediments over relatively short time-spans (10^2 and 10^3 years in magnitude). Such high resolution geochronological timescales permit the asking of a variety of research questions, including issues of standardisation in lithic production, and stasis and change in stone tool technology. However, these data also highlight the problems of artefact re-working through sediment erosion, and it is clear that considerably more work is required to address those problems. We therefore hope that this paper's focus upon geochronological frameworks and fluvial sedimentary contexts has emphasised the potential of secondary context data and the value of such work.

CHAPTER 3
GEOARCHAEOLOGY OF THE BROOM LOWER PALAEOLITHIC LOCALITY

1. INTRODUCTION

The Lower Palaeolithic locality at Broom (Figure 13) lies in the valley of the modern River Axe, on the border of Devon and Dorset. Middle Pleistocene fluvial deposits (gravels, clays, silts and sands) were first commercially exposed in the late 19th century, through the digging of the Railway Ballast Pit (ST 326020). During the 20th century major excavations were undertaken in Pratt's Old and New Pits (ST 328025), approximately 250 metres to the north of the Ballast Pit. The Ballast Pit has yielded approximately 300 artefacts, although there has been extensive mixing of the Broom materials since their original collection. Pratt's Old Pit yielded nearly 900 artefacts, mostly thanks to the work of C.E. Bean during the 1930's.

Despite the richness of the discoveries at these sites in the past (Reid Moir 1936; Shakesby & Stephens 1984; Green 1988; Wymer 1999: 182–3; Marshall 2001), the site chronology and geoarchaeological context remains only vaguely established and there has been no attempt to link the deposits with the marine isotope record.

The focus of this chapter therefore concerns a reconstruction of the Pleistocene environment of the river Axe valley, in the vicinity of the Broom locality. Particular focus was placed upon the fluvial sedimentary sequence, in light of the models and conclusions discussed in the previous chapter:

- The depositional conditions associated with the fluvial sediments.
- The palaeo-environmental conditions associated with the deposition of the fluvial sediments.
- The age of the fluvial sediments.
- The duration of the fluvial events (depositional and erosional) associated with the sedimentary sequences.

1.1 History of Research

There has been a long tradition of archaeological and geological research in the Axe valley. Evans (1872: 559) made the earliest references to Palaeolithic materials from this region, recording four palaeoliths found by workmen erecting telegraph posts between Axminster and Chard. In 1878 subsequent discoveries were made in the Ballast Pit by W.S.M. D'Urban, curator of the Exeter Museum). Fluvial gravels had been removed to a depth of 12m, only 3m above the current river level, while at other pits in the region the depth of the gravel was recorded as being lower than the river level. D'Urban observed the variety of artefact states present in the assemblage, with materials occurring in both sharp and waterworn states. Gravels were subsequently exploited at Kilmington, Chard Junction, and in the new pits in the Broom area (Pratt's Old and New Pits to the north and south of Holditch Lane respectively), which were worked in the 1930's, 1940's and 1950's.

The trade in palaeoliths during the late 19th and early 20th centuries is well documented (e.g. Roe 1981), and Broom was no exception (White pers. comm.):

"Broom, Chard.
I got none of these (they are all rather good) for under 10s/ ea, generally 12s/
The larger specimens cost 16. 18. 20 & 22s — some are the best that have been found.

Of late I have not been able to get any at any price. Same with D'Urban who bought everything — here is a scrap of one of the letters where he says he can get nothing:
"High as prices are, the men get better — where I know not"

(Fragment of a latter from W.G. Smith to Sir John Evans with reference to the prices of the Broom artefacts)

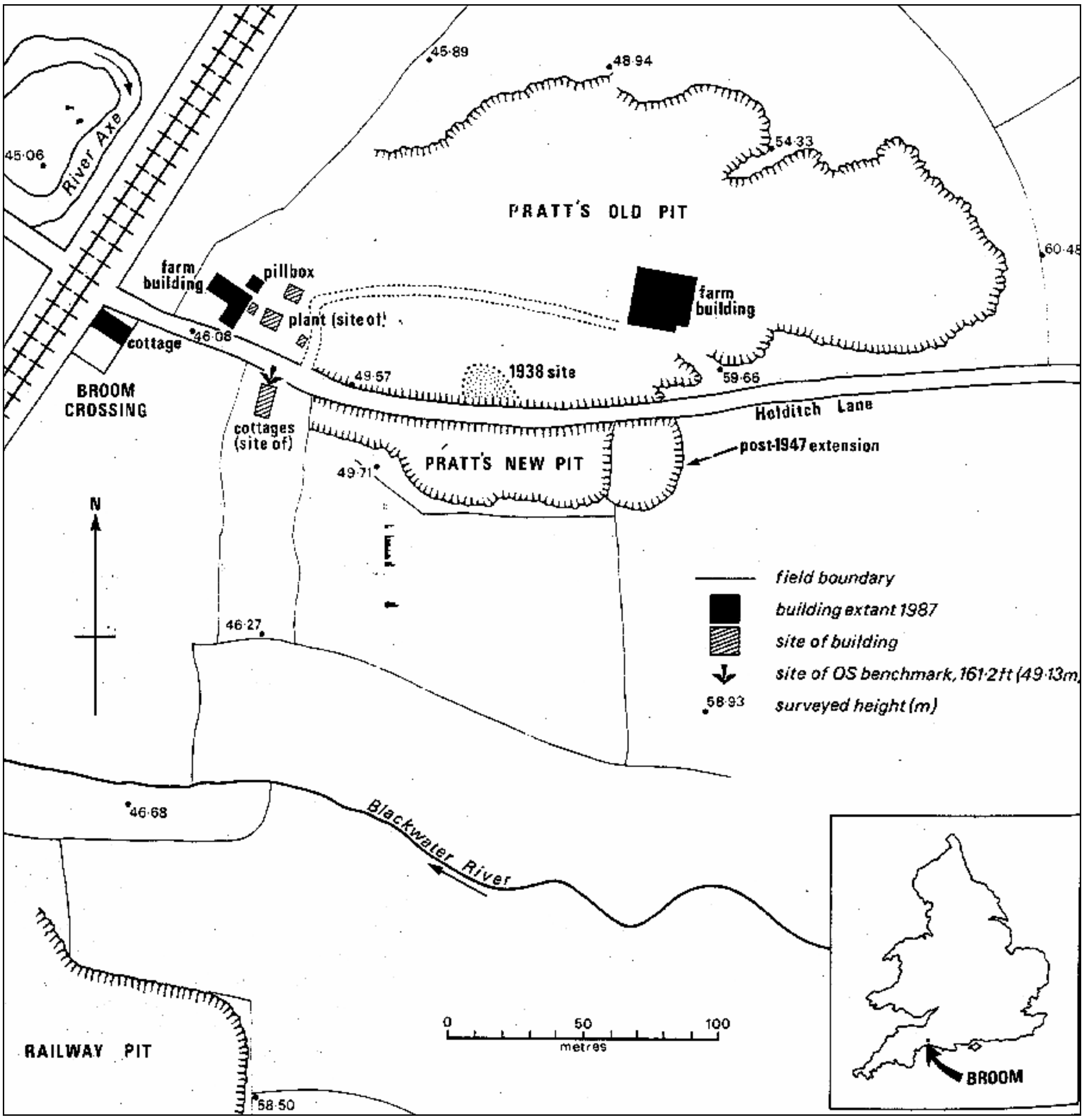

Figure 13: location of the Broom Lower Palaeolithic locality (Devon/Dorset border, UK), including the three main gravel workings (Railway (Ballast) Pit, Pratt's New Pit, and Pratt's Old Pit). (Green 1988: Figure 1).

"There are 94 stones — the two hammers not included
The 4 from Broom cost me between 12s/ and #1 ea. 9 from Canty. 12s/ ea. on the average the others 5s/6s/7s/8s — irrespective of carriage & cost of wasters
3 polished ones I gave the man £1 for & his wife (previously) a leg of mutton and a bottle of port
Some I cannot estimate, as I paid the men so much without results
If they are worth 10s/ ea. to you (one with the other) send that — if not 7s/- or 5s/- — what you like — I don't mind — I shall be satisfied any way & will send a brief receipt — cannot send any acct —
Any novelties, or stone from new places that may turn up I shall be sure to reserve for Hemel Hempstead, as my duty"

(Fragment of a letter from Worthington Smith to Sir John Evans, 25th December 1882 with reference to the purchase price of the artefacts)

Pratt's Old Pit (on the northern side of Holditch Lane, immediately east of the railway level crossing) was worked in the 1930's. Extensive observations were undertaken by C.E. Bean F.S.A (Surveyor for Sherborne), produced a collection of at least 899 palaeoliths, predominantly bifaces (Wessex Archaeology (1993b: 163) lists 1804 bifaces, 1 Levallois core and 2 Levallois flakes for the Broom sites). Bean recorded the exposed stratigraphy in sketches and photographs and concluded with Reid Moir (1936) that the deposit was tripartite, with "stratified gravel and old land surfaces" lying between cherty gravels above and flinty gravel below. They argued that fresh palaeoliths were coming from the middle bed and derived palaeoliths from the gravels above and below. During the late 1930's Pratt & Son opened their new pit, on the south side of Holditch Lane. During the late 1970's, new investigations (Shakesby & Stephens 1984; Green 1988; Scourse unpub. man.) confirmed the geological observations of Bean and Reid Moir from the 1930's. It was concluded from Bean's records that the fresh palaeoliths were from the top of the flint gravels, beneath polleniferous clays and silts that were interglacial in character.

There are very few other Palaeolithic sites yielding material from fluvial terrace gravel contexts within this region. The Chard Junction pit has yielded very little, although a Quaternary Research Association visit produced a biface and flakes from the gravel scree and reject dump (Wymer 1977). It is therefore possible that the paucity of material reflects insufficient observation at Chard Junction, the only remaining working pit in the Axe valley. Isolated bifaces have also been found on the surface of Head deposits or solid rocks on the interfluves above the coombes which cut through the plateaux. Some material has also come from the lower slopes and the small stream beds of the coombes (e.g. at Wambrook and Whitestaunton). Wessex Archaeology (1993b: 166) suggests that the artefacts from the lower levels of the coombes were originally discarded at higher levels and have descended with the Head deposits that often flank the slopes. The Head deposits extending over the plateaux contain sand and gravel and vary from 1 to 15m thickness (Ussher 1906: 48). The disturbance, reworking and movement of the deposits by solifluction and permafrost during glacial episodes are likely to have mixed palaeoliths into the sediments.

1.2 Geology of the Axe Valley

The River Axe flows through South Somerset, West Dorset and East Devon, entering the English Channel at Seaton. The river meanders in a wide floodplain between Chard Junction and Kilmington (the stretch including the Broom gravel pits). The river basin is characterised by comparatively flat-topped hills and low plateaux. Some of the west and north-west facing escarpments are prominent, although the basin tends to lack steep slopes (Shakesby & Stephens 1984: 77). The Axe has a steep profile, falling 25m in the 10km between Axminster and Seaton (Wessex Archaeology 1993b: 159).

Around Broom the River Axe cuts through Foxmould Chert Beds of Upper Greensand, bands of sandstone and chert up to 35m thick. Other lithic raw materials in this region are relatively, rare, restricted to river gravel flint cobbles and the fresh flint Chalk outcrop at Beer. Shakesby & Stephens (1984) identified a depositional regime at Broom of braided streams, operating under cold climate conditions. It has been suggested that the deposits are at least partly fluvio-glacial, deriving from an ice margin somewhere to the north of the Chard Gap (Wessex Archaeology 1993b: 166). The alternative model suggests that the deposits were largely derived from the remnant gravel patches of pre-Pleistocene age on the interfluves, and from the chert Head deposits on the slopes. Both agencies indicate a starkly different fluviatile regime during the Middle Pleistocene.

Stephens (1974) has emphasised the role of the Chard Gap (at 90m OD, compared to the local interfluves at 230–290m OD) in the origin of the Axe gravels. He argued that a pro-glacial lake may have existed in the Bristol Channel-Severn Valley as a result of ice blocking the western end of the Bristol Channel, and that the lake may have discharged southwards through the Chard Gap. This discharge event would wash masses of rock debris into the Axe Valley, accounting for the thick gravel deposits and their absence along the upper Axe Valley east of Chard. This model follows work as far back as Maw in 1864 in its view of a Bristol Channel which was once blocked with ice. Green (1974) however has challenged this interpretation, pointing out the total absence of erratics which should have been discharged by the meltwaters of a glacier lying to the north.

1.3 The Palaeo-environment

Scourse (unpub. man.; in Shakesby & Stephens 1984: 84) suggested a temperate floodplain environment of possible 'Hoxnian'[1] age. Pollen extracted from clays and silts in the Railway Ballast Pit suggested regional, boreal forest vegetation dominated by pine (*Pinus*), spruce (*Picea*) and birch (*Betula*), with silver fir (*Abies*). The tree types were probably limited to small patches in favoured localities, while open country dominated with ericaceous heath on the higher ground. Scourse concluded that the deposits were probably laid down at the end of a Middle Pleistocene interglacial (possibly the Hoxnian) or during an interstadial, perhaps within the Wolstonian[1] (*ibid.* 86–87).

Scaife (unpub. man.) extracted clay samples from palaeochannel deposits lying within the coarser river terrace gravels exposed in sections 2 and 5 (Railway Ballast Pit). The channel deposits contained fine-grained sediments comprising silts and fine to medium sands. The fine-grained silts were grey and unoxidised, and were clearly lain down in a low energy environment, perhaps on a floodplain or in a meander cut-off. The pollen data suggests a boreal environment with stands of pine woodland, and possibly occasional spruce and fir. The latter species are under-represented in pollen spectra, and may therefore have been of greater importance than suggested above. The small numbers of oak, hazel, alder, and ash are enigmatic and may represent the initial stages of vegetation succession at the beginning of an interglacial period. Alternatively, they may represent re-worked pollen from a preceding, older phase. The numbers are small however, and subordinate to the importance of the boreal woodland. The importance of the Poaceae (grasses) either indicates a local or on-site dominance (e.g. floodplain grassland or the edges of the channel) or wider areas of open grassland within scattered coniferous woodland.

The greater significance of grasses in the Scaife study (compared to the work of Scourse) may be due to the profile originating from a channel fill of different age, or from sediments of the same broad age, but spanning a different phase. The existence of the thermophiles may support the notion that the profile forms part of an interglacial sequence, although it is not clear whether this is pre-temperate or post-temperate phase.

2. MODEL OF DEPOSITION FOR THE BROOM SEDIMENTARY SEQUENCE

The Broom sedimentary sequence has been exposed in 15 sections during the excavation programme led by a team from the Department of Archaeology, University of Southampton (2000–2003). The sections were distributed between the 3 Broom pits (Railway Ballast Pit, Pratt's New Pit, and Pratt's Old Pit) and exposed aspects of the Broom tripartite sequence of upper gravels, middle beds, and lower gravels (Figure 14 & Figure 51). Recording of the excavated sections consisted of lithostratigraphic logging (Figure 17–Figure 37), section drawing, clast fabric analysis (discussed in Section 4) and photography (Figure 38–Figure 49). The lithostratigraphic logs, section drawings, selected site photographs and interpretations of fluvial regimes (Table 4–Table 25) are included.

[1] Scourse's work was undertaken prior to the major revision of British Pleistocene geochronology that occurred in the late 1980's and 1990's, in response to the MIS data and new dating frameworks (e.g. the amino-acid ratio work of Bowen *et al.* 1989 and Bridgland's (1994) investigation of the Thames terrace sequences). The Hoxnian and Wolstonian as used by Scourse therefore represent broader time periods than is currently generally accepted.

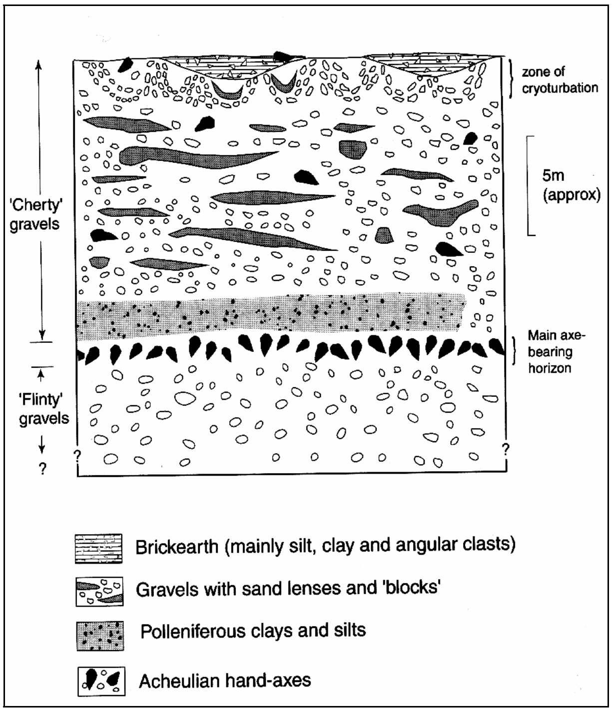

Figure 14: Broom tripartite sequence of sedimentary deposits (Shakesby & Stephens 1984: Figure 2)

2.1 Facies models and the depositional environment

The lithofacies classification scheme of Miall (1996: Table 4.1) was initially adopted for the interpretation of the sequence, as were Miall's (1996: Table 4.2) hierarchical classifications of depositional units and bounding surfaces. Also incorporated were the modified schemes of Jones *et al.* (1999: Table 3.2) and Lewis & Maddy (1999: Tables 5.1 & 5.2). However, it was rapidly apparent from the fieldwork and initial post-fieldwork examination of the data that these schemes were extremely difficult to apply to the Broom sedimentary sequences. With the exceptions of sections 9 and 14, there was little evidence of fluvial bedforms or fluvial architecture as described by Miall (1996). The Broom sedimentary facies were dominated by:

- Gmm (matrix-supported massive gravel, with no sedimentary structures (Jones *et al.* 1999: Table 3.2) or with grading (Lewis & Maddy 1999: Table 5.1).
- Gcm (clast-supported massive gravel).
- Sm (sand, fine to coarse, with massive or faint lamination).

With occasional occurrences of:

- Gm (massive or crudely bedded gravel, including horizontal bedding and/or imbrication).
- Sr (sand, very fine to coarse, with ripple marks of all types (Jones *et al.* 1999: Table 3.2) or with ripple cross-lamination (Lewis & Maddy 1999: Table 5.1).
- St (sand, medium to coarse), with solitary or grouped trough cross-beds.
- Sl (sand, very fine to very coarse), with horizontal lamination, parting or streaming lineation.
- Fl (sand, silt, mud deposits, with fine laminations, very small ripples.

The restricted exposures of the excavated sections (typically 2m width) also reduced the potential to identify and discuss channel morphology (e.g. depth/width ratios) or identify laterally-extensive fluvial structures such as bar forms (although section 1 was considerably wider, the majority of the section was inaccessible for detailed examination due to the local topography).

Despite the limitations of the sedimentary sequence exposures, it was apparent from the range of facies present (particularly in section 9 — Table 6), the clast fabric data (Section 4), and extant work (Shakesby & Stephens 1984; Green 1988 & pers. comm.) that the Broom deposits represent a fluvial sedimentary sequence. However, in light of the domination of the Broom sequence by facies Gmm (matrix-supported massive gravel), Gcm (clast-supported massive gravel), and Sm (sand, fine to coarse) it was not felt to be viable to apply the traditional models of facies classification, bounding surfaces and architectural elements (Miall 1996: Tables 4.1, 4.2 & 4.3) to the deposits. Consequently, is very difficult to discuss the fluvial palaeo-landscape or the temporal evolution of the sedimentary sequence in great detail. A basic outline therefore follows.

In general, the sequence suggests a basic evolution of the Axe Valley fluvial landscape through time, as illustrated at the Broom locality:

Cold-climate, gravel-bed, rivers (braided? anastomosing?) of high energy and multi-channel (?) type (associated with the lower gravels in the Broom sequence) >>> warm-climate rivers of low energy, sinuous (?), single-channel (?) type (associated with the Broom middle beds) >>> cold-climate, gravel-bed, rivers (braided? anastomosing?) of high energy and multi-channel (?) type (associated with the upper gravels in the Broom sequence).

It is also clear however that the Broom sedimentary sequence does not represent a homogeneous series of sediments within the macro-categories of the upper gravel–middle beds (fine grained)–lower gravel sequence. There is considerable variation within these units, with the presence of fine-grained sediments within the lower gravels (section 3, north face, Table 14, Figure 40 & Figure 41) and the upper gravels (sections 9, 10 and 13, Table 6, Table 19, Table 24, Figure 44–Figure 47 & Figure 49) indicating changes in the fluvial regime from higher to lower energy systems. These changes occur within phases of sedimentation dominated by coarse-grain gravels, and may reflect short-term shifts in the fluvial and climatic regime. Two important caveats must also be considered:

1. The erosive surfaces evident in the sequence (e.g. bounding the upper surface of the fine-grained sand units in section 9 — Figure 45 & Table 6) indicate the potential for the removal of low energy sediments during returns to high energy fluvial regimes. It is therefore likely that the fine-grained sediments within the Broom sequence are somewhat under-represented due to preservation bias.
2. The fine-grained sediments (e.g. the massive sands (Sm) in sections 10 and 13) may in some cases represent backwater conditions on the floodplain or braidplain (i.e. a spatial shift in the locations of the active, high energy channels), rather than a temporal change in climatic conditions.

Overall, the presence of fine-grained sedimentary units (sandwiched by coarse-grained gravels) between *c.* 42.50m and 44.50m O.D. (sections 2, 3 and 5, Railway Ballast Pit), *c.* 47.00m and 48.50m (section 9, Pratt's New Pit), and *c.* 50.70m and 52.00m (sections 10 and 13, Pratt's New Pit), *suggest* a series of major oscillations in the fluvial regime (Figure 16). While the error ranges associated with the OSL dates from these sediments and with the currently available ice-core data make it extremely difficult to relate specific depositional events (of fine-grained units) with specific climatic transitions, some tentative correlations are presented in Section 3.

It is also stressed that even where coarse-grained (or fine-grained sediments) are 'uniformly' distributed within an exposed section, vertical changes in grain size, quality of sorting, bedding forms and laminar structures (where present), and matrix colour (?) indicate changes (albeit less dramatic) in levels of fluvial energy and the system regime. These trends are evident in all of the major sections (Figure 17–Figure 37 & Figure 38–Figure 49), and are indicative of the dynamism of the Broom sequence. The sedimentary responses to changes in the fluvial regime are both continuous (as indicated by gradational contacts between the individual units) and episodic (marked by sharp, erosive contacts), reflecting the discontinuous nature of the terrestrial sedimentary record.

2.2 Episodic fluvial activity?

Building upon chapter 1, a key question concerns the temporal nature of the fluvial activity that generated the Broom sedimentary sequence and the context for the Lower Palaeolithic artefact assemblage. In essence, the question concerns whether the processes of erosion and deposition (cut and fill) and the sequences of high–low–high fluvial energy fluctuations occurred continuously or incorporate breaks and hiatus in activity.

It is assumed, following the extant literature (Chapter 2), that the deposition of the individual sedimentary units was a relatively rapid process, although there is relatively little data (due to the general absence of bedform data in the exposed Broom sections) currently available from the site to support this statement. The preservation of fine-grained, laminated sediments in section 14 indicates rapid deposition in a still water channel or pond, but the stratigraphy and OSL samples for this section suggest that these deposits may be considerably younger than the other sediments (as a result of these discrepancies, the data from Section 14 has been excluded from the current analysis). Moreover, the OSL chronologies are not of sufficiently high resolution to enable the modelling of sediment deposition. For example, the four OSL dates for the fine-grained sediments in section 2 (sampled from the top, middle and bottom of the unit) cover 63,000 years and are therefore of little practical use with respect to sub-MIS chronologies (see Section 3 for further details of the OSL sampling programme).

The sedimentological data does suggest episodic fluvial activity, primarily indicated by the frequent occurrence of sharp, erosive contacts (both regular and irregular) between the individual sedimentary units (Table 4–Table 25; Figure 17–Figure 37). The changes in sediment types and grain sizes (e.g. from coarse-grained sand to medium, matrix-supported gravel in section 9, south face) indicate contrasting fluvial regimes and fluvial energy levels, while the erosive surfaces (e.g. Figure 45) indicate a temporal break between the deposition of the respective sedimentary units. It is not currently possible to establish the timescales associated with the breaks in deposition, due to the general absence of bedform and architectural element data and the extremely limited possibilities for the application of well-established depositional unit and bounding surface hierarchies:

> "the textual and structural monotony of conglomerates may make recognition and correlation of bounding surfaces more difficult in these types of deposits."
>
> (Miall 1996: 81)

However, the paucity of evidence for weathering, cryoturbation and major cold climate indicators such as ice wedge casts within the sedimentary sequence suggests that the periods of depositional hiatus were probably relatively brief.

2.3 Formation of Contemporary Landsurfaces

Additional evidence for the presence of breaks in the sedimentary sequence is provided by the indicators for episodes of landsurface stabilisation development throughout the sequence. There are several examples of manganese/iron staining horizons (e.g. Figure 43) in the Broom sedimentary sequence:

- Section 2 (West face): manganese/iron horizons at 44.36m OD, 44.13m OD and 42.88m OD. Sharp, irregular boundaries with medium, matrix-supported gravel (Gmm) above, and clay below (upper horizon); sharp, regular boundaries with clay above, and cross-laminated sand (Sr) below (middle horizon); and sharp, irregular boundaries with sandy-silt (Sm) above, and medium, matrix-supported gravel below (lower horizon).
- Section 3 (South face): manganese/iron horizons at 42.37m OD and 42.32m OD. Sharp, regular boundaries with medium, matrix-supported gravels (Gmm) above and below.
- Section 3 (West face): manganese/iron horizon at 43.13m OD. Sharp, regular boundaries with medium, matrix-supported gravels (Gmm) above and below.

- Section 5 (East face): manganese/iron horizon at 42.41m OD. Sharp, regular boundaries with medium, matrix-supported gravels (Gmm) above and below.
- Section 5 (North face): manganese/iron horizons at 42.44m OD and 42.18m OD. Sharp, regular boundaries with medium, matrix-supported, horizontally-bedded gravels (Gm) above and below (upper horizon); and sharp regular boundaries with medium, matrix-supported, horizontally-bedded gravel (Gm) above, and fine, matrix-supported, horizontally-bedded gravel (Gm) below (lower horizon).
- Section 13 (west face): manganese/iron staining between 50.74m OD and 51.25m OD. Sharp, irregular boundaries with massive, medium sand (Sm), above and below.

These manganese/iron staining and horizons (sections 2, 3, 5, and 13) are suggestive of episodes of stability (possible landsurface development) and associated pedogenic activity within the sequence. The vertical position of the horizons does not provide unequivocal evidence for multiple, distinct episodes of stability, since local variations in floodplain topography (as a result of fluvial cut and fill activity) are poorly understand. Nonetheless, four separate phases of predominating floodplain stability are provisionally suggested:

1. Incorporating the horizons at 42.37m OD, 42.32m OD (both section 3, south face), 42.41m OD (section 5, east face), 42.44m OD and 42.18m OD (both section 5, north face). The presence of two horizons in sections 3 (south face) and 5 (north face) *suggest* two stable periods within the phase, perhaps only separated by short periods of time.
2. The horizons at 42.88m OD (section 2, west face) and 43.13m OD (section 3, west face).
3. The horizons at 44.36m OD and 44.13m OD (section 2, west face). The presence of two horizons in a single section face again suggests two periods of stability within the phase.
4. The staining between 50.70m OD and 51.25m OD (section 13, west face).

It is emphasised that the position of these manganese/iron layers within the soil profile and their depth relationship to the associated contemporary landsurfaces cannot be ascertained, as subsequent erosive activity has removed significant portions of the sequence. What is clear is that the unit is a post-depositional phenomena and not a primary bedform and therefore has no implications for the fluvial regime.

2.4 Summary

Analysis of the Broom sediments indicated:

1. A combination of multi-channel, high energy (braided) and single-channel, low energy (meandering) fluvial systems. Reconstruction of the floodplain environment has been difficult due to the paucity of diagnostic bedforms, although there is evidence for minor channel sediments (section 9).
2. At least four major episodes of fine-grained sedimentation, reflecting a series of probable changes in the fluvial regime from high to low-energy conditions. OSL dating (Section 3 for further discussion) suggests that the altitudinal separation of these fine-grained units (Figure 16) may reflect a genuine chronological distinction.
3. Regular, minor changes in fluvial energy levels, reflected by the variations (grain size, sorting, bedding forms, laminations and matrix colour) within coarse and fine-grained sedimentary units. Transformations in the characteristics of the deposited sediments were both continuous (gradational contacts) and discontinuous (separated by minor erosive contacts).
4. Episodic fluvial activity, indicated by the major erosive contacts separating fine-grained and coarse-grained sedimentary units (e.g. section 9).
5. Development of stable landsurfaces at different times throughout the sequence (indicated by the occurrence of multiple iron/manganese horizons), supporting the other evidence for episodic fluvial activity interspersed with periods of relative quiescence.

Overall, the analysis of the sedimentary sequences from Broom does not contradict the fluvial activity model of episodically-occurring, rapid depositional events (discussed in the previous chapter). However, the general absence of classical fluvial bedforms (coarse and fine-grained) in the Broom sedimentary sequence restricts the potential to apply the classical facies models and discuss temporal issues from a unit and bounding surface hierarchy approach.

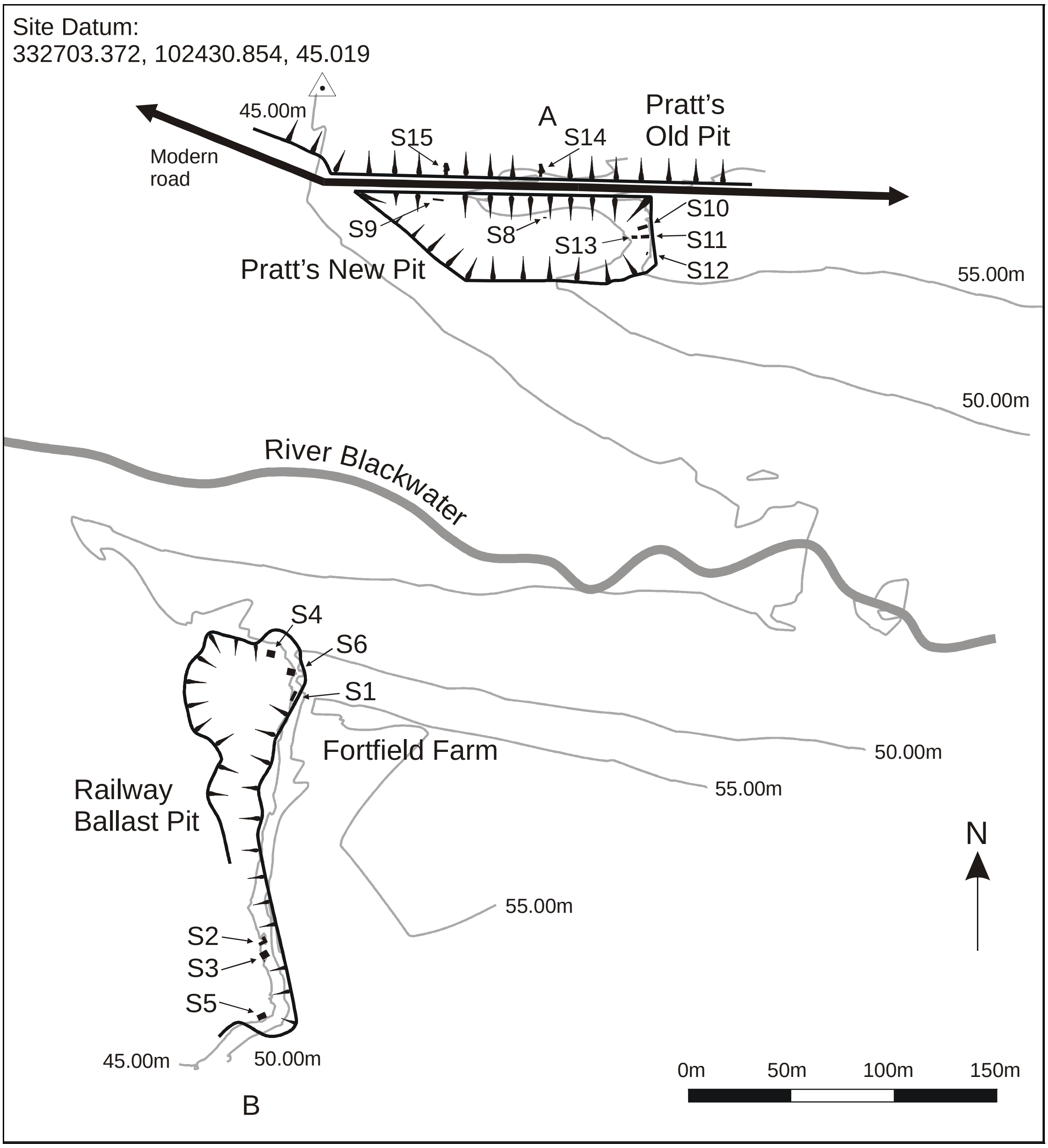

Figure 15: location of sections at the Railway Ballast Pit, Pratt's New Pit & Pratt's Old Pit, Broom, Devon/Dorset, UK)

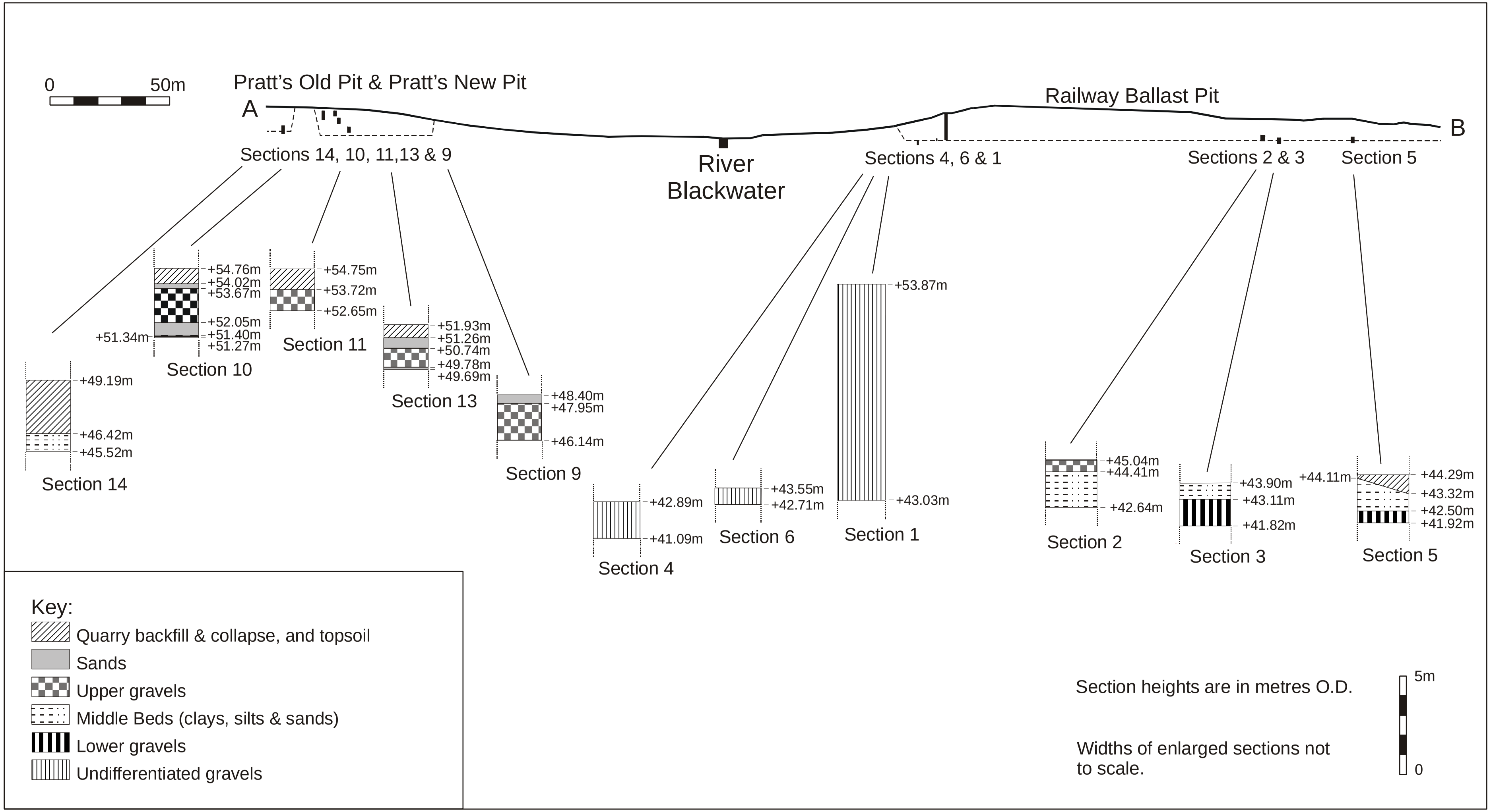

Figure 16: summary of the Broom sedimentary sequence

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Fine sand		Low energy			3
	≠				
Fine matrix-supp. gravel		Medium energy			2
	≠				
Medium matrix-supp. gravel		High energy			
	≈				
Medium matrix-supp. gravel		High energy			
	≈				
Fine clast-supp. gravel		Medium energy			
	≈				
Medium matrix-supp. gravel		High energy			
	≈				
Medium matrix-supp. gravel		High energy			1
	≈				
Medium matrix-supp. gravel		High energy			
	≈				
Fine clast-supp. gravel		Medium energy			
	≈				
Medium matrix-supp. gravel		High energy			
	≈				
Coarse matrix-supp. gravel		Very high energy			

Table 4: Section 9, East face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. — — —: regular, gradational contact

Deposit	***Contacts***	***Fluvial activity***	***Continuous activity***	***Hiatus/ erosion***	***Phase***
Slumped					
	≠				
Medium matrix-supp. gravel		High energy			8
	≠				
Medium matrix-supp. gravel		High energy			7
	≠				
Medium matrix-sup. gravel		High energy			
	≈				
Fine matrix-supp. gravel		Low energy			6
	≈				
Medium matrix-supp. gravel		High energy			
	≠				
Medium clast-supp. gravel		High energy			5
	≠				
Medium matrix-supp. gravel		High energy			
	≈				4
Fine matrix-supp. gravel		Medium energy			
	≠				
Medium matrix-supp. gravel		High energy			
	≈				3
Medium matrix-supp. gravel		High energy			
	≠				
Medium sand		Low energy			2
	≠				
Medium matrix-supp. gravel		High energy			1

Table 5: Section 9, West face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. — — —: regular, gradational contact)

Deposit	***Contacts***	***Fluvial activity***	***Continuous activity***	***Hiatus/ erosion***	***Phase***
Medium matrix-supp. gravel		High energy			12
	—				
Coarse sand		Low energy			11
	—				
Fine sand		Low energy			10
	—				
Medium sand		Low energy			9
	≠				
Coarse clast-supp. gravel		Very high energy			8
	≠				
Medium matrix-supp. gravel		High energy			
	≈				
Medium matrix-supp. gravel		High energy			
	– – –				7
Very fine matrix-supp. gravel		Low energy			
	≈				
Fine matrix-supp. gravel		Medium energy			
	≠				
Fine matrix-supp. gravel		Medium energy			6
	≠				
Fine matrix-supp. gravel		Medium energy			5
	≠				
Coarse matrix-supp. gravel		Very high energy			4
	≠				
Medium matrix-supp. gravel		High energy			
	≈				
Coarse clast-supp. gravel		Very high energy			3
	≈				
Medium clast-supp. gravel		High energy			
	—				
Medium matrix-supp. gravel		High energy			
	≈				
Medium matrix-supp. gravel		High energy			2
	≈				
Medium matrix-supp. gravel		High energy			
	≠				
Medium matrix-supp. gravel		High energy			1

Table 6: Section 9, South face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	**Contacts**	**Fluvial activity**	**Continuous activity**	**Hiatus/ erosion**	**Phase**
Slumped					
	—				
Coarse sand		Low energy			
	– – –				3
Clay		Very low energy			
	—				
Fine matrix-supp. gravel		Medium energy			2
	—				
Medium matrix-supp. gravel		High energy			1

Table 7: Section 8, East face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	—				
Medium matrix-supp. gravel		High energy			1

Table 8: Section 8, West face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Clay		Very low energy			7
	≠				
Sand/silt		Low energy			6
	≠				
Medium matrix-supp. gravel		High energy			
	≈				5
Medium matrix-supp. gravel		High energy			
	≠				
Fine matrix-supp. gravel		Medium energy			4
	≠				
Coarse sand		Low energy			3
	≠				
Clay		Very low energy			2
	≠				
Medium matrix-supp. gravel		High energy			1

Table 9: Section 8, South face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Sand		Low energy			6
	≠				
Sand/silt		Low energy			5
	≠				
Fine matrix-supp. gravel		Medium energy			4
	≠				
Medium matrix-supp. gravel		High energy			3
	≠				
Fine matrix-supp. gravel		Medium energy			2
	≠				
Medium matrix-supp. gravel		High energy			1

Table 10: Section 5, West face, Railway Ballast Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Medium matrix-supp. gravel		High energy			4
	≠				
Iron/Manganese horizon		Pedogenic? / Weathering?			3?
	≠				
Medium matrix-supp. gravel		High energy			2
	≠				
Medium matrix-supp. gravel		High energy			1

Table 11: Section 5, East face, Railway Ballast Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Coarse sand		Low energy			12
	≠				
Clay		Very low energy			
	≈				
Silt		Low energy			
	≈				
Sand/silt		Low energy			11
	≈				
Clay		Very low energy			
	≈				
Fine matrix-supp. gravel		Medium energy			
	≠				
Sand/silt		Low energy			10
	≠				
Silt		Low energy			9
	≠				
Sand/silt		Low energy			8
	≠				
Medium matrix-supp. gravel		High energy			7
	—				
Iron/Manganese horizon		Pedogenic? / Weathering?			6?
	—				
Medium matrix-supp. gravel		High energy			5
	≠				
Medium matrix-supp. gravel		High energy			4
	≠				
Iron/Manganese horizon		Pedogenic? / Weathering?			3?
	—				
Fine matrix-supp. gravel		Medium energy			2
	≠				
Medium matrix-supp. gravel		High energy			1

Table 12: Section 5, North face, Railway Ballast Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Sand/silt		Low energy			3
	≠				
Medium matrix-supp. gravel		High energy			2
	≠				
Fine matrix-supp. gravel		Medium energy			
	≈				1
Medium matrix-supp. gravel		High energy			

Table 13: Section 3, South face, Railway Ballast Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	—				
Medium matrix-supp. gravel		High energy			4
	≠				
Sand/silt		Low energy			3
	—				
Coarse clast-supp. gravel		Very high energy			2
	—				
Medium matrix-supp. gravel		High energy			1

Table 14: Section 3, North face, Railway Ballast Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Medium matrix-supp. gravel		High energy			6
	≠				
Clay		Very low energy			5
	≠				
Sand/silt		Low energy			4
	≠				
Medium matrix-supp. gravel		High energy			
	≈				3
Fine matrix-supp. gravel		Medium energy			
	≠				
Silt		Low energy			2
	≠				
Medium matrix-supp. gravel		High energy			1

Table 15: Section 3, West face, Railway Ballast Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Medium clast-supp. gravel		High energy			5
	≠				
Fine sand		Low energy			4
	≠				
Medium clast-supp. gravel		High energy			3
	≠				
Clay		Very low energy			
	≈				
Sand		Low energy			
	≈				2
Clay		Very low energy			
	≈				
Silt		Low energy			
	≠				
Medium clast-supp. gravel		High energy			1

Table 16: Section 2, West face, Railway Ballast Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Fine matrix-supp. gravel		Medium energy			3
	≠				
Fine sand		Low energy			2
	≠				
Medium matrix-supp. gravel		High energy			
	≈				1
Medium matrix-supp. gravel		High energy			

Table 17: Section 1, Railway Ballast Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Fine sand		Low energy			8
	≠				
Silt (multiple events)		Low energy			7
	—				
Silt		Low energy			6
	—				
Fine sand		Low energy			5
	—				
Silt (multiple events)		Low energy			4
	≠				
Silt (multiple events)		Low energy			3
	≠				
Clay (multiple events)		Very low energy			2
	—				
Sand/silt/clay (upwards fining)		Low energy			1

Table 18: Section 14, North face, Pratt's Old Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Medium sand		Low energy			5
	—				
Medium matrix-supp. gravel		High energy			4
	—				
Medium matrix-supp. gravel		Medium energy			
	≈				3
Medium matrix-supp. gravel		High energy			
	≠				
Medium matrix-supp. gravel		High energy			2
	—				
Medium sand		Low energy			1

Table 19: Section 13, West face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Clay		Very low energy			7
	—				
Medium matrix-supp. gravel		High energy			6
	≠				
Fine clast-supp. gravel		Medium energy			5
	≠				
Medium matrix-supp. gravel		High energy			4
	≠				
Medium sand		Low energy			3
	≠				
Medium matrix-supp. gravel		High energy			
	≈				2
Medium matrix-supp. gravel		High energy			
	≠				
Medium sand		Low energy			1

Table 20: Section 13, North face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Medium matrix-supp. gravel		High energy			5
	≠				
Fine matrix-supp. gravel		Low energy			4
	≠				
Medium matrix-supp. gravel		High energy			3
	≠				
Fine clast-supp. gravel		Low energy			2
	≠				
Medium matrix-supp. gravel		High energy			1

Table 21: Section 11, West face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Fine matrix-supp. gravel		Low energy			3
	—				
Medium matrix-supp. gravel		Medium energy			
	≈				2
Medium matrix-supp. gravel		High energy			
	≠				
Medium matrix-supp. gravel		Medium energy			1

Table 22: Section 11, South face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	—				
Medium matrix-supp. gravel		High energy			7
	—				
Fine matrix-supp. gravel		Medium energy			6
	≠				
Medium matrix-supp. gravel		High energy			
	≈				5
Medium matrix-supp. gravel		High energy			
	≠				
Fine clast-supp. gravel		Medium energy			4
	≠				
Medium matrix-supp. gravel		High energy			3
	≠				
Fine clast-supp. gravel		Medium energy			2
	—				
Medium matrix-supp. gravel		High energy			1

Table 23: Section 11, North face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Fine gravel		Medium energy			10
	≠				
Silt		Low energy			9
	≠				
Medium matrix-supp. gravel		High energy			8
	≠				
Fine matrix-supp. gravel		Medium energy			7
	≠				
Fine matrix-supp. gravel		Medium energy			6
	≠				
Coarse matrix-supp. gravel		Very high energy			5
	—				
Fine matrix-supp. gravel		Medium energy			4
	≠				
Fine sand		Low energy			3
	—				
Fine matrix-supp. gravel		Medium energy			2
	—				
Fine sand/clay		Very low energy			1

Table 24: Section 10, West face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

Deposit	Contacts	Fluvial activity	Continuous activity	Hiatus/ erosion	Phase
Slumped					
	≠				
Medium matrix-supp. gravel		High energy			12
	≠				
Silt		Low energy			11
	≠				
Medium matrix-supp. gravel		High energy			10
	≠				
Silt		Low energy			9
	≠				
Fine matrix-supp. gravel		Medium energy			8
	≠				
Medium matrix-supp. gravel		High energy			7
	≠				
Fine matrix-supp. gravel		Medium energy			6
	—				
Coarse matrix-supp. gravel		Very high energy			5
	—				
Medium matrix-supp. gravel		High energy			4
	≠				
Clay		Very low energy			3
	—				
Fine matrix-supp. gravel		Medium energy			2
	—				
Fine sand		Low energy			1

Table 25: Section 10, South face, Pratt's New Pit, Broom (≠: sharp, irregular contact. ≈: irregular, gradational contact. —: sharp, regular contact. – – –: regular, gradational contact)

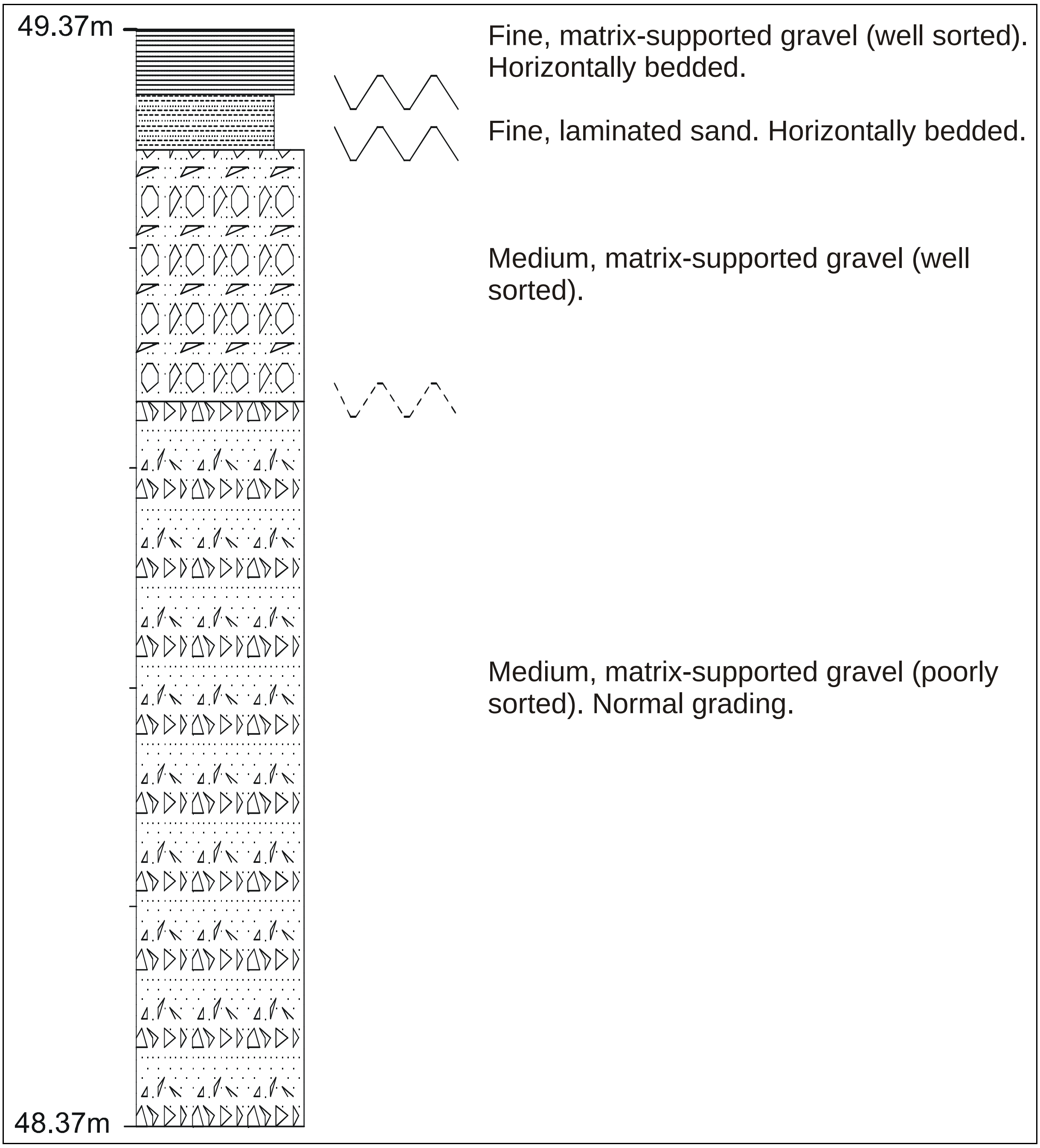

Figure 17: lithostratigraphic log, section 1 (west face), Railway Ballast Pit, Broom

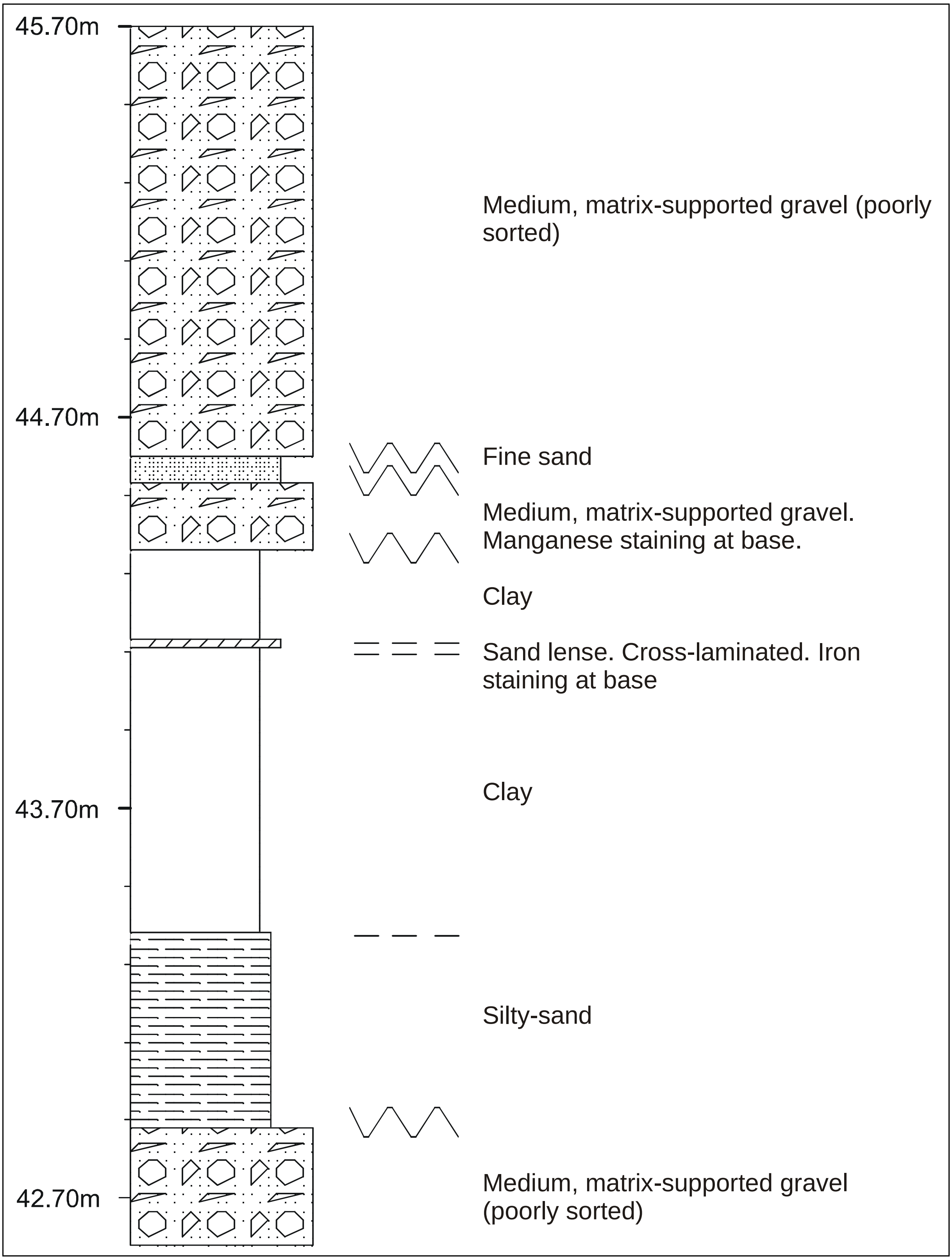

Figure 18: lithostratigraphic log, section 2 (west face), Railway Ballast Pit, Broom

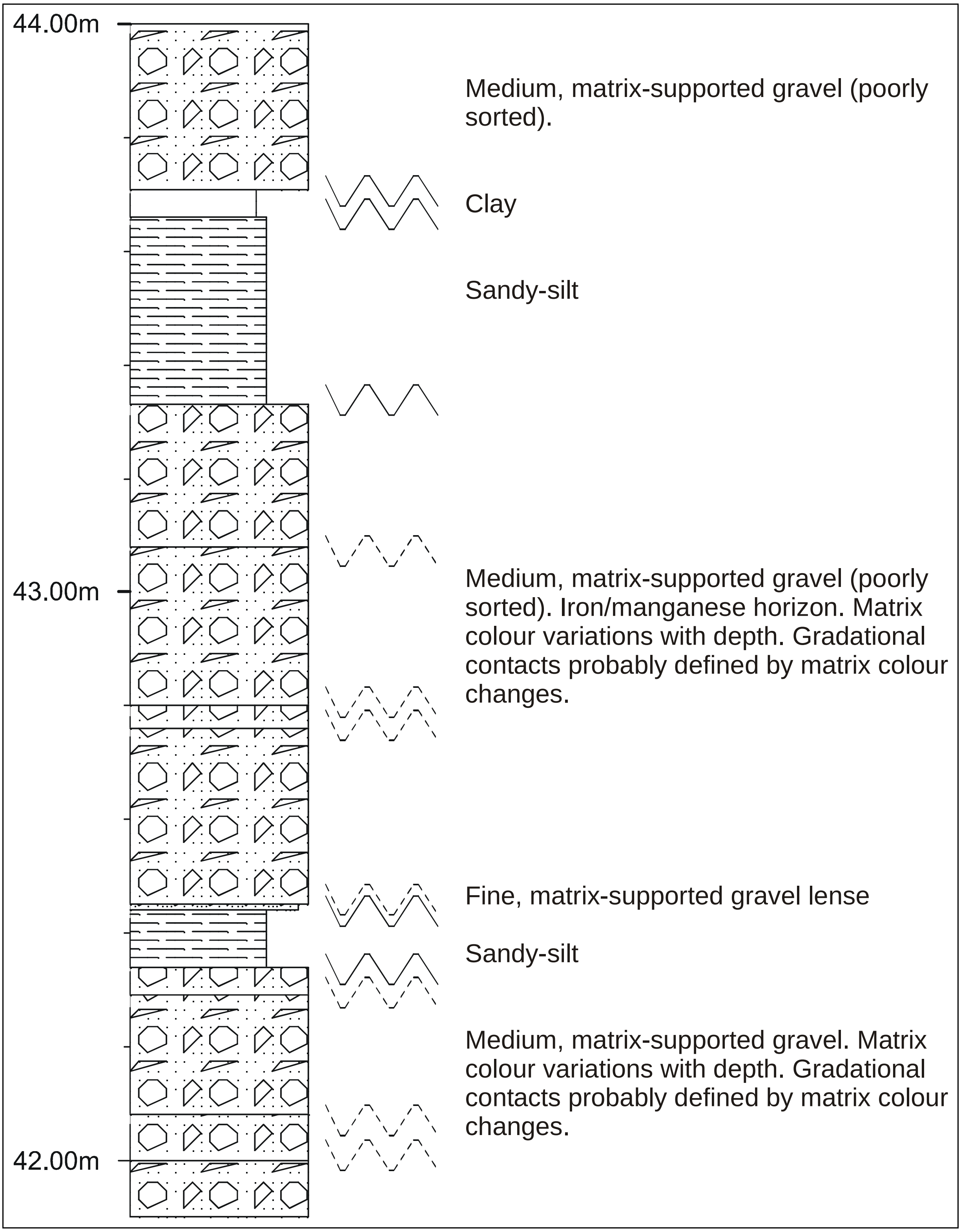

Figure 19: lithostratigraphic log, section 3 (west face), Railway Ballast Pit, Broom

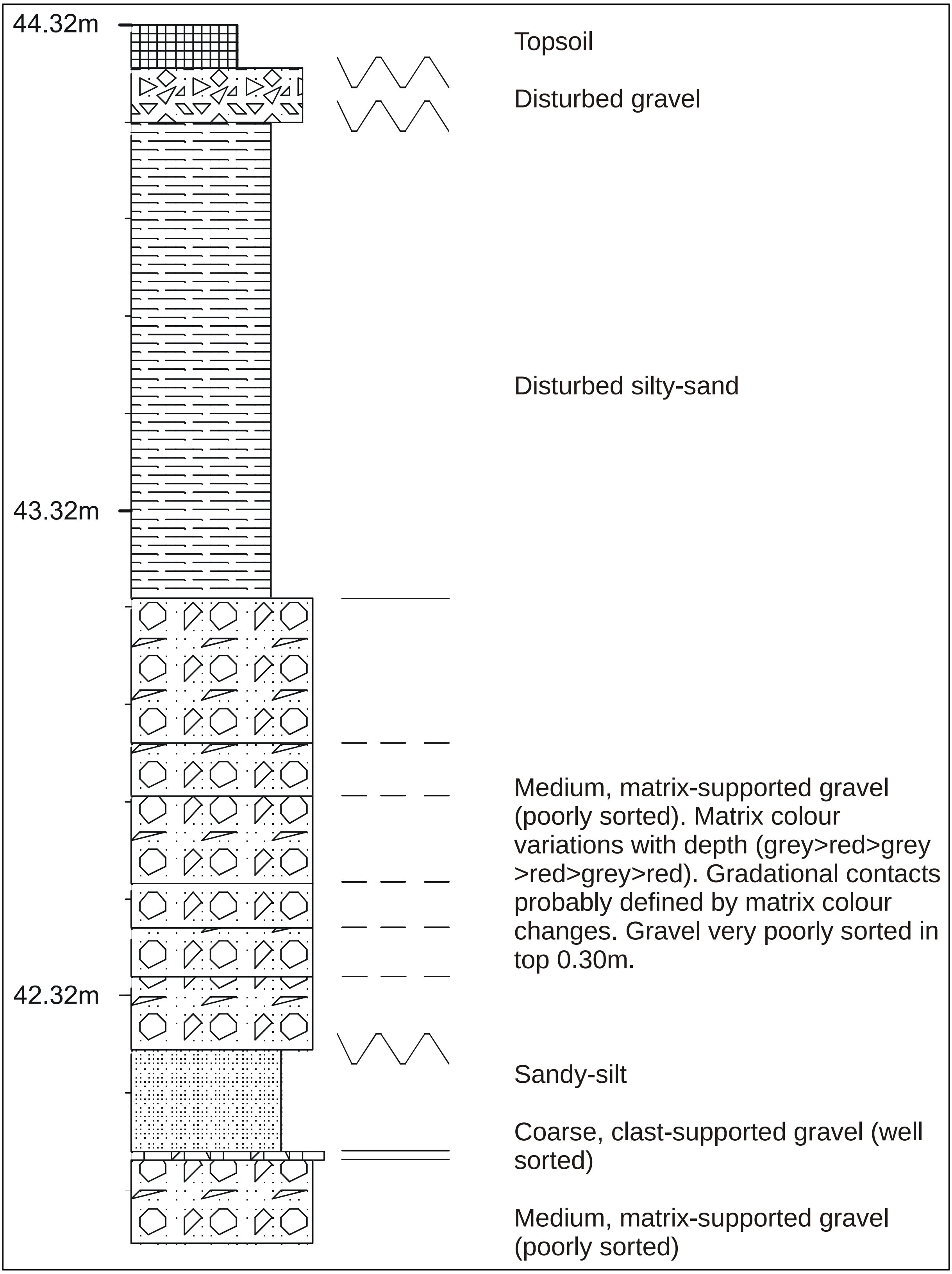

Figure 20: lithostratigraphic log, section 3 (north face), Railway Ballast Pit, Broom

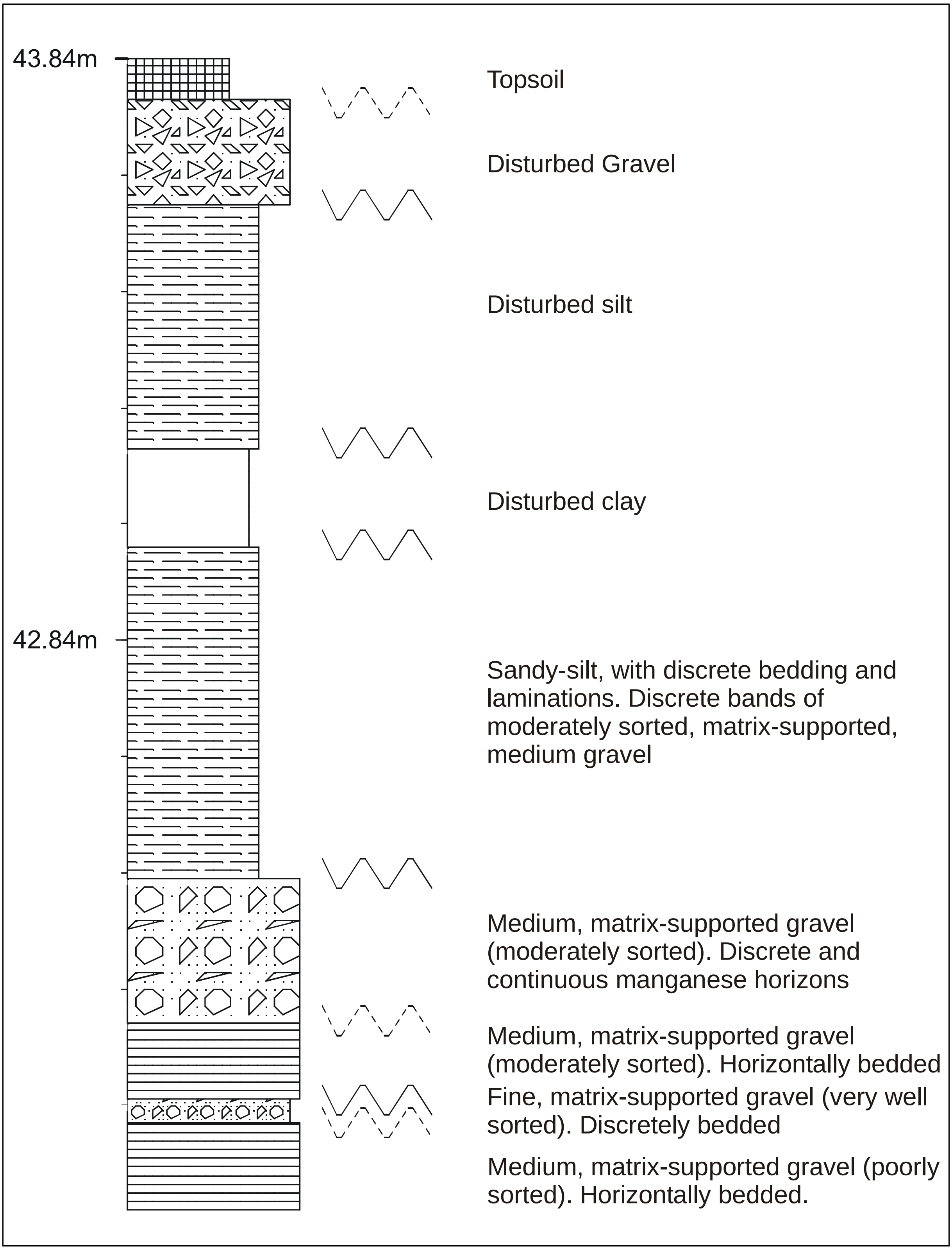

Figure 21: lithostratigraphic log, section 3 (south face), Railway Ballast Pit, Broom

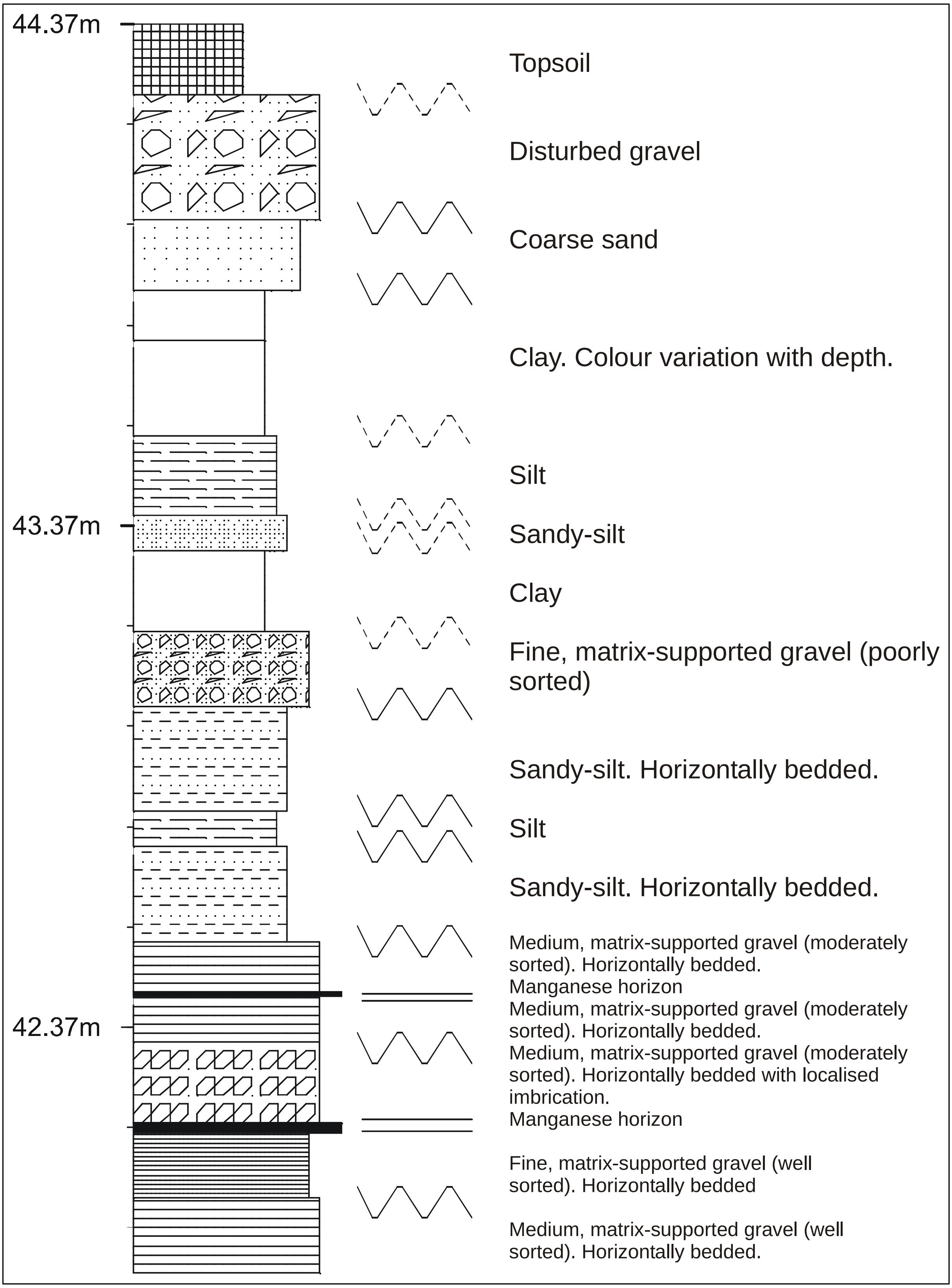

Figure 22: lithostratigraphic log, section 5 (north face), Railway Ballast Pit, Broom

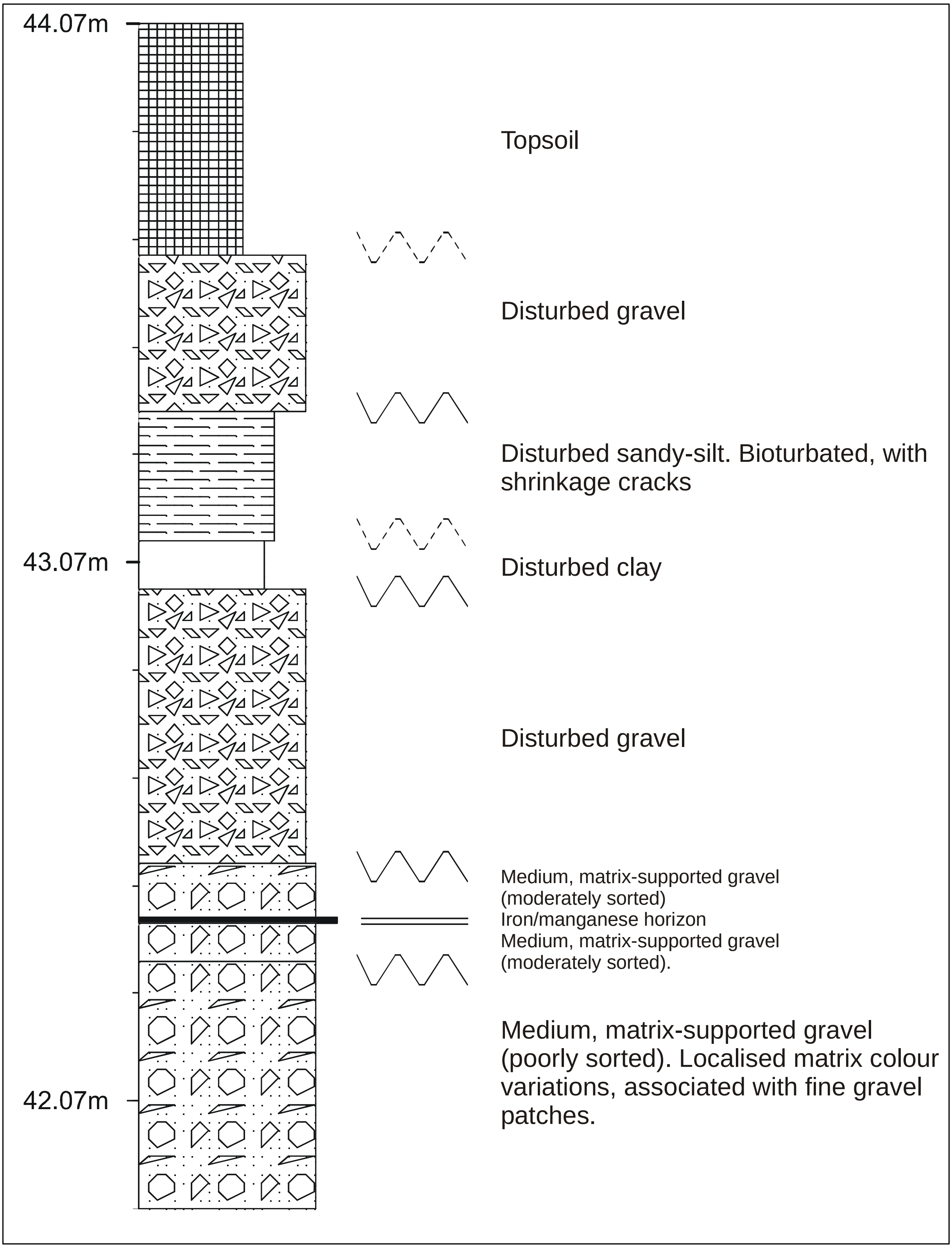

Figure 23: lithostratigraphic log, section 5 (east face), Railway Ballast Pit, Broom

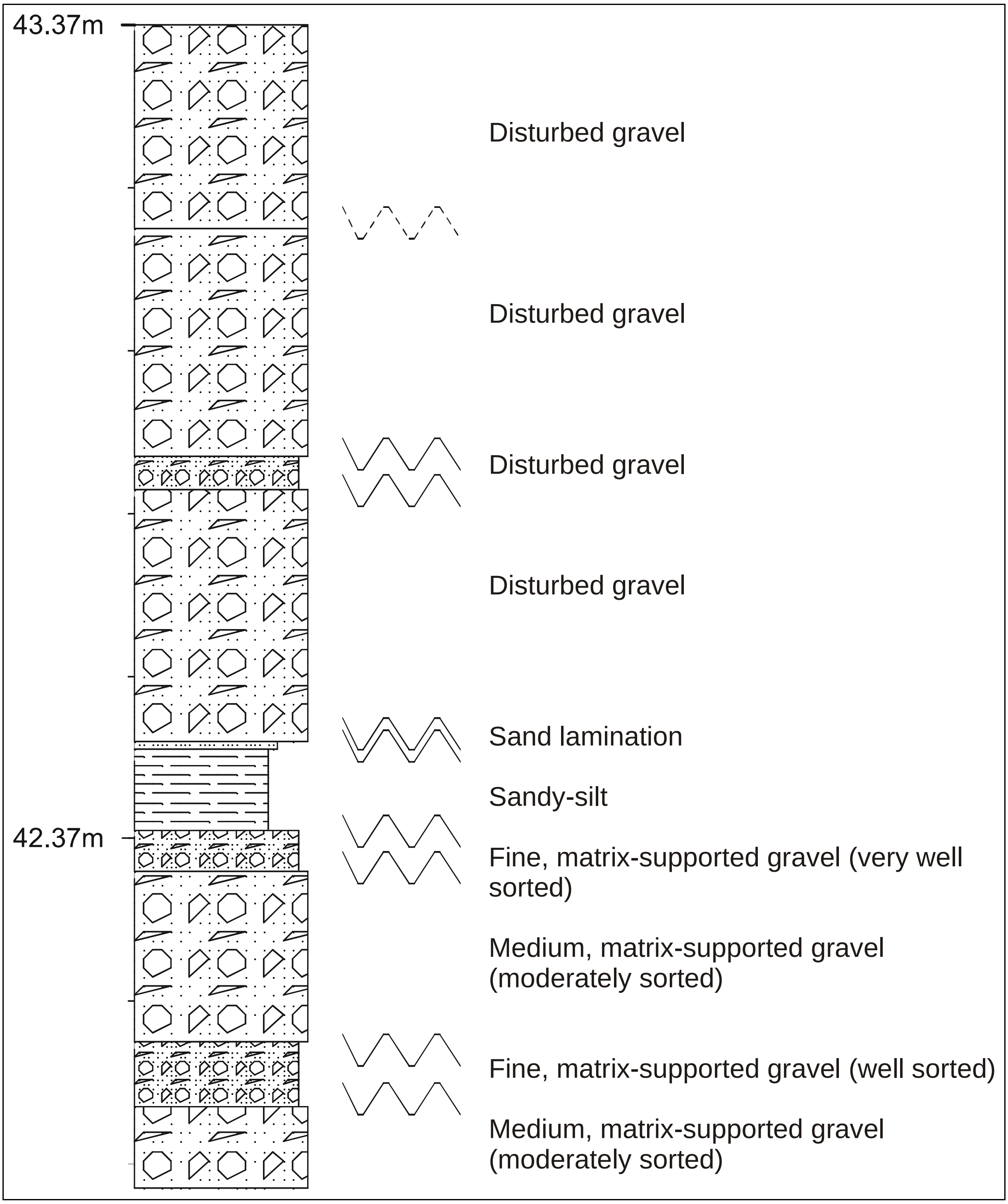

Figure 24: lithostratigraphic log, section 5 (west face), Railway Ballast Pit, Broom

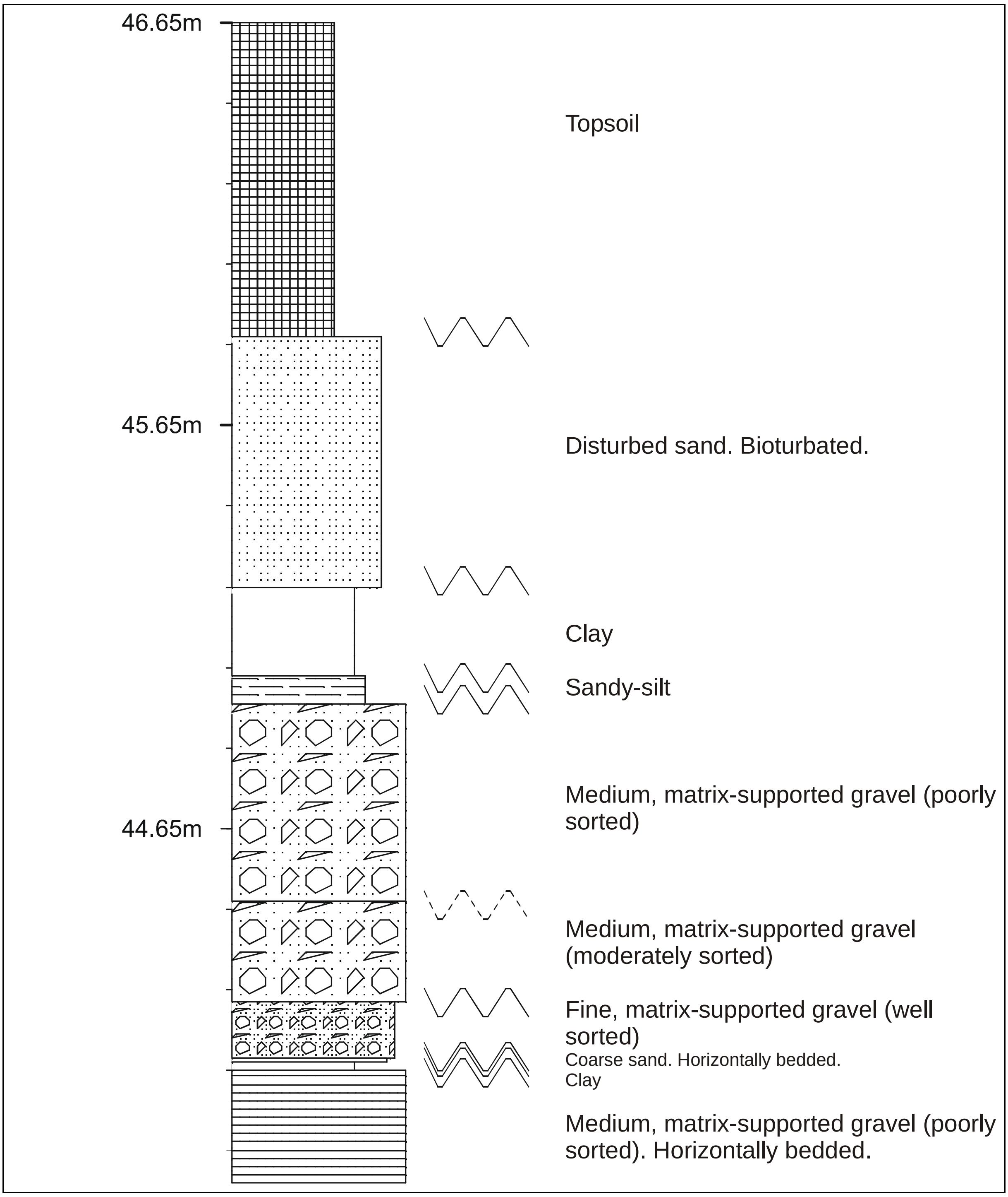

Figure 25: lithostratigraphic log, section 8 (south face), Pratt's New Pit, Broom

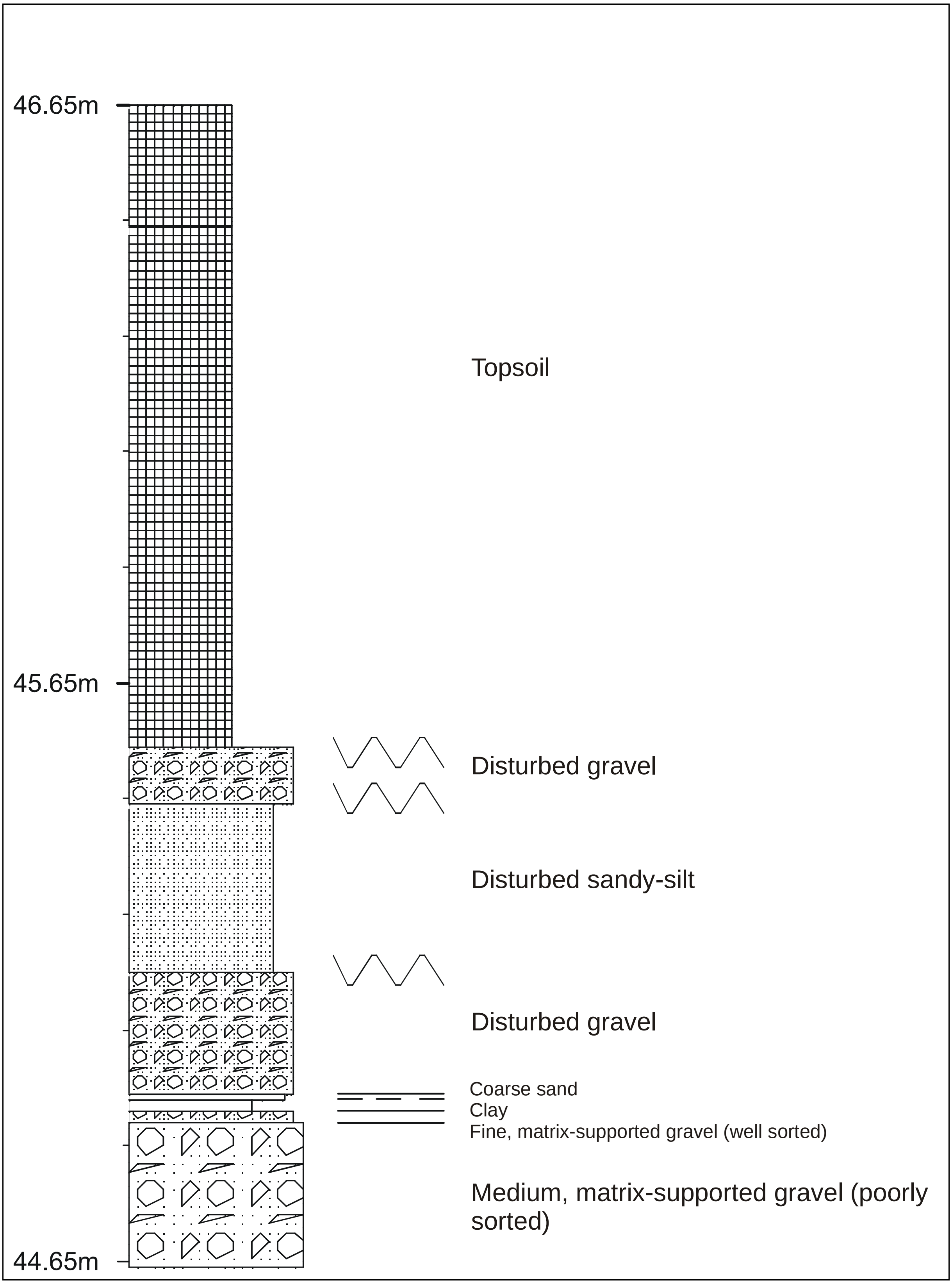

Figure 26: lithostratigraphic log, section 8 (east face), Pratt's New Pit, Broom

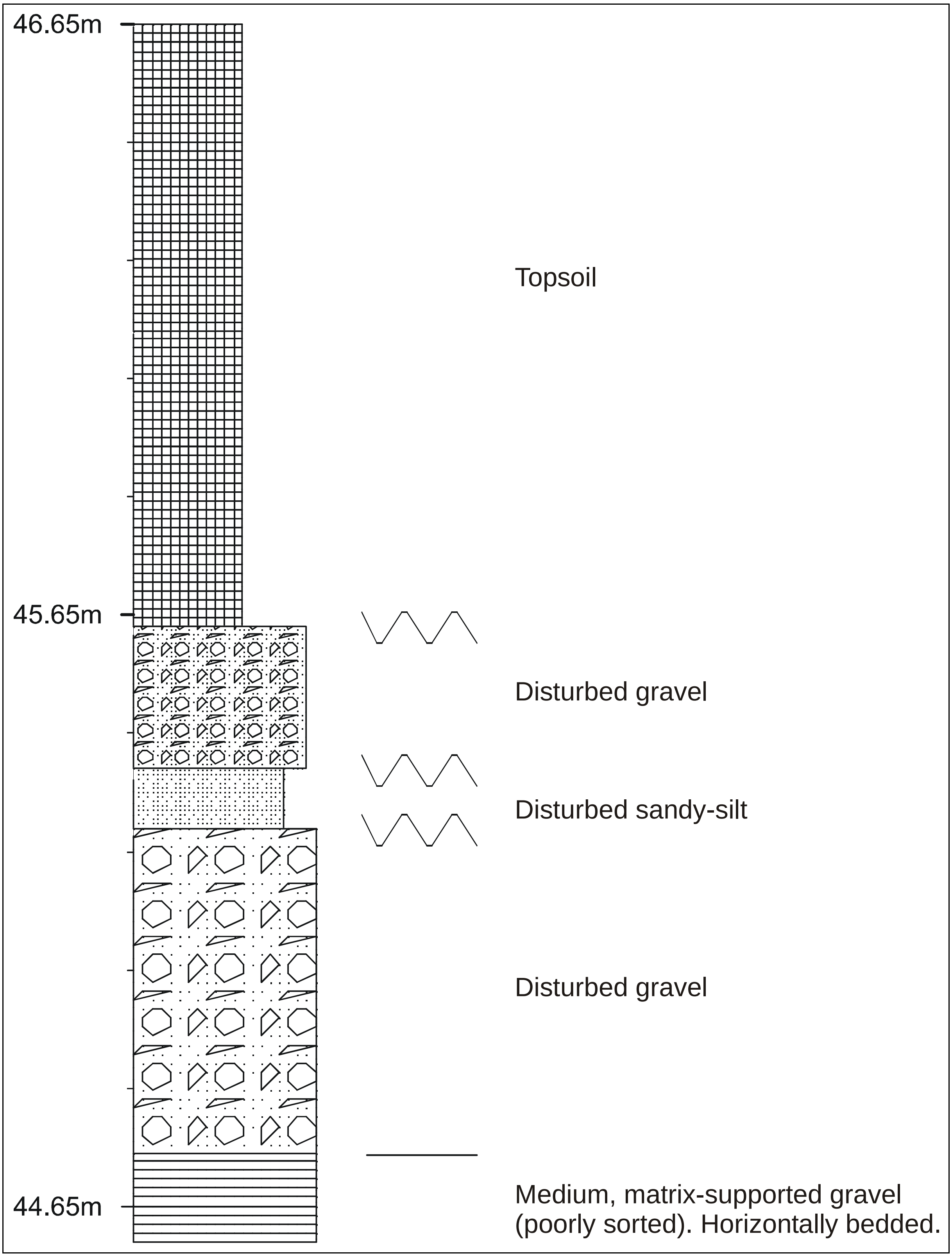

Figure 27: lithostratigraphic log, section 8 (west face), Pratt's New Pit, Broom

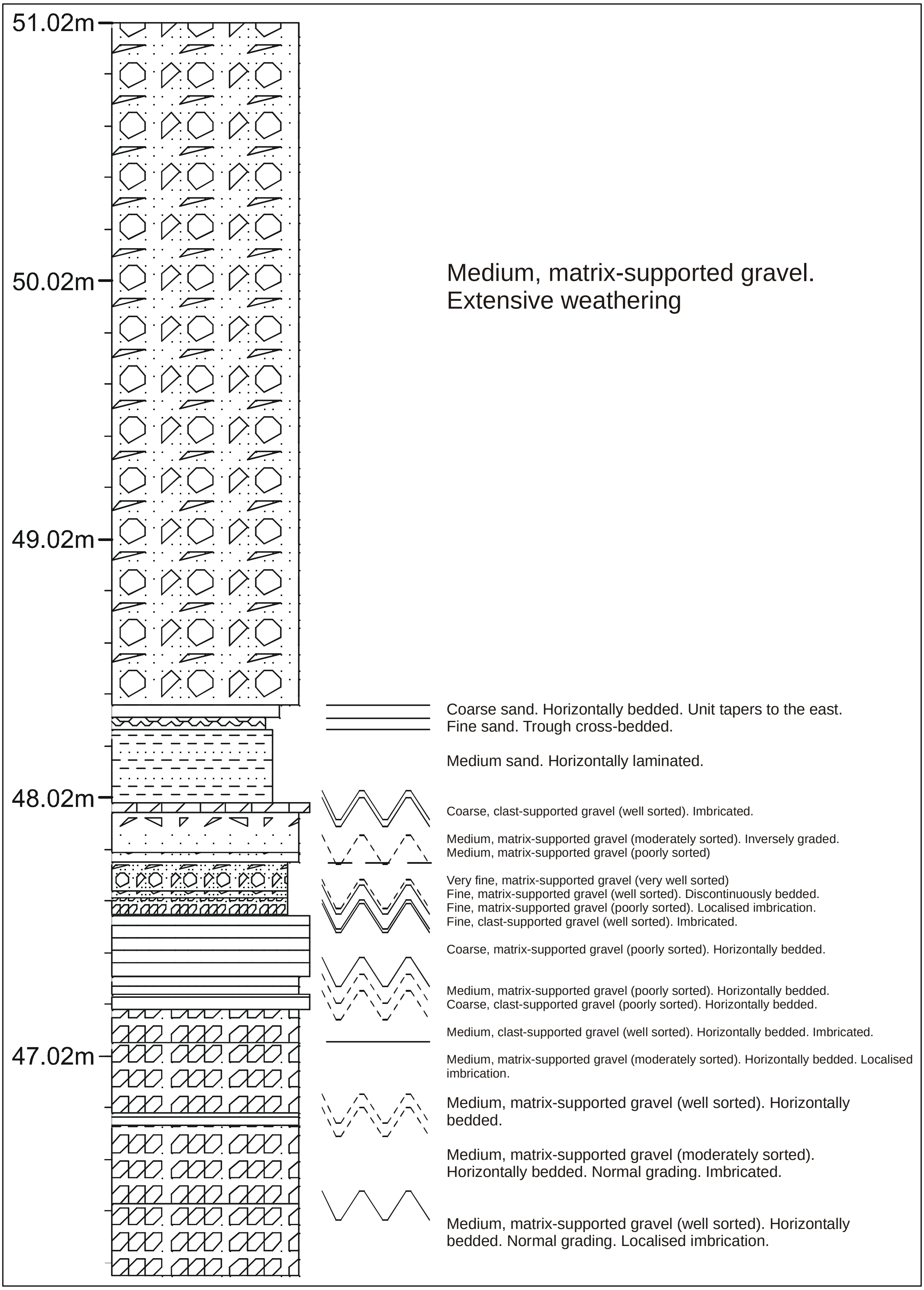

Figure 28: lithostratigraphic log, section 9 (south face), Pratt's New Pit, Broom

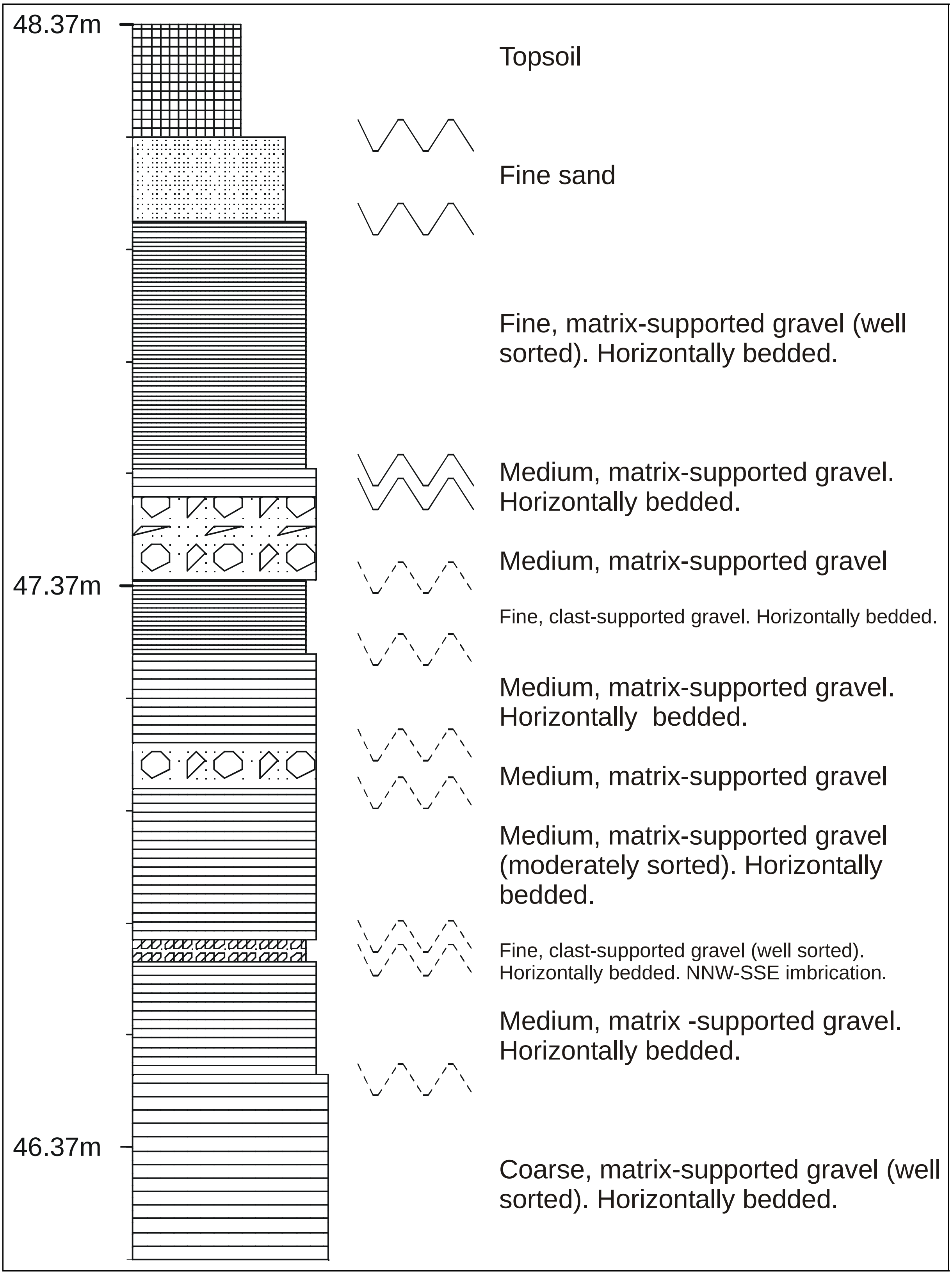

Figure 29: lithostratigraphic log, section 9 (east face), Pratt's New Pit, Broom

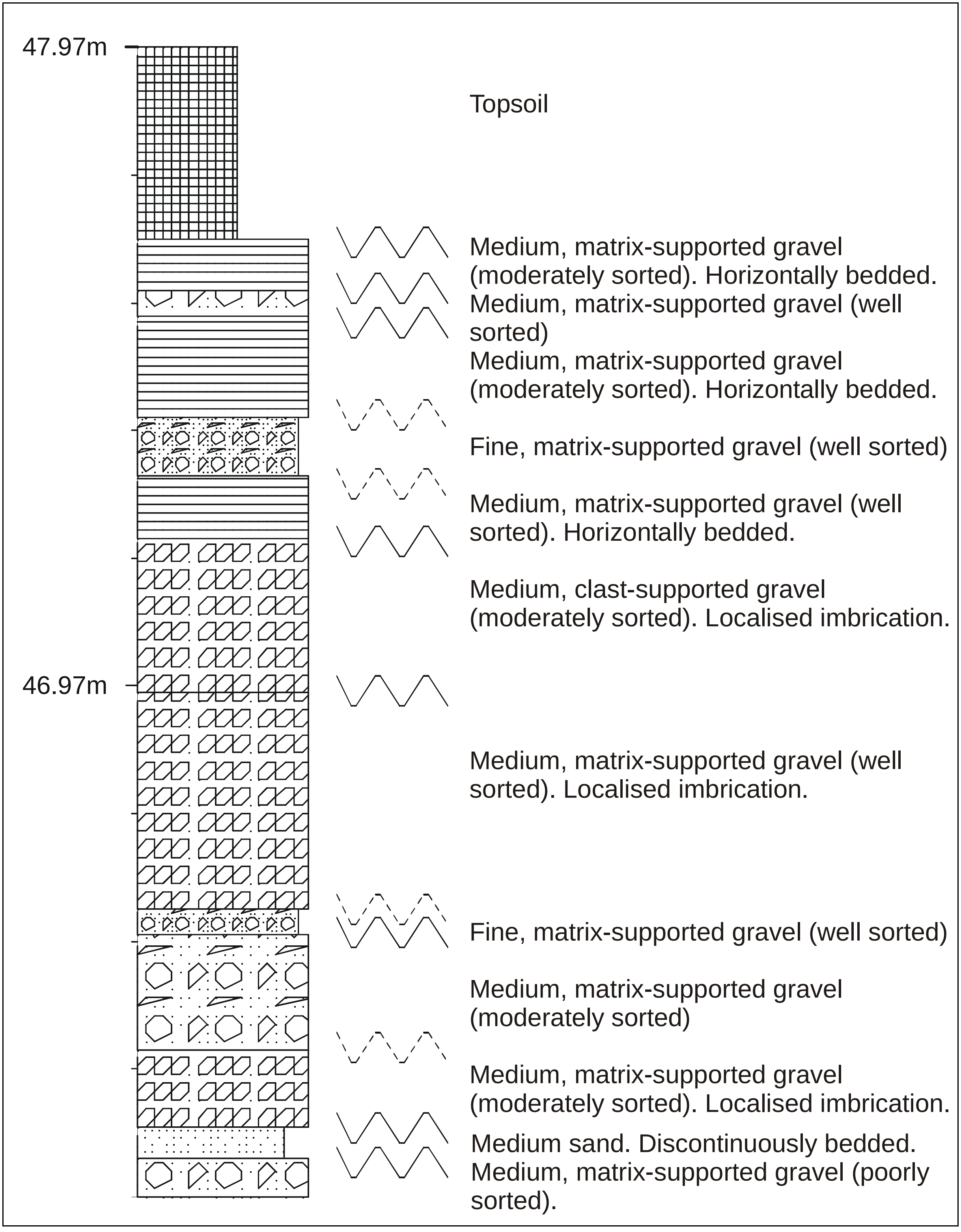

Figure 30: lithostratigraphic log, section 9 (west face), Pratt's New Pit, Broom

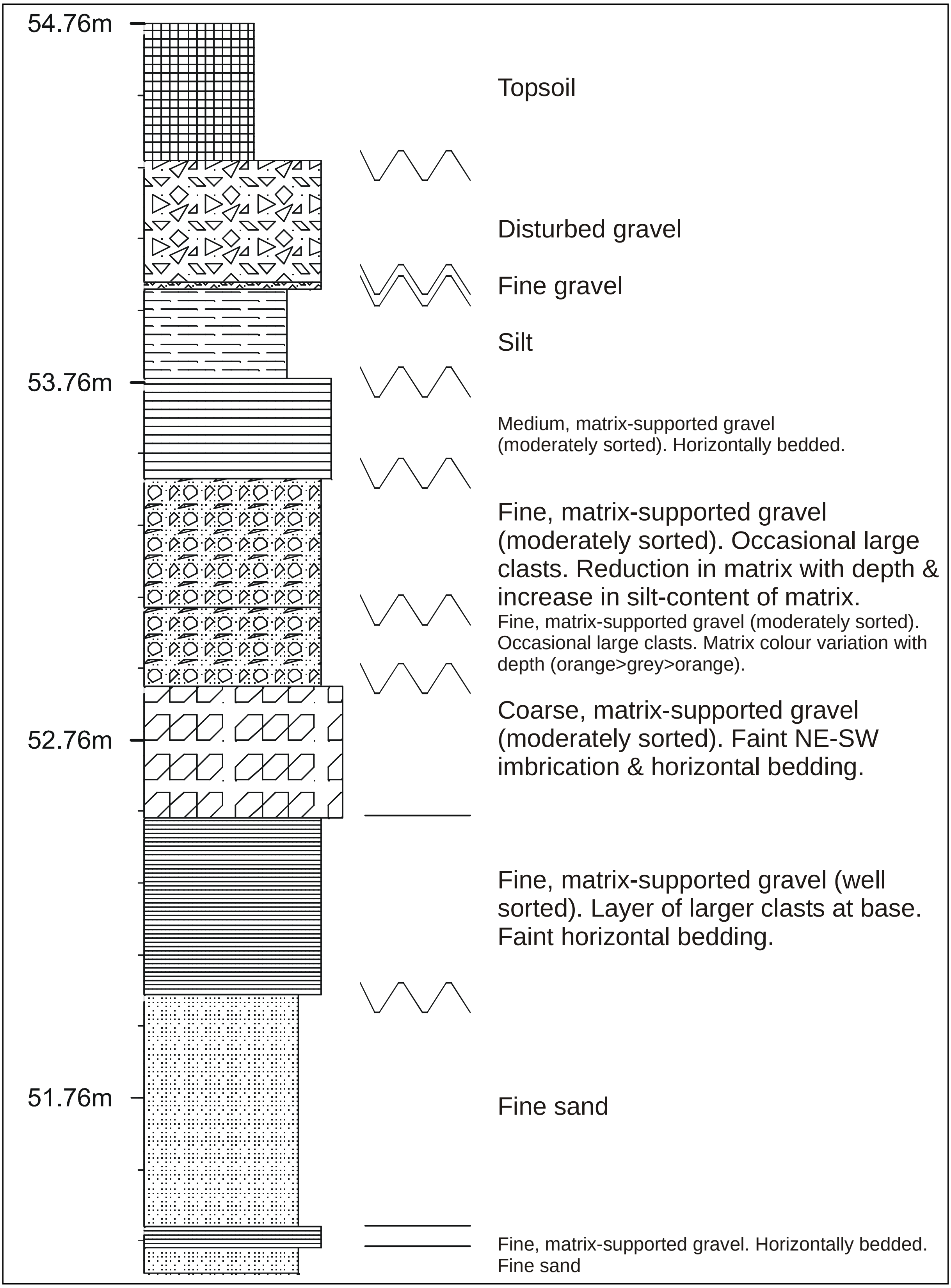

Figure 31: lithostratigraphic log, section 10 (west face), Pratt's New Pit, Broom

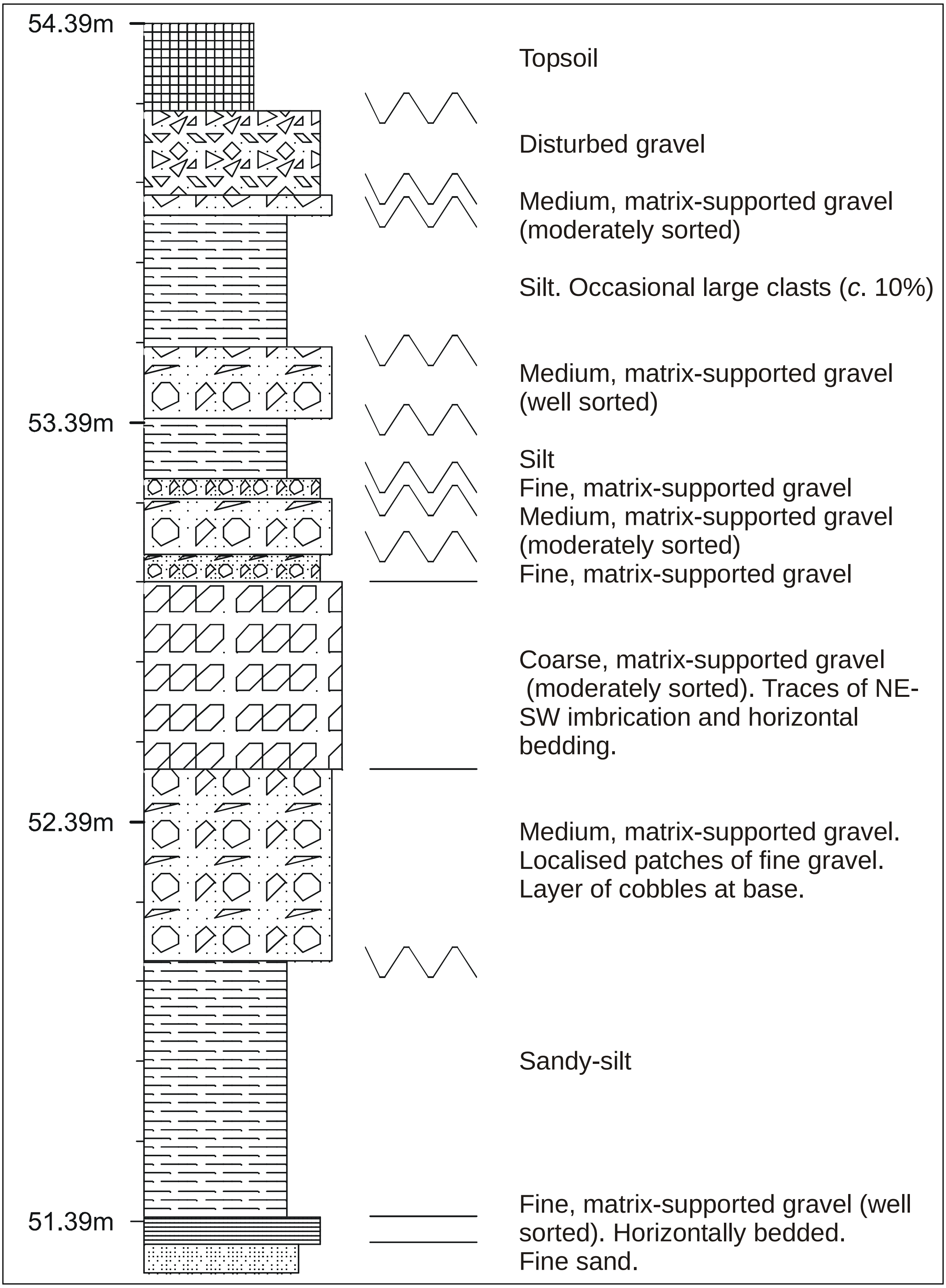

Figure 32: lithostratigraphic log, section 10 (south face), Pratt's New Pit, Broom

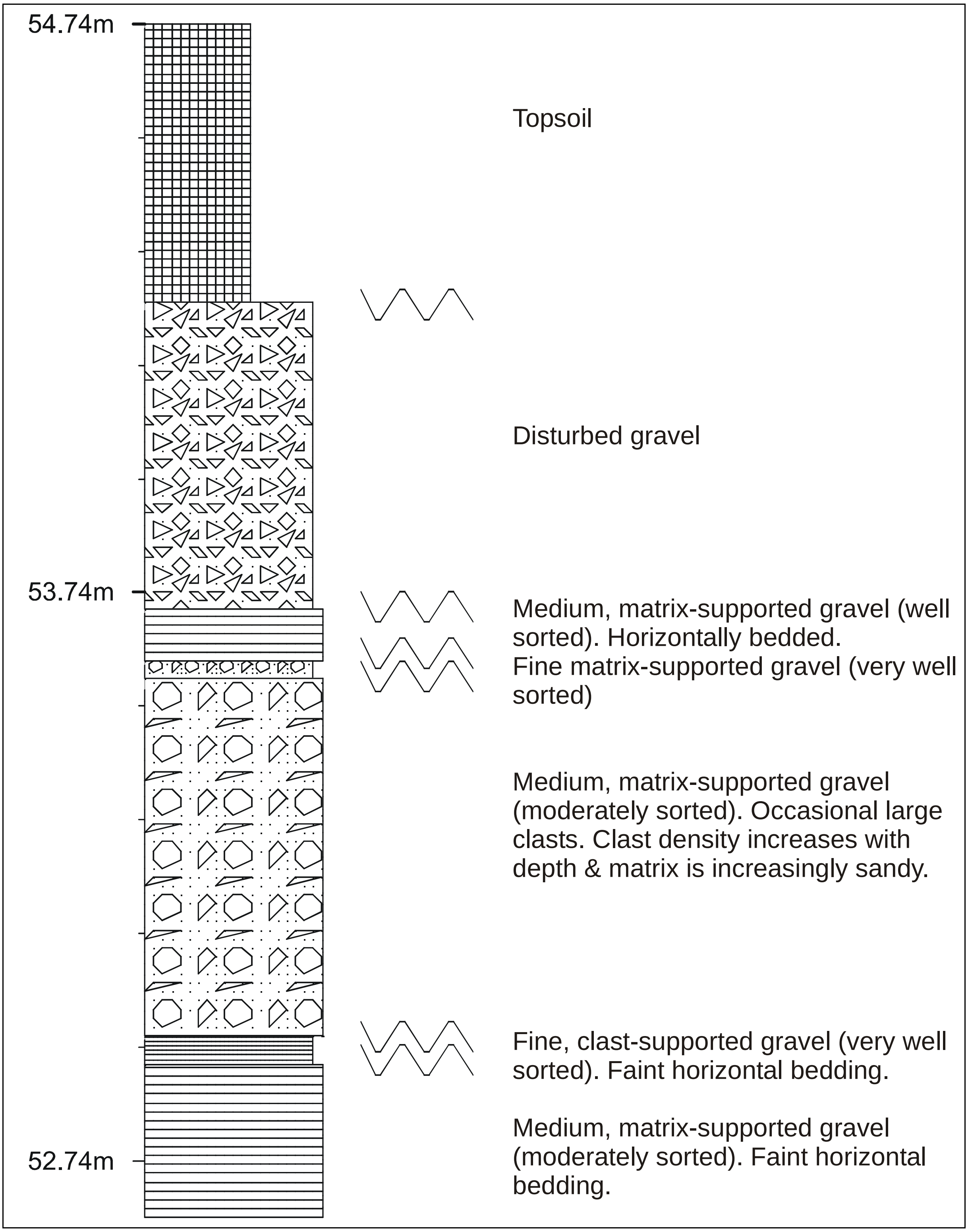

Figure 33: lithostratigraphic log, section 11 (west face), Pratt's New Pit, Broom

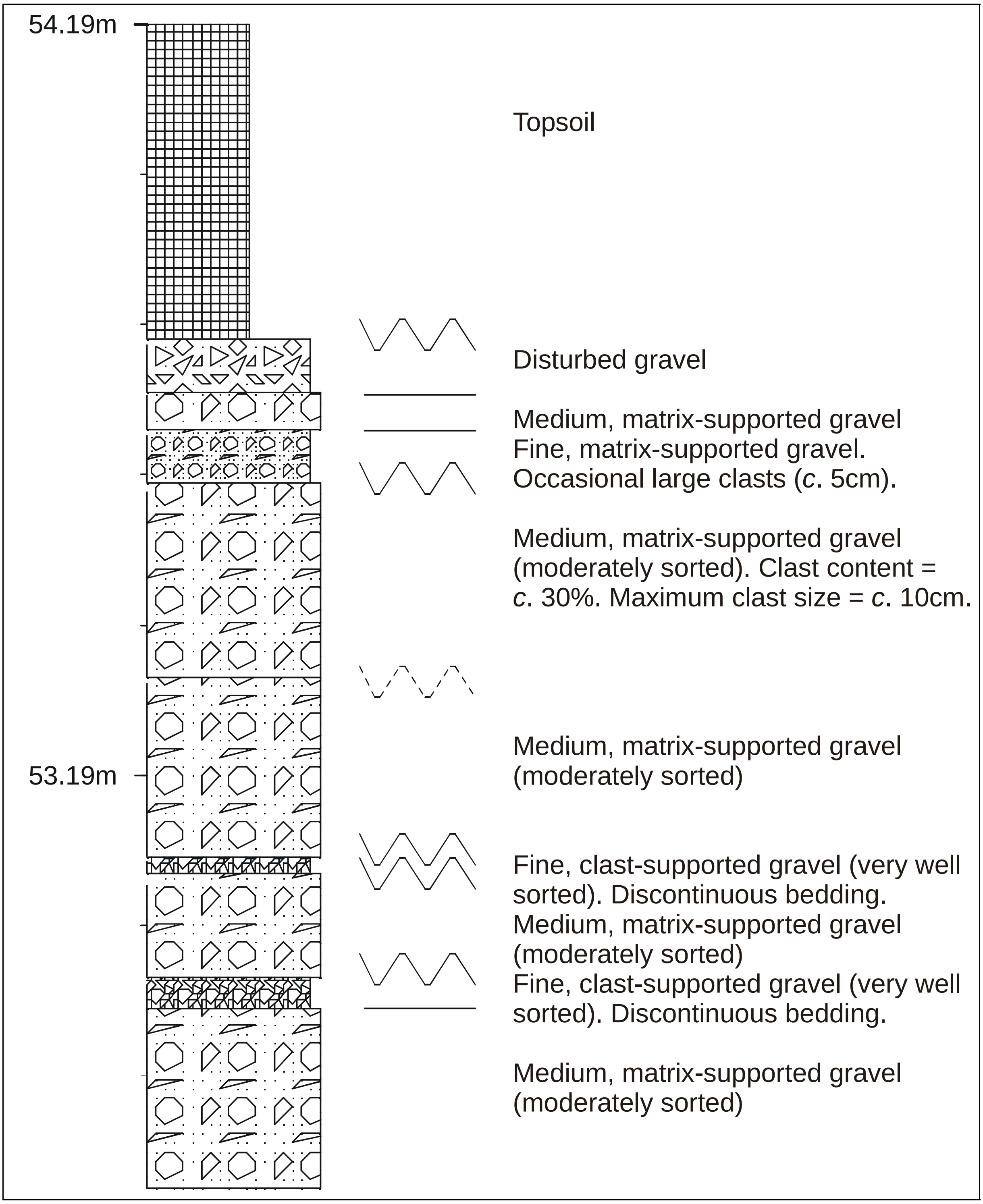

Figure 34: lithostratigraphic log, section 11 (north face), Pratt's New Pit, Broom

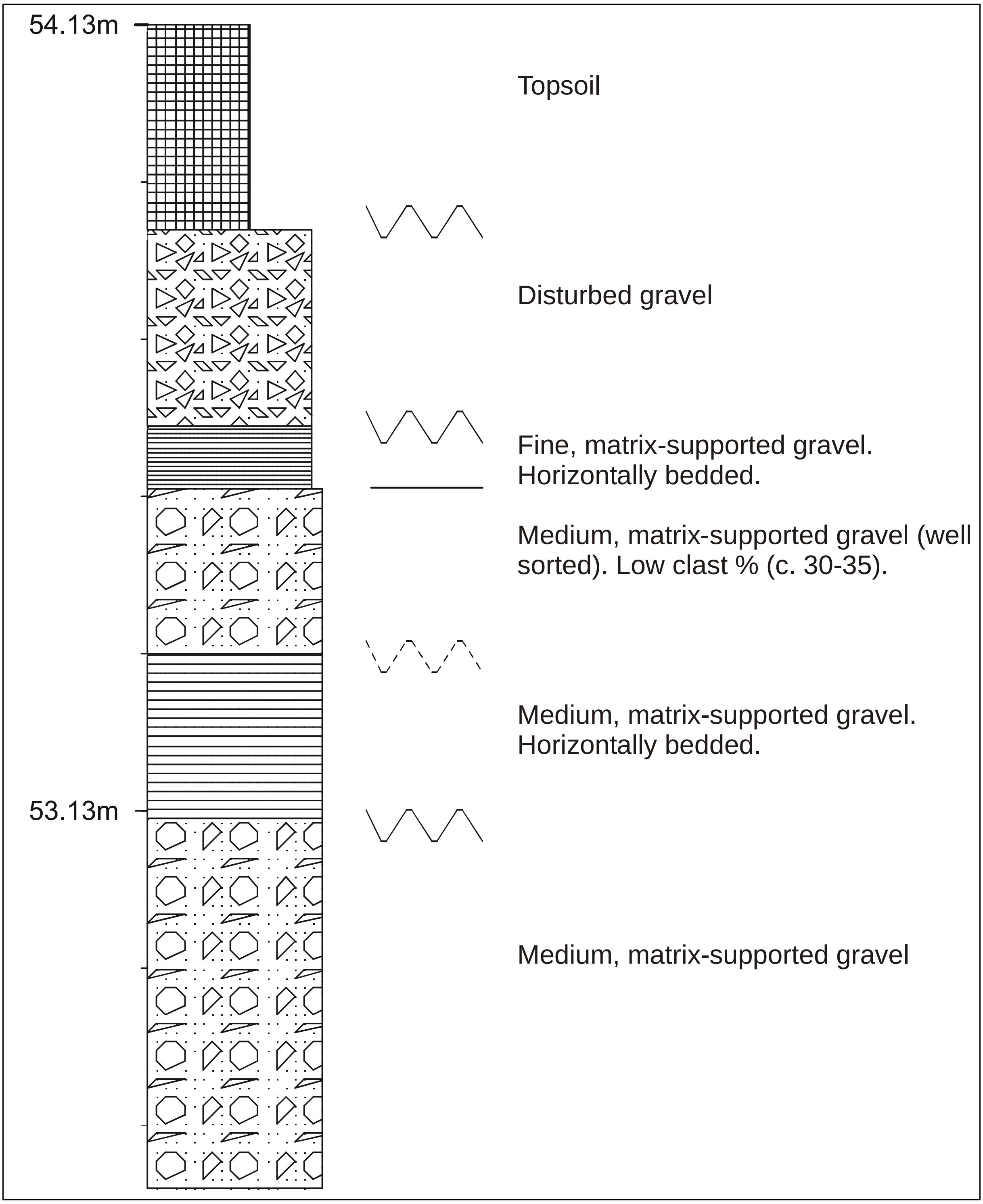

Figure 35: lithostratigraphic log, section 11 (south face), Pratt's New Pit, Broom

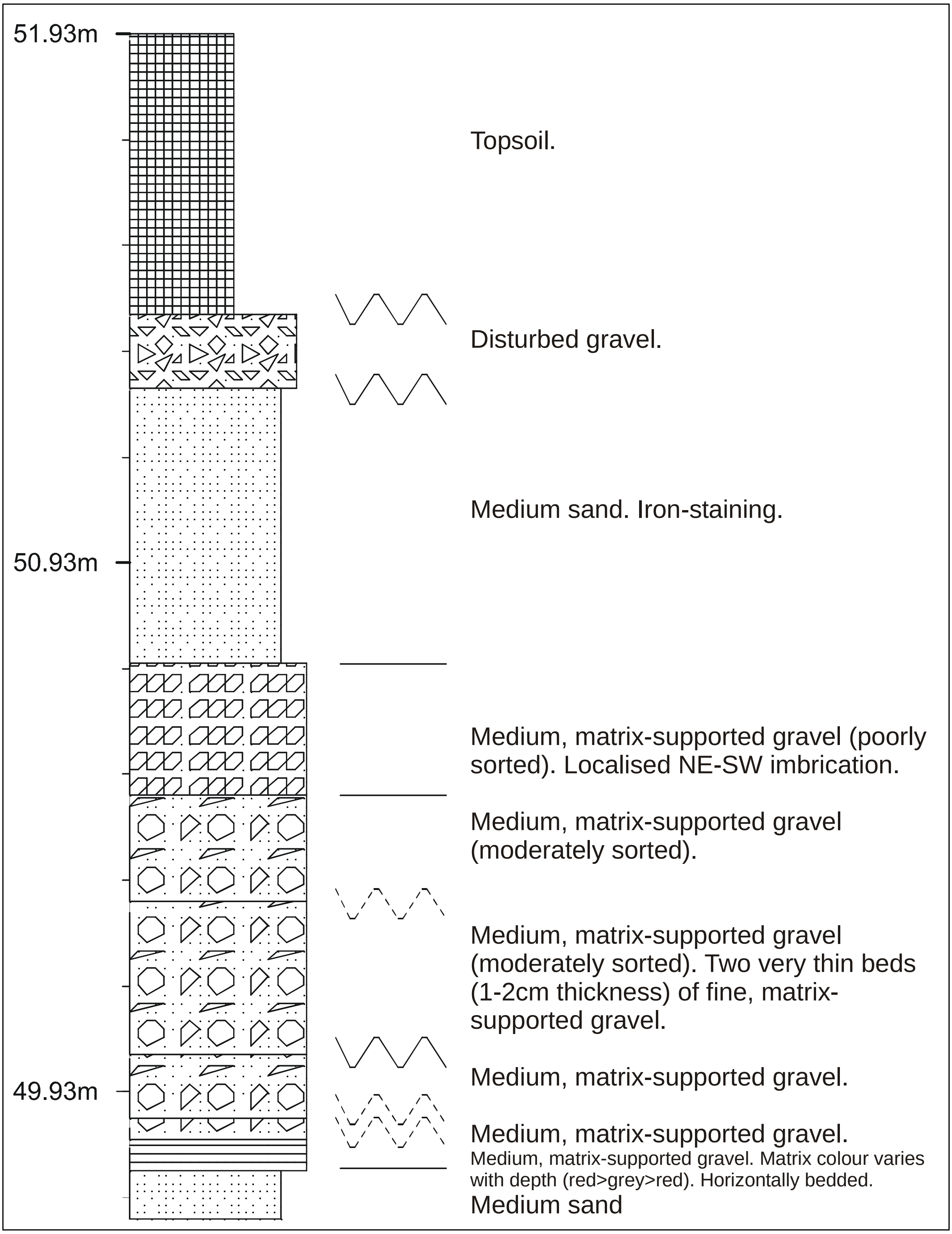

Figure 36: lithostratigraphic log, section 13 (west face), Pratt's New Pit, Broom

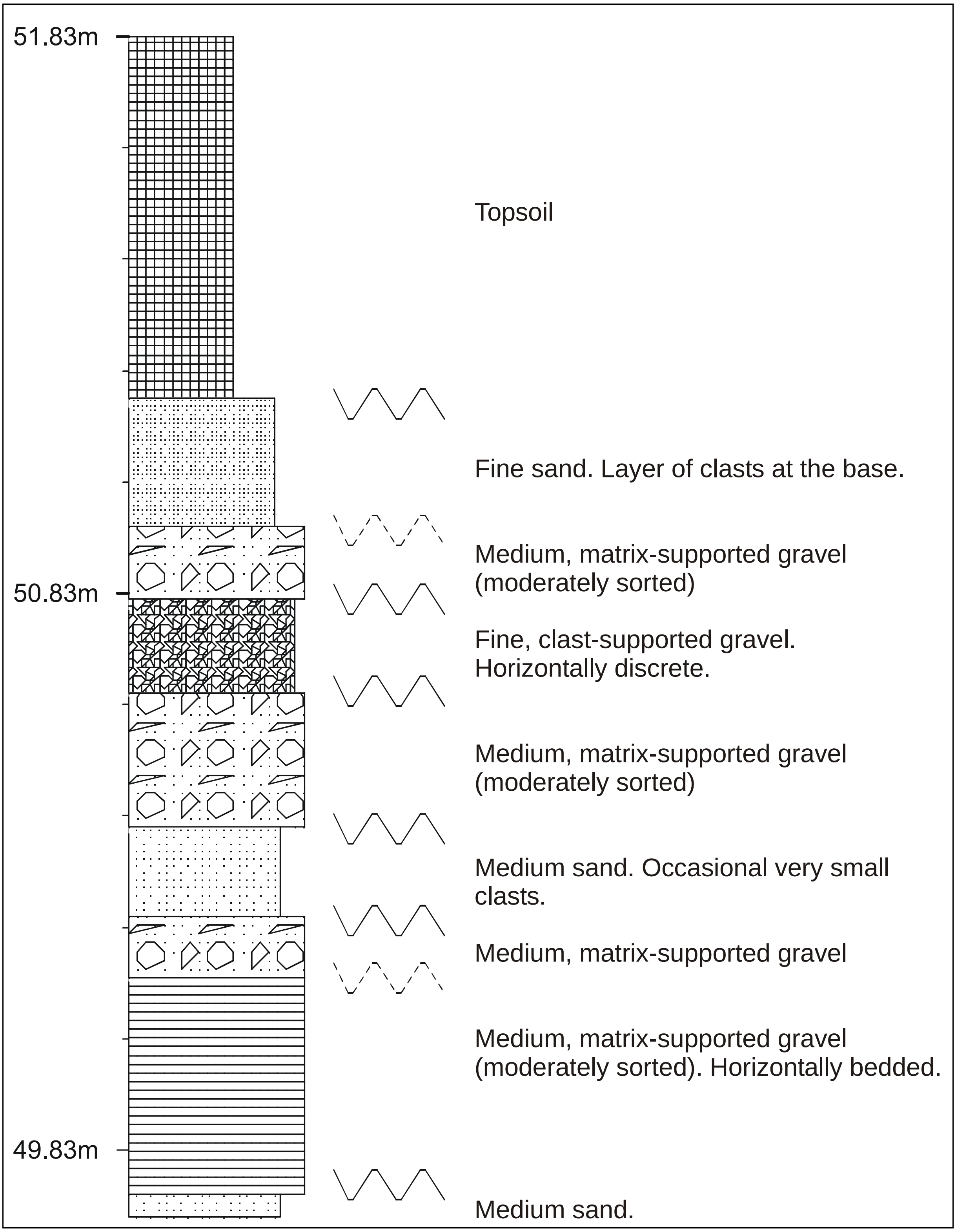

Figure 37: lithostratigraphic log, section 13 (north face), Pratt's New Pit, Broom

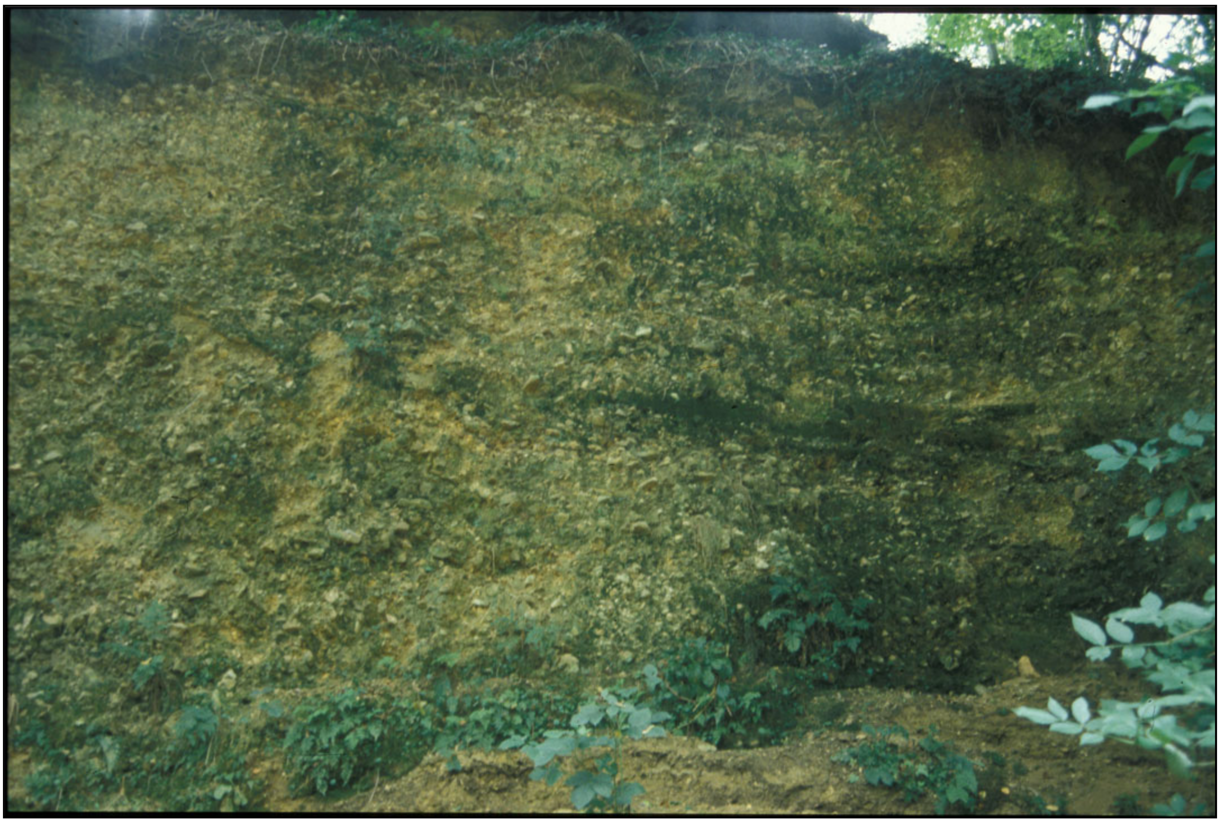

Figure 38: section 1 (west face), Railway Ballast Pit, Broom

Figure 39: section 2 (west face), Railway Ballast Pit, Broom

Figure 40: section 3 (north face), Railway Ballast Pit, Broom

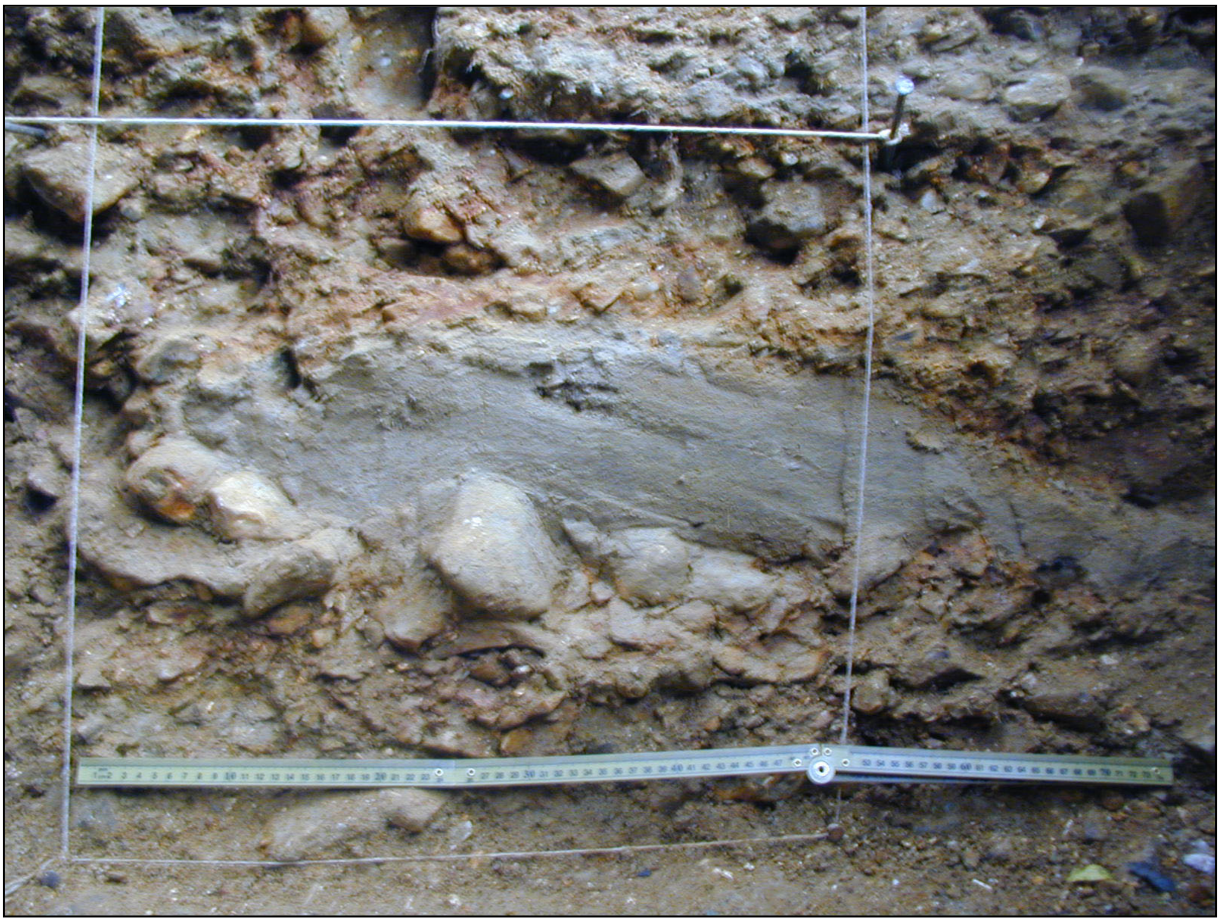

Figure 41: section 3 (north face, fine & coarse-grained sediments), Railway Ballast Pit, Broom

Figure 42: section 5 (west face), Railway Ballast Pit, Broom

Figure 43: section 5 (iron/manganese horizon), Railway Ballast Pit, Broom

Figure 44: section 9 (south face), Pratt's New Pit, Broom

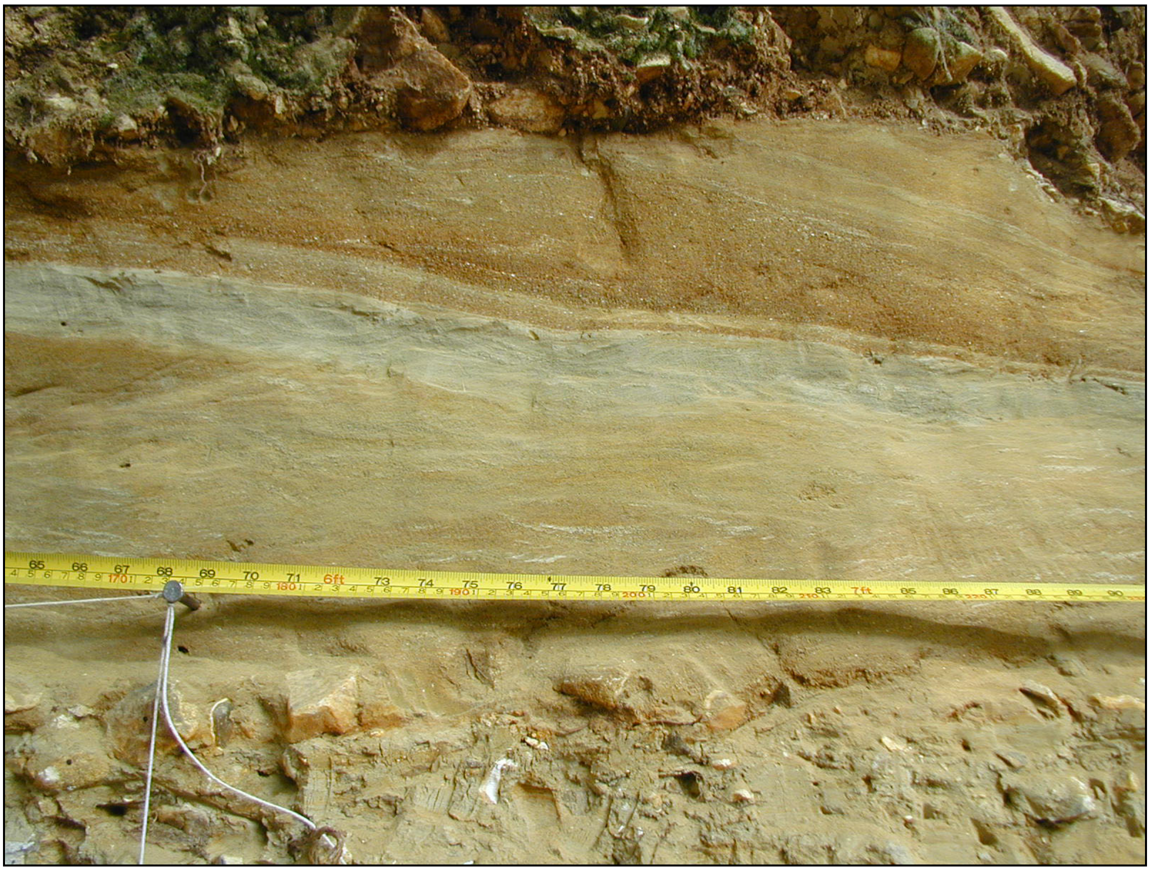

Figure 45: section 9 (south face, fine-grained sediments), Pratt's New Pit, Broom

Figure 46: section 9 (south face, trough cross-bedding), Pratt's New Pit, Broom

Figure 47: section 10 (west face, steps 2 & 3), Pratt's New Pit, Broom

Figure 48: section 11 (west face), Pratt's New Pit, Broom

Figure 49: section 13 (west face, step 2), Pratt's New Pit, Broom

3. AGE OF THE BROOM DEPOSITS (P TOMS & R HOSFIELD)

The fifteen OSL dates sampled in September 2001, January 2003 and July 2003 formed the first phase of the establishment of an absolute chronology for the prolific Acheulean artefact assemblage recovered at Broom (Wymer 1999: 182). Specific attention concerned whether the dates could indicate:

1. The age of the archaeological assemblage.
2. If the pollen assemblages (recovered by Dr James Scourse and Dr Rob Scaife) could be related to specific interglacial or interstadial phases.
3. If the model of episodic, rapid fluvial activity proposed in chapter 1 could be applied to the Broom depositional and sedimentary sequence.
4. If individual deposits could be related to specific phases of climatic transition (glacial/interglacial and stadial/interstadial) within the marine isotope record.

The fifteen dates were sampled from four different sedimentary contexts (details of the methodological procedure are included in the accompanying Centre for Archaeology report by Dr P Toms (Toms *et al.* in prep). GL02082 was sampled from a fine sand lense located within the Broom upper gravels (section 1; Figure 89). GL02083, GL02084, GL03010 and GL03011 were sampled from silt/sand sediments in the Broom middle beds (section 2; Figure 50), deposited between the Broom lower and upper gravels. GL02085, GL03004, GL03005, GL03006 and GL03007 were sampled from a coarse sand lense situated within the Broom upper gravels (section 9; Figure 93). GL03008 and GL03009 were sampled from a sand unit within the Broom upper gravels (section 13, Figure 49). GL03057, GL03058 and GL03059 were sampled from deposits in section 14 that were believed to be an extension of the middle beds within Pratt's Old Pit. The sample ages (Table 26) indicate that the deposits in section 14 are considerably younger than the remainder of the Broom Middle Pleistocene sediments, dating to the Late Devensian.

The dates are extremely surprising, particular since there had been no previous indication of deposits of that age in the earlier investigations of Broom (Shakesby & Stephens 1984; Green 1988). Our current interpretation is that the deposits either represent localised Late Devensian ponding on the surface of the Middle Pleistocene terrace, or that the sampling procedure was erroneous in this instance and that the deposits are of Middle Pleistocene age. The marked contrast between the sediments in section 14 and section 15 (sand waste from the washing plant at Pratt's Old Pit) does not support the notion that the section 14 deposits are similarly recent.

The position of the sections and stratigraphical relationships of the Broom deposits and the OSL samples (Figure 51) indicate that the twelve Middle Pleistocene dates are not stratigraphically consistent. Four of the five samples from section 9 suggest that the gravel and sand deposits in the western end of Pratt's New Pit are older than the middle beds deposits in the Railway Ballast Pit (section 2). These errors probably reflect error ranges associated with the dates, primarily because Green (pers. comm.) previously documented the middle beds in Pratt's Old Pit and Pratt's New Pit, *below* (and therefore stratigraphically earlier than) the sediments sampled in section 9 during the current investigation.

There is also considerable chronological variation in the samples from individual sedimentary units. Of the four samples from the section 2 middle beds, GL03011 (297±29 kya BP) is considerably older than the other three sample (234±26, 250±15 and 253±16 kya BP). Of the five samples from the section 9 sand unit, GL03005 (218±17 kya BP) is considerably younger than the remaining four samples (268±22, 273±22, 277±25 and 281±26 kya BP). Finally, the sand unit in section 13 yielded ages of 270±19 and 240±18 kya BP. This degree of variability does not permit the accurate dating of sedimentary units in terms of sub-MIS events. Moreover, the error ranges associated with the sample ages are an order of magnitude greater than the apparent duration of individual, sub-Milankovitch climatic events (Chapter 2; e.g. 10,000's years as opposed to 100's or 1,000's of years). Therefore, even if the multiple sample ages associated with individual sedimentary units were less widely dispersed, the error ranges associated with MIS-8 and MIS-7 deposits would not permit the development of a sub-MIS geochronology for the Broom deposits. Further details and discussion of the OSL sampling programme are included in the CfA report (Toms *et al.* in prep.) that accompanies this report.

Figure 50: OSL sampling in section 2, Railway Ballast Pit, Broom

Nonetheless, all twelve of the Middle Pleistocene OSL dates are consistent with an MIS-8 age (301–242 kya) age for the upper gravels and middle beds, with a possible expansion into MIS-7. Identifying the timing of the depositional events is more difficult, not least because of the apparent stratigraphic reversal of ages between section 2 (middle beds) and section 9 (upper gravels). The overall clustering of sample ages suggest that fluvial deposition of the middle beds and upper gravels sediments was probably occurring during the middle and later parts of MIS-8. A late Lower Palaeolithic age is therefore suggested for the Broom assemblage, which is in keeping with the nature of the artefacts (including the recorded presence of 3 Levallois artefacts). The age of the lower gravels remains unknown, as it was not practically possible to expose these sediments during the current investigation. A late stage 9/early stage 8 date seems most probable at this time, based partially on the MIS-cycle fluvial activity models summarised in chapter 1. The suggested age of the assemblage is of particular archaeological interest given the presence of three Levallois artefacts (1 core and 2 flakes (Wessex Archaeology 1993b: 163), whose first appearance in Britain has been associated with marine isotope stage 8 (Bridgland 1994). It is possible that the paucity of Levallois artefacts is related to the use of a relatively coarse chert raw material for the manufacture of the Broom artefacts, although the possible bias introduced by the selective collection of bifaces should not be discounted.

Sample	Section	Height (m OD)	Age
GL03009	13	50.96	270±19
GL03008	13	50.82	244±18
GL02082	1	48.83	248±19
GL02085	9	48.17	273±22
GL03004	9	48.17	268±22
GL03006	9	48.02	277±25
GL03005	9	47.97	218±17
GL03007	9	47.93	281±26
GL03057	14	46.14	20±1
GL03058	14	45.92	16±2
GL03059	14	45.78	29±2
GL03010	2	44.71	234±26
GL02083	2	44.02	253±16
GL03011	2	43.54	297±29
GL02084	2	43.24	250±15

Table 26: OSL dates, ordered by vertical elevation

Scourse agued that the pollen indicated a temperate floodplain environment, with deposits laid down at the end of an interglacial or during an interstadial. Scaife suggested that the presence of small numbers of oak, hazel, alder and ash might indicate the initial stages of vegetation succession at the beginning of an interglacial period. All of the OSL ages for the middle beds (the source of the pollen samples) suggest that Scourse's model of deposition at the end of an interglacial is unlikely. Both Scaife's identification of a possible vegetation succession at the beginning of an interglacial (MIS-7) and Scourse's suggestion of deposition during an interstadial are possible in the light of these dates.

Due to the variability in the sample ages from individual sedimentary units, and the overall error ranges, it is not possible to test a model of episodic, rapid deposition/incision (fluvial activity) with respect to the Broom sedimentary sequence. Similarly, relating specific deposits to phases of macro (glacial/interglacial) and micro (stadial/interstadial) climatic transition is not possible, due to the limitations of the geochronological ages and the apparent complexity of the Middle Pleistocene climate and the high frequency of stadial/interstadial events.

4. WHERE RIVERS MEET: THE AXE AND THE BLACKWATER

During the 2001 and 2002 field seasons, 22 clast fabric samples were recorded from suitable exposed sections at the Broom locality (Table 27). Following Jones *et al.*'s (1999: 48) recommendation of a 1.5:1 elongation ratio and a 50 clast sample size (minimum 25), samples 1, 3 and 5 were removed from the analysis, and samples 2, 4, 6, 7, 9, 11, 12, 16, 20, 23 and 24 were examined with caution. Clast shape was characterised from the ratios between the three axes (*ibid*: 45 & figure 3.6; Table 27). Rose diagrams of the 19 analysed samples (Figure 52–Figure 70) indicate 3 main patterns:

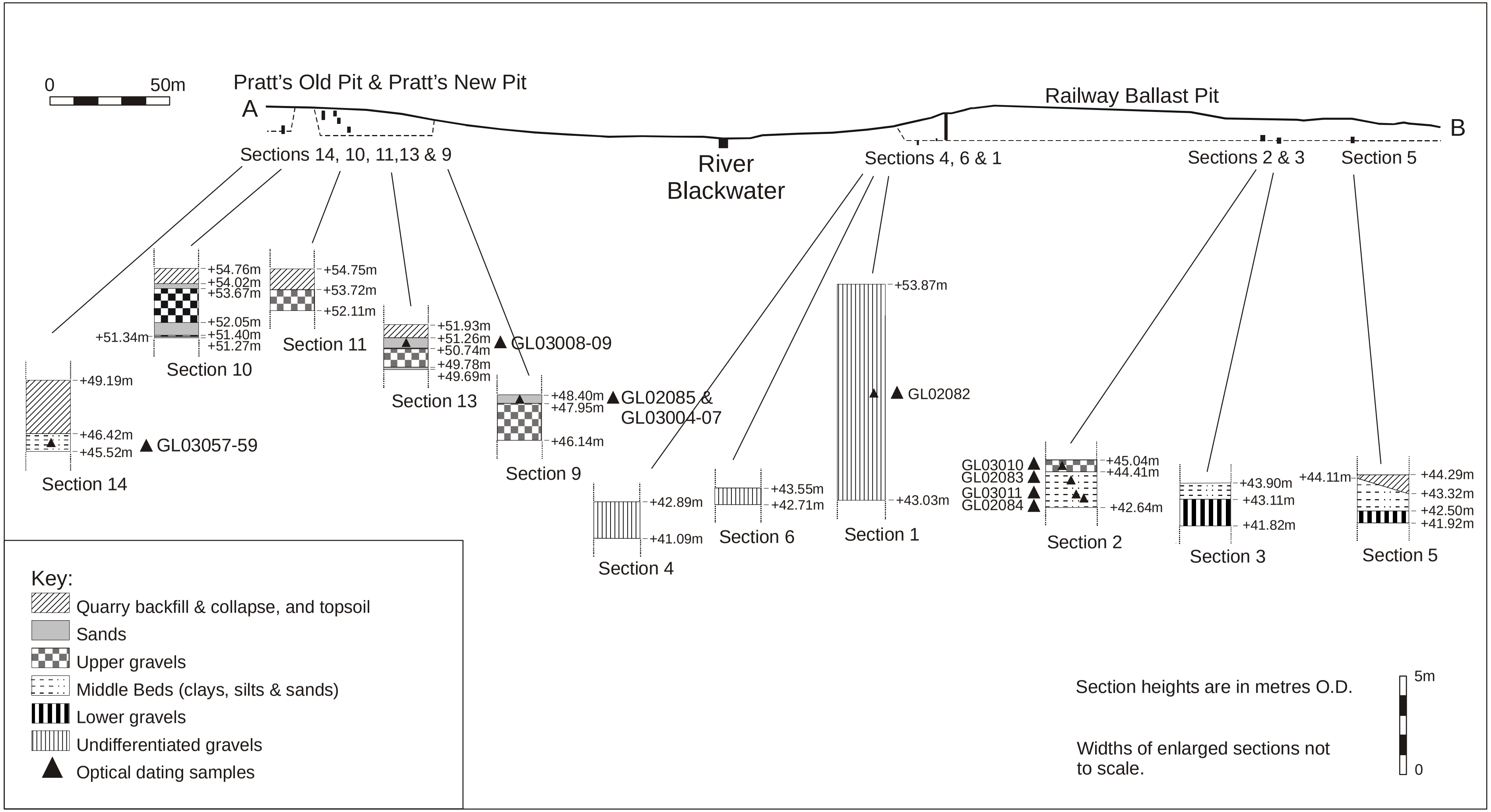

Figure 51: location of OSL samples and tripartite stratigraphy at the Broom locality

- Single, primary axis of clast orientation. Samples 6 (Figure 54), 11 (Figure 59), 13 (Figure 61) 20 (Figure 66) and 24 (Figure 70). Primary and secondary axes of clast orientation. Samples 8 (Figure 56), 9 (Figure 57), 10 (Figure 58), 14 (Figure 62), 16 (Figure 63), 17 (Figure 64), 21 (Figure 67) and 23 (Figure 69).
- No clear axis of clast orientation. Samples 2 (Figure 52), 4 (Figure 53), 7 (Figure 55), 12 (Figure 60), 18 (Figure 65) and 22 (Figure 68).

The significance of clast fabric is dictated by the form of the clast (Table 28), the characteristic modes of transportation (Table 29) and the nature of the depositional event:

Sample #	Section No.	Sample size	Elongation ratio ≥ 1.5	%
1	3	53	22	41.51
2	3	81	37	45.68
3	3	36	19	52.78
4	3	64	35	54.69
5	3	42	15	35.71
6	3	100	38	38.00
7	3	105	44	41.90
8	5	110	62	56.36
9	5	60	28	46.67
10	1	175	80	45.71
11	5	92	49	53.26
12	1	127	51	40.16
13	1	117	42	35.90
14	8	100	54	54.00
16	9	69	27	39.13
17	9	96	64	66.67
18	9	146	73	50.00
20	11	96	43	44.79
21	11	106	51	48.11
22	13	226	109	48.23
23	10	75	29	38.67
24	10	71	37	52.11

Table 27: clast fabric samples (Broom 2001 & 2002 field seasons)

Sample #	Blades	Prolates	Sample #	Blades	Prolates
2	20	17	14	20	34
4	19	16	16	16	11
6	15	23	17	37	27
7	30	14	18	48	25
8	36	26	20	24	19
9	15	13	21	18	33
10	37	43	22	68	41
11	29	20	23	14	15
12	29	22	24	24	13
13	19	23			

Table 28: clast samples by shape category (elongation ratio ≥ 1.5:1)

1. Increase in clast resistance, resulting in the clast lying in a position of maximum resistance (e.g. prolate clasts (rods) lie with the long axis parallel to flow).
2. Reduction in stream *competence* (the ability of a stream current to carry clasts), resulting in deposition of the clast, and the clast lying in the position of transport (e.g. prolate clasts lie with the long axis aligned at right angles to flow).

Form	Mode of transportation	Long axis @ right-angles to flow	Long axis parallel to flow
Prolates	Rolling around long axis	Movement at lower velocities	Movement only at higher velocities
Blades	Sliding	Movement only at higher velocities	Movement at lower velocities
Oblates	No long axis	-	-
Equants	No long axis	-	-

Table 29: clast behaviour in fluvial environments

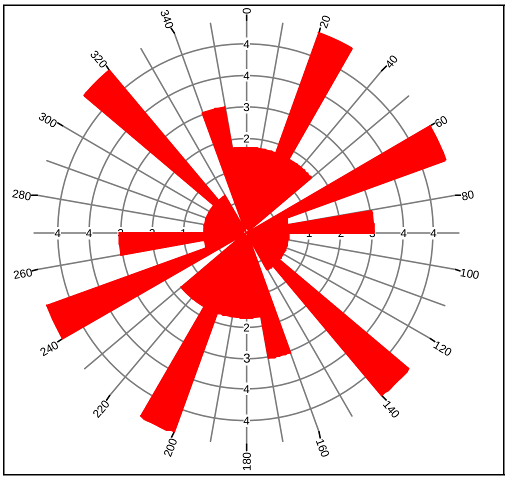

Figure 52: Rose diagram. Clast sample 2 (n=37; vector mean=80.82°)

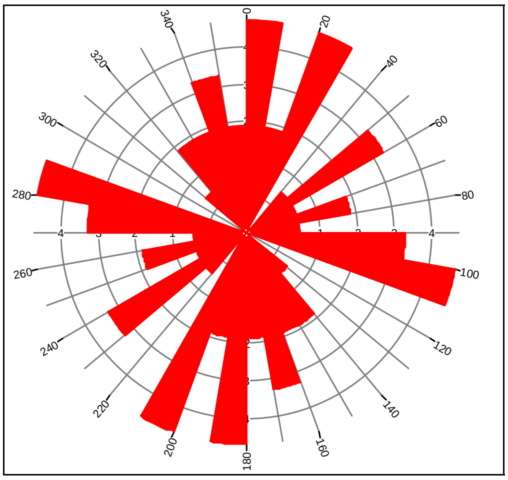

Figure 53: Rose diagram. Clast sample 4 (n=35; vector mean=81.37°)

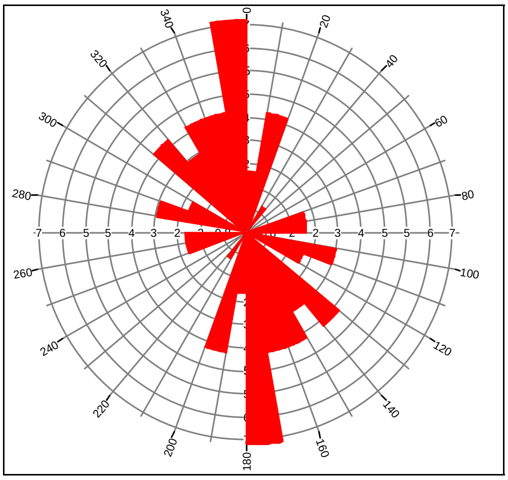

Figure 54: Rose diagram. Clast sample 6 (n=38; vector mean=306.05°)

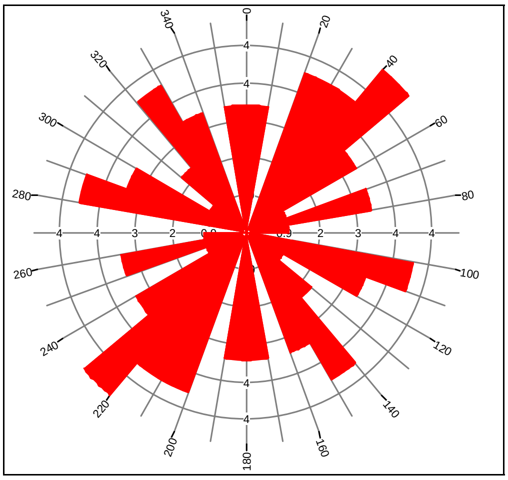

Figure 55: Rose diagram. Clast sample 7 (n=44; vector mean=82.23°)

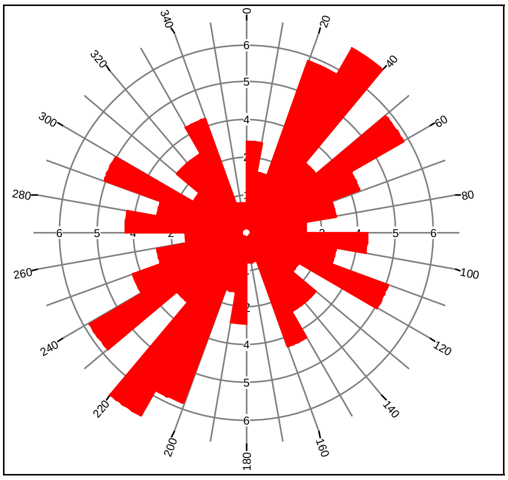

Figure 56: Rose diagram. Clast sample 8 (n=62; vector mean=76.41°)

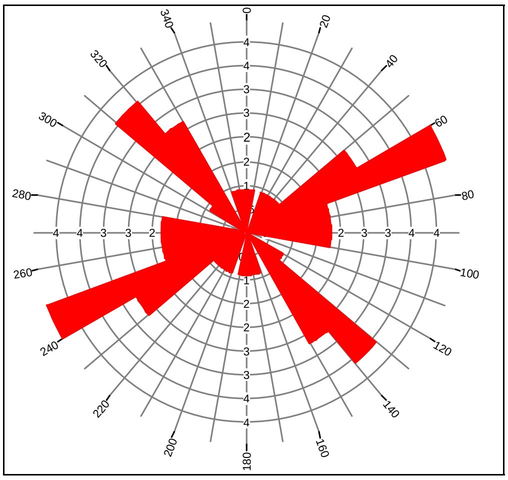

Figure 57: Rose diagram. Clast sample 9 (n=28; vector mean=88.57°)

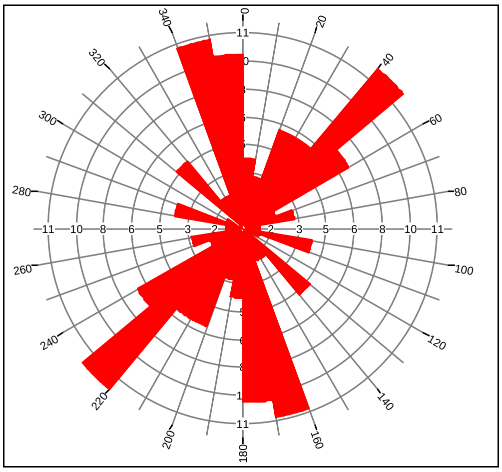

Figure 58: Rose diagram. Clast sample 10 (n=80; vector mean=86.38°)

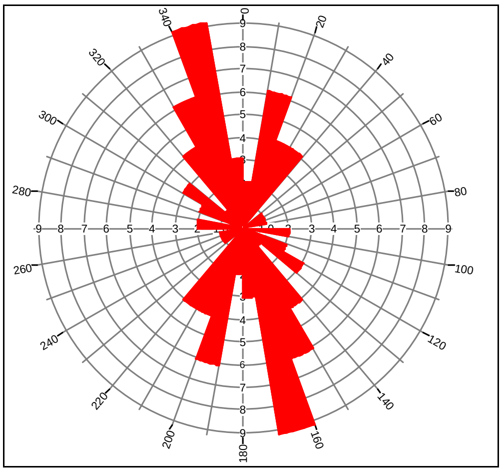

Figure 59: Rose diagram. Clast sample 11 (n=49; vector mean=288.62°)

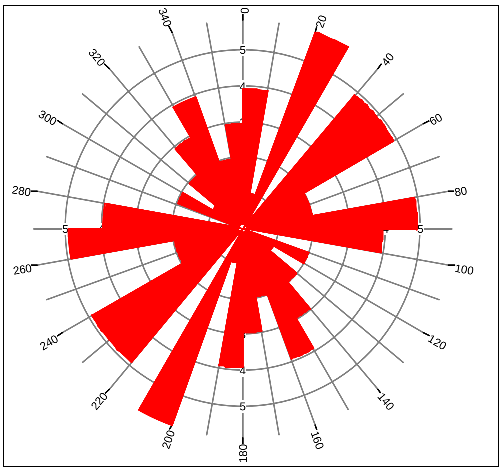

Figure 60: Rose diagram. Clast sample 12 (n=51; vector mean=80.86°)

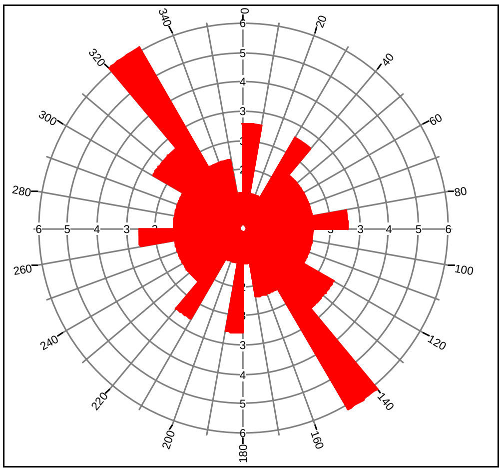

Figure 61: Rose diagram. Clast sample 13 (n=42; vector mean=276.72°)

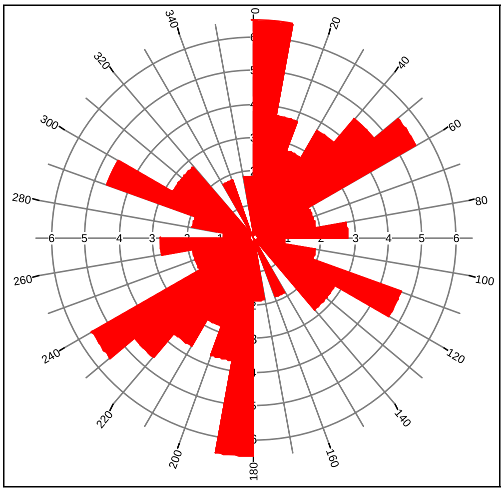

Figure 62: Rose diagram. Clast sample 14 (n=54; vector mean=64.90°)

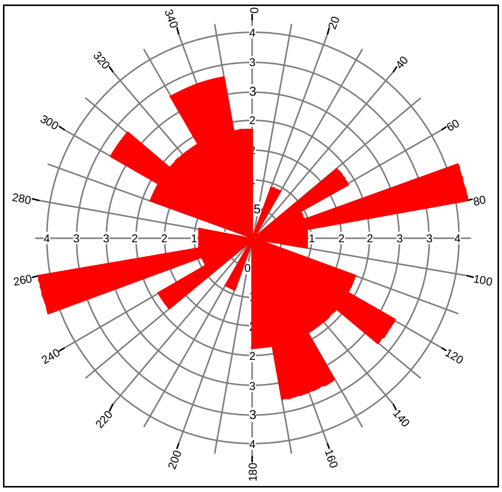

Figure 63: Rose diagram. Clast sample 16 (n=27; vector mean=297.23°)

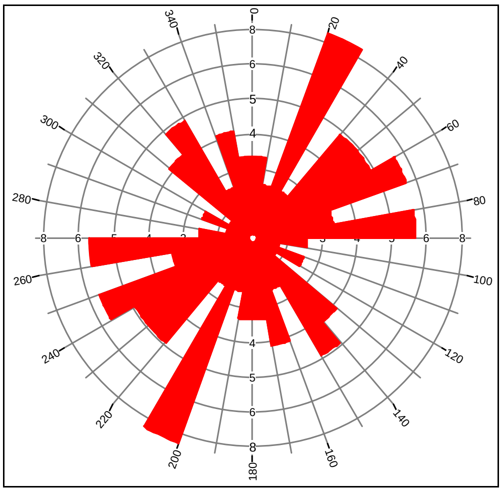

Figure 64: Rose diagram. Clast sample 17 (n=64; vector mean=80.33°)

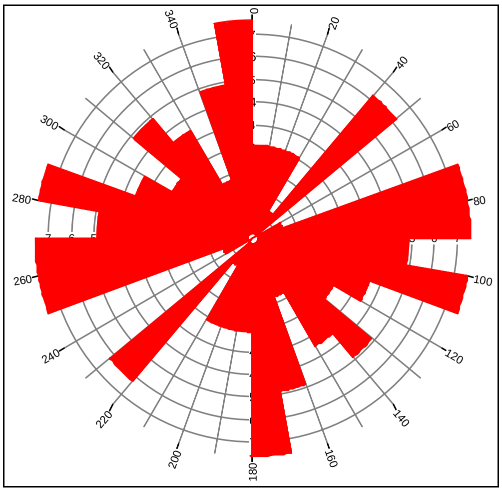

Figure 65: Rose diagram. Clast sample 18 (n=73; vector mean=280.60°)

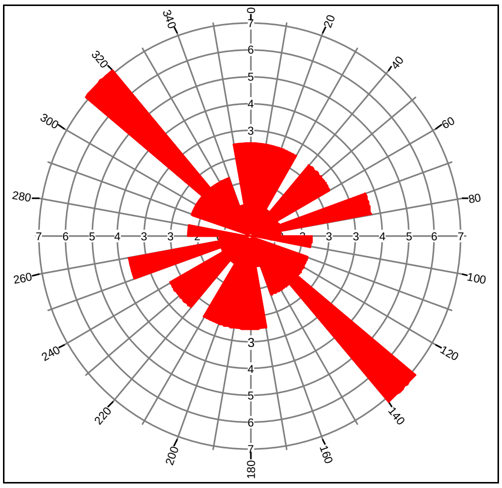

Figure 66: Rose diagram. Clast sample 20 (n=43; vector mean=88.74°)

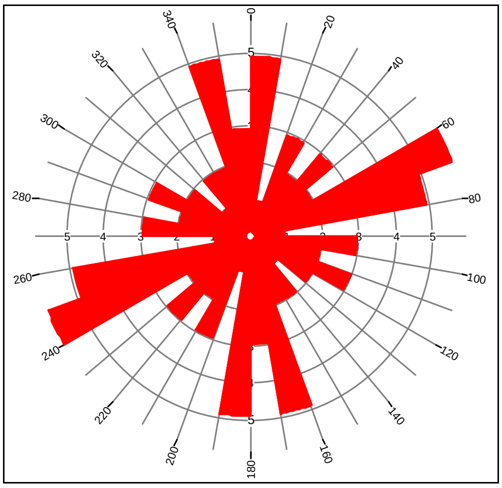

Figure 67: Rose diagram. Clast sample 21 (n=51; vector mean=85.86°)

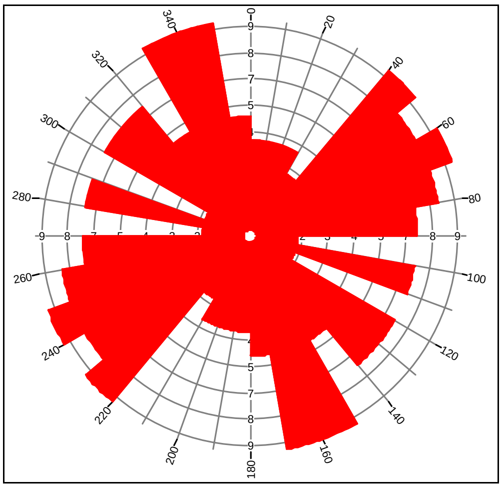

Figure 68: Rose diagram. Clast sample 22 (n=109; vector mean=274.39°)

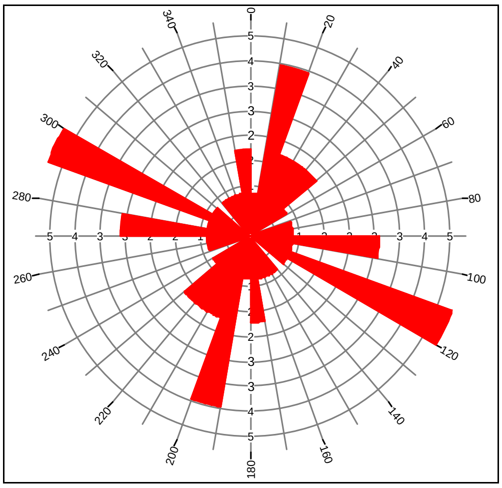

Figure 69: Rose diagram. Clast sample 23 (n=29; vector mean=80.19°)

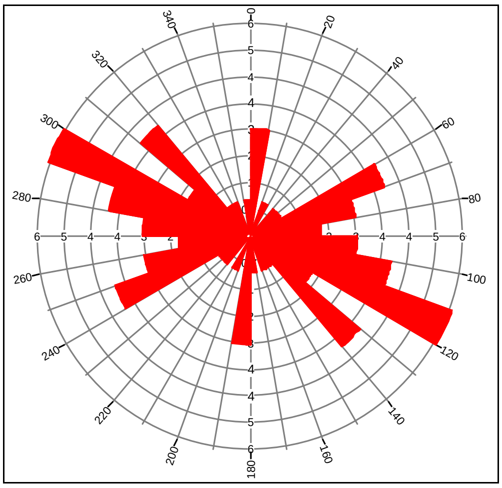

Figure 70: Rose diagram. Clast sample 24 (n=37; vector mean=275.67°)

4.1 The Lower Gravels (sections 3 and 5), Railway Ballast Pit (samples 1–9 & 11)

The samples from sections 3 and 5 were characterised by small sample sizes (n_{min}=15, n_{max}=62), with samples 1, 3 and 5 all discarded due to n>25. Samples 2, 4 and 7 (Figure 52, Figure 53 & Figure 55) indicate no clear patterning.

Sample 11 (section 5, east face, primary axis NNW–SSE, secondary axis NNE–SSW) suggests two flow vectors, although the data is rather equivocal. The blade and prolate sub-samples (Figure 71 & Figure 72) align NNW–SSE (secondary axis NNE–SSW) and NNE–SSW (secondary axis NNW–SSE) respectively. The vertical distribution of clast weights through the sample (Figure 73) suggests a *possible* reduction in stream competence through time, although there is no clear trend and the lithostratigraphic log (section 5, east face) does not record any marked changes in gravel grain size in the relevant section. A model of deposition through increasing clast resistance is therefore preferred. Overall, the data suggest NW–SE and NE–SW flow vectors, both of which are suggestive of an ancestral river Axe source for the gravels.

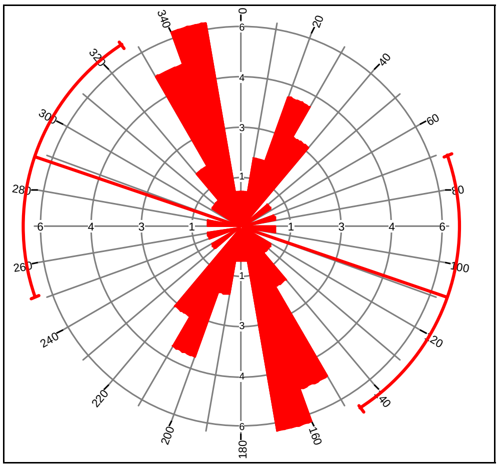

Figure 71: Rose diagram. Clast sample 11 (blades). N=29; vector mean=288.90°

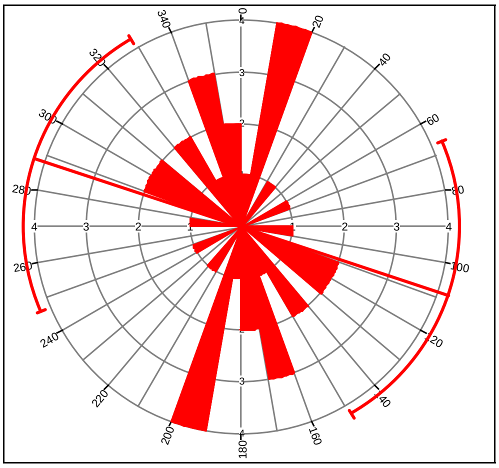

Figure 72: Rose diagram. Clast sample 11 (prolates). N=20; vector mean=288.26°

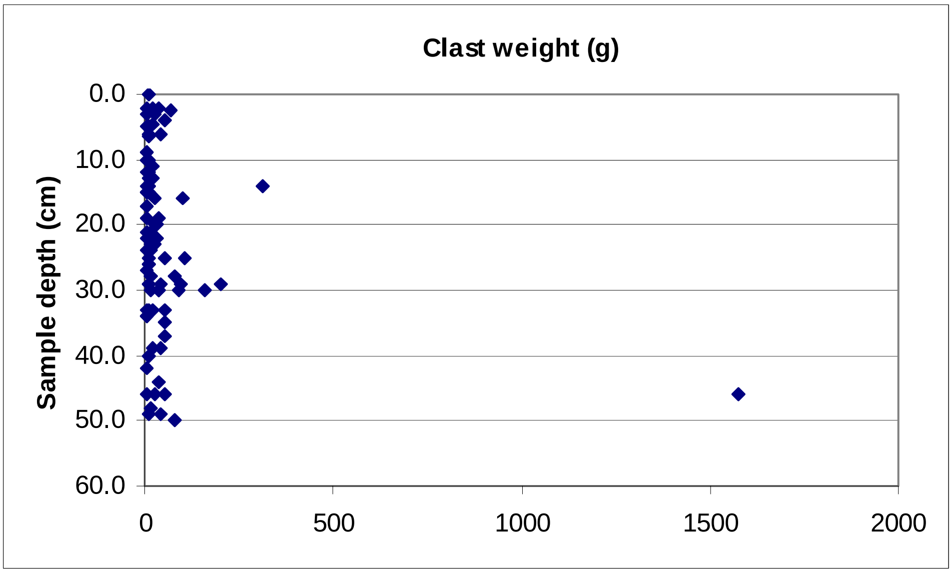

Figure 73: clast distribution by height and weight (sample 11)

Sample 9 (section 5, north face, primary axis ENE–WSW, secondary axis NW–SE) suggests a single flow vector. This is confirmed by the blade and prolate sub-samples (Figure 74 & Figure 75), which align ENE–WSW and NW–SE respectively. The vertical distribution of clast weights through the sample (Figure 76) shows no clear trends although there is a suggestion of decreasing stream competence through time. However, the lithostratigraphic log shows no marked changes in gravel clast size in the relevant section. Overall the data suggest that the overriding mode of deposition for the sample was an increase in clast resistance rather than a reduction in stream competence through time. Following a model of increasing clast resistance, blade clasts align the long axis at right angles to flow, while prolate clasts align the long axis parallel to flow. The alignment of the blade clasts (ENE–WSW) and the prolate clasts (NW–SE) therefore indicates a broadly NW–SE flow vector, suggestive of an ancestral river Axe source for these lower gravels.

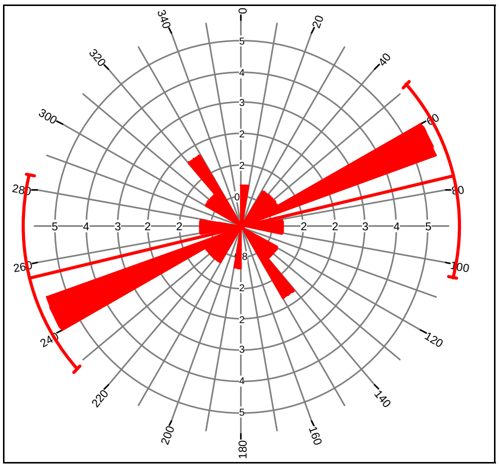

Figure 74: Rose diagram. Clast sample 9 (blades). N=15; vector mean=76.32°

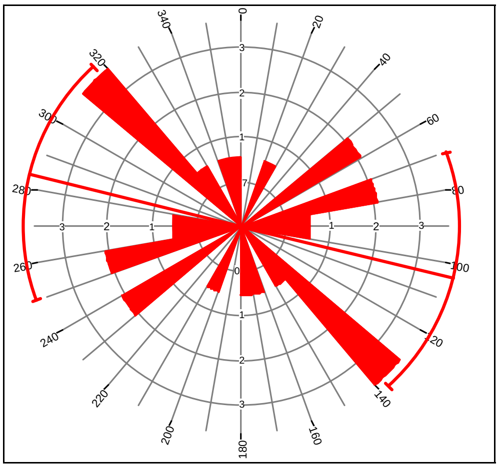

Figure 75: Rose diagram. Clast sample 9 (prolates). N=13; vector mean=283.82°

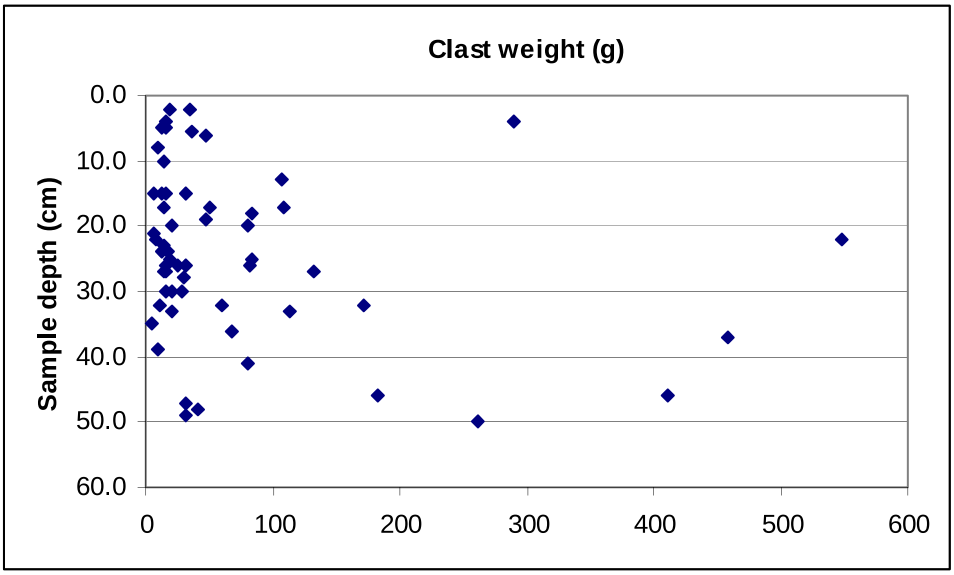

Figure 76: clast distribution by height and weight (sample 9)

Sample 8 (section 5, north face, primary axis NE–SW, secondary axis WNW–ESE) suggests the possibility of two flow vectors. The blade sub-sample (Figure 77) displays two major axes (NE–SW and WNW–ESE), although additional clast orientations are also evident. The prolate sub-sample (Figure 78) shows a clear primary axis (NE–SW). The vertical distribution of clasts through the sample (Figure 79) indicates clear evidence for the reduction of stream competence, with a trend towards small (sub 100g) clasts in the top 30 cm of the sample. Interestingly this pattern conflicts with the lithostratigraphic log (which records fine gravel at the base of the section, overlain by a series of medium gravels and manganese horizons towards the top the sample). Overall, it is suggested that the cause of deposition was a mixture of reduced stream competence and an increase in clast resistance. Under this model, blade and prolate clasts align both parallel and at right angles to flow. The data is therefore difficult to interpret, although the strength of the NE–SW axis in the samples suggests that a NE–SW flowing channel (presumably of the ancestral river Axe) played a key role in the deposition of the gravel deposits. The presence of a WNW–ESE channel is suggested.

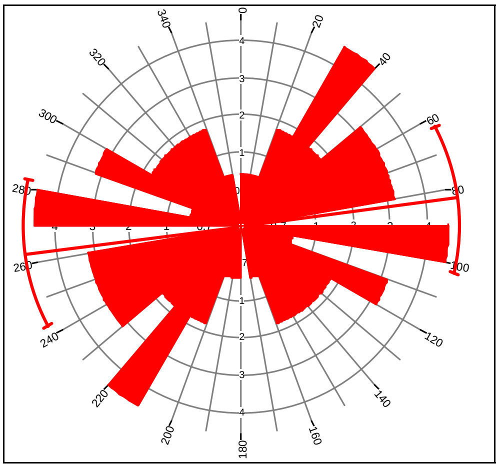

Figure 77: Rose diagram. Clast sample 8 (blades). N=36; vector mean=82.58°

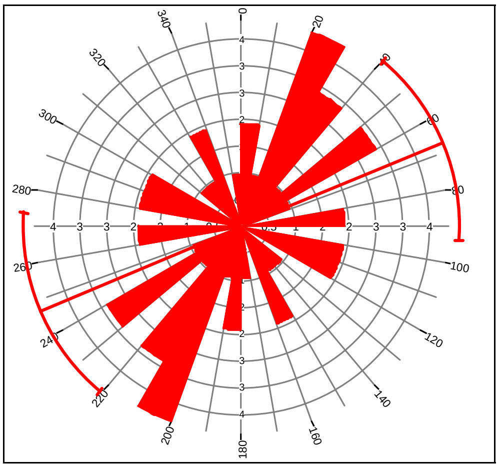

Figure 78: Rose diagram. Clast sample 8 (prolates). N=26; vector mean=67.11°

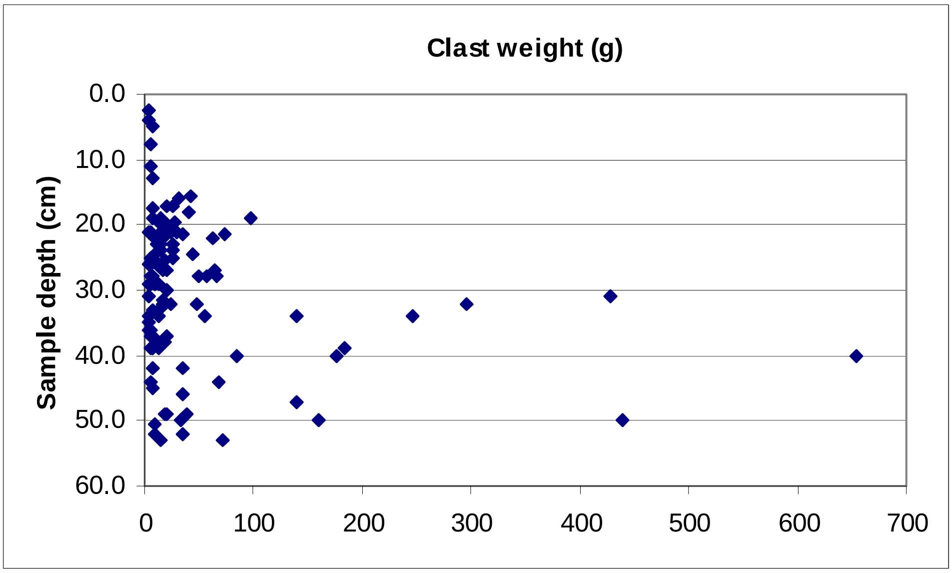

Figure 79: clast distribution by height and weight (sample 8)

Sample 6 (section 3, south face, primary axis N–S) suggests a single flow vector. The blade sub-sample (Figure 80) shows a clear primary axis (N–S) with a minor secondary axis (E–W). The prolate sub-sample (Figure 81) displays two major axes (NNW–SSE and NNE–SSW), although additional clast orientations are also evident. The vertical distribution of clasts through the sample (Figure 82) does indicate changes in stream competence through the sample, with a significant deposition of large clasts between 0.20m and 0.35m (suggesting an increase in stream energy). These changes are supported by the lithostratigraphic log, which documents a shift from matrix-supported fine to matrix-supported medium gravel. These data suggest that the cause of (at least some) of the deposition was the reduction in stream energy and competence that probably occurred in the top 20 cm of the sample. Under this model, blade clasts align the long axis parallel to flow (transport position), while prolate clasts align the long axis at right angles to flow. This interpretation suggests an N–S flow vector, when applied to the blade clast sample.

However, under this model the prolate clast sample (and a small proportion of the blade clast sample) is suggestive of an E–W flow vector. The sample and sub-sample sizes are perhaps too small to pursue this issue further, although the likeliest explanation is that the clasts were deposited through a combination of increasing clast resistance and decreasing stream competence, confusing the patterns in the clast fabric data. Overall the evidence most probably supports a N–S flowing ancestral River Axe, as indicated by the section 5 samples.

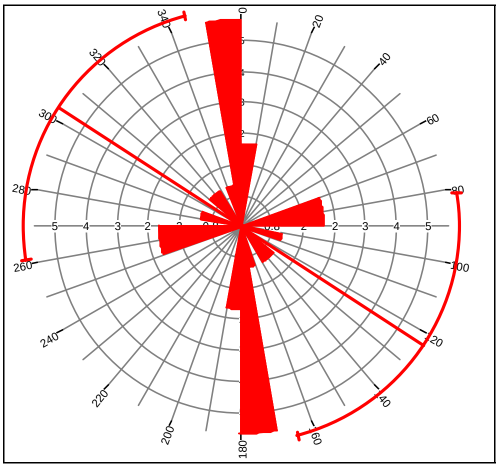

Figure 80: Rose diagram. Clast sample 6 (blades). N=15; vector mean=303.01°

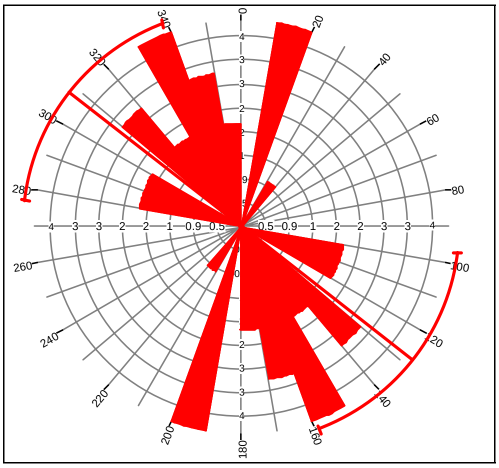

Figure 81: Rose diagram. Clast sample 6 (prolates). N=23; vector mean=307.89°

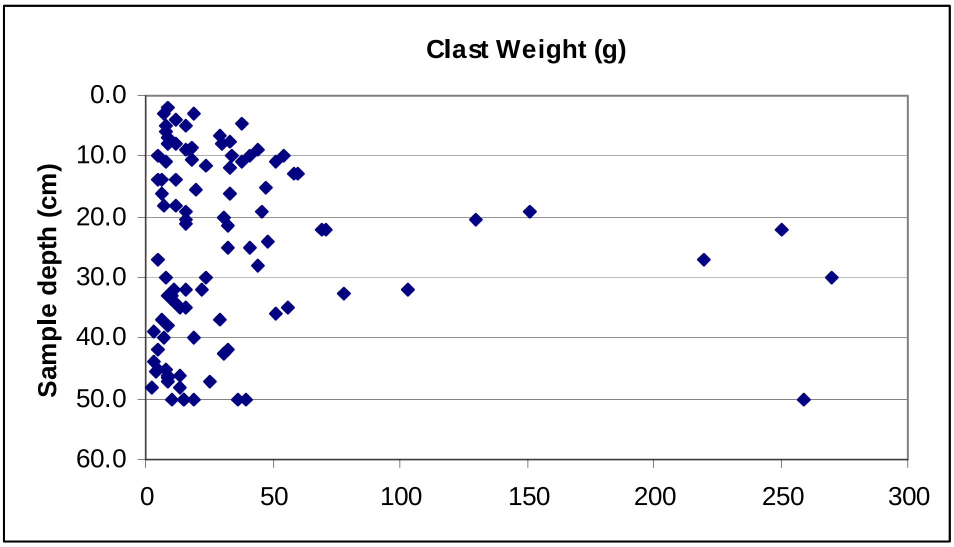

Figure 82: clast distribution by height and weight (sample 6)

Overall, the clast fabric data for the lower gravels (exposed in Railway Ballast Pit sections 3 and 5) suggests that the primary flow direction was north–south and that the source of the fluvial gravels was the Middle Pleistocene River Axe. Localised processes (e.g. channel-braiding, meander bends) may account for the other flow directions evident in the clast fabric samples, although there is possible evidence for an east bank tributary.

4.2 The Upper Gravels (sections 1, 9, 10, 11 and 13), Railway Ballast Pit and Pratt's New Pit (samples 10, 12–13, 16–18 & 20–24)

The clast samples from sections 1, 9, 10, 11 and 13 were characterised by a wide range of sample sizes (n_{min}=27 and n_{max}=108). Samples 12 and 18 showed no clear pattering.

Sample 10 (section 1, west face, major axes NNW–SSE and NE–SW) suggests two flow vectors. The blade sub-sample (Figure 83) shows primary (NE–SW) and secondary (NNW–SSE) axes, a trend reversed in the prolates sub-sample (Figure 84, primary axis NNW–SSE and secondary axis NE–SW). The vertical distribution of clasts through the sample (Figure 85) does not suggest any clear patterns with respect to changing stream competence through time. A model of deposition through increasing clast resistance would result in blade clasts lying at right angles to flow and prolate clasts lying parallel to flow. The data therefore identify a N–S flowing ancestral River Axe as the major clast source, although there is also evidence for a second channel, flowing NE–SW. This flow vector may represent a braided channel or meandering bend of the River Axe or an east bank tributary stream (perhaps ancestral to the River Blackwater).

Sample 13 (section 1, west face, primary axis NNW–SSE) suggests two flow vectors. The blade sub-sample (Figure 86) shows a primary axis (NW–SE), while the prolate sub-sample (Figure 87) shows a NNW–SSE primary axis. The vertical distribution of clasts through the sample (Figure 88) suggests possible reductions in stream competence through time (although the patterns are rather equivocal), while the lithostratigraphic log (section 1, west face) provides no clear evidence of changing stream energies (the sample area is characterised by medium, matrix-supported gravels throughout). The likeliest depositional model would appear to be one of increasing clast resistance (blades at right angles to flow and prolates parallel to flow), suggesting broadly NW–SE and NE–SW flowing channels as the major gravel sources. The channels are probably braided or meandering sections of the ancestral River Axe, although there is a possibility that the NE–SW channel may be an east bank tributary stream (see previous comments for sample 10).

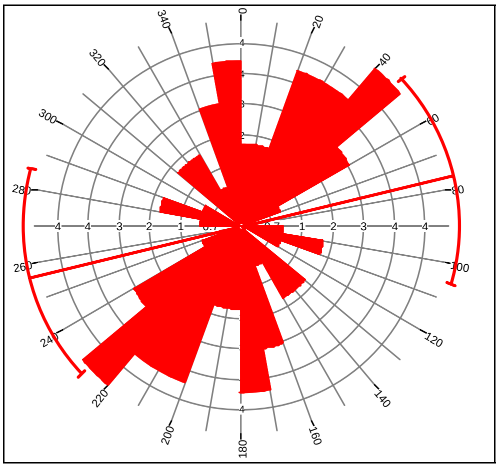

Figure 83: Rose diagram. Clast sample 10 (blades). N=37; vector mean=76.28°

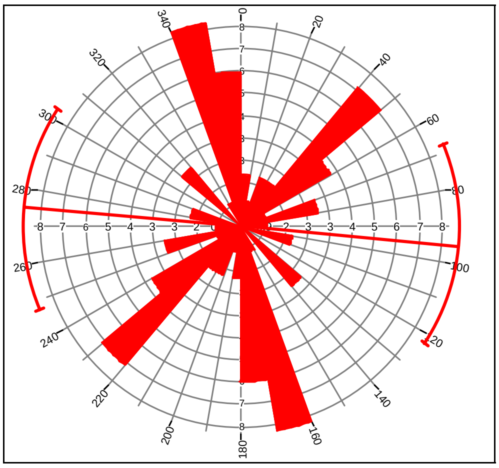

Figure 84: Rose diagram. Clast sample 10 (prolates). N=43; vector mean=275.14°

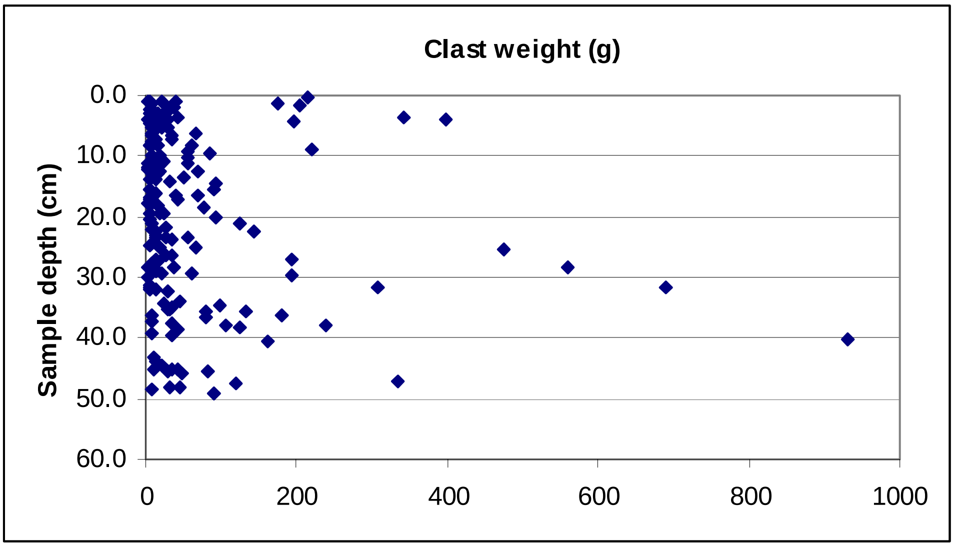

Figure 85: clast distribution by height and weight (sample 10)

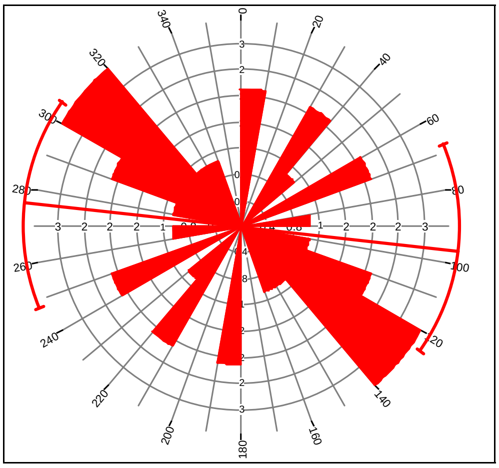

Figure 86: Rose diagram. Clast sample 13 (blades). N=19; vector mean 276.38°

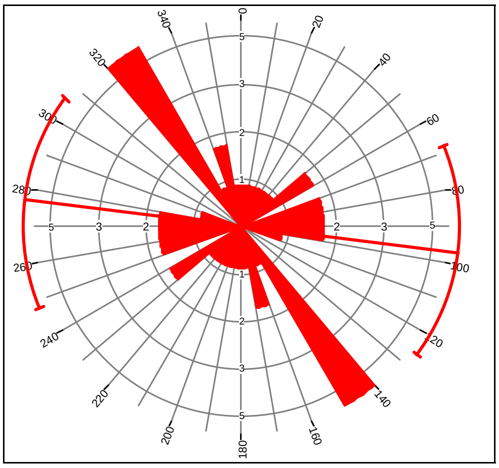

Figure 87: Rose diagram. Clast sample 13 (prolates). N=23; vector mean=277.02°

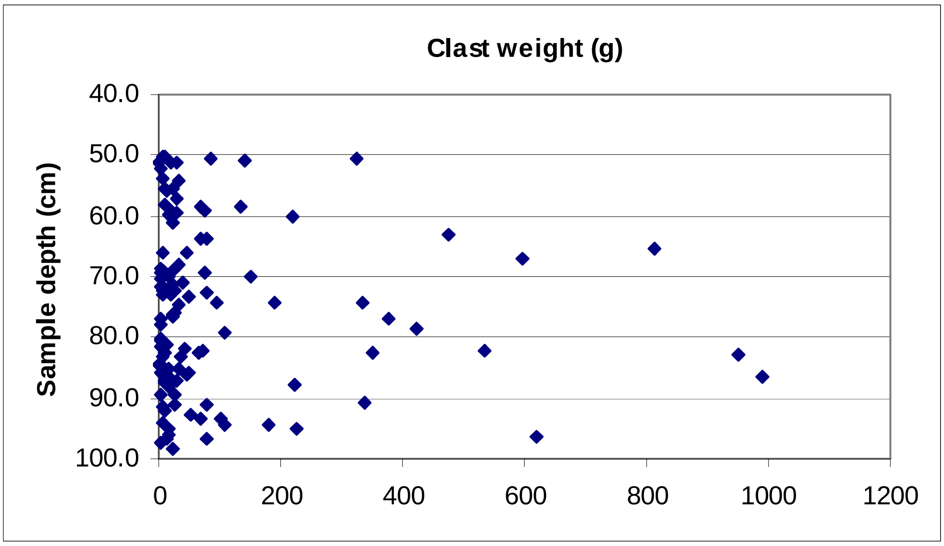

Figure 88: clast distribution by height and weight (sample 13)

Figure 89: channel profile, section 1 (west face), Railway Ballast Pit, Broom

In conclusion, the clast fabric data for the upper gravels (Railway Ballast Pit, section 1) suggests that the sediments were primarily deposited by a broadly north–south flowing ancestral River Axe. There is also equivocal evidence for the deposition of sediments by a NE–SW flowing east-bank tributary (an ancestral River Blackwater?), which is partially supported by the presence of a E–W aligned channel profile of fine-grained sands in the west face of section 1 (Figure 89). However, it is also possible that the NE–SW channel is a braided or meandering limb of the River Axe.

Clast sample 16 (section 9, south face, primary axis ENE–WSW, secondary axis NW–SE) suggests 1 major flow vector. The blade sub-sample (Figure 90) displays primary (NW–SE) and secondary (NE–SW) axes, while the prolates sub-sample (Figure 91) features a primary axis (ENE–WSW). The vertical distribution of clasts through the sample (Figure 92) does suggest evidence for a reduction in stream competence through time, particularly since the larger clasts at around 10 cm sample depth relate to a horizontally discrete cobble band that lines the base of a channel feature filled with finer-grained sands (Figure 94). However, the lithological log (section 9, south face) suggests an increase in stream energy and competence through time, with a transition from fine to medium gravels through the sample. A model of decreasing stream competence is proposed as the main depositional mechanism, although it is recognised that increasing clast resistance probably played a secondary role. Under this model, the alignment of the blade clasts parallel to flow and the prolate clasts at right angles to flow suggests a NW–SE flowing channel as the major gravel source. This channel presumably relates to the Middle Pleistocene River Axe, and the interpretation is supported by the N–S aligned fine-grained channel in section 9, with clear channel margins on its eastern edge (Figure 93), although it was not possible to expose the western channel margins due to the local topography and vegetation cover. The clasts data also suggest a possible NE–SW flowing channel, although the evidence is weaker. This channel may reflect an east bank tributary (the ancestral River Blackwater) or possibly a braided channel of the River Axe. Previous analysis by Chris Green (pers. comm.) has suggested evidence for the supply of material by an east–west flowing river system, although the evidence here suggests that the Axe was the primary source of the gravel materials.

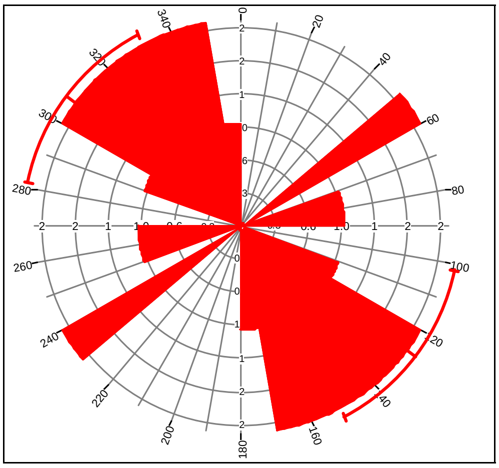

Figure 90: Rose diagram. Clast sample 16 (blades). N=16; vector mean=306.63°

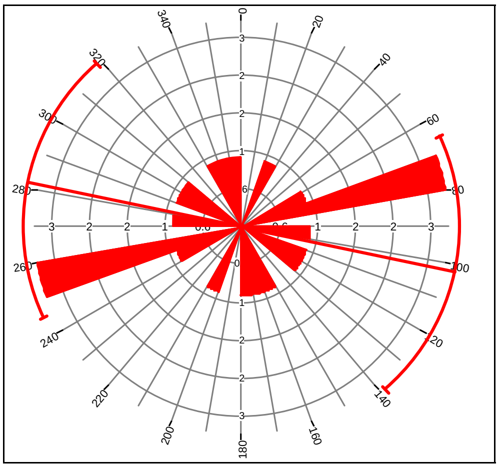

Figure 91: Rose diagram. Clast sample 16 (prolates). N=11; vector mean=281.92°

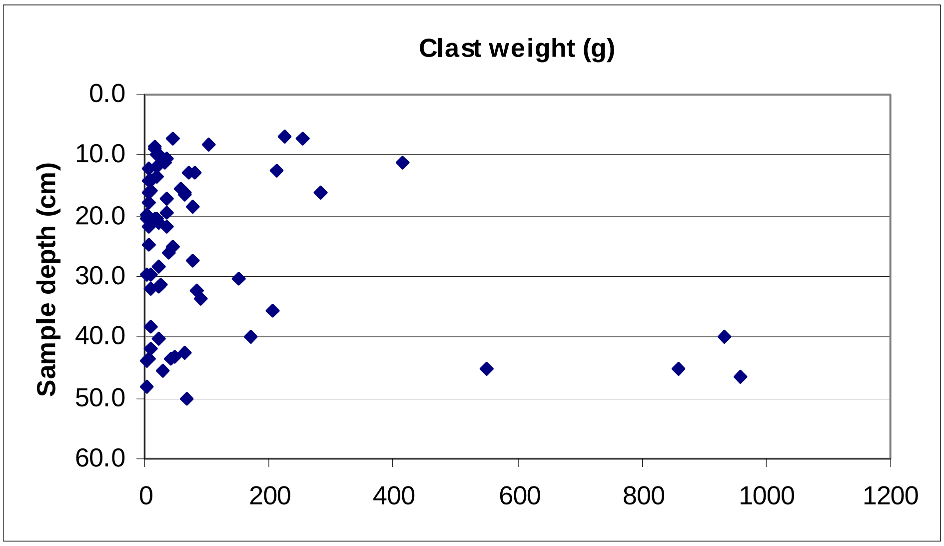

Figure 92: clast distribution by height and weight (sample 16)

Figure 93: channel feature, tapering towards the eastern margin (centre-right of image). Section 9, Pratt's New Pit

Clast sample 17 (section 9, south face, primary axis NNE–SSW, secondary axis ENE–WSW) suggests 1 major flow vectors, with a probable secondary vector. The blade sub-sample (Figure 95) indicates a primary NNE–SSW axis and a secondary ENE–WSW axis. The prolate sub-sample (Figure 96) has a primary NW–SE axis and a secondary ENE–WSW axis. The vertical distribution of clasts through the sample (Figure 97) suggests an increase in stream competence through time, indicating that the major mode of deposition was increasing clast resistance. This is also supported by the lithostratigraphic log (section 9, south face) which records a general increase in stream energy in a shift from clast and matrix-supported medium gravels to clast and matrix-supported coarse gravels. Under a model of increasing clast resistance, the alignment of the blade clasts at right angles and the prolate clasts parallel to flow indicate a NW–SE flowing channel as the major gravel source, presumably the ancestral River Axe. This is in-keeping with the evidence from sample 16 (also from the south face of section 9) and the orientation of the channel feature in section 9 (Figure 93). The clast samples also suggest a possible NE–SW flowing tributary channel, following the pattern demonstrated by sample 16.

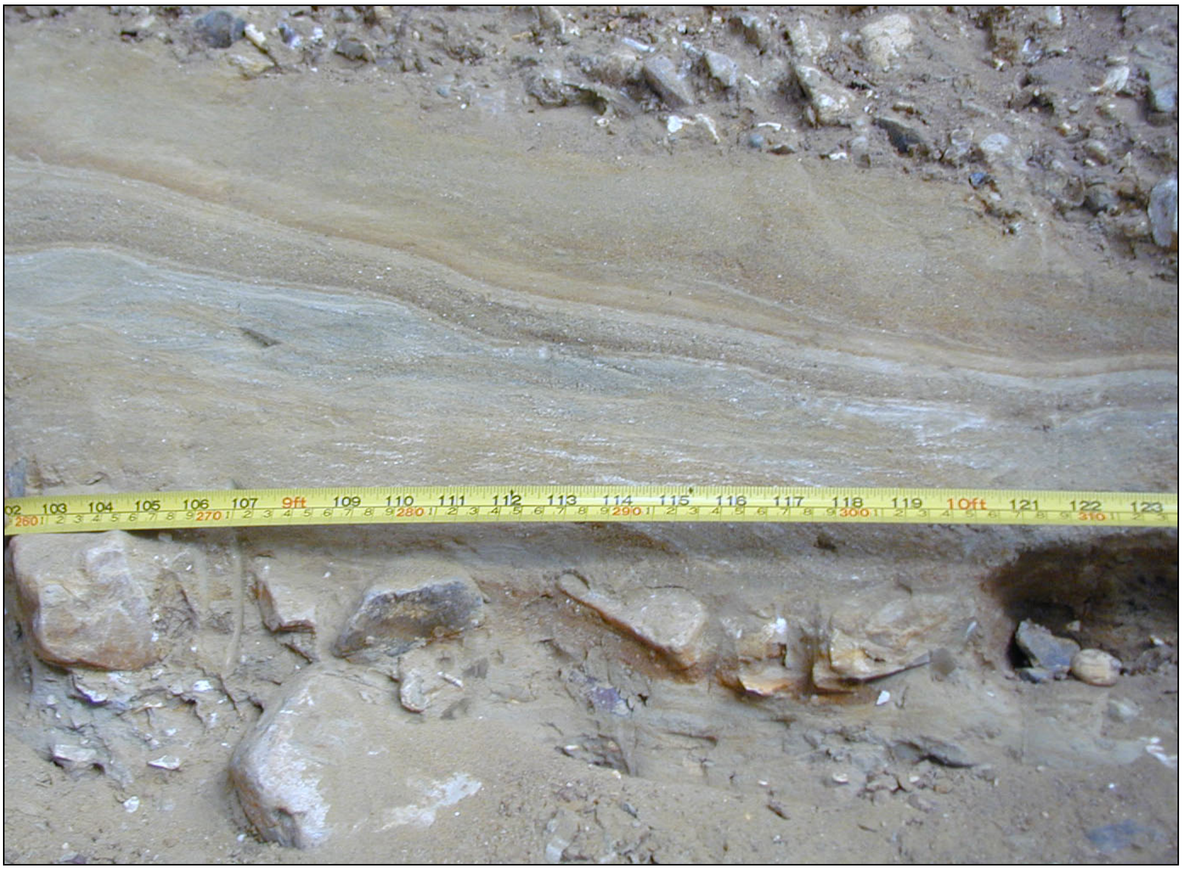

Figure 94: cobble band lying at base of channel sand deposits (section 9, Pratt's New Pit, Broom)

There are no clear patterns in clast sample 18 (section 9, south face), and nor are there any marked trends in the blade sub-sample (Figure 98). However, the prolate sub-sample (Figure 99) reveals clear primary (ENE–WSW) and secondary (NNW–SSE) axes. The vertical distribution of clasts through the sample (Figure 100) shows no clear evidence of a reduction in stream competence, suggesting that the major mode of deposition was an increase in clast resistance. This conclusion is also supported by the lithostratigraphic log (section 9, south face), which records a continuity of medium, matrix-supported gravels through the sample. Under a model of increasing clast resistance, the parallel to flow aligned prolate clasts indicate an E–W flowing channel as a probable major source for the gravels, although there is also evidence for a NW–SE flowing channel. These data support the suggestions made for samples 16 and 17, namely that there is evidence for two flow directions in the fluvial deposits of section 9. These flow vectors may reflect multiple braided or meandering channels from a predominantly N–S flowing ancestral River Axe. However, combined with the earlier work of Chris Green, it is possible that these deposits preserve evidence of a confluence between the N–S flowing River Axe and an E–W flowing River Blackwater. Nonetheless, it is important to stress that the blade clasts (and the overall sample) show a generally confused pattern, and the above conclusion should be treated with caution.

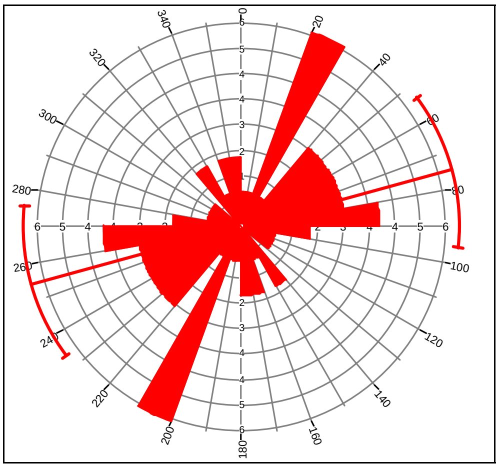

Figure 95: Rose diagram. Clast sample 17 (blades). N=37; vector mean=74.62°

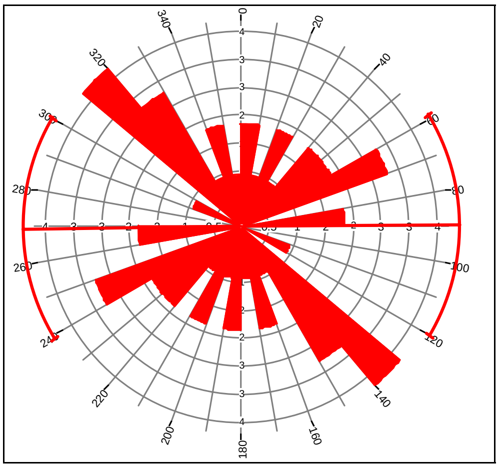

Figure 96: Rose diagram. Clast sample 17 (prolates). N=27; vector mean=89.48°

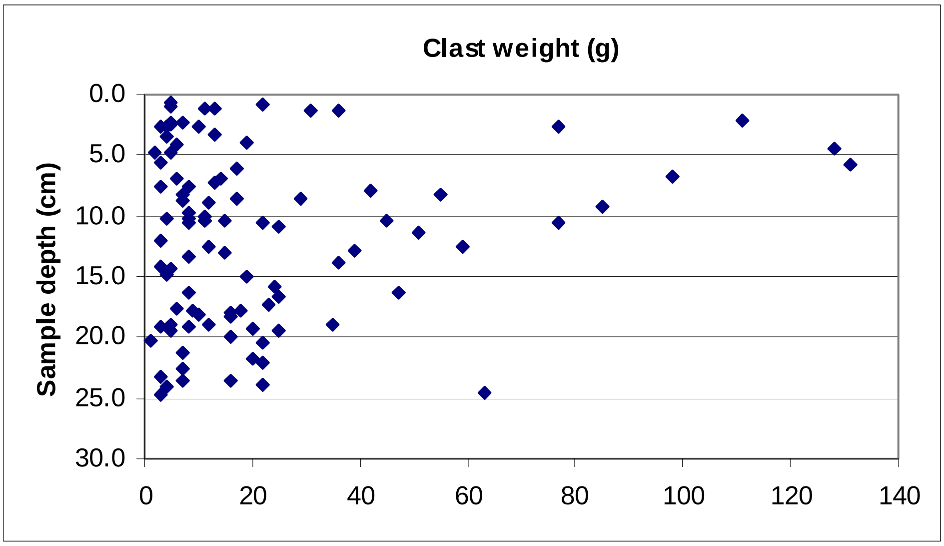

Figure 97: clast distribution by height and weight (sample 17)

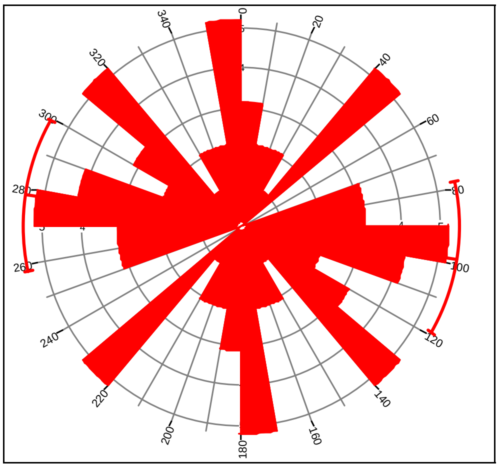

Figure 98: Rose diagram. Clast sample 18 (blades). N=48; vector mean=278.57°

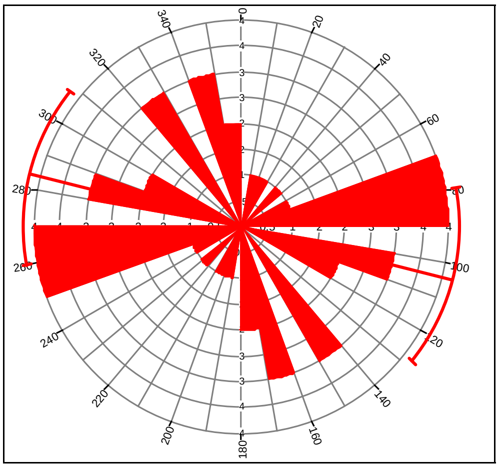

Figure 99: Rose diagram. Clast sample 18 (prolates). N=25; vector mean=284.06°

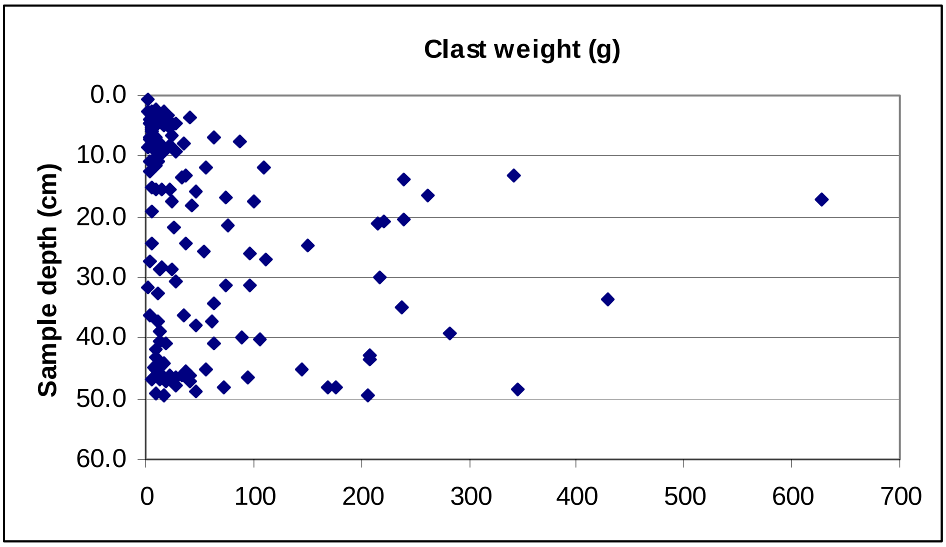

Figure 100: clast distribution by height and weight (sample 18)

Sample 20 (section 11, west face, primary axis NW–SE) indicates a single major flow vector. The blade sub-sample (Figure 101) suggests a primary and secondary axis, although these are rather poorly defined.

The prolate sub-sample (Figure 102) indicates a clear primary axis (NW–SE). The vertical distribution of clasts through the sample (Figure 103) suggests a slight decrease in stream competence. The lithostratigraphic log (section 11, west face) indicates localised trends of reduced stream competence (indicated by narrow beds of fine gravels), although the dominant deposits are matrix-supported medium gravels. Overall, the proposed mode of deposition is increasing clast resistance. Following this model, the prolate clasts would suggest a NW–SE channel (ancestral River Axe?) as the major source of the gravels. The blade clasts provide a far less clear pattern, possibly suggesting both N–S and E–W flowing channel systems. In general however, the data indicate a broadly N–S orientated channel.

Sample 21 (section 11, south face, primary axis ENE–WSW, secondary axis NNW–SSE) indicates two flow vectors. The blade sub-sample (Figure 104) indicates a primary (ENE–WSW) and secondary axis (NNE–SSW). The prolate sub-sample (Figure 105) has a single primary axis (NNW–SSE). The vertical distribution of clasts through the sample (Figure 106) provides no clear evidence for a reduction in stream competence through time, suggesting that the major cause of deposition were increases in clast resistance. The lithostratigraphic log (section 11, south face) supports this interpretation, revealing a uniform sequence of matrix-supported medium gravels. Following a model of increasing clast resistance, the sample indicates a major N–S flowing channel supplying the majority of the gravel deposits, although there is also evidence in the blade clast sample for an E–W flowing channel of secondary importance. Overall, the data again stress the importance of the N–S flowing Pleistocene River Axe as a major source of the fluvial deposits, although it also hints at the possible confluence between the Axe and an east bank tributary (the ancestral River Blackwater?), which may have also supplied a minority of the gravel deposits.

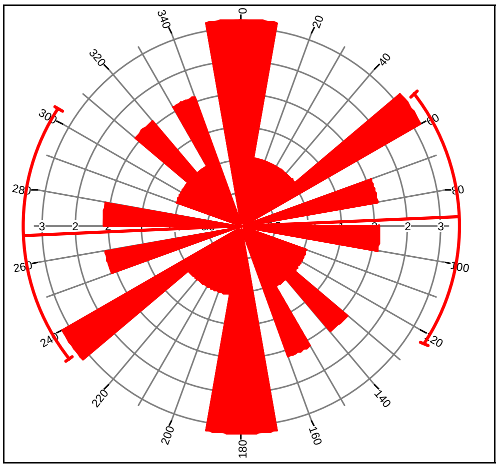

Figure 101: Rose diagram. Clast sample 20 (blades). N=24; vector mean=87.56°

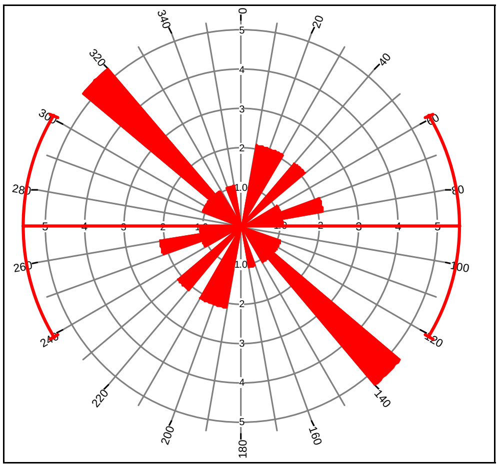

Figure 102: Rose diagram. Clast sample 20 (prolates). N=19; vector mean=89.98°

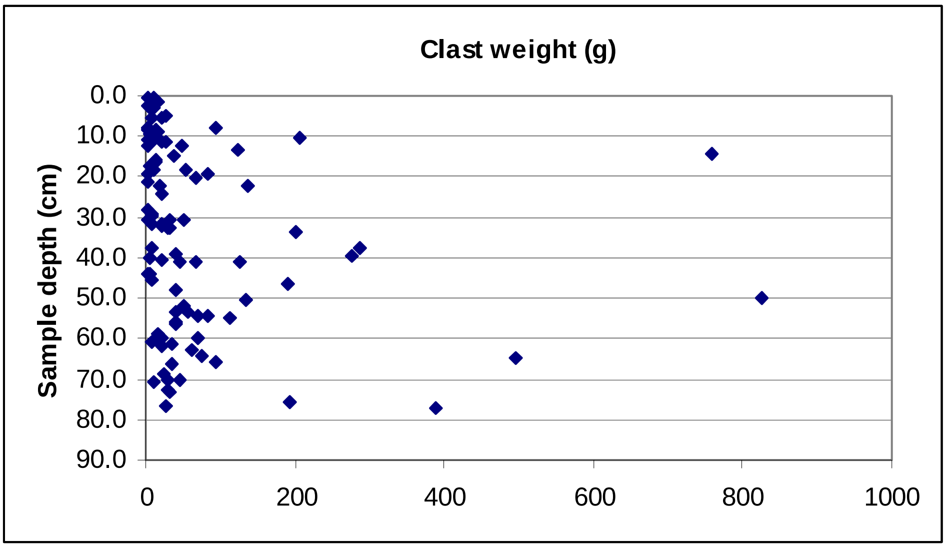

Figure 103: clast distribution by height and weight (sample 20)

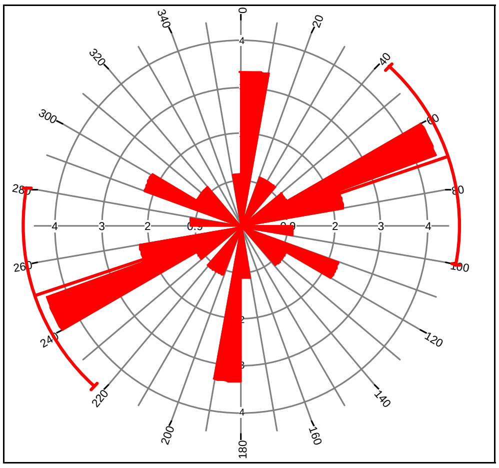

Figure 104: Rose diagram. Clast sample 21 (blades). N=18; vector mean=71.44°

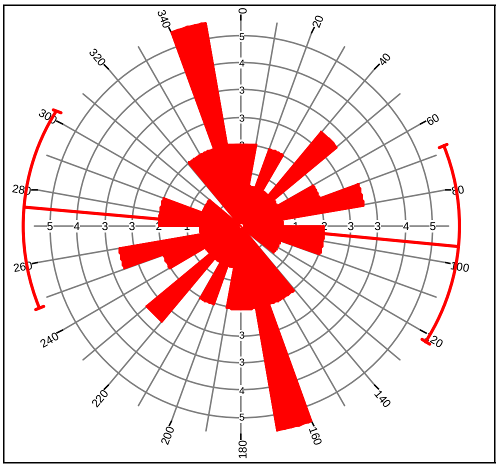

Figure 105: Rose diagram. Clast sample 21 (prolates). N=33; vector mean=275.09°

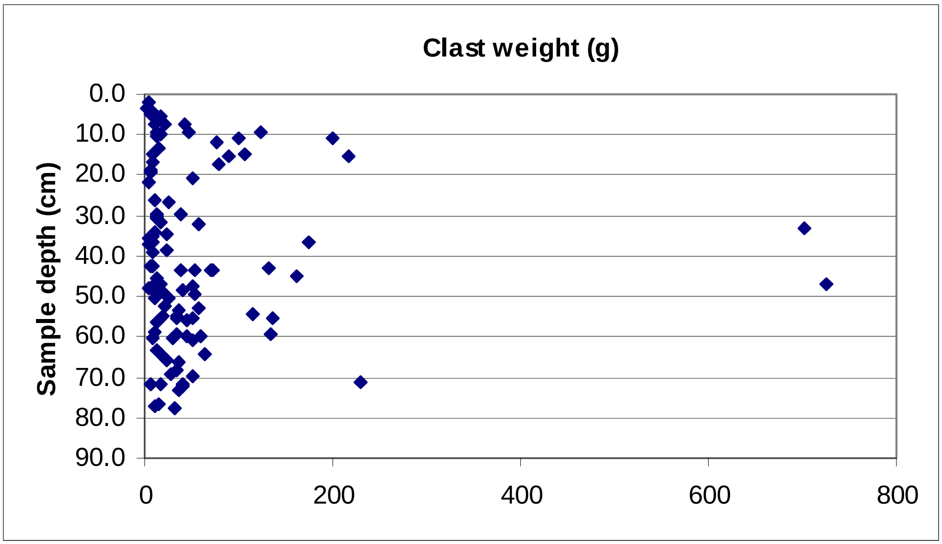

Figure 106: clast distribution by height and weight (sample 21)

Sample 22 (section 13, west face, primary axis NNW–SSE, secondary axis NE–SW) suggests two flow vectors. The blade sub-sample (Figure 107) suggests a primary (NNW–SSE) and secondary axes (NE–SW), although the general data patterning is rather unclear. The prolate sub-sample (Figure 108) indicates a clear primary axis (ENE–WSW) and a broad secondary axis (predominantly NW–SE). The vertical distribution of clasts through the sample (Figure 109) does not reveal any clear evidence of decreasing stream competence through time, suggesting that the proposed mode of deposition is through increasing clast resistance. The lithostratigraphic log (section 13, west face) supports the interpretation, recording a sequence dominated by matrix-supported, medium gravels, interspersed with occasional very thin beds of fine gravel. Under a model of increasing clast resistance, both the blade and prolate clast samples suggest a ENE–WSW flowing channel as the major source of the gravels, although there is also evidence for a broadly NW–SE aligned secondary channel. It is difficult to differentiate between an ancestral River Blackwater or a braided/meandering channel of the Axe as the ENE–WSW flowing system, but in general the data (combined with the other upper gravel samples) suggest the fluvial deposits of an east bank tributary, and perhaps evidence of a confluence between this tributary and the River Axe.

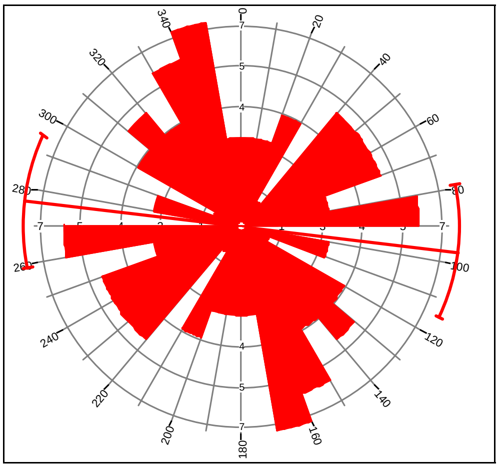

Figure 107: Rose diagram. Clast sample 22 (blades). N=68; vector mean=276.80°

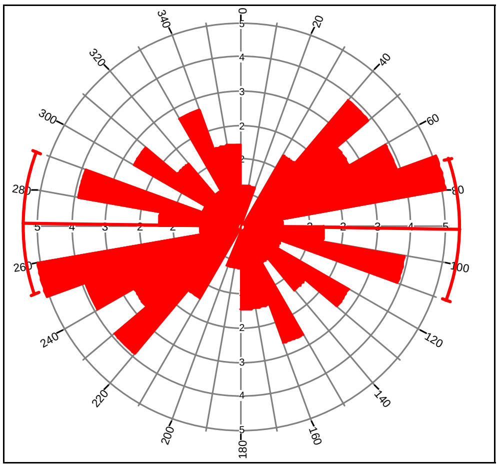

Figure 108: Rose diagram. Clast sample 22 (prolates). N=41; vector mean=270.88°

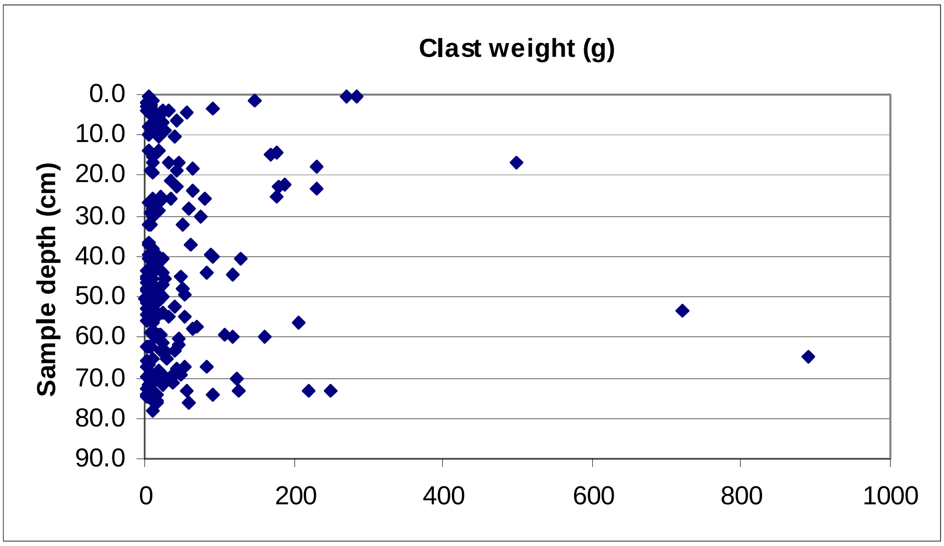

Figure 109: clast distribution by height and weight (sample 22)

Sample 23 (section 10, west face, primary axis WNW–ESE, secondary axis NNE–SSW) suggests two flow vectors. The blade sub-sample (Figure 110) suggests primary (NNE–SSW) and secondary axes (WNW–ESE), although there are a series of other clasts orientations (notably N–S and NE–SW). The prolate sub-sample (Figure 111) indicates a clear primary axis (WNW–ESE) and secondary axis (NE–SW). The vertical distribution of clasts through the sample (Figure 112) suggests a possible reduction in stream competence through time, although the patterning is rather equivocal. The lithostratigraphic log (section 10, west face) records a fine, matrix-supported gravel throughout the sample (with slightly larger clasts at the base and small patches of very fine gravel), and supports a general interpretation of the mode of deposition as increasing clast resistance. Under this model, both the blade and prolate clast samples suggest a WNW–ESE flowing channel as the major source of the gravels, with evidence for a broadly NE–SW aligned secondary channel. The WNW–ESE and NE–SW channels could represent the braided or meandering channel of either the Axe and/or the Blackwater, although in the light of the other samples, an Axe source for the WNW–ESE channel seems more probable. Once again however, the data seem to point towards the fluvial deposits from a confluence, either between the Axe and the Blackwater rivers, or between the braiding channels of the Axe.

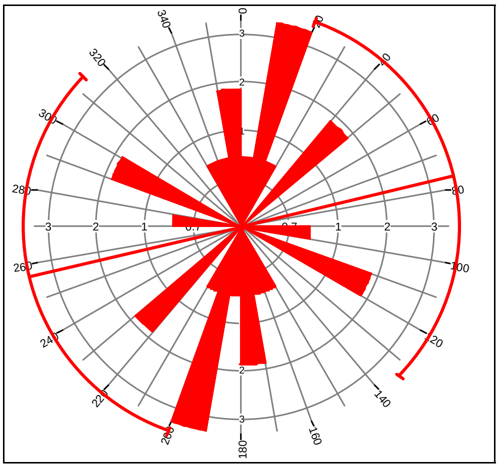

Figure 110: Rose diagram. Clast sample 23 (blades). N=14; vector mean=76.62°

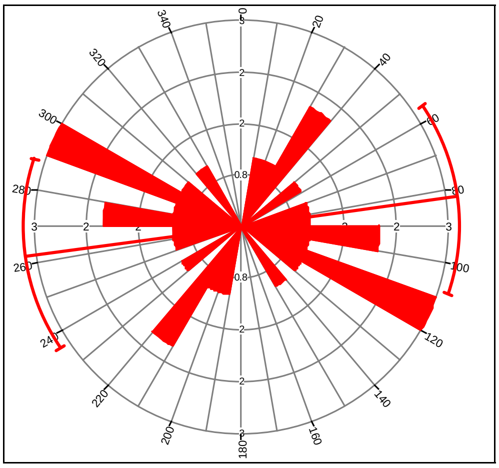

Figure 111: Rose diagram. Clast sample 23 (prolates). N=15; vector mean=82.15°

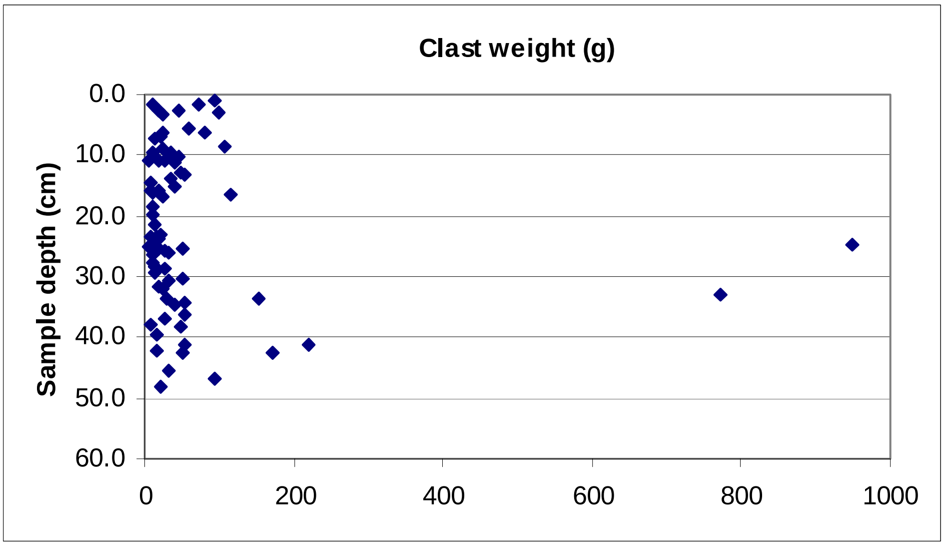

Figure 112: clast distribution by height and weight (sample 23)

Sample 24 (section 10, north face, primary axis WNW–ESE, secondary axes NW–SE and ENE–WSW) suggests two flow vectors. The blade sub-sample (Figure 113) suggests a primary (WNW–ESE) axis, and a series of subsidiary clast orientations (e.g. N–S and ENE–WSW). The prolate sub-sample (Figure 114) indicates a clear primary axis (ENE–WSW) and a secondary axis (WNW–ESE). The vertical distribution of clasts through the sample (Figure 115) suggests a possible reduction in stream competence through time. However, the lithostratigraphic log and section drawing (section 10, north face) records a matrix-supported, medium gravel throughout the sample (with localised patches of fine gravel), and supports a general interpretation of the mode of deposition as increasing clast resistance. Under this model, the prolate sample strongly suggests a E–W flowing channel. The blade data are more equivocal, but appear to indicate a broadly NE–SW channel. In general, the data indicate fluvial gravel deposited by two channels (flowing E–W and NE–SW respectively), probably representing a confluence between channels of the River Axe and its east bank tributary, the Blackwater.

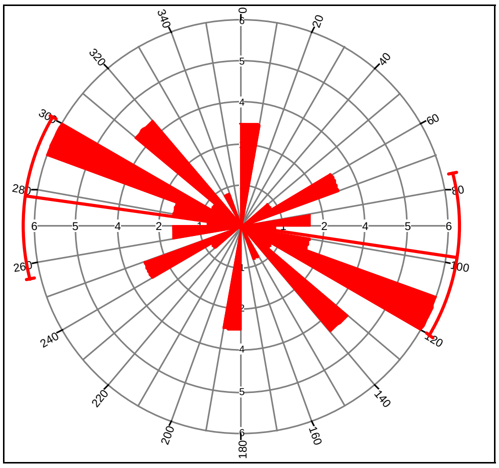

Figure 113: Rose diagram. Clast sample 24 (blades). N=24; vector mean=278.06°

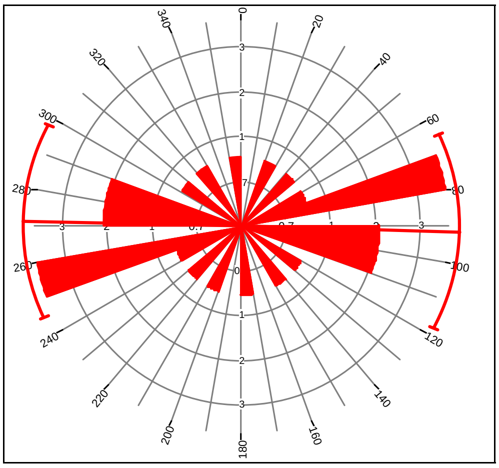

Figure 114: Rose diagram. Clast sample 24 (prolates). N=13; vector mean=271.53°

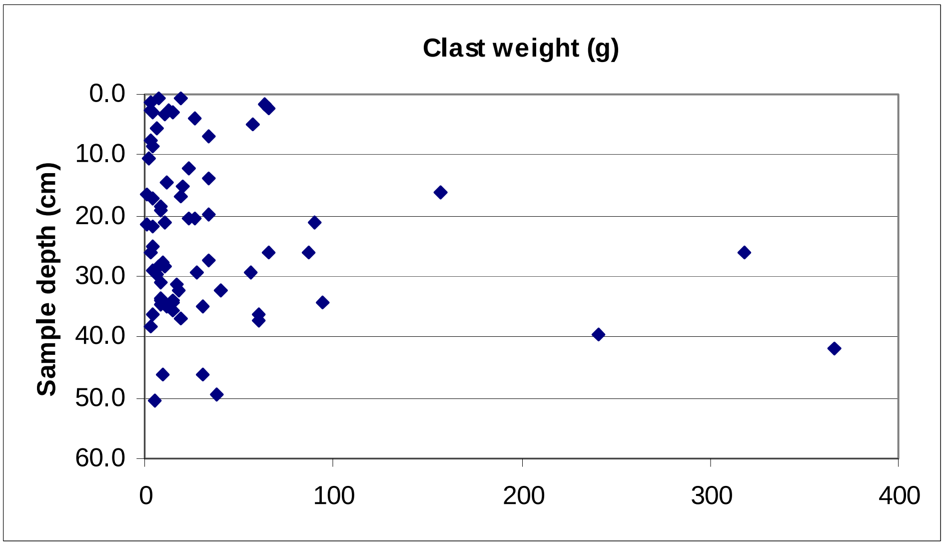

Figure 115: clast distribution by height and weight (sample 24)

In general, the clast fabric data for the upper gravels (exposed in Pratt's New Pit sections 9, 10, 11 and 13) suggest that the primary source of the fluvial gravel deposits was the N–S flowing Middle Pleistocene River Axe. However, there was also a significant supply of sediments from the E–W flowing Pleistocene River Blackwater, and the data suggest that the confluences (contemporary with the deposition of the sediments) between the channels of these systems may have occurred in the region of the Pratt's New Pit exposures. The range of clast fabric orientations suggests that braided and meandering channels were common and may have flowed for short distances in significantly different directions to the overall system vector (Figure 116).

In conclusion, the clasts fabric data for the upper gravels (in both the Railway Ballast Pit and Pratt's New Pit) indicates that the River Axe was the major fluvial system and source of the gravel deposits, but that there was also significant sediment supply from the east bank River Blackwater tributary. The data suggest that the confluence between the two systems was *c.* 150–200m north-east of its current location during the period of the Middle Pleistocene contemporary with the deposition of the sediments.

Figure 116: meandering channel system, Avon Ystwyth, Wales

4.3 Upper/Lower Gravels (section 8), Pratt's New Pit (sample 14).

The stratigraphic affinities of the sediments (coarse-grained gravels and fine-grained sands, silts and clays) exposed in section 8 were difficult to establish. This was primarily due to the disturbance of the sediments in the upper part of the exposure (suggesting the possibility of slumped deposits) and the small dimension of the exposure. The elevation of the deposits suggested that the exposed gravels might be the lower gravels, lying beneath the middle beds, although this remains a preliminary conclusion.

Sample 14 (section 8, south face, primary axis NNE–SSW, secondary axis WNW–ESE) suggests two flow vectors. The blade sub-sample (Figure 117) suggests two primary axes (NNE–SSW and WNW–ESE). The prolate sub-sample (Figure 118) indicates a clear primary axis (NNE–SSW), but a far less clearly defined secondary axis (a range of orientations are present). The vertical distribution of clasts through the sample (Figure 119) suggests a clear reduction in stream competence through time. The lithostratigraphic log (section 8, south face) records a changing sequence of fine and medium matrix-supported gravels through the sample, although the trend of reduced stream competence through time is less clearly indicated. A model of deposition through reduced stream competence is tentatively proposed, although the probable role of increased clast resistance in the depositional process is acknowledged. Under this model, the blade clasts suggest NNE–SSW and WNW–ESE channel flows, while the prolate sample suggests a broadly E–W flowing channel. In general, the data indicate fluvial gravel deposition by two channels (flowing broadly E–W and NE–SW respectively), of which the E–W channel appears to have been a more significant source of gravel sediments. The data probably represents a confluence between channels of the River Axe and its east bank tributary, the Blackwater. However, it is stressed that the mode of clast deposition in this sample is not clear, and that therefore the interpretation could easily be reversed, highlighting the NE–SW flowing channel (the River Axe) as the primary depositional system.

In general, the data from section 8 (sample 8) follow the pattern established in the other, higher elevation, clast samples from Pratt's New Pit — namely the presence of both the Axe and the Blackwater systems and evidence for possible channel confluences.

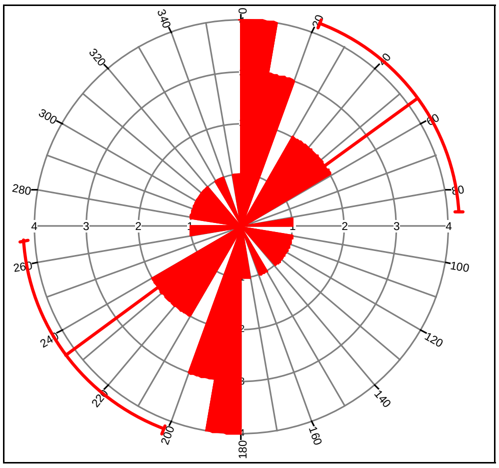

Figure 117: Rose diagram. Clast sample 14 (blades). N=36; vector mean=82.58°

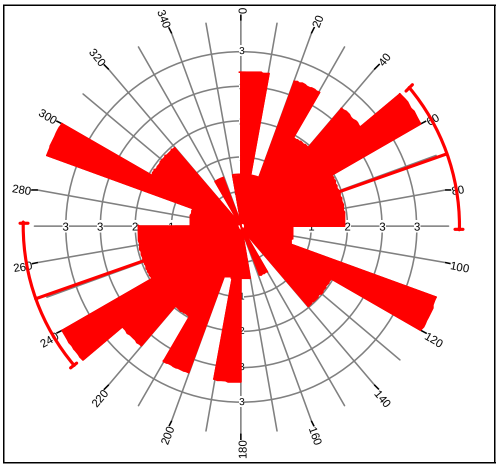

Figure 118: Rose diagram. Clast sample 14 (prolates). N=26; vector mean 67.11°

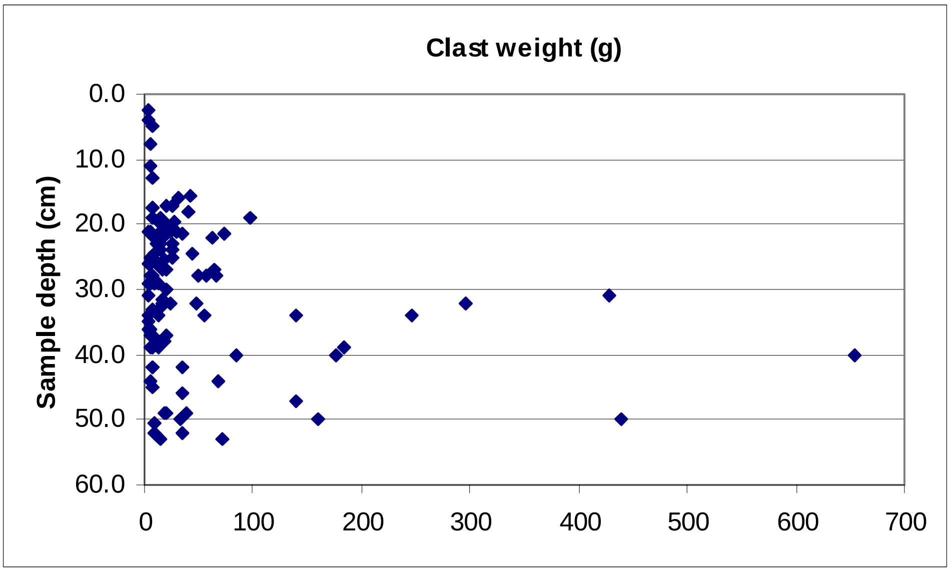

Figure 119: clast distribution by height and weight (sample 14)

5. CONCLUSIONS

This chapter has been concerned with a reconstruction of the Pleistocene environment of the River Axe valley in the vicinity of the Broom locality. The case study was intended both as a test case for the models of Middle Pleistocene fluvial activity proposed in chapter 2 and also to provide a geoarchaeological context for the exploration of the Broom secondary context archaeological assemblage (chapter 4). The reconstruction paid specific reference to four themes, and these are reviewed below:

- The depositional conditions associated with the fluvial sediments.
- The palaeo-environmental conditions associated with the deposition of the fluvial sediments.
- The age of the fluvial sediments.
- The duration of the fluvial events (depositional and erosional) associated with the sedimentary sequences.

5.1 Depositional conditions

Due to the paucity of diagnostic bedforms and fluvial architecture in the Broom sediments, it is difficult to reconstruct the fluvial palaeo-landscape in great detail. The major sedimentary trend through time (coarse-grained gravels > fine-grained sediments > coarse-grained gravels) suggests a broad cycle of cold-climate river regime (multi-channel? braided?), changing to a warm-climate regime (single-channel? meandering?) before returning to a cold-climate pattern. The structure of the fine-grained sediments deposited within coarse-grained sequences (e.g. in section 9 and section 1,) suggests channels with high width-depth ratios, indicative of braided rather than meandering systems. However, the possible impacts of high energy erosion of fine-grained sediments must be kept in mind when interpreting those deposits. The laminated, fine-grained sediments in section 14 probably indicate sediment accumulation in still water conditions (e.g. abandoned channels), but OSL samples from these deposits suggest that the sediments may date from the Late Devensian and therefore have no environmental association with the other Middle Pleistocene deposits. The fine-grained sediments in the Railway Ballast Pit (sections 2, 3 and 5) have been previously interpreted as floodplain overbank deposits (Scourse unpub. man.), and the current work has produced no evidence to reject this interpretation.

The sequence also provided extensive evidence of short-term variation in the fluvial regimes, notably illustrated by the occurrence of fine-grained sediments within coarse-grained gravel deposits (e.g. section 1, section 9, section 10 and section 13). It is suggested that the Broom rivers were responding to relatively brief, sub-MIS climatic oscillations (as are increasingly being revealed in the global climatic record). These responses were recorded in the Broom sequence by major shifts between fine and coarse-grained sediment and minor variations in the grain size, sorting and (where present) bedding of the sediments.

A cautionary note is sounded however, with respect to the small exposures investigated and the potential for apparently temporal (vertical) variation to be a result of migrating river channels and the exposure of a different sub-environment of the floodplain.

The clast fabric data suggest (in contrast to previous suggestions from Green (pers. comm.) that the major source of the fluvial sediments at Broom was the River Axe, for both the upper and lower gravels (and probably the middle beds as well). Nonetheless, the River Blackwater was a significant east bank tributary, and appears to have confluenced with the River Axe in the area of Pratt's New Pit, during the period when the upper gravel sediments were accumulating. It is not yet clear whether the position of the Blackwater and its sedimentary contribution was the same during the accumulation of the Lower Gravel, as these are not currently exposed in Pratt's New Pit.

5.2 Palaeo-environmental conditions

The work of Scaife (unpub. man.) and Scourse (unpub. man.) has provided good evidence for the Broom palaeo-environment. There was a general consensus, favouring a boreal environment with pine woodland and small amounts of spruce, fir and birch. The dominance of grasses was noted (although they were of greater significance in the Scaife samples), and patchy woodland coverage was proposed. Scourse favoured a model of open country dominated by heath on the higher ground, while Scaife argued for floodplain grassland with scattered woods.

The initial OSL dates (Section 5.3 below) do not support Scourse's conclusion of deposition the end of a Middle Pleistocene interglacial, although his alternative model (interstadial age) and Scaife's argument for an early interglacial age are both feasible on the current dates.

5.3 Age of the Broom sequence

The initial OSL dates suggest a mid–late MIS-8 age for the middle beds and upper gravels in the Broom sequence. The age of the lower gravels remains uncertain, although the likeliest estimate is probably late stage 9–early stage 8. There is considerable stratigraphical confusion in the dates (e.g. the apparent reversal of the sample ages for the middle beds (section 2) and the upper gravels (section 9), perhaps due to the error ranges associated with OSL samples of Middle Pleistocene age. There is also notable variation in multiple OSL samples from individual sedimentary units (e.g. the dates from section 2, section 9 and section 13).

Given the error ranges on the dates and the variation in sample ages from single sedimentary units, no attempt was made to relate individual sedimentary units to specific palaeo-climatic events (e.g. stadial/interstadial events or the MIS-8/7 glacial/interglacial transition).

5.4 Duration of the fluvial events

Estimating the duration of the fluvial events (deposition, erosion and quiescence) represented in the Broom sedimentary sequence has been extremely difficult, mainly due to the geochronological limitations of the OSL-derived ages. The field data from Broom does not provide a clear picture to either refute or support the model of rapid fluvial activity proposed in the previous chapter.

The evidence of multiple landsurface development throughout the sequence (indicated by iron/manganese horizons) suggests some significant hiatus and periods of relative stability, although the lack of weathering evidence, cryoturbation features and cold-climate indicators such as ice wedge clasts (in what was a predominantly cold-climate environment), would suggest that the breaks in fluvial activity were not of considerable length.

In general, the evidence suggests a model of episodic fluvial activity during mid–late marine isotope stage 8 (280–240 kya BP), interspersed with periods of stability and landsurface development. The Broom evidence therefore provides partial support to the model of fluvial sequences presented in the previous chapter, although it is not clear whether the Broom fluvial activity relates to minor or major phases of climatic transition.

5.5 Archaeological Applications

With respect to the archaeological content of the Broom sediments, a series of preliminary observations can be drawn:

1. *If* the artefacts are all contemporary with their individual sedimentary contexts (the lower gravels, middle beds, and upper gravels), then the Broom assemblage represents several thousand years of occupation in the River Axe landscape. Under this model, the presence of a repetitive morphological form (approximately 20% of the Broom bifaces are amygdaloid in form) within the assemblage requires detailed investigation with respect to: its provenance (are all these artefacts from the middle beds?); the possibilities of transmitting techno-cultural knowledge over such a long time-span; and the potential relationships between the raw materials and artefact morphology.
2. If the artefacts represent a single occupation, what mechanisms can explain their incorporation throughout a sedimentary sequence that accumulated episodically over several thousand years?
3. Although it is possible that the artefacts recovered from the upper gravels were re-worked during late stage 8 by erosional processes from the fine-grained middle beds sediments, this interpretation cannot explain their presence in the lower gravels.
4. For significant periods of time, the River Axe floodplain (a boreal environment with pine woods and grasslands) would have been inhabitable, with stable landsurfaces forming on the fluvial sediments. The floodplain would therefore act as an intermittent, potential location for episodic hominid activity and artefact discard, prior to their subsequent incorporation with the fine and coarse-grained sediments.
5. If the artefacts have been fluvially transported prior to their incorporation within the sediments, can any assessment be made of their spatial and temporal origins?

These issues are examples of the processes and questions that are central to the understanding of the secondary context archaeology, and are addressed in the next two chapters.

CHAPTER 4

CASE STUDY INVESTIGATION OF THE BROOM LOWER PALAEOLITHIC ASSEMBLAGE

1. INTRODUCTION

Chapter 3 provided the geoarchaeological and geochronological context for a case study investigation of the Lower Palaeolithic secondary context assemblage from Broom. This resource offers an invaluable opportunity to test whether a palimpsest artefact assemblage can yield high resolution archaeological information with respect to; (1) the original geographical source(s) of stone tools recovered from a secondary, fluvial context; and (2) potential temporal patterning in the technological composition of the assemblage. The investigation of these issues is tenable for the Broom artefact assemblage thanks to the existence of C.E. Bean's detailed archive, including his field notebook and collection of site photographs. The Bean archive has been examined previously (Green 1988), but is re-investigated here with emphasis upon a more detailed technological examination of the artefacts and a new approach to the issue of artefact transportation within a fluvial environment.

This chapter is therefore concerned with an assessment of the relative homogeneity and/or heterogeneity of the Broom artefact assemblage, in terms of the spatial and temporal origins of the recorded artefacts. The Broom assemblage is compared against the Dunbridge assemblage (recovered from river terrace gravels in the valley of the River Test, Hampshire (Dale 1912a, 1918), both to test the transferability of the analytical methodologies and to explore the potential variability in spatio-temporal structure that may exist between different secondary context assemblages. Specifically, the analysis of the Broom artefact assessment explores:

- The technological characteristics of the artefacts within the assemblage.
- The stratigraphic origins of individual artefacts.
- The potential source(s) of the artefacts, prior to fluvial transportation, as indicated by abrasion, edge micro-flaking and morphological data.

2. THE BEAN ARCHIVE

The Bean archive was compiled by the late Charles Bean, F.S.A., Surveyor for Sherborne and a keen (and distinguished) amateur archaeologist. It documents 90 visits made by Bean to the site of Broom between September 1932 and October 1941, and his recovery of large numbers of Palaeolithic artefacts from the fluvial sediments of the River Axe that were exposed at the site. Bean's records documented the development of the working faces at Broom, the exposure of the sediments (also recorded in sixty site photographs), the artefacts (Section 2.3), and are a companion to the Bean collection of over 900 Palaeolithic stone tools (Green 1988: 173). One of the most valuable aspects of the Bean archive are the site plans and sections that he drew at intervals between 1935 and 1931, reproduced here as Figure 120–Figure 128.

2.1 Development of the Broom sites

In 1932, Pratt's Old Pit (lying to the north of Holditch Lane) extended approximately 75m from east to west, and 30m from north to south. The pit was worked on two, slightly uneven, levels, with a lower floor at *c.* 47.5m OD (in August 1933 the lowest point of the pit was described as lying approximately 8 feet below the road level at the cottages (*c.* 49m OD) and an upper floor approximately 1.5m above. At the

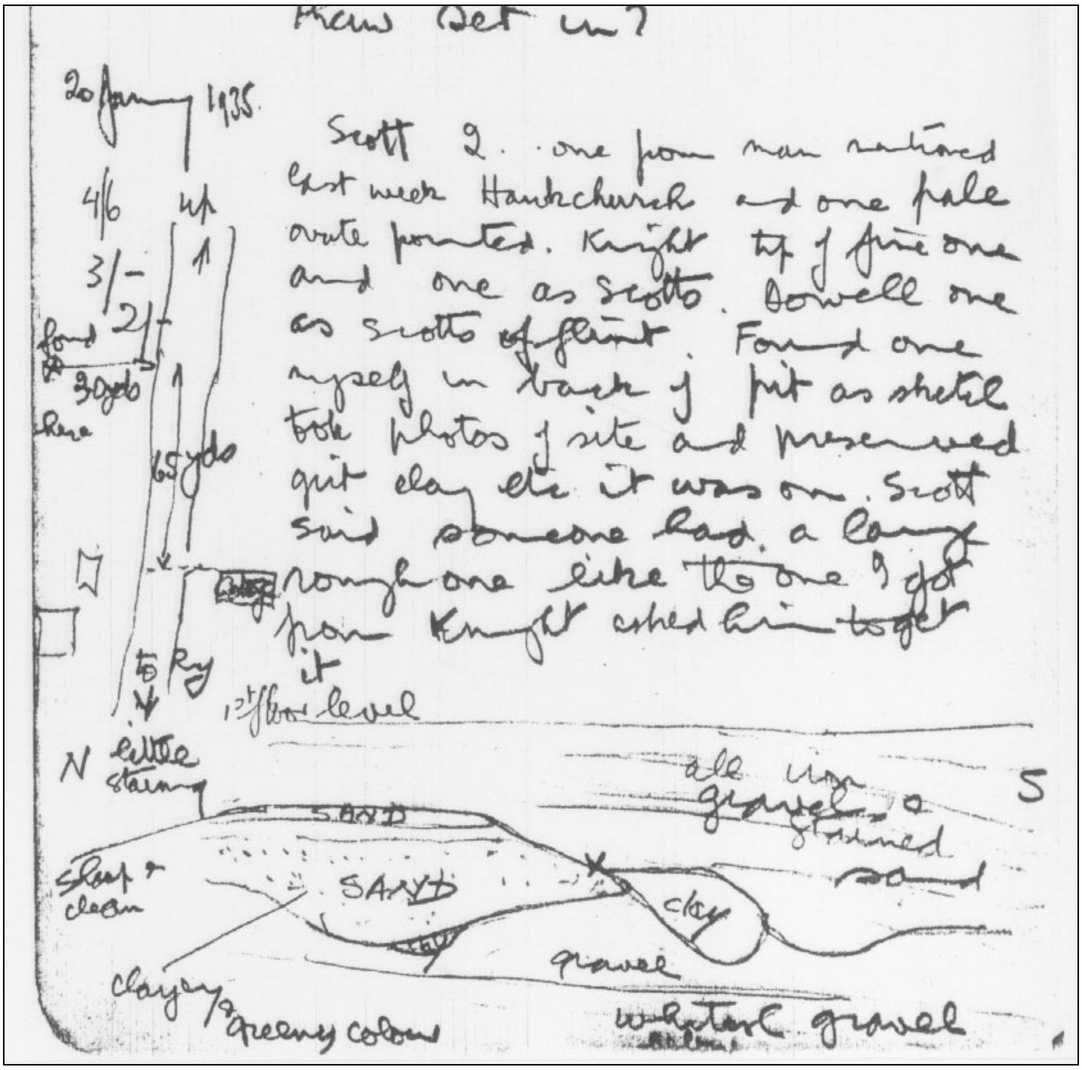

Figure 120: plan and section sketch of Pratt's Old Pit, Broom by C.E. Bean (20th January 1935)

eastern end of the working pit, the original ground surface was at *c.* 50m OD (in 1932), roughly 5m above the surface of the River Axe floodplain. Work at these levels continued until the autumn of 1935 (Figure 120–Figure 125), mainly exposing a reddish coloured gravel. Bean's photographs indicate crude bedding in the gravel, while irregular units of finer-grained material were evident at varying levels. There is some confusion as to the identity of this unit, since Green's (1988: 174–176) description suggests that this is the upper gravel, although the stated elevations (47.5–49.0 O.D.) indicate that it may represent the middle beds, as described by Shakesby & Stephens (1984; Green 1988: 174). Bean's entry for February 24th 1935 records that the pit output was approximately 60 tons per day (*c.* 330 tons per week) and he estimated that 150 tons of excavated gravel was yielding 6 bifaces.

In 1935, excavation extended below the previous pit floor, exposing a paler-coloured lower gravel. This gravel was subsequently found to represent the lowest, visible unit of the Broom sedimentary sequence throughout the pit. During 1935, the excavations indicated a ridge-like swell of the lower gravel that ran from east to west across the pit. In most parts of the pit, the lower gravel was separated from the overlying reddish gravel by beds that displayed numerous lithological changes, and consisted of sand and clay as well as gravel (Green 1988: 174–175). This latter unit is most probably the Broom middle beds.

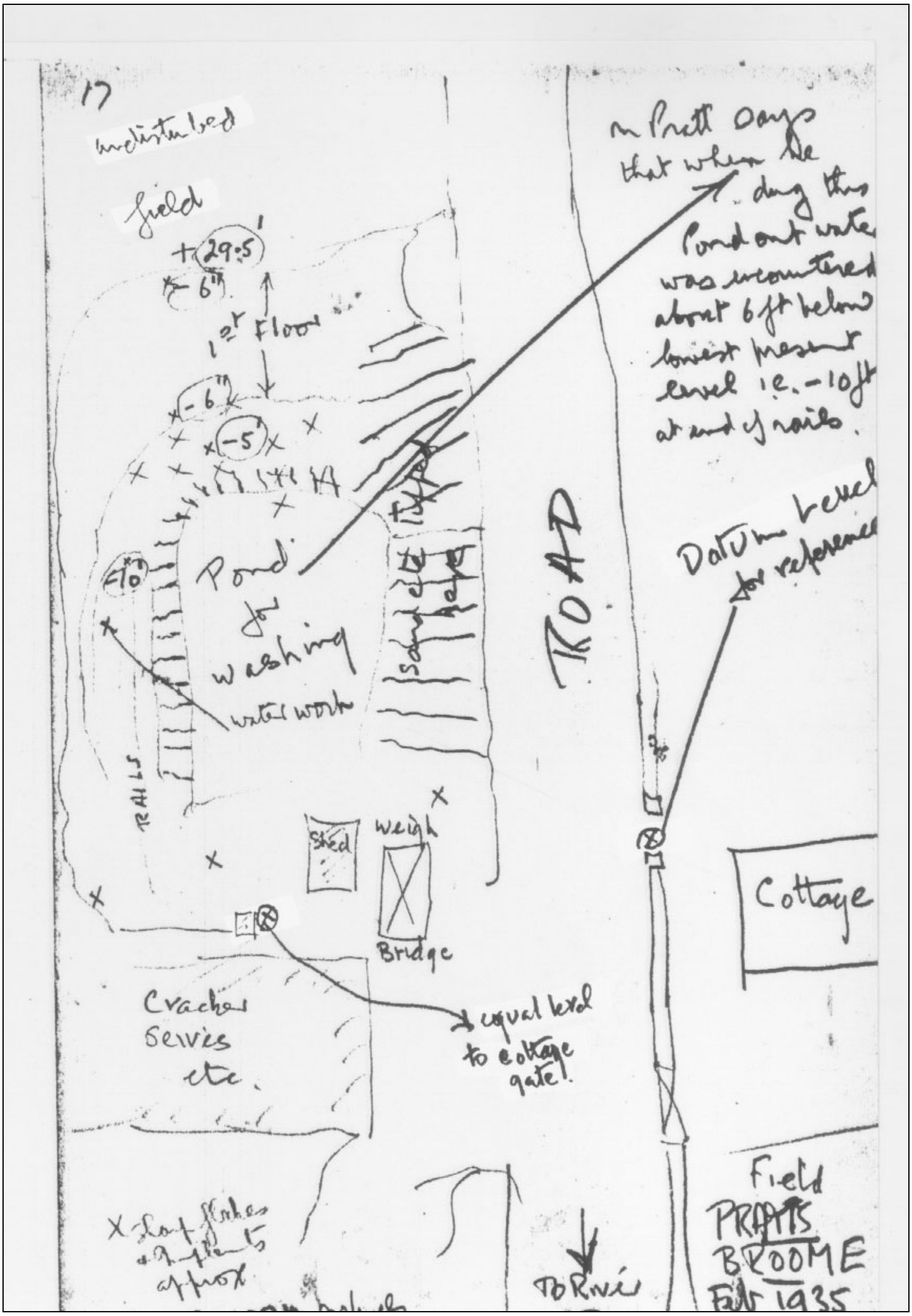

Figure 121: plan of Pratt's Old Pit, Broom by C.E. Bean (February 1935)

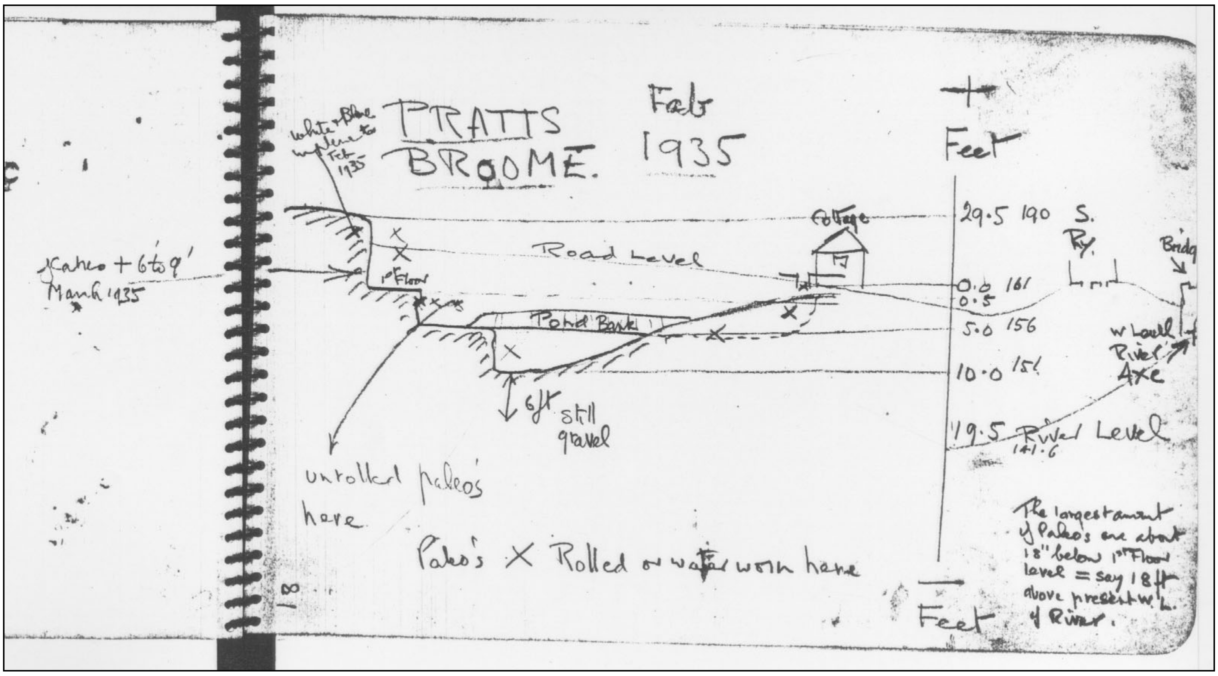

Figure 122: section of Pratt's Old Pit, Broom by C.E. Bean (February 1935)

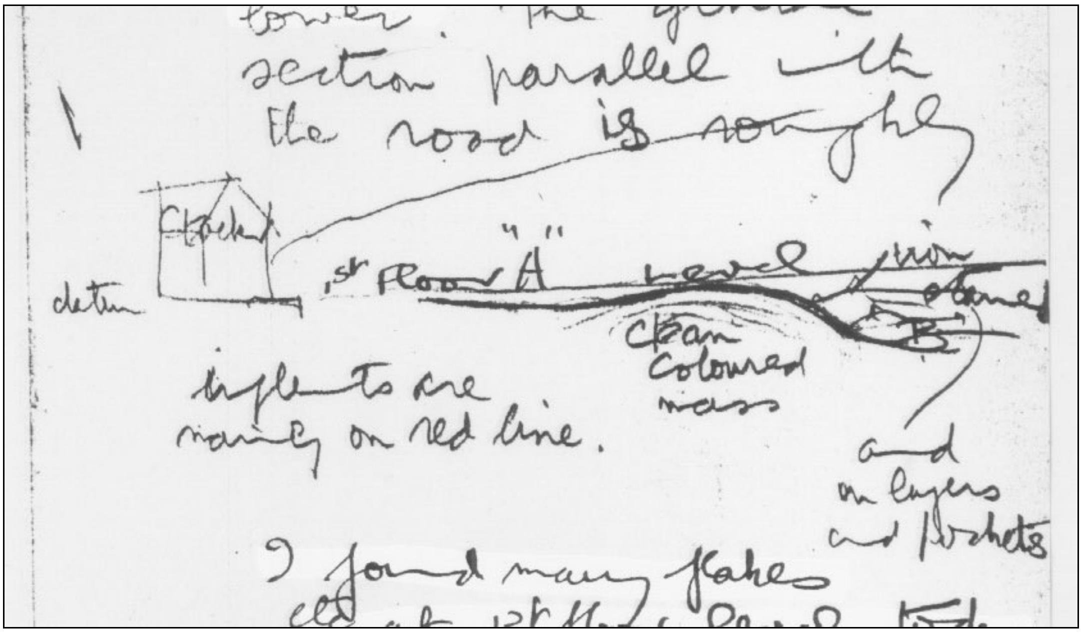

Figure 123: section sketch of Pratt's Old Pit, Broom by C.E. Bean (14th April 1935)

A brief summary of the three units is given here, following Green (1988: 175–176):

2.1.1. The Lower Gravel

The lower gravel is pale-grey or white in colour. The unit is well stratified, with horizontal bedding prevalent. Clasts are mainly smaller than in the upper gravel, while beds and lenses of sand are less common and thinner but laterally persistent, giving an impression of more regular bedding. There is occasional interruption of the horizontal beds by shallow, crossed-bedded units. Bean suggested that the gravels contained more flint than chert. The upper surface of the lower gravel lies at about 47.5m OD, rising to just over 49m OD at the crest of the swell and declining to below 47.5m in the south-eastern corner of the pit. 3.5–5.0m exposures of the Lower Gravel were provided in various parts of the pit, but its base was never seen.

2.1.2 The Middle Beds

Individual beds of this unit are limited both in thickness and lateral extent. In combination, they form a distinctive association, in which fine-grained sediments are more common than in either the Lower or Upper Gravel. Nonetheless, gravel is still the predominant lithology in the Middle Beds. The unit is separated by a sharp boundary from the Lower Gravel, but is generally less easy to distinguish from the Upper Gravel, forming irregular and discontinuous seams, lenses and masses in its lower part.

Clays and sandy-clay or loams are common with the clay beds typically brown in colour, and less commonly greenish-grey and bluish-grey. In some cases the clay beds contain scattered stones, while streaks of black staining are occasionally recorded, usually toward the bottom of the Middle Beds. Red, green and pale-coloured sands also occur in the Middle Beds. The gravels are characterised by coarse texture and open fabric, with heavy rust-coloured or black staining. These gravels beds were referred to by Bean as 'red beds' and are a notable feature of the Middle Beds association. The Middle Beds generally occur between 49.75m and 47.6m OD, except in the south-eastern quarter of the pit, where they descended to 45.5m OD.

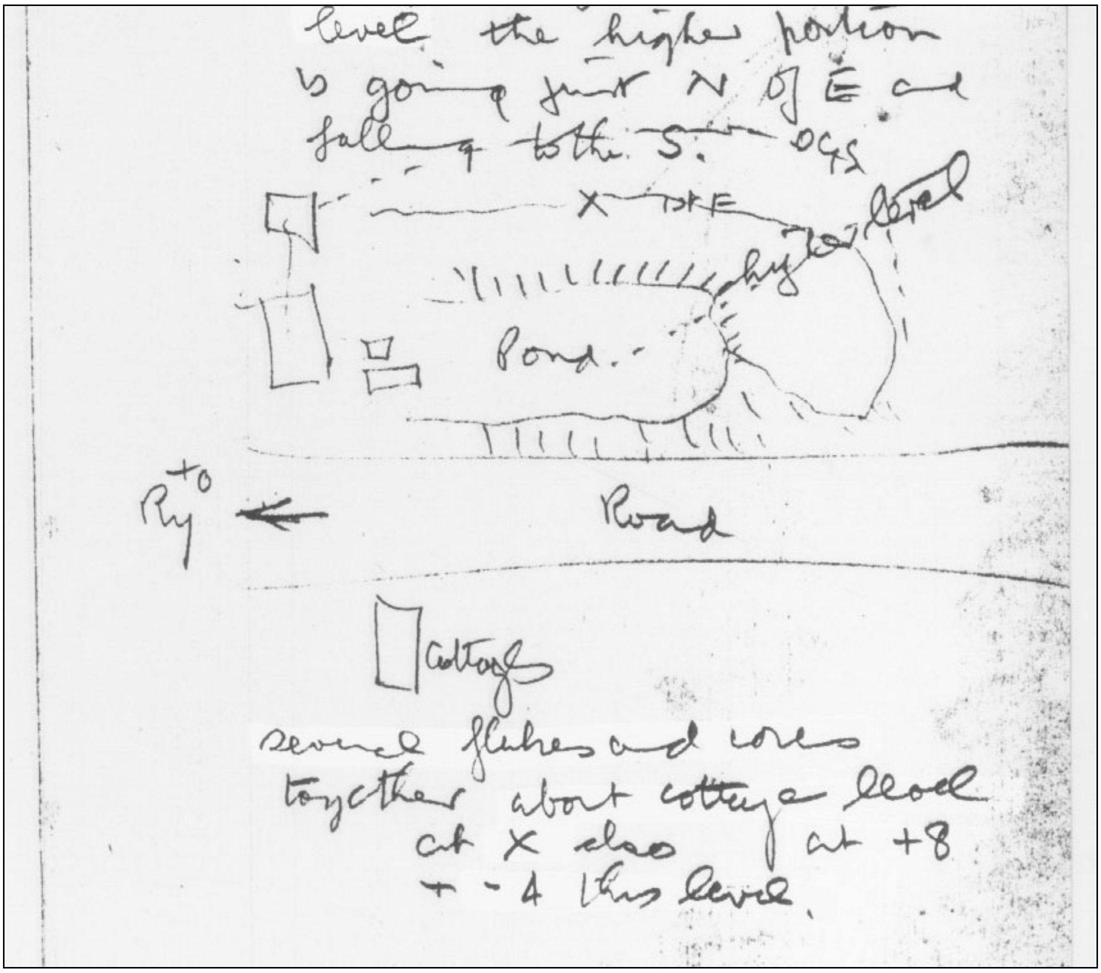

Figure 124: plan of Pratt's Old Pit, Broom by C.E. Bean (23rd June 1935)

2.1.3 The Upper Gravel

This unit is less regularly stratified than the Lower Gravel. It is generally coarse and reddish in colour, while seams, lenses and masses of sand or loam, often green in colour, are common. Up to 9m of the Upper Gravel was exposed in the Old Pit.

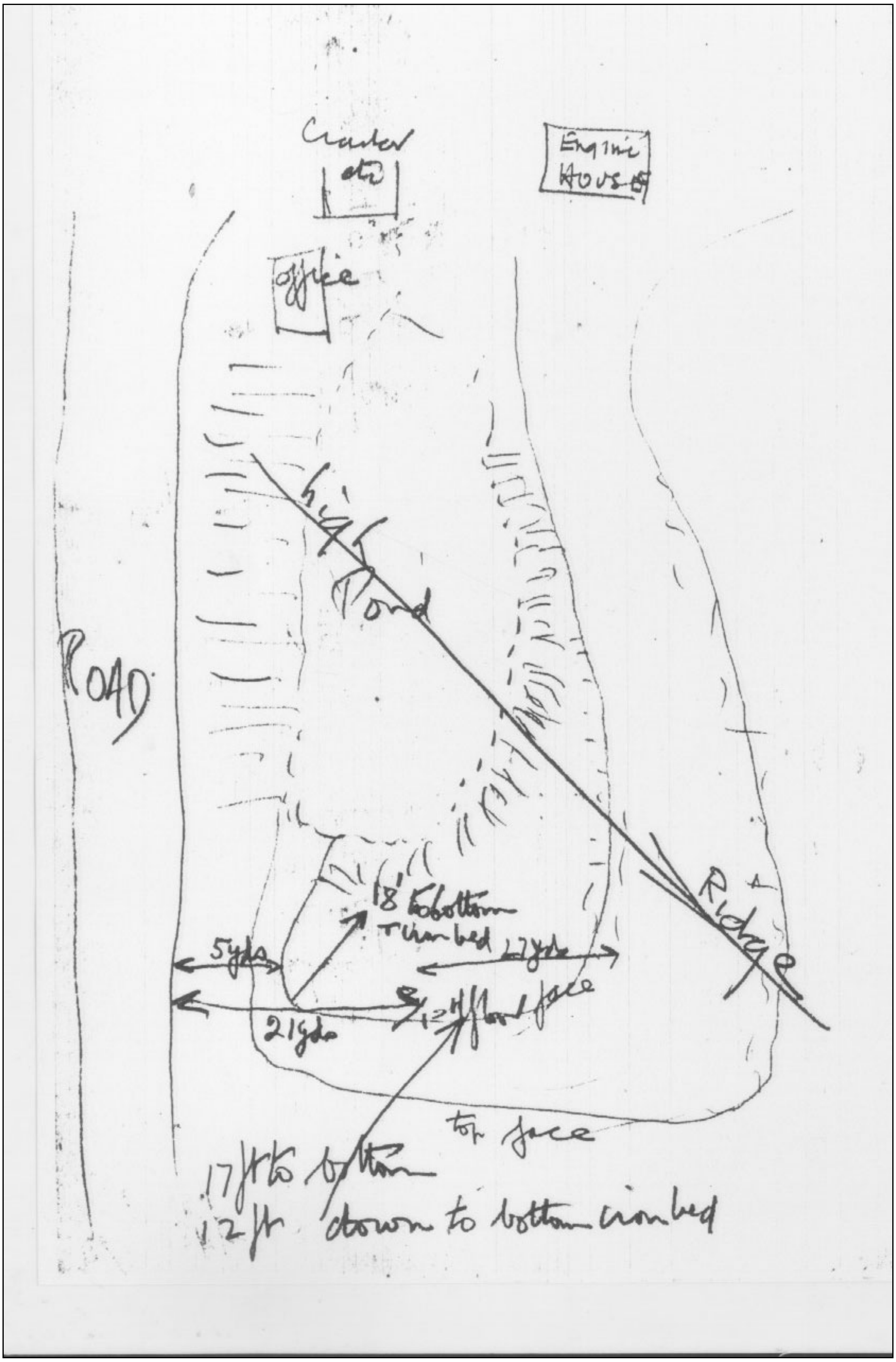

Figure 125: plan of Pratt's Old Pit, Broom by C.E. Bean (June/July 1935)

2.2 Development of the Bean archive

The archive was compiled by C.E. Bean between 1932 and 1941. Due to the absence of records for the period up to September 1933, it is not possible to plot site visits and artefact recovery rates for the entire period (*c.f.* Sampson 1978), although Green (1988) recorded the following patterns:

"Before 1935, 165 implements were acquired but few details of provenance are noted. Between February and December 1935, 24 visits were made to Broom, and 111 implements were acquired (apparent rate of recovery 0.36 implements per day). The provenance of many of these implements is recorded. In the following nine months the site was not visited. Then between September 1936 and March 1938, 17 visits were made to the site and 140 implements were acquired (apparent rate of recovery 0.26 implements per day). Provenance is infrequently recorded. During the next ten months, to the end of 1938, 507 implements were acquired (rate of recovery 1.68 implements per day). Many of these implements came from one small area…and details of provenance are recorded in considerable detail. After January 1939 few implements were found. The material acquired in 1941 included implements from the New Pit to the south of Holditch Lane."

(Green 1988: 177)

It is clear from the Bean's notebook entries that much of the artefact material and the information regarding their provenance came from the workmen at Broom. Although Green (1988: 176) has argued that there is no indication that purchase prices (for artefacts) varied according to their provenance in the pits, Bean himself was aware of the limitations of the recorded information, observing that:

"The Dowel family are prone to fabricate sites which they think will please you or enhance the values."

(C.E. Bean archive, 24th March 1935)

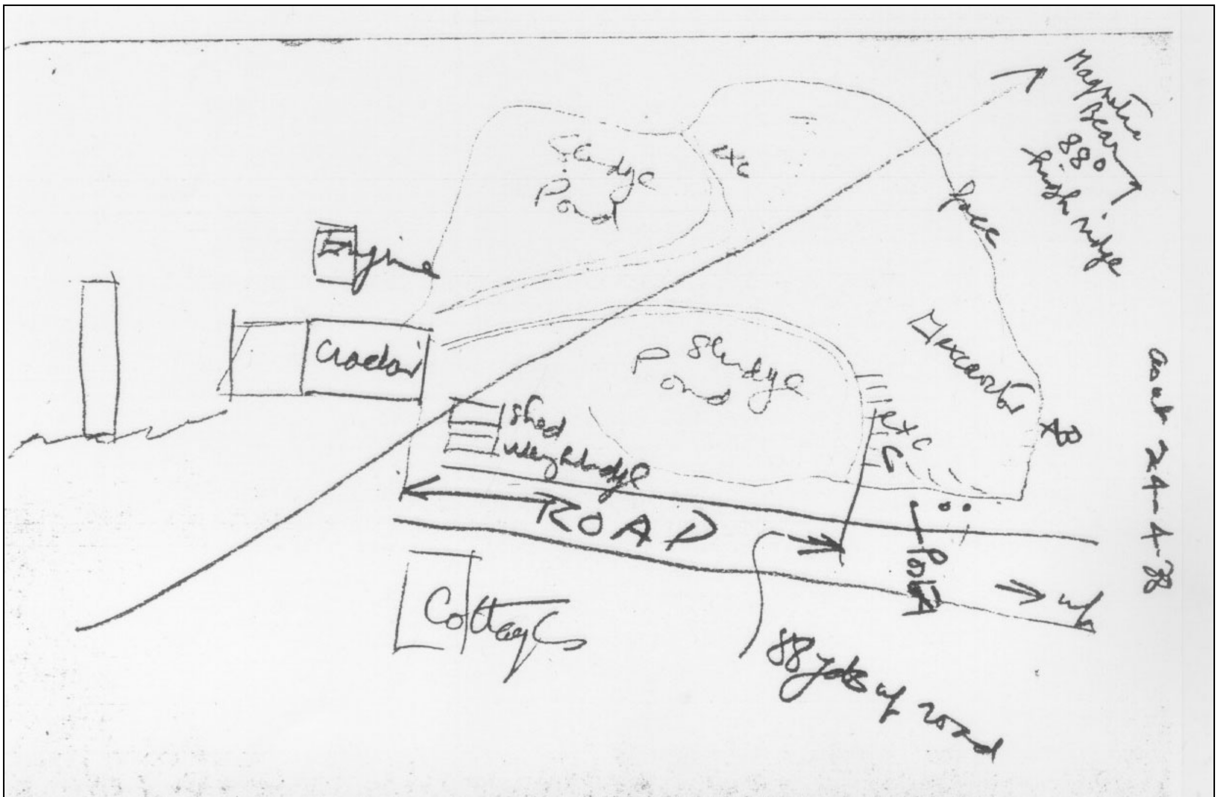

Figure 126: plan of Pratt's Old Pit, Broom by C.E. Bean (24th April 1938)

So as in many cases where artefact recovery was primarily undertaken by the pit employees, caution must be given to the interpretation of the stratigraphic data from Broom (e.g. Roe 1981). As noted by Green (1988: 177), the quality of the provenance data in the Bean archive does vary considerably. In some cases, artefacts are simply listed by number and associated with the labourer who recovered them or sold them to Bean:

"18th August 1935	*2/-*	*Scott one no 264*
	2/6	*Collins Hawkchurch one no 265"*

(C.E. Bean archive, 18th August 1935)

In other cases, much more information was recorded, including the depth and location within the pit from which the artefact was recovered:

"7th July 1935	*1/-*	*Pratt gave me one he had found near engine house at datum level no 246* *Picked out 252 about 12 ft below 1st floor level in bottom of iron bed clayey patch"*

(C.E. Bean archive, 7th July 1935)

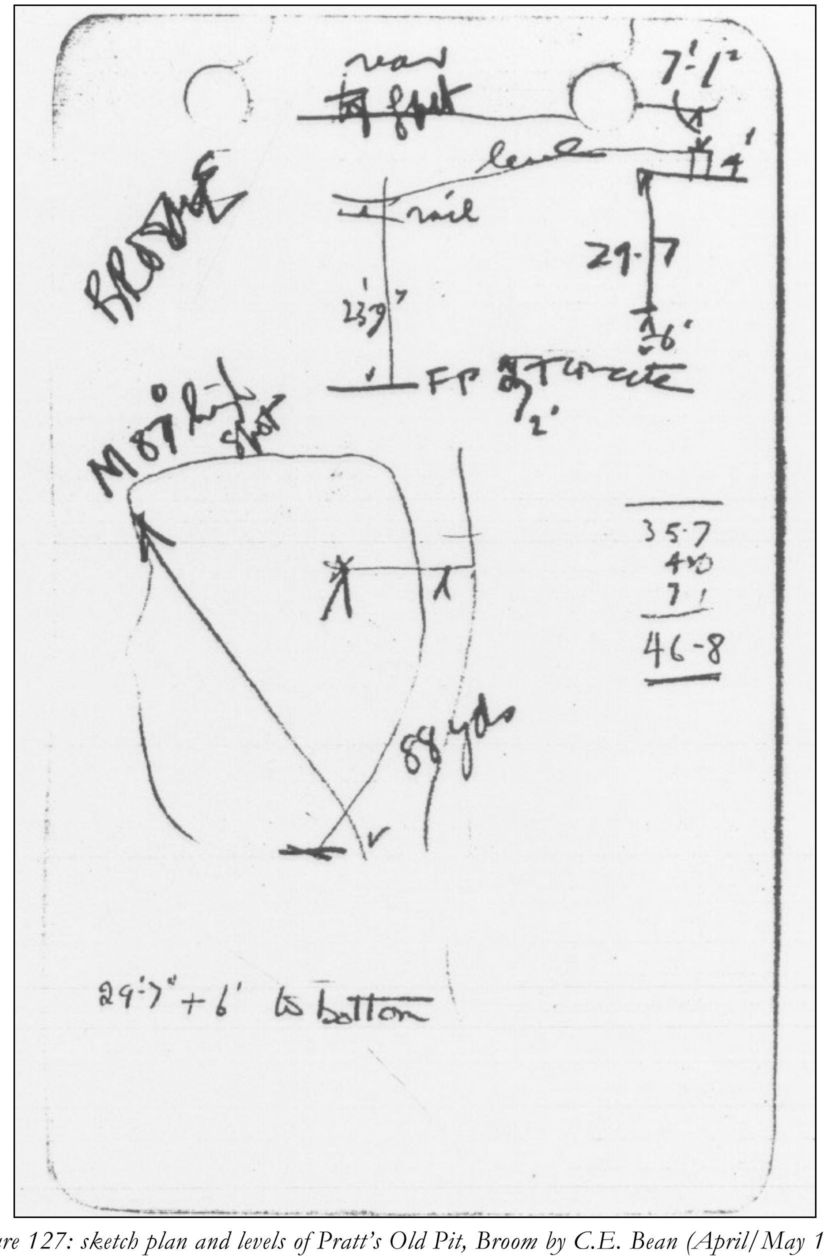

Figure 127: sketch plan and levels of Pratt's Old Pit, Broom by C.E. Bean (April/May 1938)

Two of the commonest references with respect to the depth of the artefacts are the '1st floor level' and the 'datum level', indeed there are several references to apparently unrolled material from the levels at, or immediately below, the site datum. Both the datum level and the 1st floor are clearly marked on Bean's sketches (Figure 121 & Figure 122), and although the datum (a cottage threshold on the south side of Holditch Lane) no longer exists, its height (approximately 49m OD) was reconstructed by Green (1988: 178). Figure 122 suggests that the 1st floor level lay approximately 6 inches below the datum level. Following Green (1988), these levels and the frequency of artefact descriptions relating position to the datum (e.g. "*From the lower level, in the 'Red Bed' at -2–+2 road level cottage [datum level]*") form the basis of the attempts to sub-divide the assemblage by the stratigraphic position of the artefacts (Section 4).

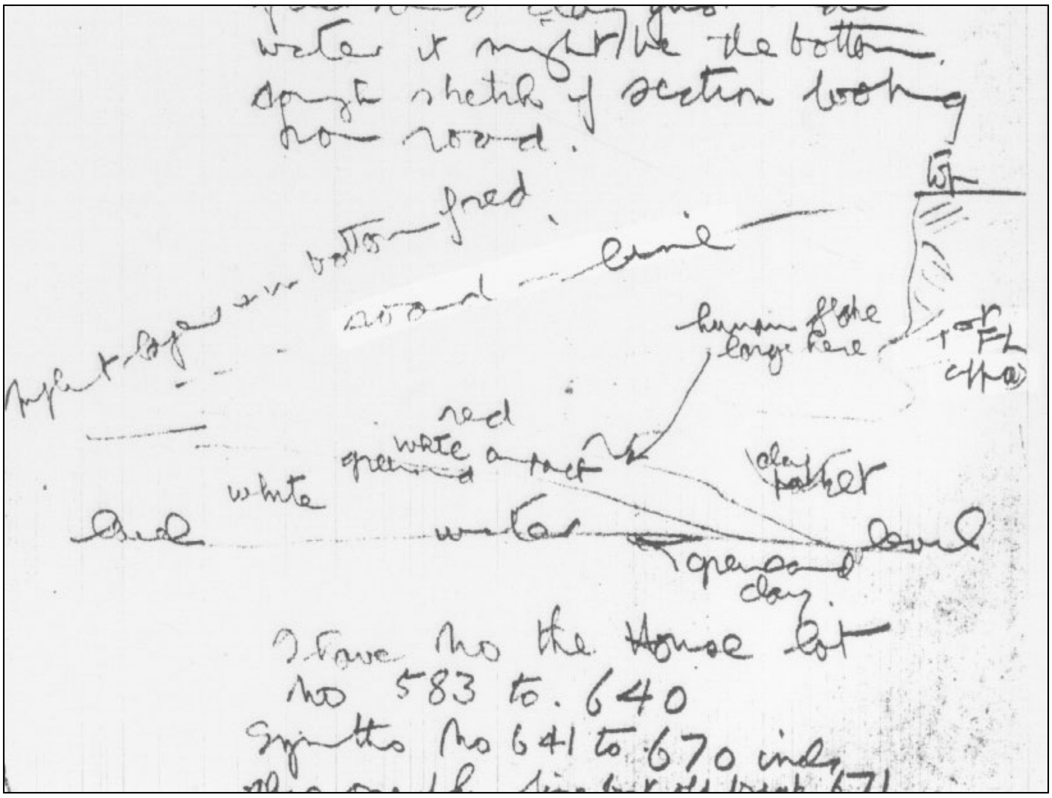

Figure 128: section sketch of Pratt's Old Pit, Broom (26th June 1938)

Green (1988: 179) notes that the majority of the Palaeolithic artefacts with recorded levels lay in the Middle Beds. He suggests that they were most common (63%) in the iron-stained gravels (the so-called red beds), which were the source of many of the isolated, individual specimens. The Bean archive suggests that a relatively concentrated collection of rolled and unrolled material was recovered during 1938 from deposits of the Middle Beds type, abutting the southern edge of the pit that runs parallel with Holditch Lane. In this area (referred to by Green (1988) as the '1938 Locality'), the upper surface of the Lower Gravel was inclined towards the east and fell below its normal level of 47.5m OD, to approximately 45.5m OD. Individual elements of the overlying Middle Beds dipped conformably with the surface of the Lower Gravel. The Lower Gravel was overlain by a bed of compact sandy-clay (yellowish white in colour) that contained bifaces, débitage flakes and large blocks of chert, all of which were in an apparently unrolled condition (but see later comments regarding Bean's classification of artefact abrasion). This bed was overlain by a 'red bed' comprising approximately 0.6m of heavily iron-stained gravel, with a coarse texture and open fabric. Bifaces and débitage flakes (both rolled and unrolled) were found in this bed, while the workmen reported that concentrations of up to 30 bifaces had been found in this bed:

"they once found 30 in a heap in centre of red bed…all ovates" [Unfortunately the Bean archive does not clearly indicate the artefact numbers of these ovate bifaces]

(C.E. Bean archive, 27th November 1938)

At its western end, the 'red bed' passed upwards into the Upper Gravel, although a clear boundary is absent. However, immediately above the 'red bed' (and sometimes penetrating into it), were numerous seams, pockets and irregular bodies of fine-grained sandy-clay material, from which bifaces were recovered. As Pratt's Old Pit was worked eastwards, the sandy-clays were found to form a continuous bed that was subsequently encountered in all areas at the eastern end of Pratt's Old Pit, and throughout Pratt's New Pit (dug immediately to the south of Holditch Lane). Bifaces were found (albeit in smaller numbers), in Pratt's New Pit beneath the clay layer, in beds that were very similar to those forming the lower part of the Middle Beds in the 1938 Locality in Pratt's Old Pit.

2.3 Bean's artefact archive

In his recording of the artefacts, Bean documented 12 variables:

1. Shape (Bean created 17 shape categories: Figure 129, Figure 130 & Figure 131).
2. Raw material (flint or chert).
3. Waterworn condition (much rolled, medium rolled, slight(ly) rolled, sharp and very sharp).
4. Colour (white, grey, blue, yellow, brown, dark brown, honey and light honey, although it become apparent during the examination of the archive that a wider range of colour categories were ultimately employed by Bean).
5. Weight (ounces).
6. Height, thickness & width (inches)
7. Depth found.
8. Whole or broken.
9. Projections (this category is rather ambiguous, with Green (pers. comm.) suggesting that it refers to unflaked or incompletely flaked areas interrupting the regular outline of the implement. Although entries under this variable are infrequent, they tend to refer to 'at side' or 'on side').
10. Remarks (the most common entries refer to the location of the knapping platform (at the base or at the side), the quality of the implement (e.g. very rough or fine), or its geo-chemical modification (e.g. evidence of iron-staining).
11. Year found.
12. Edge profile (although the accompanying sketch is rather unclear, the categories would appear to be S, reversed S, straight and sinuous).

The Bean collection is dominated by chert implements (97%, n=871), with a small number of flint artefacts (3%, n=29). This is unsurprising given the local geological setting, with the River Axe cutting through Foxmould Chert Beds of Upper Greensand, exposing bands of sandstone and chert up to 35m thick. It has also been noted that other lithic raw materials in this region are relatively rare, limited to river gravel flint cobbles, a fresh flint chalk outcrop at Beer, and a fine-grained, black chert, that was known to have outcropped at the east Dorset/West Devon coast during Mesolithic times. The current analysis (see below) has identified cobbles as the probable blank form for 52% (n=12) of the sampled flint implements with a known blank form (n=23), with the remainder formed on flakes (n=8) and nodules (n=3). This suggests that raw material acquisition (at least for flint) may have been a primarily local activity (although it is noted that the blank forms for 58% (n=32) of the sampled flint artefacts are unknown).

The bifaces are dominated by Bean's type 4 (Figure 129). This is best described as a 'lop-sided' ovate or cordate, or amygdaloid form (51%, n=457 — these figures different slightly from those presented by Green (1988: Figure 5). Bean noted that the bulge or swelling generally contained a platform or the site of a knapping platform, suggesting technological affinities with the side-struck flakes of the African Acheulean (e.g. the Victoria West tradition — Goodwin 1929; Fluck 2002). However, the current analysis has indicated that where a knapping platform can be identified, it tends to occur in the butt region of the biface rather than on the sides. In other words, there is no evidence for European/African links in technological practise. The other main types in the Broom assemblage are Bean's type 10 (12%, n=109), which has general affinities with Wymer's pointed (type F) and sub-cordate (type G) bifaces; type 3 (8%, n=76), broadly similar to Wymer's pointed (type F) biface; type 5 (7%; n=65), suggestive of Wymer's ovate (type K biface); and type 16 (6%, n=62), with parallels to Wymer's sub-cordate (type G) biface. One of the key goals of the current analysis of the assemblage was therefore to classify the bifaces according to the Wymer terminology, facilitating comparison with other assemblages. The most important aspect however, concerned an evaluation of the apparent dominance of the amygdaloid form. An initial, visual inspection of the Bean collection had suggested that these types did not comprise over 50% of the assemblage. A focus was therefore placed on the identification of asymmetrical ovate forms ('amygdaloids') during the re-examination of the collection. Of equal importance was to examine whether specific types occurred throughout the stratigraphic sequence or only at specific locations within the fluvial deposits.

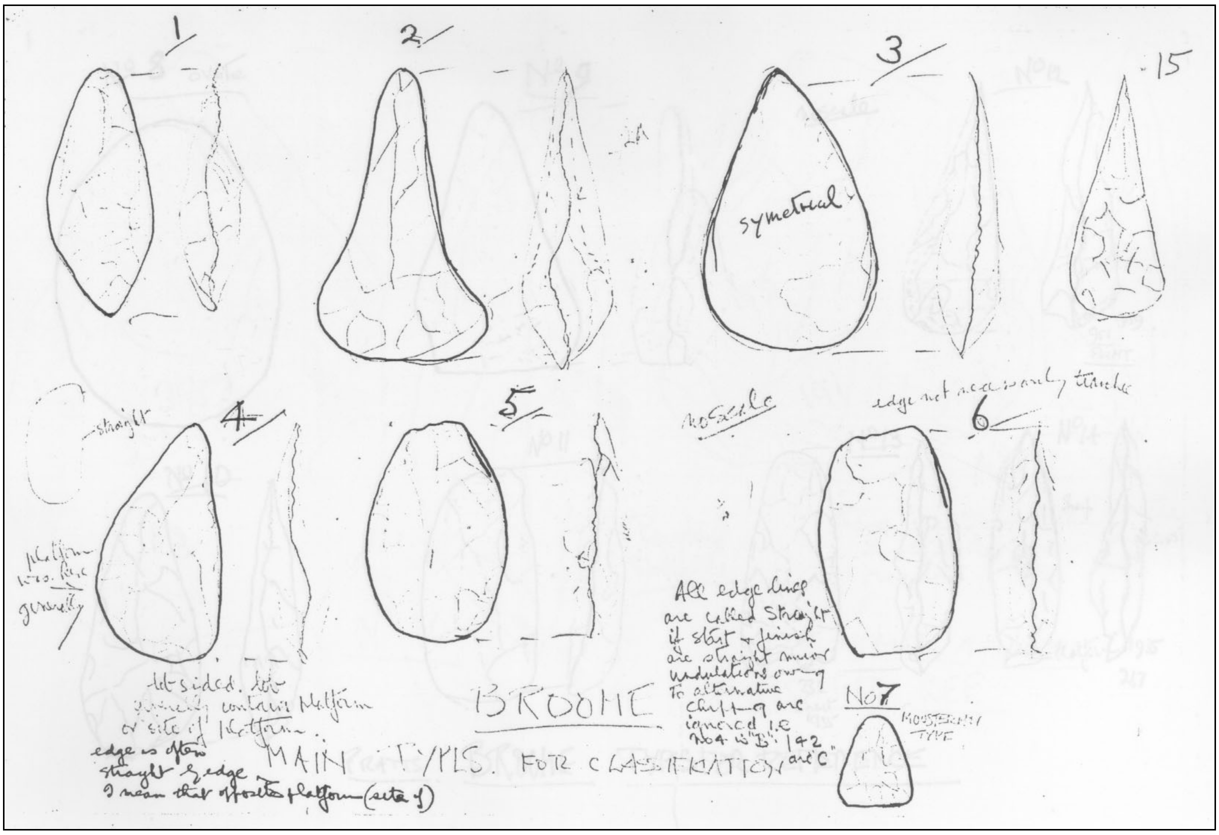

Figure 129: C.E. Bean's biface shape types (1, 2, 3, 4, 5, 6, 7 & 15).

Physical condition	n	%
Not recorded	1	0.1
Much rolled	18	2.0
Medium rolled	37	4.1
Slight(ly) rolled	122	13.5
Sharp	601	66.7
Very sharp	122	13.5
Total	**901**	**100.0**

Table 30: Broom artefact abrasion categories by C.E. Bean

Bean's characterisation of the abrasion of the artefacts is difficult to assess, since his criteria for distinguishing, for example, sharp and much rolled implements cannot be assessed quantitatively. Nonetheless, his records suggest that the majority of the assemblage was probably only subject to a minor amount of fluvial transportation and damage. Sharp condition implements dominate the assemblage (67%, n=601), with significant proportions of very sharp (14%, n=122) and slight(ly) abraded (14%, n=122) implements (Table 30). The key goals for the re-analysis were therefore a quantified study of artefact abrasion and testing whether there was evidence for homogenous 'clusters' and/or *in situ* material within the assemblage.

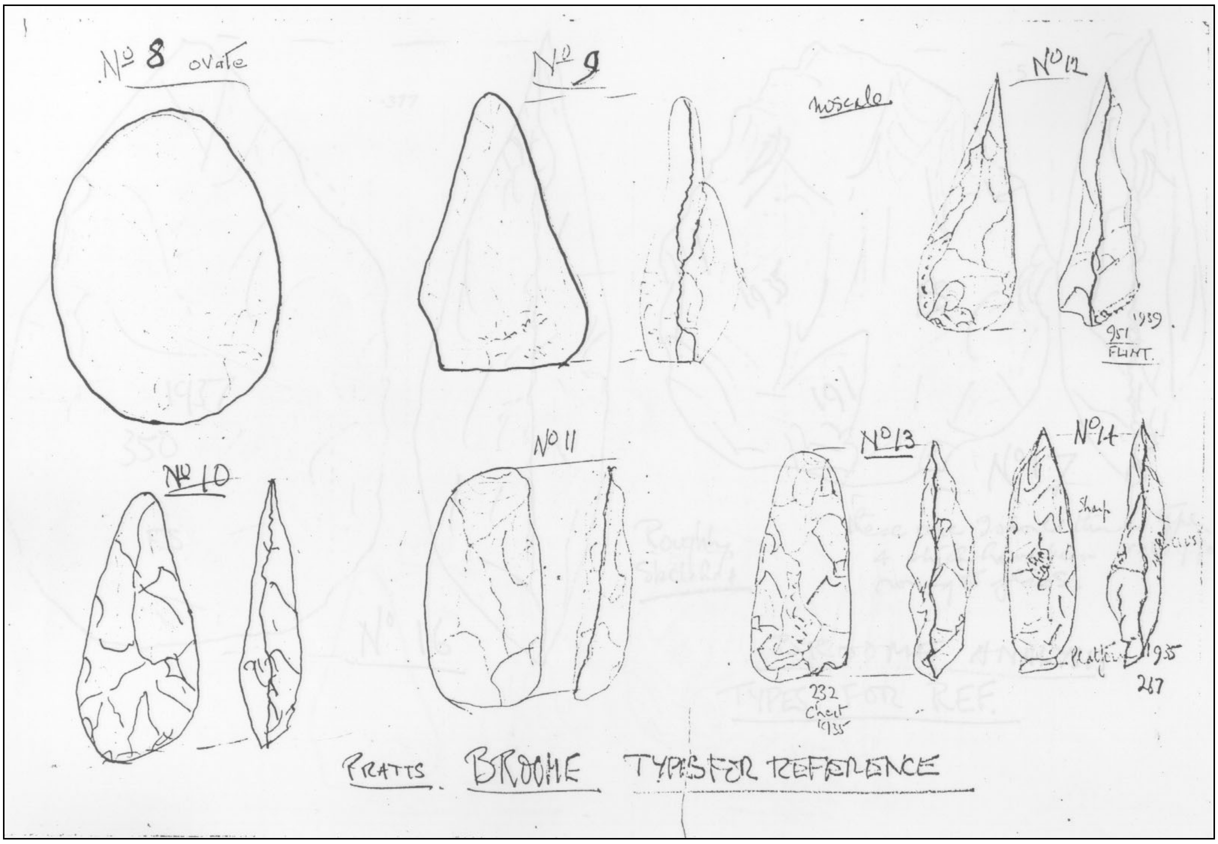

Figure 130: C.E. Bean biface shape types (8, 9, 10, 11, 12, 13, & 14)

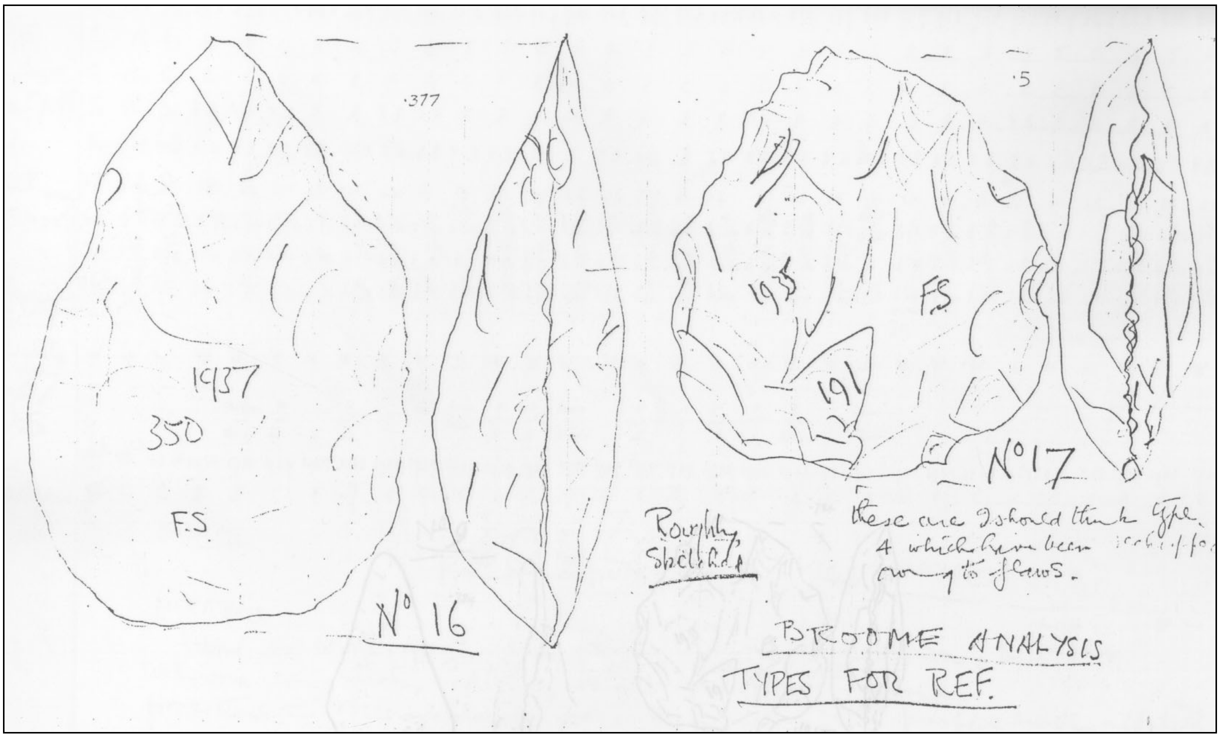

Figure 131: C.E. Bean biface shape types (16 & 17)

3. CURRENT ANALYSIS OF THE BROOM ASSEMBLAGE

977 bifaces were sampled, 767 from the Bean collection and 210 from the Royal Albert Memorial Museum and Art Gallery, Exeter collection. 188 non-bifaces were also sampled from the Bean collection (Table 31), of which 33 'artefacts' were found to be natural upon re-examination. 45 non-bifaces were sampled from the Royal Albert Memorial Museum and Art Gallery, Exeter collection, along with a further 50 bifaces, which were not subjected to detailed analysis due to their physical condition. Although the total number of artefacts from the Broom deposits remains unclear, the current re-investigation has suggested a minimum total of 1321 (Table 36), based partially on the previous work of C.P. Green (1988).

Green's analysis of the Bean collection and documentary archive (Green 1988: 177) concluded that it comprised "over 900 hand-axes of Acheulian type, together with waste flakes, unfinished implements and large blocks of unworked, or roughly prepared, chert" (although only 899 hand-axes were listed in the accompanying summary tabulation (Green 1988: Table 1). Conversion of the Bean archive into a digital database as part of the current project suggested 901 bifaces, and this total is broadly in-keeping with the previous work of Green. Bean's own archive records that he collected 1003 implements from Broom between 1932 and 1939, and examination of the archive suggest that he used the term implement to refer to bifaces and (occasionally) diagnostic flake tools such as scrapers and 'flake knives'. An additional difficulty concerns the absence of 83 artefact identifier numbers (in the sequence 1–1058) and the duplication of 35 artefact numbers (and other symbol identifiers) in the Bean archive and on the physical artefacts (Table 32 & Table 33). Green (pers. comm.) produced an overall summary for the Bean collection (Table 34) that indicates a total of 1016 Broom artefacts in the Bean collection (including material from the Railway Ballast Pit, Pratt's Old Pit and an additional pit, referred to as the Council Pit).

Examination of the artefacts collections at the Royal Albert Memorial Museum and Art Gallery, Exeter collection indicated a total of 260 bifaces and 45 non-bifaces (Table 35). The source of these artefacts is not clear, but it is assumed that they represent material collected from both the Railway Ballast Pit and Pratt's Old Pit (Bean's own archive makes numerous references to material being sold to other collectors during the 1930's when he was visiting the pit). There is also documentary evidence for the trade in Broom artefacts from the Railway Ballast Pit during the late 19th century (Section 1.1, Chapter 3).

It is clear that any current estimate of the size of the Broom assemblage is a minimum, rather than a maximum value, due to the existence of Broom artefacts in museums other than Exeter, the unknown destination of artefacts collected or purchased by parties other than C.E. Bean

Artefact Type	**Sample size**
Blade	1
Broken Roughout	1
Core Scraper	1
Denticulate	1
Flake	24
Biface Fragment	23
Biface Butt	2
Biface Tip	5
Notched Scraper	1
Retouched Flake	46
Rock	33
Roughout	5
Roughout Fragment	1
Scraper	12
Uniface	31
Uniface Fragment	1
Total	**188**

Table 31: non-bifaces artefact sample from the Bean collection

Artefact Identifier Numbers					
67	92	102	123	144	148
151	179	184	207	252	271
272	286	289	295	302	304
305	308	320	325	327	328
329	332	334	351	357	358
359	367	368	369	373	375
381	407	409	410	414	430
527	559	662	670	754	759
803	973	974	975	976	977
978	986	1032-1058			

Table 32: missing artefact identifier numbers in the C.E. Bean Broom collection and documentary archive

Artefact Identifier Numbers					
16	22	100	107	189	190
239	264	265	267	269	270
281	315	343	356	418	419
514	530	583	589	620	623
689	689	755	761	928	956
1013	- (Page 27)	… (Page 27)	5.. (Page 24)	No nº (Page 28)	

Table 33: duplicate artefact identifier numbers in the C.E. Bean Broom collection and documentary archive (page numbers refer to the documentary archive)

Artefact Source	**Sample size**
Bean collection (incl. flakes)	980
Broom (Pratt's Pit) – number obscure	4
Broom (Pratt's Pit) – unnumbered	29
Broom (Railway Pit)	2
Broom (Council Pit)	1
Total	**1016**

Table 34: total artefacts in the C.E. Bean collection (calculated by C.P. Green (pers. comm.). Pratt's Pit refers to Pratt's Old Pit.

Artefact type	**Sample size**
Bifaces	260
Flakes	15
Retouched flake	8
Scraper	17
Uniface	2
Knife	1
Notch	1
Roughout	1
Total	**305**

Table 35: total artefacts from Broom in the Royal Albert Memorial Museum and Art Gallery, Exeter collection

Source	**Total**
Bean collection	1016
Royal Albert Memorial Museum and Art Gallery, Exeter collection	305
Total	**1321**

Table 36: minimum totals for the Broom artefact assemblage

3.1 Biface typology

Examination of artefact typology using the Wymer (1968: Fig. 27) matrix of biface shapes classification (Figure 132) broadly duplicated many of the patterns suggested by Bean's earlier work. Cordate/ovate

(28%, n=272), cordate (19%, n=183), and pointed (11%, n=109) forms were dominant, with smaller proportions of ovate (7%, n=65) and sub-cordate (6%, n=54) bifaces and other transitional forms (e.g. sub-cordate/cordate, pointed/sub-cordate, and sub-cordate/ovate bifaces). Bean's types 3, 4, 5, 10 and 16 displayed affinities with all of these types, and while direct correlation of the two schemes is rather impractical, the general patterns suggested are similar.

The key difference however, concerns the absence of a single dominant type in the Wymer scheme, unlike the status of the lop-sided ovates/amygdaloids in the Bean scheme. In the current analysis, lop-sided forms were characterised by the presence of macroscopic asymmetry in the artefact plan form. This contrasted with a recent study by Binyon (2002), who statistically manipulated digital images to classify artefact symmetry and asymmetry. However, it is argued here that for artefact symmetry/asymmetry to be significant, it must have been discernable to the knapper at the time of manufacture (rather than just to pixel detection routines), hence its classification by eye in this research. These types comprised only 24% (n=232) of the sample, suggesting that while these artefacts form a significant element of the Broom assemblage, they are not as dominant as suggested by Bean. These asymmetrical, lop-sided forms were associated with a range of Wymer types, although as with the total sample, cordate/ovate (42%, n=98) and cordate (22%, n=50) biface types were the two main categories. The presence/absence of biface types in the total assemblage and the asymmetrical and plano-convex samples is summarised in Table 37.

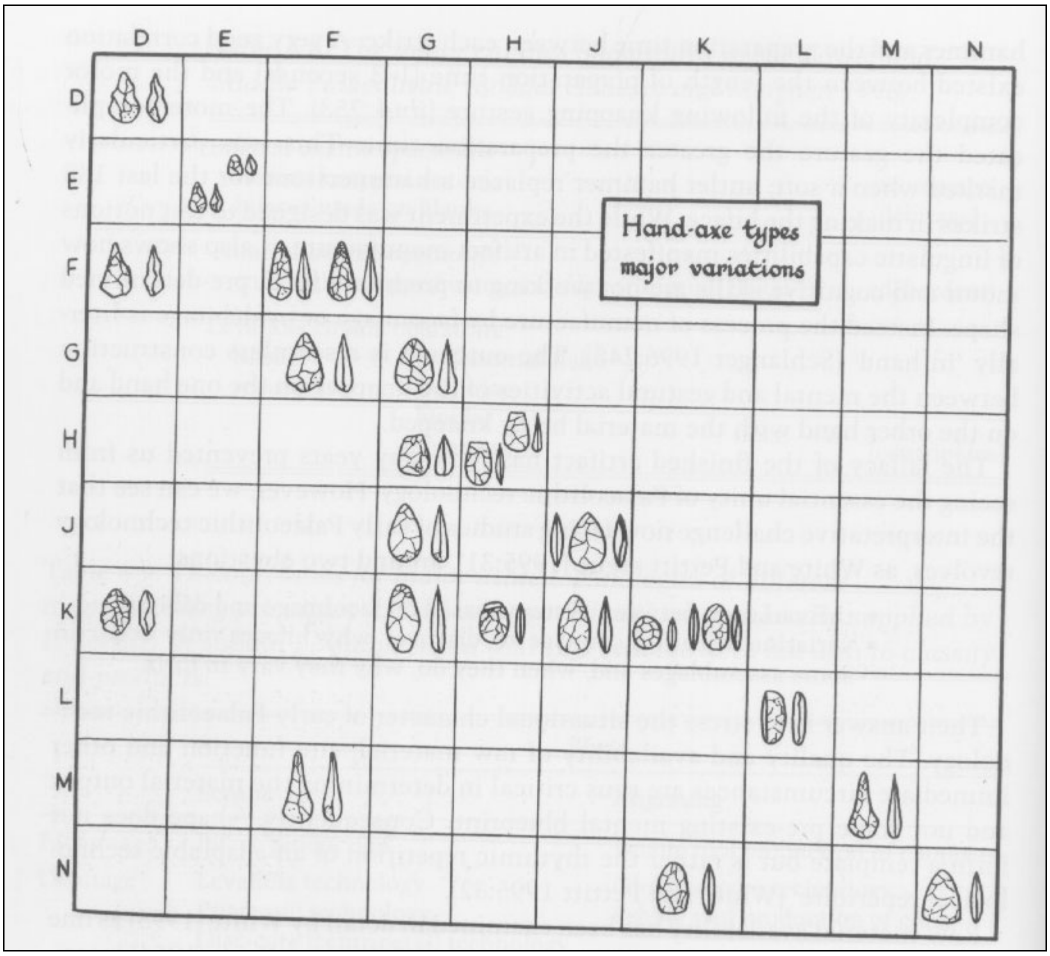

Figure 132: Wymer (1968: Fig. 27) matrix of biface shapes. D: stone-struck crude biface. E: small, irregular biface. F: pointed biface. G: sub-cordate biface. H: cleaver. J: cordate biface. K: ovate biface. L: segmental 'chopping' tool. M: ficron biface. N: flat-butted cordate biface (or bout coupé).

There are only small numbers of distinctive typological forms, although they are present in the assemblage. These types include 25 ficrons (3%, including pointed/ficron forms), 26 cleavers (3%, including ovate/cleaver and sub-cordate cleaver forms) and 12 flat-butted cordates (1%, including ovate/flat=butted cordate forms). As with the lop-sided forms, one of the key goals of the analysis was to investigate whether these distinctive types occur throughout the Broom sequence or are localised in their distribution. However (and unlike the lop-sided forms), the very small numbers of these types does introduce the problems of sample size. Nonetheless, it is noticeable that with the exception of 1 pointed/ficron form, none of these types were produced in association with the lop-sided forms, reflecting the tendency of the latter to occur in association with ovates and cordates.

Biface types	**Types present**	**With plano-convex profiles**	**With asymmetrical plan form**
Crude stone-struck (D)	✓	✓	✗
Crude stone-struck/Pointed (DF)	✓	✓	✗
Small, irregular (E)	✓	✓	✗
Pointed (F)	✓	✓	✓
Pointed/Sub-cordate (FG)	✓	✓	✓
Pointed/Ficron (FM)	✓	✓	✗
Sub-cordate (G)	✓	✓	✓
Sub-cordate/Cleaver (GH)	✓	✓	✗
Sub-Cordate/Cordate (GJ)	✓	✓	✓
Sub-Cordate/Ovate (GK)	✓	✓	✓
Cleaver (H)	✓	✓	✗
Cleaver/Ovate (HK)	✓	✓	✗
Cordate (J)	✓	✓	✓
Cordate/Ovate (JK)	✓	✓	✓
Ovate (K)	✓	✓	✓
Ovate/Flat-butted cordate (KN)	✓	✓	✗
Segmental chopping tool (L)	✓	✗	✗
Ficron (M)	✓	✗	✗
Flat-butted cordate (N)	✓	✓	✗

Table 37: presence/absence of Wymer biface types in Broom assemblage

There is also a significant element of the biface sample that is plano-convex in profile (21%, n=204). However, following the patterns seen in the overall sample and lop-sided sub-sample, these bifaces are dominated by cordate/ovate (30%, n=61) and cordate (17%, n=35) types. Cleavers, ficrons and flat-butted cordates were also produced (albeit in small numbers) with plano-convex profiles.

Biface tips were dominated by irregular rounded (45%, n=439), rounded (15%, n=145) and ogee points (10%, n=98), which is relatively unsurprising given the dominance of cordate/ovate, cordate, pointed and ovate forms in the overall assemblage. However, field-based experimental work by Hosfield & Chambers (Afon Ystwyth Experimental Archaeology Project) and flume-based experimental studies by Chambers have observed that biface tips are vulnerable to damage and potential modification during fluvial transport. The analysis of tip type patterning in this archaeological assemblage is therefore restricted to robust trends. However, it is noticeable that there is a very small presence of tranchet tips (1%, n=10) in the assemblage.

Biface butt forms were dominated by trimmed flat (54%, n=531) and trimmed (21%, n=201) types, suggesting a preference for circumferential cutting edges, which also corresponds with the dominance of ovates, cordates and cordate/ovates in the assemblage. Interestingly, there was also a significant presence of natural (10%, n=98) and part trimmed/part cortex (12%, n=121) types, suggesting a diverse approaches to knapping of the biface butt, either extensive flaking (the dominant technique) or minimal working (only 25 of the bifaces showed evidence of partial trimming).

3.2 Biface morphology

The biface sample was dominated by specimens weighing between 100g and 500g (mean = 422.07g, mode = 334g, median = 393g; Figure 133). The distribution had a wide range (range = 2399g) and was strongly skewed, with a long tail to the right (skewness = 1.5414; kurtosis = 6.7895), reflecting the presence of a small number of heavier artefacts in the sample.

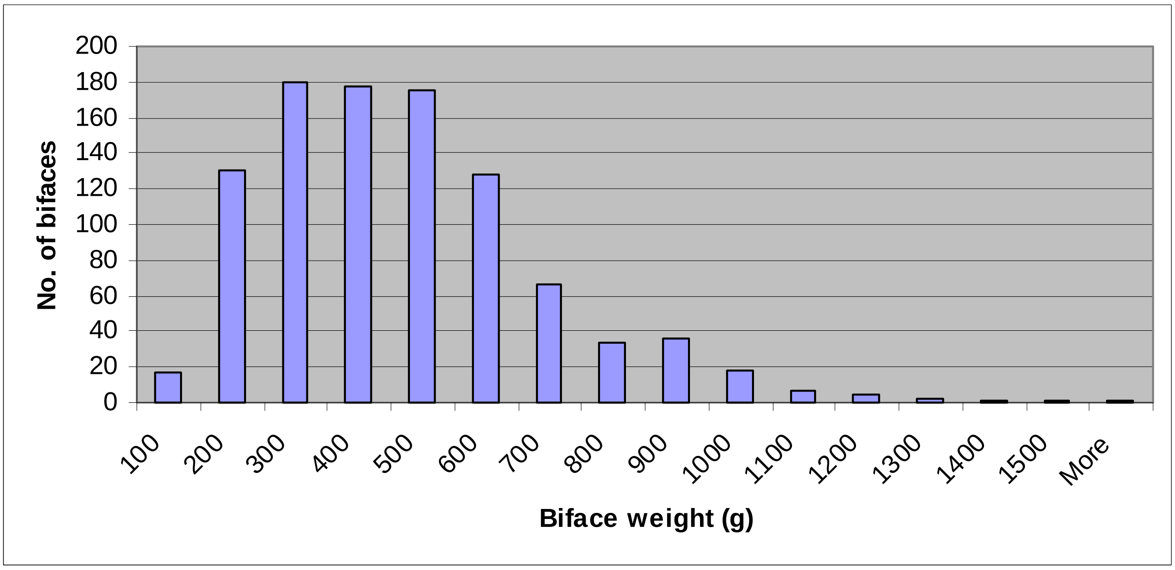

Figure 133: biface weight distribution (class interval = 100g)

The pattern of biface weight distribution contrasts with the distributions of both biface length (Figure 134) and breadth (Figure 135), both of which display normal distributions, with short tails and little evidence of skewness ($skewness_{length}$ = 0.2354; $kurtosis_{length}$ = 0.3654; $skewness_{breadth}$ = -0.1760; $kurtosis_{breadth}$ = 1.0687). The biface sample (by length) is dominated by artefacts between 100 mm and 160 mm in length (mean = 133.02 mm, mode = 138.80 mm, median = 131.80 mm). The biface sample (by breadth) is dominated by artefacts between 60 mm and 105 mm (mean = 86.84 mm, mode = 94.70 mm, median = 87.70 mm).

The pattern of biface weight distribution shows stronger parallels with the distribution of biface thickness (Figure 136), which displays a slightly skewed distribution with a tail to the right (skewness = 1.0509; kurtosis = 5.4324). The biface sample (by thickness) is dominated by artefacts between 20 mm and 50 mm (mean = 34.67 mm, mode = 34.2 mm, median = 34.2 mm).

However, the correlation coefficients (r) between the four variables, indicate that the strongest positive relationship exists between biface length and weight (r = 0.89), followed by biface breadth and weight (r = 0.82) and thickness and weight (r = 0.72). The correlation coefficients also indicated that the relationships between biface length and thickness (r = 0.65) and breadth and thickness (r = 0.54) were relatively weak, suggesting that there was not a clear relationship between increasing length/breadth and thickness in the biface assemblage.

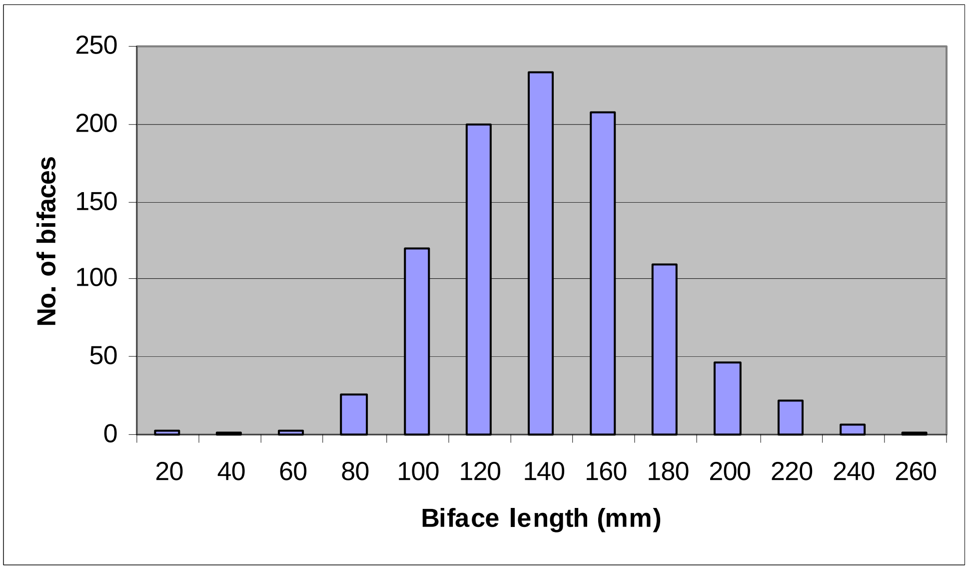

Figure 134: biface length distribution (class interval = 20 mm)

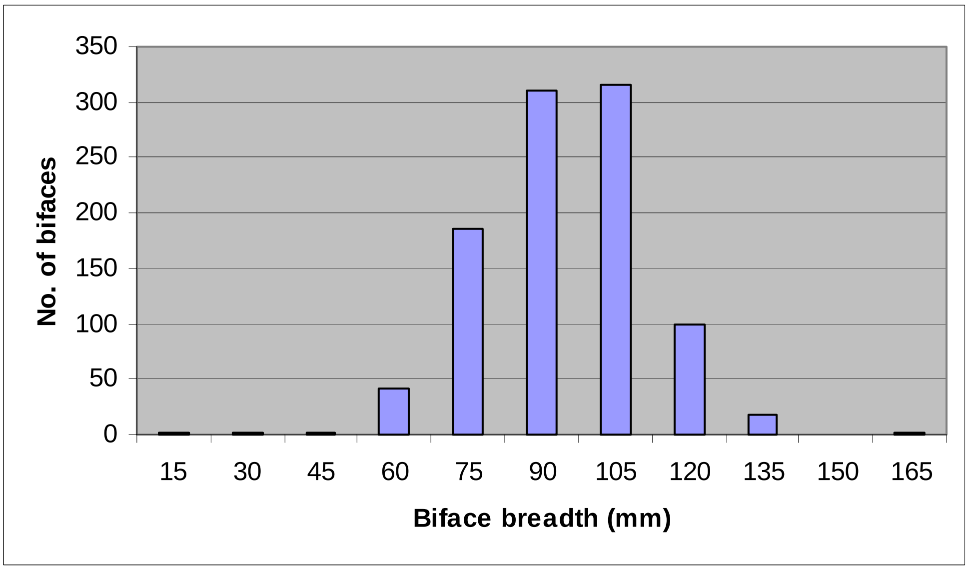

Figure 135: biface breadth distribution (class interval = 15 mm)

3.3 Biface technology

3.3.1 Raw Materials

Following the work of Bean, the majority of the biface sample was produced in chert (94%, n=921), with a small sample of flint bifaces (6%, n=55) and a single example made from quartzite. The chert was sub-divided during recording into fine-, medium- and coarse-grained chert, which suggested that coarse-grained material was least frequently used (18% of the total sample, n=178), although fine-grained chert (28%, n=269) was also in a minority in comparison with medium-grained materials (49%, n=474).

The ratios for the production of the major artefact forms (ovates, points, cordates and sub-cordates) in the different raw material types showed no significant differences to the overall proportion of raw material types recorded in the assemblage (Table 38). The data therefore indicate no support for the selective use of raw material to produce different biface forms (*c.f.* White 1998b).

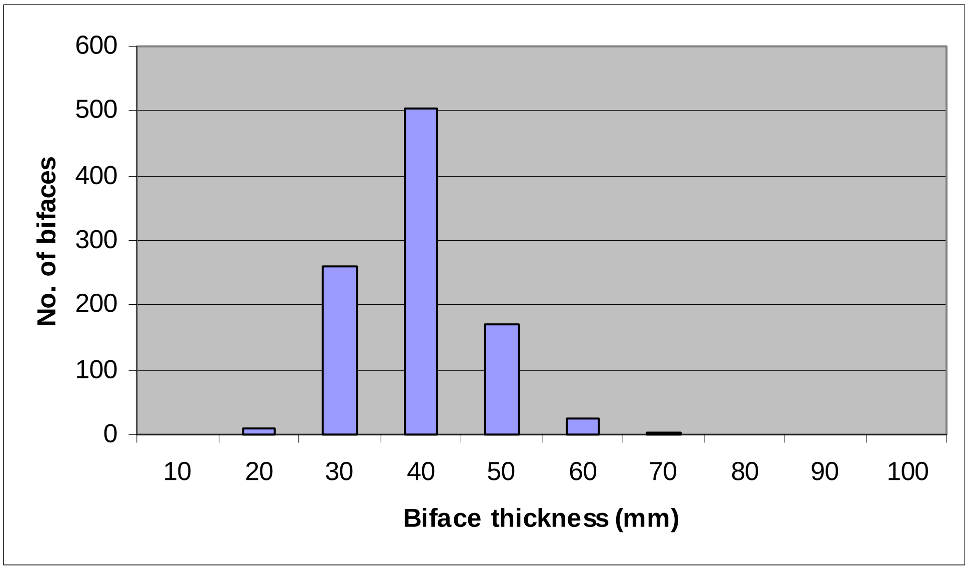

Figure 136: biface thickness distribution (class interval = 10 mm)

Artefact Type	Raw Material Category							
	Flint		Fine-grained chert		Medium-grained chert		Coarse-grained chert	
	%	n	%	n	%	n	%	n
Point	7.18	14	27.69	54	49.74	97	15.38	30
Ovate	5.00	20	25.50	102	48.75	195	20.75	83
Cordate	5.11	27	26.89	142	49.05	259	18.94	100
Sub-cordate	6.56	17	28.96	75	45.95	119	18.53	48
Assemblage	5.64	55	27.56	269	48.57	474	18.24	178

Table 38: biface types by raw material category ('transitional' types, e.g. ovate/cordate are counted in both categories. % values calculated for each row)

The proportions of distinctive biface types (cleavers, ficrons and flat-butted cordates) produced in each raw material category were also generally similar to the overall sample. In the case of ficrons, the majority of artefacts were produced on fine- (32%, n=8) and medium-grained (40%, n=10) chert, with small numbers produced on coarse-grained chert (12%, n=3) and flint (16%, n=4). Cleavers were predominantly produced on medium-grained chert (52%, n=13), with smaller numbers produced on fine-grained (36%, n=9) and coarse-grained chert (12%, n=3). Given the small sample size, it is difficult to attribute significance to the absence of cleavers produced in flint. Flat-butted ovates were also mainly produced on medium-grained chert (50%, n=6), with small numbers made on fine-grained chert (33%, n=4), flint (8%, n=1) and coarse-grained chert (8%, n=1).

The plano-convex bifaces in the assemblage were produced on all the assemblage raw material types, in ratios very similar to the overall sample: medium-grained chert (46%, n=94); fine-grained chert (27%, n=56); coarse-grained chert (21%, n=43); and flint (5%, n=11).

3.3.2 Blank Forms

Identifying the blank forms used in biface production is typically difficult as diagnostic features such as flake butts, bifacial cortex, tabular cortex and cobble cortex are commonly removed during the process of turning a blank into a biface. In the majority of cases at Broom, identification of blank form was not possible (60%, n=590). In those cases where a positive identification was possible, flakes were the dominant blank type (53% of the positively identified sample, n=205), although there was also a significant number of cobbles (24%, n=94 — these values increase to 39%, n=149 if naturally fractured cobbles and flaked cobbles are added to the cobble sample). There were no clear relationships between blank form and the distinctive bifaces types (cleavers, ficrons, flat-butted cordates), although this analysis was hindered by the difficulty in assessing blank form and the small numbers of the three distinctive biface types in the assemblage. This was also the case with the relationship between blank form and tranchet flake removals, which showed no clear patterns.

The major biface types did demonstrate some interesting patterns with respect to blank form. Points showed little preference (where the blank form could be identified) for production on either cobbles or flakes (cobbles 52%, flakes 48%), while sub-cordates, cordates and ovates all showed a preference (once again, where the blank form could be positively identified) for production on flakes (sub-cordates: 78%; cordates: 74%; ovates: 100%). Given the difficulty of blank form identification, caution is advisable with the interrogation of this pattern, but it is interesting that the highest proportion of flake use is associated with ovate forms, suggesting parallels with the conclusions of White (1998b).

3.3.3 Edge Profiles

The biface edge types are dominated by sinuous and straight edges. The most dominant pattern is a two straight edges (47%, n=455), with significant examples of one straight and one sinuous edge (27%, n=266) and a two sinuous edges (22%, n=212). There are very few examples of S-twist profiles, either on both edges of a biface or just one edge (4%, n=37). Moreover, in many cases the S-twists are not pronounced, and in no examples were they as diagnostic as the S and Z-twisted ovates documented by White (1998a). For all examples of the S-twist profiles, there was no suggestion of selective production in particular raw materials, with medium-grained chert (60%, n=22) dominant, and smaller amounts of the other materials: fine-grained chert (30%, n=11), coarse-grained chert (5%, n=2), and flint (5%, n=2). With respect to blank forms and S-twist profiles, the sample was too small to draw any clear patterns, although it may be significant that both cobbles (n=2) and flakes (n=5) were present in the sample.

These patterns in edge form are also very similar for the sub-sample of lop-sided forms, suggesting that there were few differences in the techniques of production for these asymmetrical bifaces. The two straight edges pattern is again dominant (50%, n=116), with a significant presence of bifaces with one straight and one sinuous edge (28%, n=66) and bifaces with two sinuous edges (17%, n=40). As previously, S-twist edges are rare (3%, n=7). The sub-sample of plano-convex bifaces also demonstrated these broad patterns, with the two straight edges dominant (47%, n=96), with a significant presence of one straight and one sinuous edge bifaces (34%, n=69) and a small number of two sinuous edges (18%, n=36).

There was no noted pattern in the relationship between sinuous edge profiles and cobble blank forms. Where sinuous edges occurred on either one or both profiles, flake blanks (including side-struck flakes) occurred in 64% (n=70) of cases, compared to 36% (n=39) for cobbles (including flaked cobbles and naturally fractured cobbles). Where sinuous edges occurred on both of the biface profiles, flake blanks occurred in 62% (n=53) of cases, compared to 38% (n=32) for cobbles. In both instances, the ratio of blanks to cobbles was similar to that shown for the entire assemblage, suggesting that there was not a premeditated selection of cobbles for rapid, on-the-spot production of 'crude', relatively unrefined bifacial tools.

There was some evidence of variation from the general edge profile pattern when the distribution was examined in terms of biface butt types, although the overall patterns were generally similar to the complete assemblage. In all instances, the two straight edge types was dominant, but it was highly dominant in the partly trimmed butt category (75%, n=18), whereas in all other cases the figure varied between 41% and 49% (excluding the part trimmed flat category with a sample size of 1). The straight edge/sinuous edge and sinuous/sinuous edge categories were the other major types present. The straight/edge sinuous edge type ranged from 12.5% (associated with part trimmed butts) to 33% (associated with part trimmed/part cortex butts), while the sinuous/sinuous edge type ranged from 12.5% (natural and part trimmed butts) to 28% (trimmed butts).

3.3.4 Biface Refinement

There was little evidence to suggest that there was a relationship between raw material and the degree of biface refinement (as measured by a % cortex index and a number of flake scars index). For flake scars to be counted they had to greater than 1 cm in any dimension. This avoided the potential confusion caused by the inclusion of micro-flaking (caused by fluvial transport) to the edges of the biface. The average number of dorsal flake scars ranged from 16.8 (coarse-grained chert) to 20.3 (flint), with the average number of ventral flake scars ranging from 14.1 (coarse-grained chert) to 18.2 (flint). Although there was a small increase in average flake scar numbers with increasingly fine-grained raw material, the data did not suggest a clear relationship between manufacturing refinement and raw material quality.

Similarly there was no clear evidence for a raw material quality/biface refinement relationship in the pattern of biface cortex. Average dorsal cortex % values ranged from 5.9% (medium-grained chert) to 8.6% (fine-grained chert), while average ventral cortex % values ranged from 6.8% (coarse-grained chert) to 10.6% (fine-grained chert). In this instance, there was no clear linear relationship between average cortex % and increasingly coarse-grained raw material.

3.4 Biface Transport

Assessment of whether the bifaces had been subjected to fluvial transport was based on a range of recorded attributes, the quantified abrasion (width) of the bifaces' flake scar ridges (following Wymer 1968; Shackley 1974, 1975; Hosfield 1999); the presence, intensity and location of micro-flaking on the biface edges; and the presence, density and location of incipient percussion cones on the artefacts' dorsal and ventral faces. It was apparent that all of the bifaces had been subject to some degree of fluvial transportation, although it was also clear that relatively few had been transport long distances.

Modelling the distances that each artefact may have been transported prior to deposition is much more complicated, and the full methodology is outlined in Section 4. In outline, it involves a combination of quantified abrasion data, experimental archaeological data, artefact profiles (e.g. plano-convexity and the presence/absence of a biface 'spine'), and photographic evidence. The modelled distances (Figure 137) were, of course, never intended as absolute distances — but it is suggested that the robust nature of the data do indicate some probable patterns with respect to the sources and generic catchment of the assemblage.

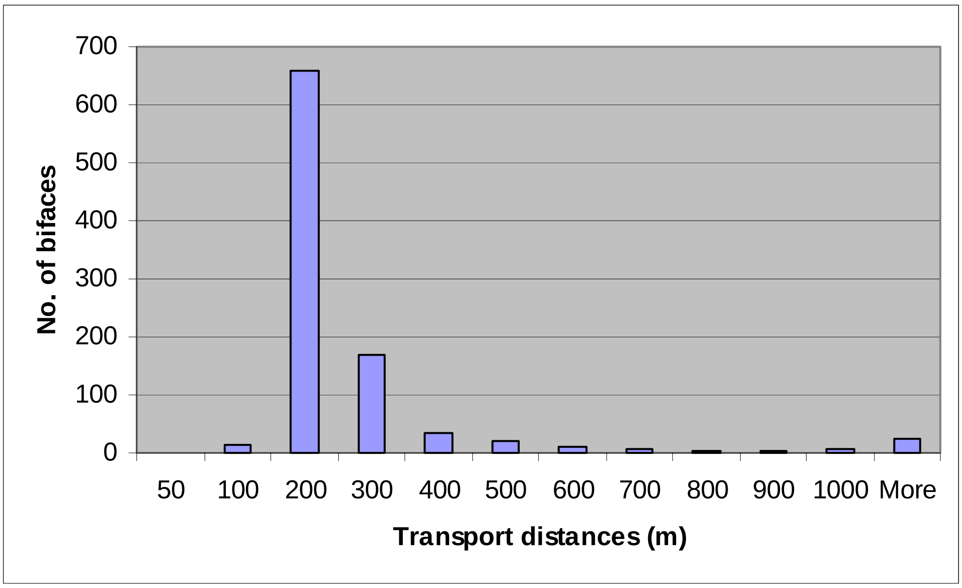

Figure 137: biface transport distances (modelled) distribution

The data suggest that the majority of the bifaces (*c*. 89%) have been fluvially transported a short distance, probably less than 200–300m, prior to their incorporation into the sediments at Broom. Nonetheless, there is a significant component of the assemblage that has probably been transported over greater distances, probably more than 500–1000m.

3.5 Summary

The biface assemblage from Broom is summarised as follows:

1. A predominance of cordate/ovate, cordate and pointed forms (Wymer types J/K, J and F), with cordate, ovate and cordate/ovate (intermediate) forms representing over 50% of the sampled assemblage.
2. Cleavers, ficrons, and flat-butted cordates are present, albeit in small proportions.
3. The typological composition of the assemblage is broadly replicated in the plano-convex and asymmetrical (lop-sided) sub-samples.
4. Tip types were dominated by irregular, rounded forms, although the vulnerability of tips to damage during fluvial modification restricted the significance of any subtle patterning.
5. Tranchet tips were present, but in very small numbers.
6. Trimmed flat butts were dominant, suggesting a preference for fully circumferential cutting edges on the bifaces.
7. Biface weight was clustered between 100g and 500g, although there was a total weight range of 2399g.
8. Fine and medium-grained cherts were predominantly utilised for biface production. There was no association between the grain size of the raw material and the types of bifaces produced.
9. Although positive identification was difficult, bifaces produced on both flake and cobble blanks formed significant elements of the assemblage. There is weak pattern indicating a possible preference for flank blanks in the production of sub-cordates, cordates and ovates.
10. The biface edges were dominated by straight and sinuous profiles. These patterns held true for the plano-convex and asymmetrical sub-samples. S-twist profiles were relatively rare and rather equivocal. There were no clear associations between S-twists and raw material quality, or between sinuous edges and the use of cobble blanks.
11. There was no evidence of any relationship between raw material quality (fine to coarse-grained) and the degree of biface refinement (measured by the number of flake scars and the percentage of unremoved cortex).
12. Although all of the assemblage has been subject to fluvial transportation, the majority of the bifaces appear to have been derived from a nearby source and have probably been transported only a few hundred metres prior to deposition into the sediments at Broom.

3.6 The non-biface assemblage

The non-biface assemblage consisted of a range of artefact types, including biface fragments, débitage flakes, retouched flakes, scrapers, unifaces and roughouts (Table 31 & Table 35). The ratio of non-biface to biface material (1:5.14) is in marked contrast to the ratios resulting from experimental knapping activity, as demonstrated by Newcomer (1971), who produced four bifaces and generated 195 flakes (although their size was not specified), and Wenban-Smith (1996), who created four bifaces, generating 210 flakes ≥ 20 mm. It indicates that the material is not in primary context (i.e. that hominids were not episodically knapping bifaces and other tools on the surface of the fluvial sands and gravels, as those sediments were deposited upon the floodplain), although it is also likely that the ratio is depressed due to the tendency of the pit labourers to ignore flake materials. The presence of roughouts indicates that bifaces were being produced in the vicinity of Broom. The presence of other tool types (particularly scrapers and retouched flakes) suggests that the assemblage is not purely the product of a biface manufacturing site, but rather that other activities were also undertaken.

Nonetheless, the stratigraphic origins of the non-biface material, particularly the flakes, are significant since the presence of débitage material in fluvial sediments has often been taken as evidence of assemblages that are either in primary context or have suffered minimal disturbance and transportation. The Bean archive indicates the collection (both by the Pratt's Old Pit labourers and by Charles Bean himself) of flakes from throughout the sequence — the coarse-grained upper and lower gravels and the finer-grained middle beds. However, the majority of references to flake material are associated with the datum level (the approximate height of the middle beds):

"I found many flakes in the large stone bed equals about road level cottages to -2 ft [the general level of the middle beds]*."*

(C.E. Bean archive, 3rd March 1935)

"Found several flakes in face exposed about 3 ft above floor level cracker [the general level of the middle beds]*…the cores and flakes look very fresh."*

(C.E. Bean archive, 9th June 1934)

"Found several flakes and a rough implement about 12" below 1st floor level [the general level of the middle beds]*."*

(C.E. Bean archive, December 1934)

"Found many flakes myself just below first floor [the general level of the middle beds] *in compact bed at back of pit."*

(C.E. Bean archive, 27th January 1935)

It is difficult to assess Bean's claims for 'fresh' flakes, mainly due the problems of identifying flakes with a clear stratigraphic provenance in the Bean collection. Nonetheless, the current analysis suggests that the majority of the flakes showed evidence of some degree of fluvial transport. It is concluded, therefore, that the majority of the flakes recovered from Pratt's Old Pit were probably found in association with the middle beds and that these flakes were probably subjected to short distances of transport in the low-energy flow conditions that deposited the fine-grained sediments of the middle beds. Nonetheless, there is also evidence for the presence of flakes in the coarse-grained upper and lower gravels:

"Many flakes 2' above datum = Rd level cottage in stiff clayey sand [the middle beds]*…found core or at least, I think it is, at 13 ft above datum also at about 10 ft above datum flakes etc* [the height of the upper gravels]*."*

(C.E. Bean archive, 7th April 1935)

"Several flakes and cores together about cottage level at X [the middle beds] *also at +8*[ft] *and -4*[ft] *this level* [the upper and lower gravels]*."*

(C.E. Bean archive, 23rd June 1935)

"Large flake at 10 ft deep back of pit = 19 ft above datum [the upper gravels]*."*

(C.E. Bean archive, 18th August 1935)

The presence of flakes in the upper and lower gravels suggests that the Broom sequence does not represent a single, minimally disturbed occupation (the archaeology of the middle beds), surrounded by occasional stray biface finds in the coarse-grained sediments above and below. The general condition of three flakes recovered from the upper gravels in Pratt's New Pit (during the 2002 excavations by the University of Southampton) also indicates that these flakes were fluvially transported and not discarded by hominids on the floodplain. Detailed transport modelling of the non-biface assemblage was not undertaken due to the very small numbers of suitable flake scar ridges on these artefacts.

In general therefore, the presence of flakes in the Broom sequence has been documented from the Bean archive, the Bean collection and the finds from the current excavations. However, despite the reference to cores within the Bean archive (see above), the current analysis has been unable to identify any core material within the Bean collection.

Examination of the assemblage indicated no evidence of Levallois material (either flakes or cores), although Wessex Archaeology (1993b) did list 2 flakes and 1 core. This discrepancy cannot currently be resolved, although even if these artefacts were located, their small numbers would necessitate caution with respect to the behavioural interpretation of the Broom assemblage. Nonetheless, the presence/absence of Levallois material obviously carries implications with respect to artefact-chronologies for the British Isles (Bridgland 1996). Examination of the Bean collection also yielded a single large blade. The flint blade is not abraded, edge damaged, stained or patinated, suggesting that it may have originated from the surface at Broom and therefore be far younger in age. However, it is also difficult to demonstrate that this artefact was the product of systematic blade production, and it could have been produced during the reduction of a tabular nodule.

Overall, the presence and probable condition of the non-biface artefacts at Broom suggests that the entire sedimentary sequence contains bifaces, non-bifaces (e.g. unifaces and scrapers) and flakes that have been derived (albeit over relatively short distances) from upstream areas and re-deposited in the floodplain sediments at Broom.

4. ARTEFACT ABRASION AND TRANSPORTATION

This section provides a detailed account of the new methodology developed by JCC to model the spatial origins of bifaces recovered from secondary fluvial contexts. This work forms part of JCC's recently submitted PhD thesis (Chambers in prep.) and has been utilised in the current project given its suitability for the research questions being investigated here.

4.1 Introduction to artefact abrasion studies

It has long been noted that artefacts recovered from river 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 arêtes (flake scar ridges). In freshly knapped bifaces arêtes rise thin and proud from the body of the biface. As artefacts become incorporated within active fluvial systems they behave as clasts, rolling, saltating, sliding and colliding with other clasts. These impacts reduce the height and increase the width of the arêtes. Such damage increases with time and transportation, and the recognition that artefacts are not all abraded to the same states facilitated a gross interpretation of the degree of transportation within high-energy contexts that the artefacts had been subjected to. Artefacts, such as bifaces, with sharp edges and little visible abrasion to the arêtes found in association with knapping débitage and perhaps faunal remains were considered to remain in close proximity to their original point of use and discard. Those artefacts that displayed 'very rolled' characteristics were considered to have been transported significant distances within the river channel environment.

Two major approaches for quantifying artefact abrasion have been proposed (reviewed below); those based on a visual assessment of the relative degree of damage an artefact has sustained (e.g. Wymer 1968) and those based on techniques pioneered by Shackley (1974; 1975) that utilise microscopic technology to objectively measure arête widths in micrometres.

4.2 Visual assessment of biface abrasion

Prior to the work of Shackley, 'naked eye' visual assessment of biface abrasion was the only means by which to assess the degree of damage artefacts had sustained. These visual assessments generated a range of user-specific descriptive terms such as 'mint', 'fresh', 'worn', 'rolled'. The inherent subjectivity of such terms was compounded by an absence of standardised terminology. An attempt at standardisation was proposed by Wymer (1968: plate xi), suggesting five categories to encompass the range of abrasion damage displayed by artefacts recovered from river gravels. These categories were mint, sharp, slightly rolled, rolled and very rolled, with artefacts in the rolled and very rolled categories displaying arêtes widths of up to $^1/_{32}$ and $^1/_8$ of an inch respectively *(ibid.)*.

This standardisation allowed different workers to apply the same terminology to different artefacts and assemblages of artefacts, and provided a means of quantifying the most abraded artefacts recorded. However standardisation of a subjective classificatory system does not in itself reduce the potential inter-observer variability.

4.3 Microscope Techniques: objective assessment of biface abrasion

During the course of analysis of derived context lithic assemblages from the Mousterian site of Great Pan Farm on the Isle of Wight, Shackley (1973, 1974, 1975) determined that an absolute means of measuring and describing artefact abrasion was required. To avoid confusion between use wear and abrasion damage Shackley's analyses focused on the arêtes of bifaces, which she examined under an x75 microscope eyepiece calibrated to 10μm (Shackle 1975). For recording purposes, Shackley (*ibid.*) divided each biface into imaginary thirds of tip, mid and butt sections documenting the width of 25 arêtes across the entire artefact, collected roughly equally from each third. These 25 arête values were combined to produce an average observed arête width for the entire artefact. This methodology was applied to both experimental (tumbling mill abraded) and archaeological examples, providing information on artefact abrasion development, and a means with which to provide objective measurements and classification of abraded archaeological lithics. The tumbling mill experiments undertaken by Shackley (*ibid*: 43–46) revealed that a variety of factors including artefact shape, raw material, nature of abrasive material and transportation type could affect the development of arête abrasion. However, in the standardisation of abrasion recording and description, potentially subtle variations in abrasion development were obscured by the generation of an average abrasion value for the entire artefact. To further facilitate quantification of results, Shackley (*ibid.*) also proposed a scheme to correlate the commonly used verbal descriptive terms of artefact abrasion with the damage sustained by her experimental bifaces during the tumbling mill experiments (Table 39).

The generation of an average abrasion value, or index value, for each artefact provided a quantified manner of assessing both individual, and more importantly assemblages of, abraded artefacts. The recording of arête widths at the micrometer scale led to the recognition that artefacts which may not appear abraded to the naked eye, can have sustained transport-related arête damage. This is best demonstrated by Shackley's analysis of the assemblage from Great Pan Farm on the Isle of Wight (*ibid.*). Non-microscopic evaluation of the assemblage had not revealed any trace of abrasion damage and the artefacts were therefore considered to have been manufactured at a nearby occupation site and not regarded as having been subjected to any notable degree of transportation. Measurement of the arêtes of these artefacts under a microscope showed that many did indeed show traces of abrasion resulting from incorporation within active fluvial systems, suggesting that the Great Pan Farm assemblage is not as homogenous in spatial origin as visual assessment alone would suggest (*ibid.*).

Ridge Width (μm)	**Common Description**	**Shackley's Index Value**
0–10	Mint	0
10–20	Very Fresh	1
20–50	Fresh	2
50–100	Slight Abrasion	3
100–200	Abraded	4
200–300	Heavily Abraded	5
300+	Very Heavily Abraded	6

Table 39: abrasion indices and verbal description correlation (Shackley 1975)

As the example of Great Pan Farm highlights, the major motivation behind Shackley's methodology was to provide a means of assessing the integrity of 'assemblages' recovered from high-energy contexts. An implicit assumption in the consideration of such assemblages had long been that if artefacts occur in large numbers then they cannot have travelled far within the fluvial system, as sustained transportation would distribute the archaeological material over a large area. Whilst not directly addressing transport duration, a quantifiable means of assessing artefact abrasion at the sub-millimetre scale allows both the identification of homogenously abraded 'assemblages within assemblages' and, conversely, also allows for the damage and variation in seemingly non-abraded assemblages to be examined in greater detail than the human eye alone can detect.

Despite the inherent advantages in being able to provide absolute values rather than subjective descriptions for abraded arêtes, Shackley's methodology has not been widely implemented. Applications of microscope recording of archaeologically abraded lithic material appear to have been limited to the work undertaken by Shackley (1973, 1974, 1975) and a slightly revised methodology proposed by Hosfield (1999). It seems most likely that microscopic recording of artefact abrasion has not been implemented further as a result of both the perceived indecipherable nature of artefact transportation within river gravel deposits, and the time consuming nature of the technique.

4.4 Artefact abrasion and transportation (i)

As outlined above, artefact abrasion whether subjectively categorised or microscopically measured has been used as indicators of the relative amount of fluvial transportation individual artefacts or a population of stone tools have been subjected to. The development of an absolute means of recording arête abrasion damage provided a foundation for further investigations into the perceived homogeneity of large secondary context assemblages, but also for relating abrasion damage development to transportation duration in more absolute terms.

Experiments conducted by Harding *et al.* (1987) set out to investigate taphonomic aspects of secondary context assemblage formation and artefact modification. By monitoring the dispersal and damage sustained by replica bifaces emplaced within different sub-environments in the Afon Ystwyth (mid-Wales) the relationship between distance and damage could be considered.

60 replica bifaces were emplaced at different locations within the braided channel environs of the Afon Ystwyth during a period of peak discharge. Monitoring of where these artefacts were recovered and what damage they had received revealed the following (*ibid.*):

- Artefacts within active fluvial environments behave as the local mobile sediment, therefore;
- Transportation is an episodic phenomenon, with periods of movement tending to be followed by longer periods of stasis.
- There is an inverse relationship between the distance transported and artefact size.
- Biface wear also appears to be an episodic phenomenon.

Within these experiments attention focused on weight loss and polish development, rather than specific arête measurements of abrasion development. A strong relationship could be demonstrated between distance moved and weight lost, which did not appear to be related to the original size of the replica artefact (*ibid.*; these experiments are discussed in further detail in chapter 5). With regard to artefact modification as a result of fluvial transportation, the most interesting findings of the Harding *et al.* (*ibid.*) experiments are the common occurrence of weight loss resulting from the detachment of small flakes from the edges of the biface during artefact–clast impacts. This indicates that solely focusing upon the arêtes of an abraded biface will not represent the entire transportation history that an artefact preserves.

4.5 Artefact abrasion and transportation (ii)

Very few attempts have been made to correlate abrasion development and real world transportation distances, perhaps once again reflecting the perceived difficulties of unravelling the relationship between fluvially transported artefacts, their depositional contexts and the resulting damage artefacts sustain.

The most detailed research in this area is that undertaken by Hosfield (1999). Devising an adaptation of Shackley's methodology, where 15 rather than 25 data points are selected across the biface, Hosfield (*ibid.*) combined the quantitative abrasion data provided by microscopic arête width recording with the abrasion damage sustained within fluvial environments generated by the experiments of Harding *et al.* (1987) and his own experimental abrasion development data on replica artefacts.

Based on the sum of these data Hosfield (1999) devised seven preliminary rates of wear values (*ibid*: 116–117) based on differing combinations of potential abrasion values prior to the bifaces incorporation into the river environment. The expansion of this model to include a greater archaeological sample facilitated the refining of an average wear rate of 0.1475 $\mu m\ m^{-1}$. These results allow artefacts recovered from river gravel contexts to be 'back-tracked' from their findspots to a modelled discard area (*ibid*: 121). This represents a significant move towards accurately modelling hominid activities within landscapes dominated by high-energy artefact recovery contexts.

4.6 A summary of extant abrasion assessment methodologies

While the numerical dominance of Palaeoliths recovered from high-energy contexts within the Palaeolithic record of Britain, has long been acknowledged, the ways in which we try and interrogate this data set remain limited, with the visual categories proposed by Wymer 35 years ago, remaining the most commonly employed way of describing secondary context artefacts. The simplicity and speed of this technique has obvious advantages, however analysis at such a simplistic level provides no meaningful information about the duration and variety of fluvial transportation that artefacts have been subjected to. It does not facilitate the interrogation of the spatial origins of an assemblage in anything other that the most crude of terms. As artefacts recovered from secondary contexts do preserve detailed information about the nature and duration of the transportation regimes they have been subjected to, as demonstrated by the work of Shackley (1975) and Hosfield (1999), by failing to evaluate this evidence we are also failing to do justice to a substantial portion of the Palaeolithic record.

If we accept that, as Harding *et al.* (1987) demonstrated, once incorporated in active fluvial systems bifaces behave as clasts, we must also accept that detailed evaluation of the damage they sustain as part of these active fluvial systems can inform us of how and in what manner they have been transported. This may be best achieved by taking an 'artefact biography' (Chambers in prep.) approach, where individual artefacts form the basic unit of analysis, through a return to considering the entire *état physique* of artefacts. This informs us of the damage they have sustained, while experimental data offers a means of evaluating how this damage is most likely to have occurred.

4.7 Differential abrasion development

Analysis of bifaces recovered from the gravels of the Axe River and Solent River system showed that abrasion development does not occur in a uniform manner across the entirety of an artefact (Chambers in prep). In all but the most minimally abraded examples, areas or zones of more pronounced abrasion could be identified either within a single face or in comparison of the abrasion characteristics present on each face. This prompted a re-evaluation of existing abrasion recording methodologies. It was recognised that despite the difficulties in obtaining microscopic arête abrasion values, such data provide the most reliable and repeatable means of measuring abrasion damage. Shackley's (1974) original recording technique of dividing each artefact into imaginary thirds was expanded to divide each face into six portions (Figure 138).

Whilst it is acknowledged that ideally every arête value on an abraded biface would be recorded, in the absence of scanning equipment of high enough resolution to automate this process, this was considered to be currently outside the realms of achievable data recording. Therefore two arête widths, which typify that zone of the biface, are recorded for each portion. Arête widths are recorded in a systematic manner, progressing from Zone 1 to Zone 6 for each face, generating a total of 24 arête values for each biface, a data set highly comparable to Shackley's original 25 measurements methodology. This zone-based recording technique allows areas of more pronounced abrasion damage to be identified, rather than normalised during the generation of an average abrasion value for the entire artefact as advocated by previous microscopic studies of abrasion damage.

Areas of pronounced abrasion damage can be seen on the vast majority of archaeologically abraded material so far examined from sites on the Solent River system and the River Axe, and it is postulated that these different abrasion characteristics represent different durations and types of transport.

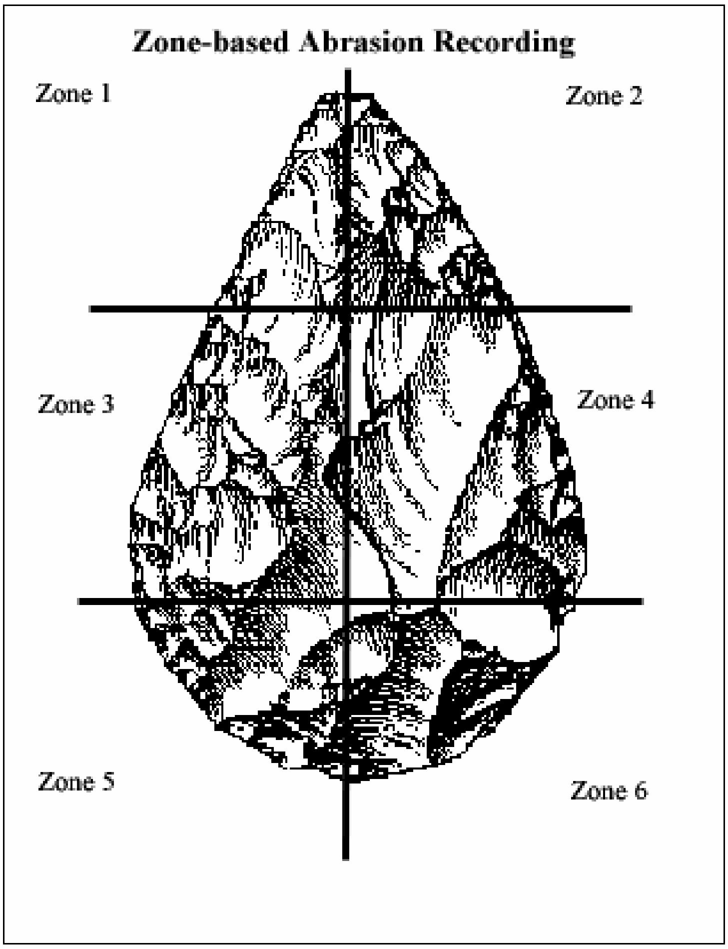

Figure 138: zone based recording of biface arête abrasion damage

4.8 Movement within fluvial contexts

Returning once again to the demonstration by Harding *et al.* (1987) that from a fluvial transportation perspective, discarded bifaces are simply clasts endowed with cultural significance, we can attempt to understand the processes and types of transportation that they have been subjected to. These attempts can be aided by a review of the extant engineering literature pertaining to particle (clast) movement within fluid systems.

Two main types of fluvially induced movement have been identified by civil and hydraulic engineering research: suspended load and bed load transport. Movement in bed load transportation regimes takes the form of types of movement that involve contact with the underlying channel bed. In contrast, suspended load transportation refers to the movement of particles within the fluid flow, without significant contact with the channel bed (e.g. Lee *et al.* 2002; van Rijn 1984).

Within the fields of both civil and hydraulic engineering the modelling of suspended load transportation remains highly problematic. Models that do exist have focused on very small (sub-millimetre particles, and require the computation of a range of variables (such as exact flow speed, water density and particle population statistics) beyond the resolution it is currently possible to determine for Pleistocene sediments.

The artefact abrasion experiments have therefore concentrated on the damage patterns that result from different types of bed load transport.

Bed load transportation can be divided into three main categories, sliding motion, rolling and saltating motion. Sliding transportation is the movement that occurs when the particle achieves movement primarily by retaining contact with the channel bed without suffering any rotation about its long axis. Movement by rolling motion also maintains a predominantly constant contact with the channel bed, though movement occurs via rotation. Saltation is defined by the Oxford English Dictionary as:

"A mode of transport of hard particles over an uneven surface in a fluid stream (as a wind or river), in which they progress in leaps, and on falling to the surface either bounce up for another leap or impart their momentum to other particles which on rising are accelerated forward by the stream"

Some researchers (e.g. Einstein 1942, 1950; Engelund & Fredsøe 1967) have sought to include saltation within the suspended modes of transport, though it is much more common for saltation to be regarded as an aspect of bed load transportation (e.g. van Rijn 1984; Lee *et al.* 2002; Nino & Garcia 1998; Lee *et al.* 2000; Sekine & Kikkawa 1992; Murphy and Hooshiari 1982), as part of the continuum of rolling/saltating motion. It should however be remembered that while two major modes of transportation have been identified these modes are not entirely distinct, but rather are connected by a region of overlap (Sekine & Kikkawa 1992).

Most bed load transport has been demonstrated to affect only the surface layers of particles within the channel bed (Einstein 1942, 1950; van Rijn 1984). Einstein (1950) calculated that the thickness of this layer was approximately twice the average particle size, van Rijn's (1984) results indicated that this layer may be up to 10 times the thickness of the average particle and that the effects of gravitational forces dominate movement.

Civil and hydraulic engineers have demonstrated that the most common type of bed load movement is that of saltation and/or rolling, with sliding motion being much less likely to occur. This pattern was found to be unaffected by flow velocity or particle size (e.g. Einstein 1942; Sekine & Kikkawa 1992; Wiberg & Smith 1985, 1989). While such studies have been undertaken on small particles, the largest being 2 cm (van Rijn 1984), the clarity and repetition of this preference for rolling and saltation merited investigation to see if archaeological materials would display similar preferences. Any trends within transportation typology could then be related to abrasion development both on experimentally and archaeologically abraded materials.

The modelling of particle movement by engineers is generally based on the recreation of an array of variables which remain unknowable for archaeological secondary context assemblages. However, the general trends such research has highlighted, such as the tendency for bed load transport to occur only in surface layers of any given channel bed, and furthermore for this bed load transport to be dominated by rolling or saltating movement can enhance the ways in which we consider modelling artefact movement in fluvial environs.

4.9 The Flume Experiments

Flume equipment provides the opportunity to recreate fluvial conditions with a greater degree of control and higher artefact recovery rates than can be maintained in real world contexts. Flume experiments evaluating the survival potential of different archaeological lithic materials have been previously undertaken, most notably in the work of Schick (1986) who charted the winnowing effects of different flow velocities on different size classes of tools and débitage. These experiments were geared towards aiding the interpretation of *in situ* knapping scatters (*ibid.*), facilitating an understanding of what *remains* at the original locations of hominid behaviour rather than an understanding of what happens to the artefacts that move. Flume experiments were also undertaken by Shackley (1974, 1975) as a key component of her investigations into abrasion measurement and artefact abrasion classification, unfortunately these data are neither published, nor included in detail as part of her PhD thesis.

Flume experiments were therefore undertaken to allow the development of transport related damage to be evaluated in conjunction with analysis of the type of movement artefacts were most likely to be subjected to (Chambers in prep). The advantage of undertaking these types of experiment under laboratory conditions, as opposed to within real fluvial contexts, are that within a glass lined flume both the type and duration of movement can be easily recorded. Variables such as flow and flume angle can be recorded and altered providing a much greater degree of control than can be achieved in real world contexts. The tendency found within engineering research for bed load transport to occur only within surface layers permitted the minimal lining of the flume with gravel, further facilitating the identification of the type of movement artefacts undertook. A flume environment was felt to be more realistic a fluvial analogue than a tumbling mill due to the ability of artefacts within the flume to engage in more extensive lateral movement than is possible within the confines of a tumbling mill.

As a link between abrasive material and arête abrasion development had been identified by Shackley (1975), it therefore also seemed probable that artefacts of different raw materials would become abraded at different rates. Replica bifaces of both fine (flint) and coarse grained (chert) raw materials were therefore prepared. Prior to the commencement of the flume experiments the metric and arête values for each artefact were recorded. The character of the artefacts edges were also recorded with regard to the degree of small flakes removed around the circumference as a direct result of knapping.

Artefacts were introduced to the gravel lined flume individually and in raw material pairs, (one 'spinal', one plano-convex) though for most flume runs only one artefact was included to aide the accurate recording of the transportation type. Abrasion, edge and weight loss data were recorded after set distance intervals. For the first 100m of transportation these data were recorded every 10m, between 100–200m recordings occurred after every 25m and beyond 200m data were recorded after every 50m of movement. As a result of the adoption of a zone based, systematic and repeatable arête recording methodology, each of the flume run recordings can be plotted graphically, with the abrasion development of each zone of the biface discernable and comparable. Graphic samples of the experimental data, representing the trends outlined below are shown in Figure 139–Figure 141.

The flume experiments revealed the following general trends:

- Fine- and coarse-grained raw materials develop damage at differing rates:
  - Fine-grained materials show lower initial (non-transported) arête values, and show slower arête width increase than coarse-grained materials.
  - Coarse-grained materials display higher initial (non-transported) arête values than fine-grained materials, and within the first 300–350m of fluvial transportation arête width increases quickly.
  - Once past 400m of fluvial transportation this pattern reverses itself, as the arête width increase in coarse grained material appears to stabilise and slow, whereas the arête widths on the fine grained material began to increase more quickly.
- Artefact morphology affects transportation type:
  - Bifaces with pronounced plano-convexity showed a tendency to firstly orientate themselves with their flat face in contact with the flume bed.
  - Once in this position they became orientated parallel to flow direction and were most likely to move via sliding motion.
  - Increase in flow velocity did not affect this tendency.
  - Increase in flume angle from horizontal to up to -10° increased the likelihood of sliding motion, flat face down, in plano-convex bifaces.
  - Bifaces without plano-convexity (referred to as 'spinal' bifaces) showed a tendency to orientate themselves perpendicular to flow direction, with no facial preference.
  - Once in this position they were most likely to move via rolling or saltating motion
  - Increase in flow velocity did not affect this tendency.
  - Increase in flume angle from horizontal to up to -10° did not affect this tendency.
  - This pattern of morphological governed movement occurs in both fine and coarse-grained raw materials.

- Transportation type affects the damage sustained:
  - Bifaces that have moved via rolling or saltating sustain arête damage that is highly variable within a single face.
  - The thickest parts of the biface are more likely to become most heavily abraded.
  - While the individual arête widths on a single face may be variable, when the range and distribution of arête widths of each face is considered against that of the other face general consistency can be demonstrated. Due to the systematic, zone-based arête recording technique, the abrasion signature of each face can be plotted and compared (Figure 139 & Figure 140).
  - Bifaces that have moved via rolling or saltation are more prone to sustain edge damage in the form of small flake removals (referred to as 'micro-flaking'). Micro-flaking intensity increases with transportation distance.
  - Plano-convex bifaces, moved by sliding, show more consistent arête width values to their flat face, the result of grinding of the arêtes as they slide over the flume (channel) bed.
  - The convex face of plano-convex bifaces moved by sliding motion can show variable arête widths, the result of clast bombardment. This abrasion signature can also be plotted and compared (Figure 141).
  - Bifaces that have moved via sliding motion are unlikely to sustain discernable quantities of micro-flaking.

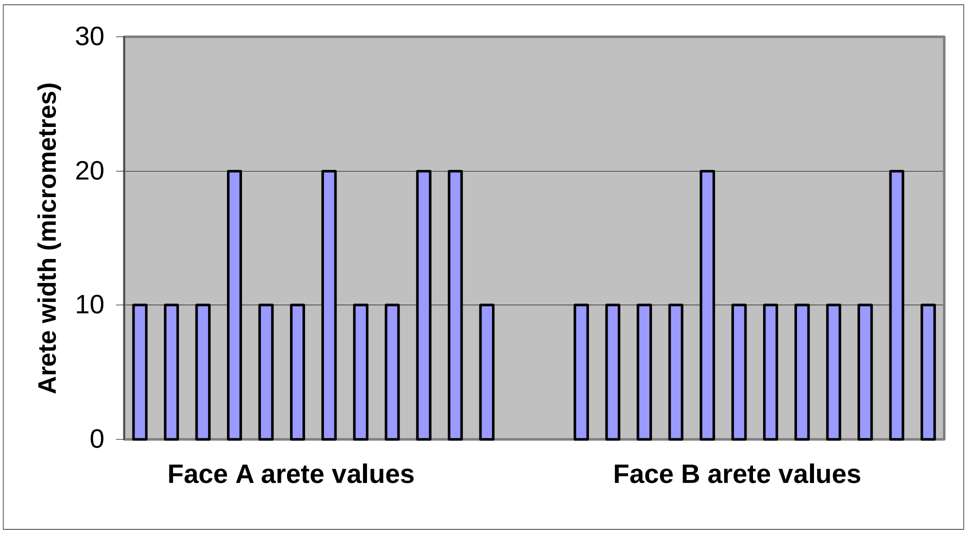

Figure 139: Sample experimental saltation abrasion data ('spinal' flint biface after 10m saltation (no edge damage). After minimal transportation, arête values within a single face can be seen to vary, though comparison of the general abrasion pattern of both faces shows consistency

The experiments have generated a large data set pertaining to the abrasion (and edge damage) development of both fine and coarse grained raw materials under the most common modes of bed load transportation. These data demonstrate that the dominant transportation regime influences the damage that artefacts sustain. Artefacts of different raw materials abrade at different rates, but appear to show similar general damage development patterns. Artefact morphology is also a significant factor in abrasion development as only plano-convex artefacts showed an inclination towards sustained sliding motion.

This data set can be used in comparisons with archaeologically abraded artefacts, providing a means with which to evaluate the most probable transportation regime and the distances they have been subjected to.

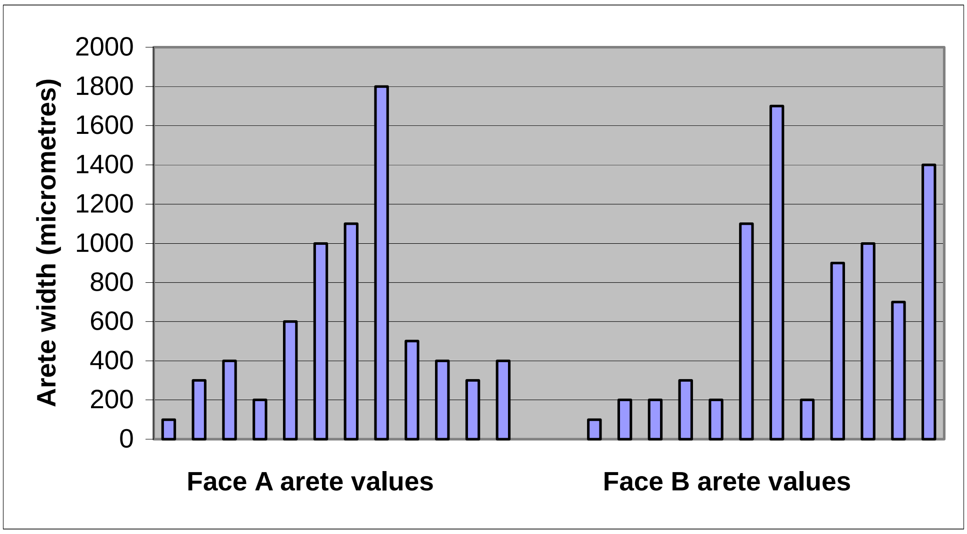

Figure 140: Sample experimental abrasion data ('spinal' flint biface after 500m saltation (moderate edge damage). After 500m of predominantly saltation movement, the variability within each face has increased, but the inter-face consistency remains.

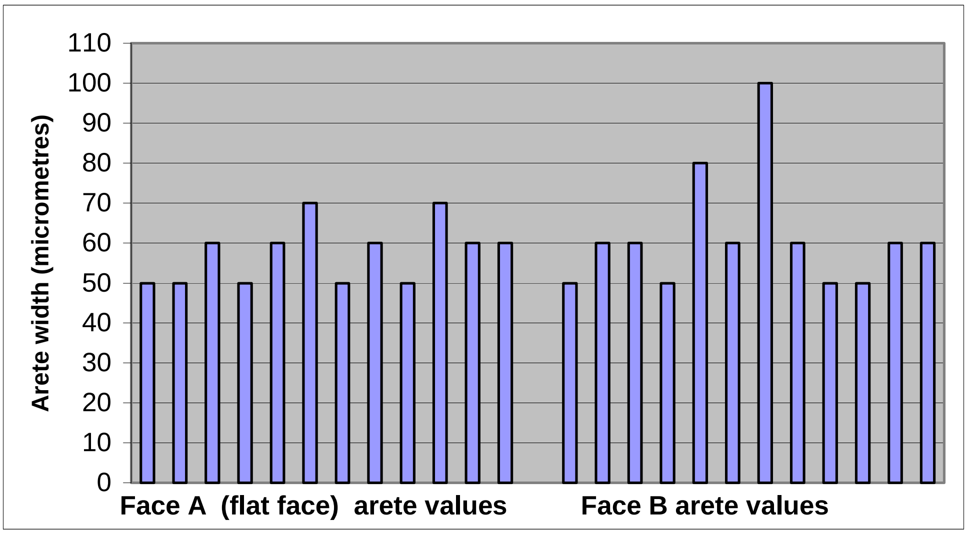

Figure 141: Sample experimental abrasion data (chert plano-convex biface after 100m sliding (no edge damage). After 100m of predominantly sliding motion on the flat face (Face A), the consistency of arête widths on this face can be seen, in comparison to the more variable pattern displayed by the 'spinal' face (Face B)

4.10 Archaeological applications of flume data

The experimental data set generated by the flume transportation of different raw material and morphological forms of biface, provide a basis with which to more meaningfully evaluate archaeologically abraded bifaces than can be achieved using extant techniques (e.g. Wymer 1968; Shackley 1975; Hosfield 1999), as they inform us not only of relative degrees of transportation but also transportation type and duration. They have also highlighted the need to evaluate the entirety of individual artefact's *état physique*, not only the arête widths when considering fluvial transportation damage. There are however shortcomings within the dataset. It was not possible to model the damage sustained by artefacts that have not themselves been moved, but that become entrained and are subsequently bombarded by smaller (and therefore mobile) clasts or silt. Neither has it been possible to evaluate the damage sustained during suspended mode transportation. It is acknowledged that during Pleistocene conditions flow velocity was probably high enough for fluvial particles the size of bifaces to enter into suspended flow at specific times.

As it is anticipated that the damage sustained in such conditions would largely depend on the size and velocity of other suspended particles (data not readily available for many secondary context archaeological assemblages) it is felt the current geomorphological, archaeological and engineering models do not yet lend themselves to the generation of appropriate experimental models. Therefore the value of the bed load transportation model data created in the flume experiments described above lies in its ability to provide a *minimum* transportation distance dataset to which archaeologically abraded data can be compared.

A flow chart for the comparison of archaeologically abraded material to the experimental data set is shown in Figure 142. Prior to comparison, artefact abrasion data should be recorded in the zone based manner outline in Section 4.7 and Figure 138, which facilitates an understanding of where each arête value has been recorded on the biface and then identification of correlations with the experimental data set.

Once archaeological abrasion has been recorded in a zone based manner, the patterns of damage preserved on each face can be evaluated. The simplest way to represent this data has proved to be in the form of bar charts (e.g. Figure 139–Figure 141), as this allows easy distinction between the two main forms of abrasion damage (intra-face zonal variability with inter-face consistency (Figure 139) or intra-face consistency on a single face and intra-face variability on the other (Figure 141).

As the flume experiments have shown only bifaces that display marked plano-convexity are likely to have moved substantial distances via sliding motion, the next stage in correlating the experimental and archaeological abrasion and damage data is to assess the plano-convexity of the archaeological artefact.

Plano-convex artefacts are next checked for edge damage in the form of micro flaking to parts of, or all, of their circumference. If the artefact has been subjected to sliding alone, then little or no edge damage will have developed and the arête damage sustained can be directly correlated with the sliding experimental data of the appropriate raw material type. If small quantities of edge damage are present then minimal amounts of rolling or saltating movement have occurred, but the dominant form of transport will have been sliding as represented by the relative consistency of the arête widths of the flat face. Such artefacts can also be directly compared to the experimental sliding data. If a plano-convex artefact shows substantial amounts of edge damage then it is unlikely to have been moved primarily by sliding motion, as it is the edge impacts that happen during rolling and/or saltation which cause the removal of small flakes from the edges of artefacts. Such artefacts can therefore be cautiously correlated with the saltation experimental data set.

The pattern of intra-face consistency of arête widths on one face and intra-face variability on the other can occasionally be seen on non plano-convex archaeological artefacts. If such artefacts also display edge damage (the result of rolling and/or saltation) then they can be considered to have been primarily transported via these means and can also therefore be cautiously correlated with the saltation experimental data set. If they do not show edge damage then they are unlikely to have rolled or saltated very far. The most plausible scenario for the development of such a damage signature is that the artefact has not moved very far as part of a bed-load movement regime. It is more likely to have become partly buried or entrained somewhere within the fluvial system and has suffered from extensive clast bombardment, by smaller, more mobile particles. It is also possible that this damage signature may result from prolonged burial within silts, unfortunately no experimental data set currently exists for such a scenario.

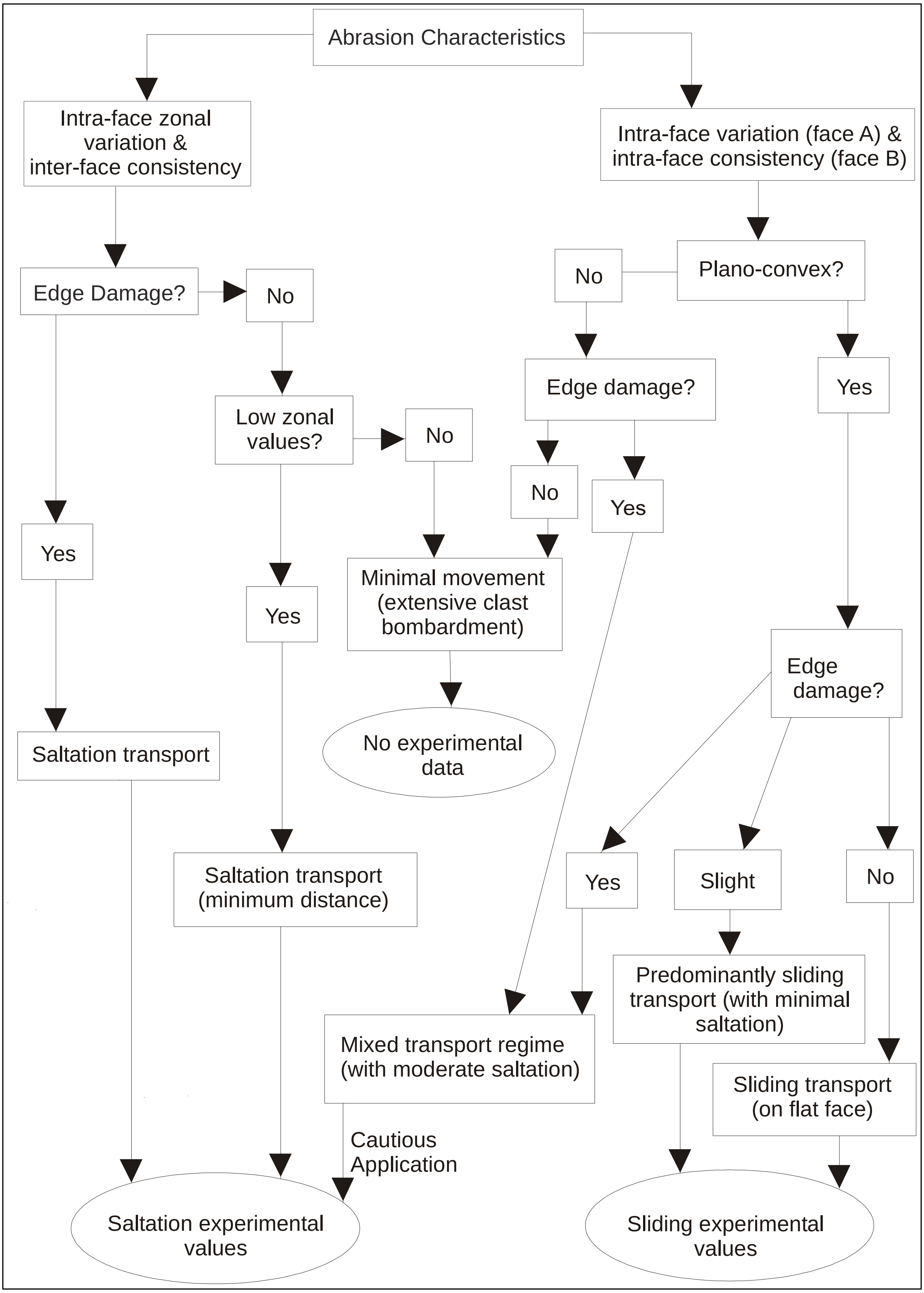

Figure 142: interpretation of artefact transportation from abrasion and biface morphology data

The abrasion signature of intra-face zonal variation and inter-face consistency is most commonly an indicator of rolling and/or saltation motion. If graphic representation of archaeological bifaces reveals this pattern of abrasion damage, once again the next stage in correlation is the assessment of edge damage. If the biface shows the development of edge damage, then it is mostly likely to have been primarily transported by rolling or saltation and can be compared to the saltation experimental data set of the appropriate raw material. If the biface displays the intra-face zonal variation and inter-face consistency indicative of rolling and saltation motion but no edge damage then several transportation scenarios present themselves. If the arête values (zonal values in the flow chart) are low then it is likely that the artefact has rolled or saltated, but not for very great distances. Such bifaces can be compared to the lower end of the experimental saltation data set of the appropriate raw material. If the arête widths are large then it is unlikely that the biface could have rolled or saltated the distances implied by the arête damage without sustaining micro flaking to its edges. Such a damage signature is indicative of minimal artefact movement, combined with large quantities of clast bombardment or silt coverage during periods of partial burial. No experimental data set exists for this scenario.

4.11 Fluvial transportation of the Broom assemblage

The Broom artefacts are manufactured on both flint and chert. Most of the bifaces have been made on locally available greensand chert. Greensand chert is a highly variable raw material and each artefact has been classified in this analysis as falling into one of three categories (fine-, medium- and coarse-grained) based on a visual assessment of grain size. Fine-grained chert has been considered to sustain abrasion damage in a similar manner to flint, and bifaces of fine-grained chert are modelled against the flint experimental data set. Coarse-grained chert replica bifaces were incorporated within the flume experiments and have their own data set for experimental and archaeological comparisons. Many of the Broom bifaces are manufactured on medium-grained chert blanks. An experimental medium-grained abrasion development data set has been created, through correlation with the extant fine- and coarse-grained experimental data. It is assumed that medium grained chert will abrade in a rate intermediate to that of fine and coarse grained materials.

The following discussion illustrates the correlation of experimental and archaeological abrasion data with an example from the Broom biface assemblage (Figure 143). Biface 210 (Bean collection) is made of coarse-grained chert and was therefore compared to the experimental coarse-grained chert data sets (saltation and sliding). The biface is not plano-convex and examination of the artefact's edges showed a moderate amount of edge damage in the form of micro-flaking (Figure 144). The arête signature of biface 210 (Figure 145) was therefore compared with the saltation data set, rather than the sliding data, and was fond to correlate with 200m, saltation signature for a coarse-grained biface (Figure 143).

It can be seen that though these data are highly comparable they do not correlate exactly. The nature of the application of this data is such, that comparisons are made to the experimental data and a 'best fit' scenario adopted. It is postulated that the observed minor variation reflects the episodic nature of fluvial transportation, perhaps representing small sliding events or episodes of partial burial, within the overall saltating regime.

Each Broom biface was compared to the appropriate raw material and transportation experimental data set, as outlined in Section 4.10 and illustrated above. The Broom biface abrasion data is included on the accompanying CD (see the text file 'readme.txt' and the database file 'Bean Collection Database_EHCopy.mdb). The experimental data set is included in J. Chambers' PhD thesis (submitted to the University of Southampton and currently awaiting examination; Chambers in prep.). These results of the Broom biface analysis and distance modelling are firstly presented in terms of distance transported, irrespective of the type of movement identified (Figure 137).

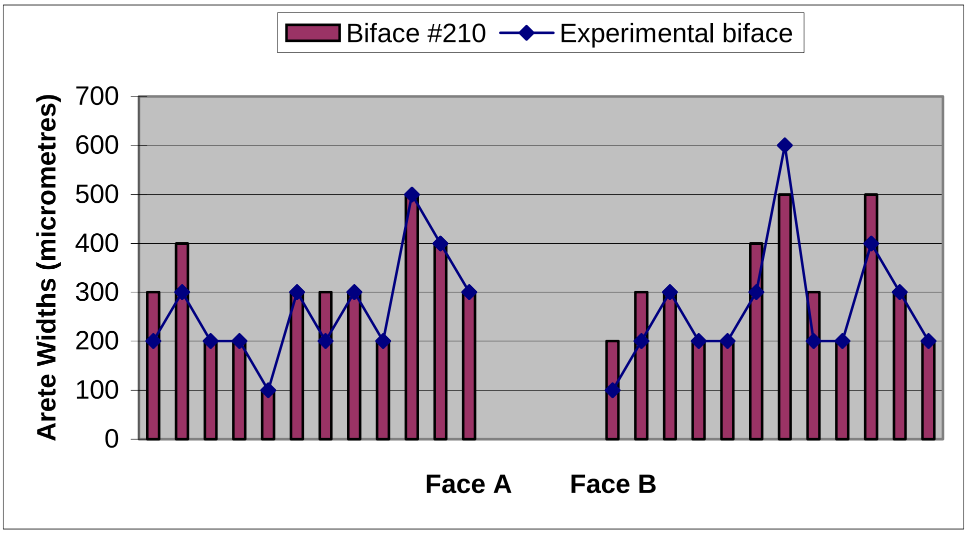

Figure 143: comparison of experimental (coarse-grained chert biface, saltation, 200m) and archaeological (Broom biface 210) abrasion data

Figure 144: Broom biface #210, including edge micro-flaking

Consideration of the transportation data preserved on the entire biface sample (Figure 137) clearly shows that the majority of the artefacts have probably travelled less than 300m from their original point of discard. Constraints of the experimental data set inhibit the specific modelling of distances beyond one kilometre, however this can be seen to represent a very small percentage of the assemblage. These results would seem to indicate the Broom assemblage has a relatively small main spatial catchment area, that most artefacts have only been reworked over distances of several hundred metres rather than for many kilometres. This has significant implications for the ways we view the preserved evidence of hominid landscape behaviour (Section 6).

This data would appear to support the assertion that the large assemblage of artefacts within the river gravels at Broom have not travelled *far* from their original point of discard in the Axe Valley landscape. It is also interesting to note that none of the examined bifaces appear to have been fluvially transported distances of less than 50m, so while the Broom bifaces can generally be regarded as being of relatively local origin, the spatial interpretation of their abrasion damage would indicate that they have all moved beyond any acceptable definition of *in situ.* It is also worth reiterating that this modelling is based on the experimental reproduction of damage sustained during bed load transportation, it is entirely possible that the distance data generated is a substantial under estimation, as many of these artefacts may also have been moved as suspended load within periods of high energy fluvial activity.

When the assemblage is considered in terms of the type of transportation undertaken, it can be seen that saltation is by far the most common mode of movement (Figure 146) The dominance of saltated bifaces reflects both the propensity for particles (be they clasts or artefacts) to move in this manner identified by engineering research (e.g. Einstein 1942), and the relative scarcity of plano-convex artefacts within the Broom assemblage (22%, n=142).

Figure 145: Broom biface #210 (face B), including arêtes

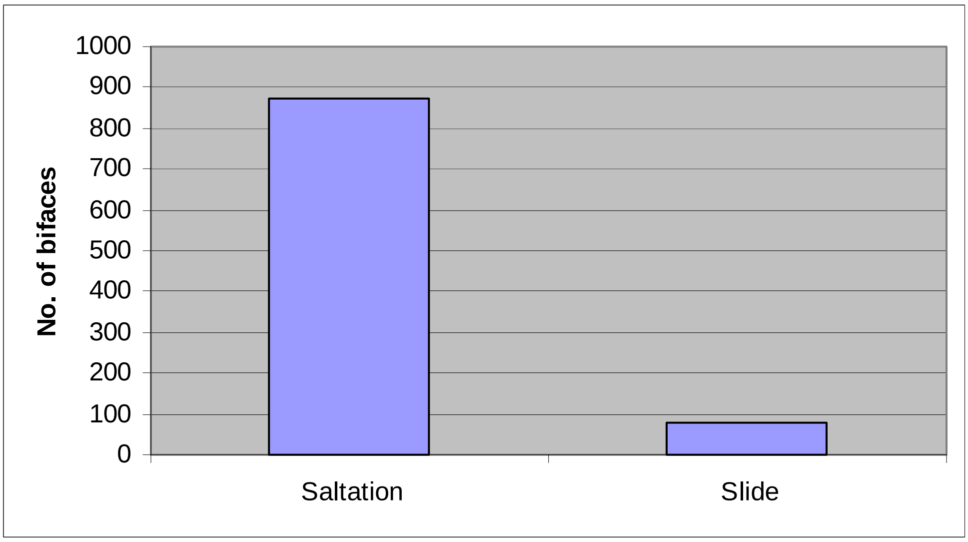

Figure 146: occurrences of saltation and sliding movement within the Broom biface assemblage

The component of the Broom biface assemblage that shows evidence of transportation via saltation (Figure 147), mirrors the pattern of movement seen in the entire sample. The majority of the sample has been transported approximately 250m, with less than 3% of the sample (22/872) showing evidence of fluvial transportation distances of more than one kilometre. The transportation distances appear to be broadly unaffected by artefact type, raw material type, artefact shape, thickness or refinement (Section 6).

As described above, the number of bifaces which show evidence of moving through sliding motion is small. The sliding distances presented in Figure 148 once again show the predominance of artefacts transported for approximately 200–300m.

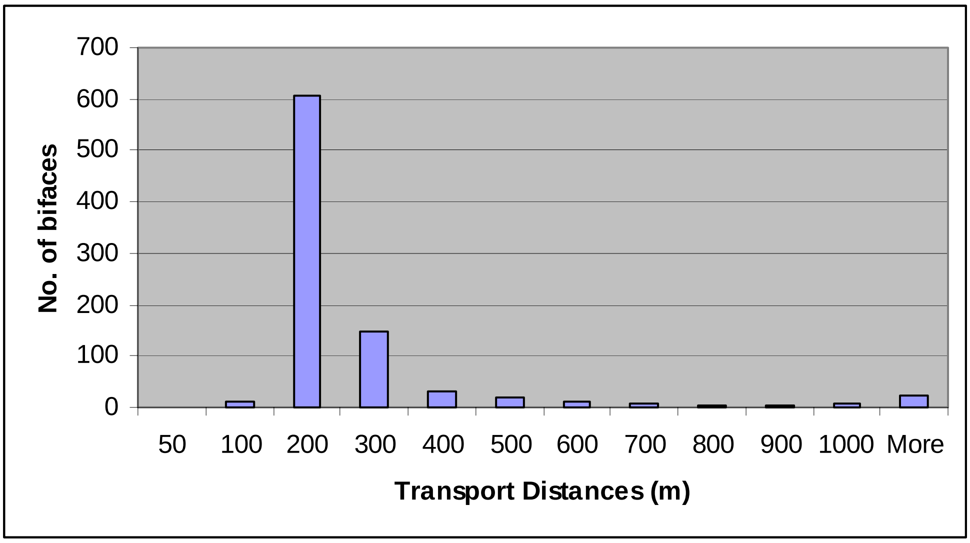

Figure 147: Broom bifaces transported by saltation (class interval = 100m)

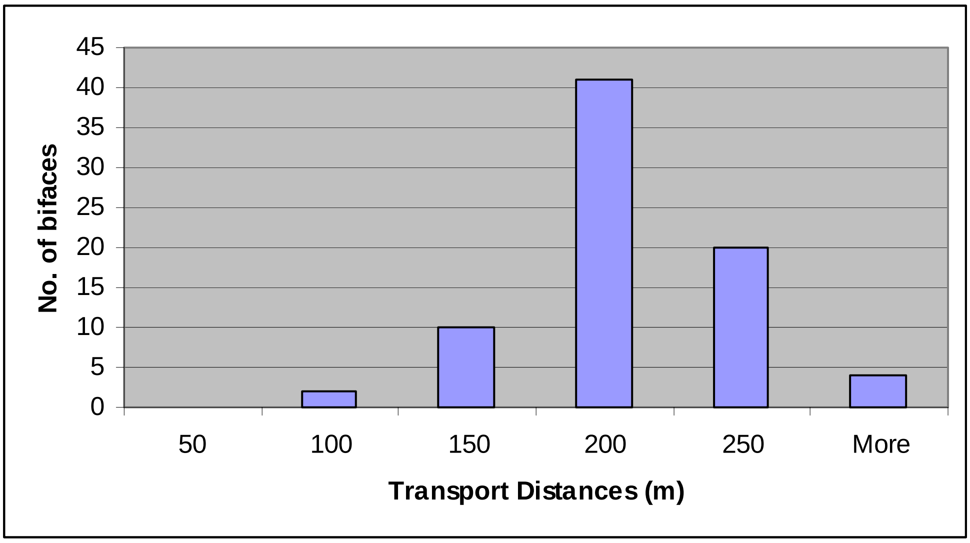

Figure 148: Broom bifaces transported by sliding (class interval = 100m)

To summarize, the comparison of the transportation evidence preserved in the examined sample of Broom bifaces against the data generated by flume experiments is indicative of a relatively local accumulation of artefacts from within 200–300m. No artefacts appear to have been transported less than 50m, and only a very small percentage of the entire sample can be demonstrated to have been fluvially transported over a kilometre. It is possible that these highly transported bifaces have been fluvially re-worked from older terrace deposits in upstream areas of the Axe valley, though provenancing and archive quality prohibit confirmation of this hypothesis.

5. STRATIGRAPHIC ORIGINS OF THE ASSEMBLAGES

One of the key aims of this module was to test whether the Broom assemblage is essentially homogeneous, or whether it is a mixed palimpsest formed of a series of smaller, heterogeneous samples. This question was addressed by sub-dividing the assemblages into spatial sub-units (Section 4) and stratigraphic sub-units (this section). The division of the assemblage into stratigraphic sub-units sought to test whether:

1. There were significant differences in the typological composition of the biface component in each of the sub-units.
2. There were significant differences in the technological aspects (e.g. raw material type and form) of the biface component in each of the sub-units.

The stratigraphic sub-division was based on the tripartite sedimentary sequence at Broom (lower gravels–middle beds–upper gravels), the datum level documented by C.E. Bean at c. 49m OD, and those artefacts for which a stratigraphic level (relative to the datum) was recorded by C.E. Bean. Green (1988: Table 2) suggested four categories of artefact levels (datum ±1m; below datum -1m; below datum; above datum), into which he fitted 109 bifaces, 27 flakes and 6 other artefacts. A similar classification was undertaken here, based on the current biface sample (977 bifaces) and a re-analysis of the Bean archive. Three categories were suggested: above datum (22 bifaces, Table 40); datum level ±1m (72 bifaces, Table 41); and below datum (52 bifaces, Table 42). The datum level ±1m is argued to broadly lie at the elevation of the middle beds, although there is inevitably some local variation.

Biface number	Description
23	5 ft above road level
66	6 ft above datum
76, 77, 85	From surface at back of pit
79	4 ft above the cracker level (approximately equal to the 1st floor level)
100	Above datum
107	1st floor + 0–5 ft
158	23 ft above datum
265	Above 1st floor level
371, 372, 374	15 ft above 1st floor level
386	Near surface at back of pit
493	From top 4 ft of gravel
787	Found at top of pit in sand bed
796, 797, 798, 799, 800, 801	From higher levels of pit (probably above datum)

Table 40: biface numbers and stratigraphic descriptions for the above datum sub-sample

Biface number	Description
1, 20, 29, 31	About 30 ft deep
7	Red bed about 30 ft deep = 2 ft above road level at end of cottage
12	Cottage gate level or upto 6 ft below
49, 53, 64, 68, 99, 108, 237, 246, 264, 537	Datum level
82, 84	About 30' deep (approximately equal to the datum level)
86, 227, 951	1st floor level
90	Road level opposite cottage
183	Datum ±1 ft
6, 35, 87, 118, 120, 121, 125, 127, 128, 130, 135, 139, 142, 159, 161, 162, 164, 165, 166, 167, 169, 170, 171, 172, 173, 174, 177, 189, 191, 192, 194, 195, 594	Datum ±2 ft
85, 190/2, 208	Datum -2 ft
18, 93, 238, 240	Datum ±3 ft
115, 132, 232, 233, 234, 235, 236, 241	Datum -3 ft
131	Datum ±4 ft

Table 41: biface numbers and stratigraphic descriptions for the datum sub-sample

Biface number	Description
4	Upto 6 ft below cottage gate level
5	8 ft below the road on the southwest side of the cottage
10, 656	Lowest portion of pit (heights based on dates of artefact recovery)
17	Bottom of pit in sand bed
24	Clay bed below 1st floor
58, 96, 126, 134, 136	Below datum
122, 137, 336, 388, 512, 514, 515, 517, 518, 519, 520, 521, 522, 524, 525, 526, 529, 530, 531	Below the 1st floor level
113, 229	Lower level at back of pit
153, 242	4 ft below datum
203, 209, 210, 217	5 ft below datum
116	5–10 ft below datum
469, 471, 473, 474, 475, 476, 478, 479, 480, 481, 482, 484	0–20 ft below datum
103	50 ft deep 'Red Bed'

Table 42: biface numbers and stratigraphic descriptions for the below datum sub-sample

This stratigraphic sub-division obviously makes the assumption that the three units and their contained artefacts are chronologically distinct. The OSL dates for the Broom sediments do not provide an absolute geochronology for the intervals between the three units, but samples GL02083–85, GL03004, GL03006–7 and GL03010 suggest that the interval between the middle beds and the upper gravels may be at least 20,000 years. It should be stressed of course, that there are essentially two models for the supply of artefacts into the fluvial sediments that accumulated at Broom:

1. Over a series of chronologically distinct events, artefacts are discarded onto the floodplain (either upstream or at Broom) and rapidly incorporated into the accreting fluvial sediments — i.e. the artefacts are broadly contemporary with their sedimentary context (within ±10's of years) and the artefacts from each chronologically distinct event are not contemporary with each other.
2. Artefacts are discarded onto the floodplain and subsequently buried into the deposits. Subsequent migration of the River Axe across its floodplain leads to the gradual release of material into the fluvial system and their gradual deposition within the accreting sedimentary sequence — i.e. the artefacts are not contemporary within their final sedimentary context, but are contemporary with each other.

An assessment of these alternative models is given in the following chapter, and is also discussed in terms of the stone tool assemblages in the conclusion at the end of this chapter.

Comparison of the typological and technological characteristics of the three sub-units indicates little significant variation, either from each other, or the overall assemblage pattern (Section 3). However, it should be stressed that the small sample sizes create difficulties in detecting subtle trends, and that these comparisons are therefore based upon general patterns. The above datum sub-sample showed clear similarities with the overall assemblage:

- Biface typology is dominated by cordate/ovate forms (40%, n=9), with a combination of ovates, cordates, points and sub-cordates making up the remainder. There is a single cleaver, but no ficrons or flat-butted cordates. The cordate/ovate types also dominated the asymmetrical (lop-sided) and plano-convex biface sub-samples.
- Blank forms (Figure 155) were predominantly unidentified (68%, n=15), although those that were positively identified indicated a mixture of cobbles (57%, n=4) and flakes (43%, n=3).
- Raw material types (Figure 156) were dominated by medium-grained chert (45%, n=10), with small quantities of fine (27%, n=6) and coarse-grained chert (22%, n=5) and flint (5%, n=1).
- Tip types are dominated by irregular rounded (32%, n=7), rounded (14%, n=3) and ogee points (14%, n=3), although the previous comments regarding potential damage and alteration of biface tips during fluvial transport should be recalled. There is a single example of a tranchet tip.
- Butt types (Figure 157) were dominated by trimmed flat (45%, n=10) and trimmed (32%, n=7) types.
- Biface weight (Figure 149) was clustered between 300g and 500g (60%, n=12), with a total weight range of 1113g.
- Biface edges (Figure 158) were dominated by straight and sinuous profiles (95%, n=19), with the sample sub-dividing as follows: straight/sinuous edges (41%, n=9); double straight edges (36%, n=8); and double sinuous edges (18%, n=4). In the case of asymmetrical (lop-sided) bifaces the sample size is unfortunately far too small (n=4) to discuss any further comments.
- Bifaces were concentrated in the 100–300m abrasion categories (70%, n=14), with a scattering of more heavily abraded examples (Figure 150).

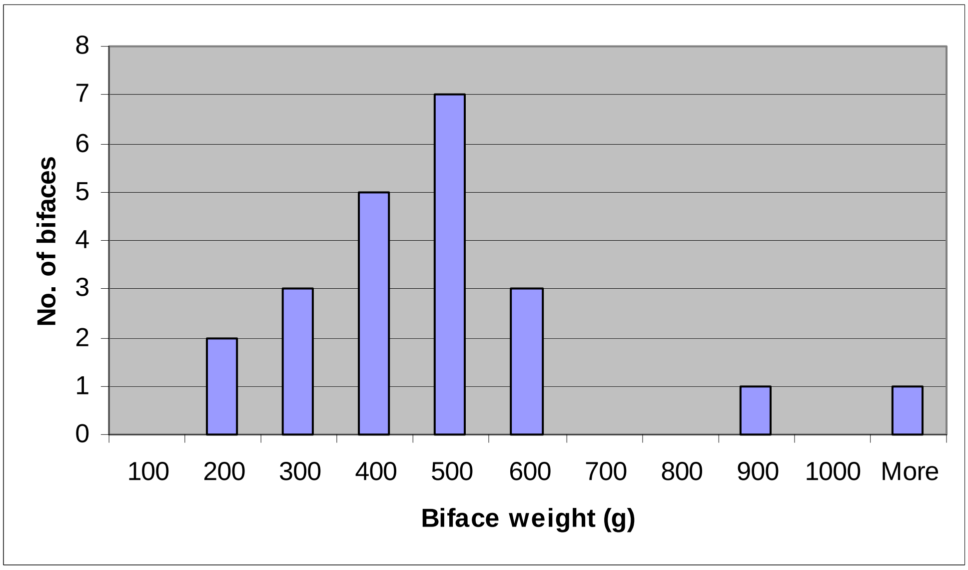

Figure 149: biface weight distribution (above datum sample)

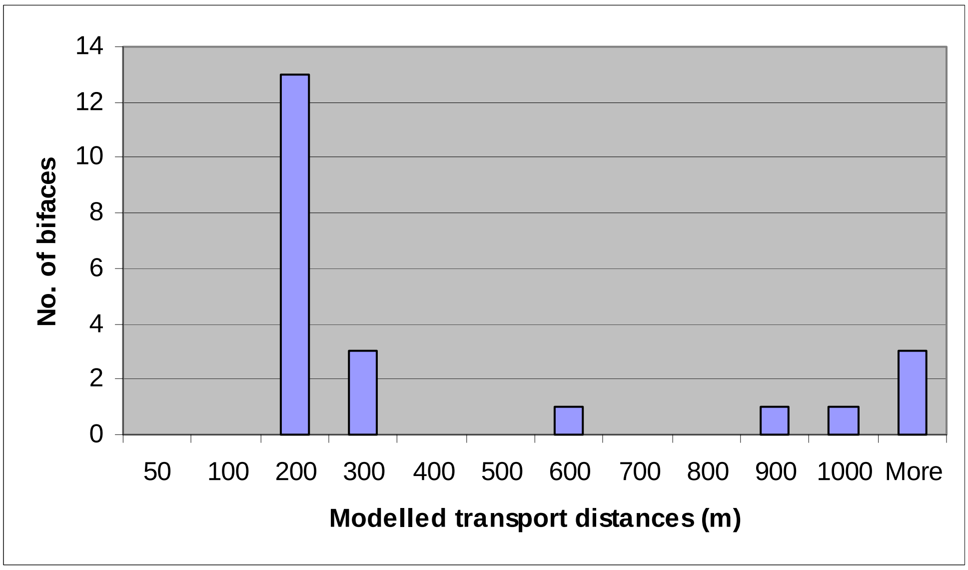

Figure 150: biface transport distances (modelled) distribution (above datum sample)

The datum sub-sample also showed clear similarities, with both the overall assemblage and the other sub-samples:

- Biface typology is dominated by cordates (35%, n=25), with smaller numbers of ovates, cordates, sub-cordates, points and transitional forms. Although the dominant category (cordates (Wymer type J) differs from the other samples and overall assemblage (cordate/ovates (Wymer type JK), it is suggested here that this difference is of relatively minor importance, particularly as cordate/ovates (14%, n=10) are the joint second largest category in this sample. Cleavers, ficrons and flat-butted cordates were all present in this sample in very small numbers. The cordate forms (75%, n=12) also dominated the asymmetrical (lop-sided) forms, with the remainder of these forms consisting of cordate/ovate (n=3) and pointed/ficron (n=1) types. The plano-convex biface forms consisted of a mixture of a mixture of types, although it is perhaps noticeable that this sub-sample contains 4 pointed/ficron forms (21%).
- Blank forms (Figure 155) were predominantly unidentified (67%, n=48), although those that were positively identified indicated a mixture of cobbles (33%, n=8) and flakes (46%, n=11).

- Raw material types (Figure 156) were dominated by medium-grained chert (47%, n=34), with smaller quantities of fine- (25%, n=18) and coarse-grained chert (19%, n=14) and flint (8%, n=6).
- Tip types are dominated by irregular rounded (38%, n=27), ogee (15%, n=11) and rounded points (13%, n=9), although the previous comments regarding potential damage and alteration of biface tips during fluvial transport should be recalled. There are no examples of tranchet tips.
- Butt types (Figure 157) were dominated by trimmed flat (58%, n=42), although there was a notable presence of part trimmed/part cortex butts (16%, n=12) and trimmed (15%, n=11) types.
- Biface weight (Figure 151) was clustered between 100g and 500g (75%, n=54), with a total weight range of 1288g.
- Biface edges (Figure 158) were dominated by straight and sinuous profiles (97%, n=70), with the sample sub-dividing as follows: double straight edges (58%, n=42); straight/sinuous edges (26%, n=19); and double sinuous edges (13%, n=9). This overall pattern is replicated on asymmetrical (lop-sided) bifaces: double straight edges (50%, n=8); straight/sinuous edges (38%, n=6); and double sinuous edges (13%, n=2).
- Bifaces were concentrated in the 100–300m abrasion categories (88%, n=63), with a scattering of more heavily abraded examples (Figure 152).

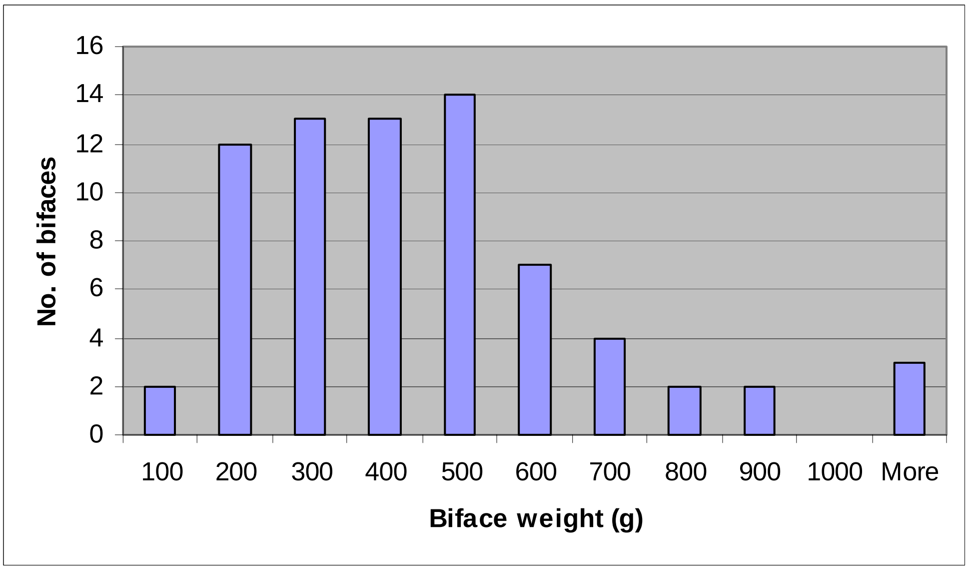

Figure 151: biface weight distribution (datum sample)

The below datum sub-sample also showed clear similarities, with both the overall assemblage and the other sub-samples:

- Biface typology dominated by cordate/ovate (31%, n=16) and cordate (23%, n=12) forms, with a combination of ovates, points and sub-cordates making up the bulk of the remainder. There is are 2 cleavers and a single ficron, but no flat-butted cordates. The cordate/ovate types also dominated the asymmetrical (lop-sided) bifaces, while the plano-convex bifaces were a mixture of cordate, cordate/ovate, sub-cordate and ovate types.
- Blank forms (Figure 155) were predominantly unidentified (63%, n=33), although those that were positively identified indicated a mixture of cobbles (26%, n=5) and flakes (63%, n=12).
- Raw material types (Figure 156) were dominated by medium-grained chert (44%, n=23), with smaller quantities of fine (25%, n=13) and coarse-grained chert (19%, n=10) and flint (10%, n=5).
- Butt types (Figure 157) were dominated by trimmed flat (54%, n=28) and trimmed (25%, n=13) types.
- Biface edges (Figure 158) were dominated by straight and sinuous profiles (92%, n=48), with the sample sub-dividing as follows: double straight edges (37%, n=19); straight/sinuous edges (31%,

n=16); and double sinuous edges (25%, n=13). This overall ordering is replicated on asymmetrical (lop-sided) bifaces, although the sample size is too small (n=10) to make any further comments.
- Bifaces were heavily concentrated in the 100–300m abrasion categories (96%, n=48; Figure 153).

However, the 'below' datum sample also indicated a minor contrast with respect to tip types and biface weight:

- Although tip types are still dominated by irregular rounded forms (38%, n=20), there is also a significant proportion of irregular pointed types (21%, n=11). These are very uncommon in the other sub-units, and also in the overall assemblage (6%, n=60). However, the previous comments regarding potential damage and alteration of biface tips during fluvial transport should be recalled. There are no examples of tranchet tips.
- Biface weight was clustered between 200g and 600g (62%, n=32), with a total weight range of 653g (Figure 154). The relative small weight range might suggest a greater imposition of 'standardisation' or consistency with respect to biface size (as measured by weight). However, caution should be applied here, since the role of clast size (taking the biface as an unusually shaped clast) may have been extremely important with respect to patterns of transport and deposition during the accumulation of the Broom sediments.

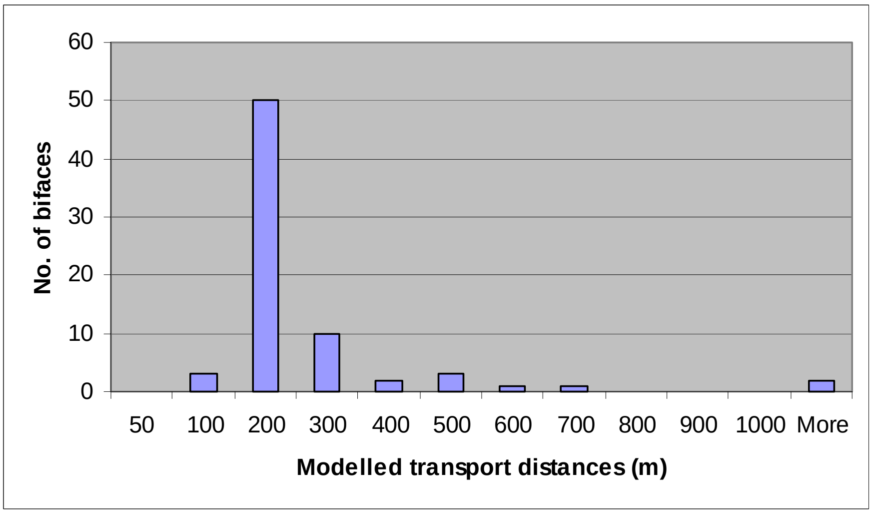

Figure 152: biface transport distances (modelled) distribution (datum sample)

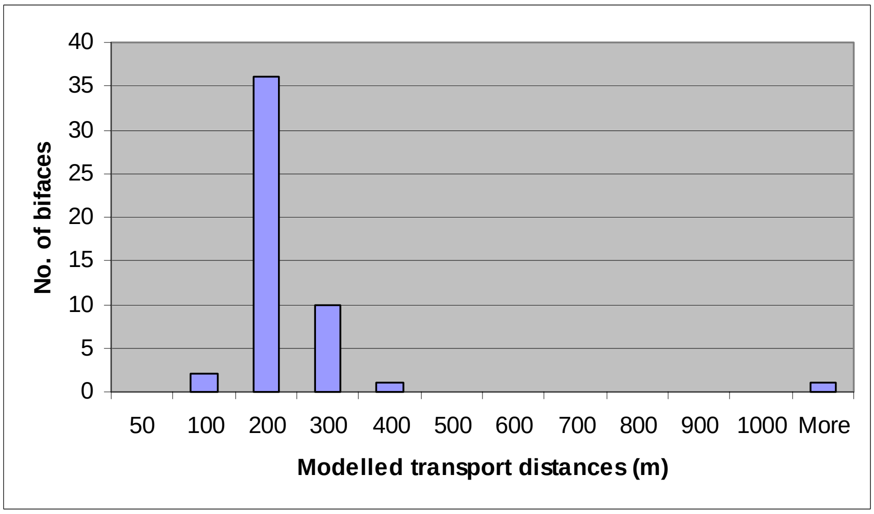

Figure 153: biface transport distances (modelled) distribution (below datum sample)

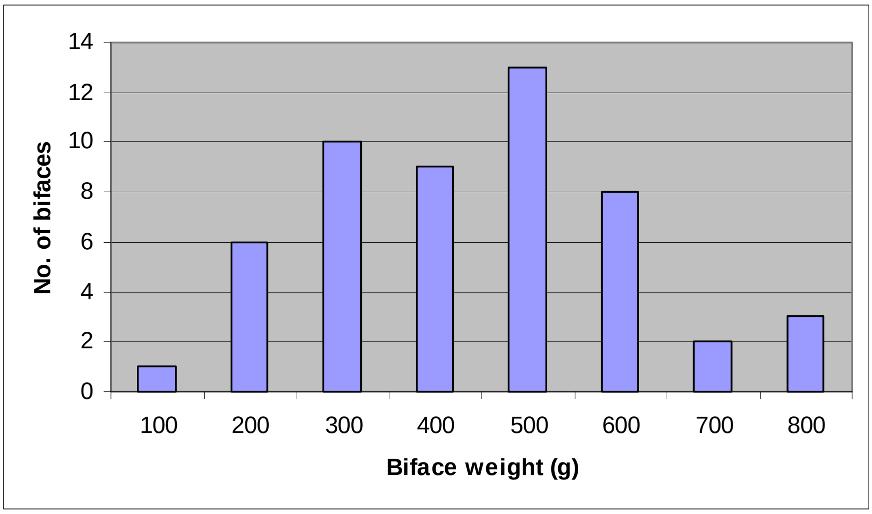

Figure 154: biface weight distribution (below datum sample)

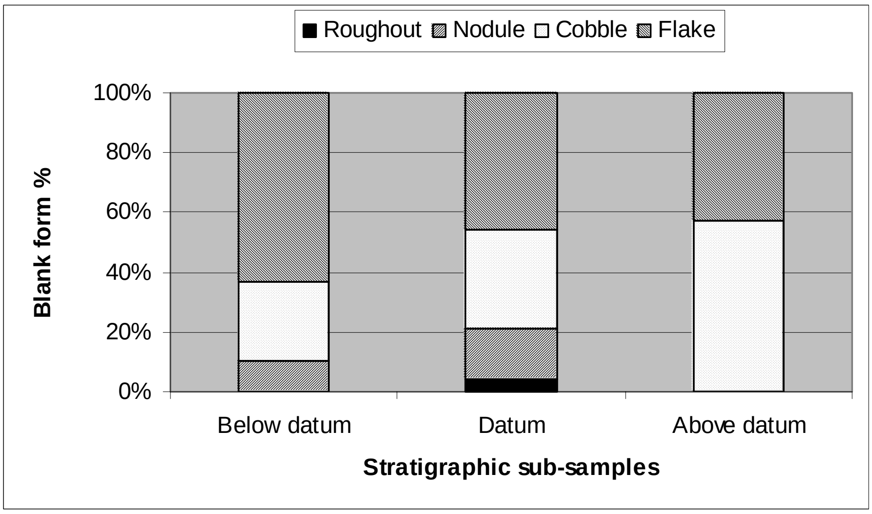

Figure 155: blank form distribution, by stratigraphic sub-sample

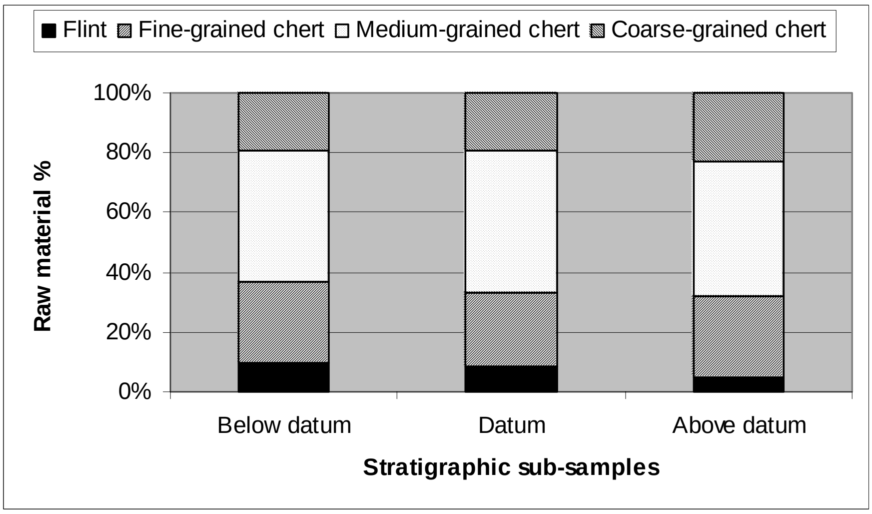

Figure 156: raw material distribution, by stratigraphic sub-sample

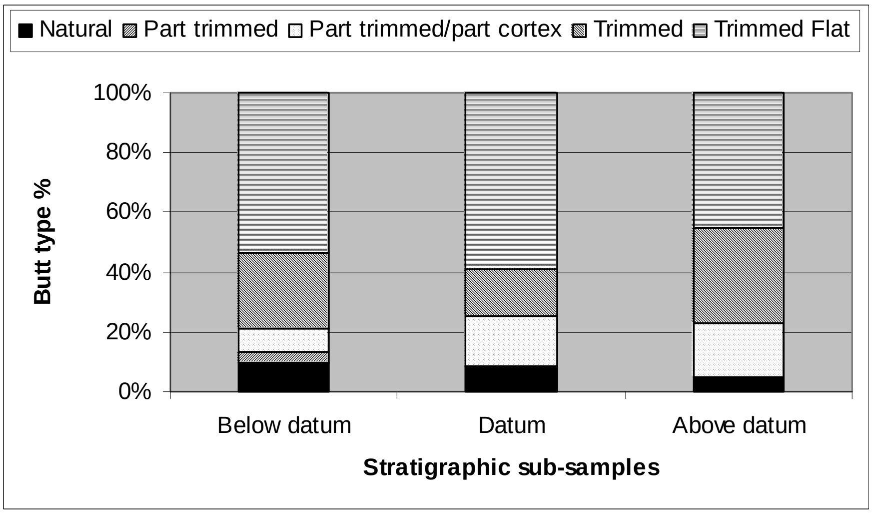

Figure 157: butt type distribution, by stratigraphic sub-sample

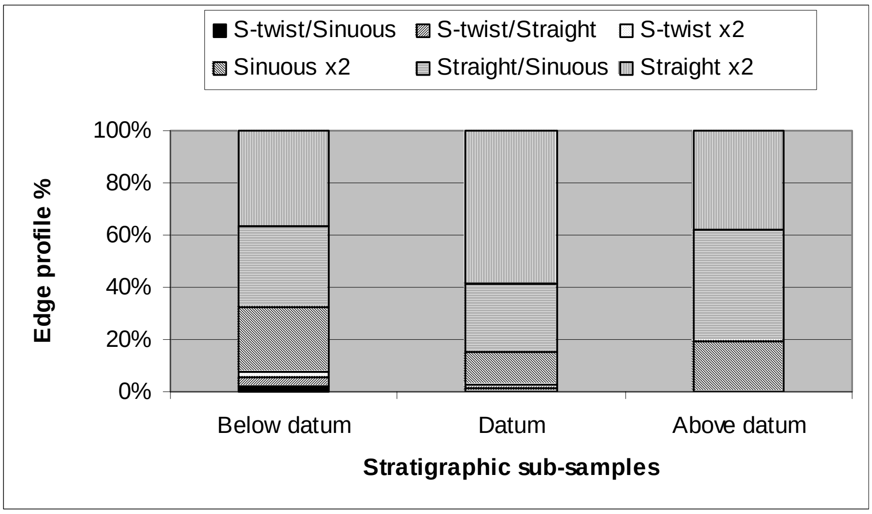

Figure 158: edge profile distribution, by stratigraphic sub-sample

The patterns evident in the three sub-samples suggest that there are no significant changes in the typological and technological composition of the biface assemblages through time (following the assumption that the three sub-samples are chronologically distinct with respect to their stratigraphic position within the sedimentary sequence). Specifically, the following points are stressed:

1. There are no major changes in the patterns of bifaces types (predominantly cordate/ovate forms), raw material usage (primarily medium-grained chert), blank forms (cobbles and flakes — although the sample sizes are rather small to place much emphasis on these patterns, particularly given the problems of positive identification of blank forms), tip types (irregular rounded — but recall comments regarding fluvial damage to biface tips), butt types (trimmed flat and trimmed types) and edge types (straight and sinuous profiles) throughout the sedimentary sequence.
2. The low level usage of flint in all three samples suggests that this raw material was never abundantly available from the local environment at any point (this obviously assumes that flint would have been a preferred material when 'easily' obtainable, and it is possible that flint may not have been highly sought after, as knapping experiments (by JCC) have indicated that fine-grained chert materials possess a similar range of flaking properties.
3. None of the artefacts are in 'mint' condition and all suggest some degree of fluvial transportation. The below datum sample suggests the greatest spatial homogeneity, with a probable local catchment source indicated (within 200–300m of the Broom sediments?). This pattern is also

replicated in the other samples, although there is more evidence of 'stray' artefacts derived over greater distances in these samples.

4. Smaller artefacts (as measured by weight) were more common in the datum sample, while the below datum sample was characterised by a narrower range of biface weights. These patterns may reflect taphonomic processes (flow energy), the quality and/or size of available raw materials, or short-lived hominid preferences for bifaces of a particular size. Given the general absence of variation and patterning in the assemblage, the taphonomic hypothesis is provisionally highlighted here.
5. There are no flat-butted cordates present in the below datum and above datum samples, and no ficrons in the above datum sample. Cleavers, ficrons and flat-butted cordates are all present in the datum sample. However, it is argued that the sample sizes are too small (particularly given the low proportions of these artefacts in the overall assemblage) to place any emphasis on this patterning. This is also the case with tranchet tips, which only occur in the above datum sample.
6. Plano-convex bifaces show a wider range of types in the datum sample, although this is probably related to sample size. In all samples, cordate/ovate forms are well represented.
7. The sample sizes associated with asymmetrical (lop-sided) forms are too small to place emphasis on any apparent patterns in the data.

In conclusion therefore, the data suggest a general trend of stasis in the biface sub-assemblages distributed through the Broom sedimentary sequence, with little evidence of change through time. This trend may reflect either:

1. General stability in biface manufacturing techniques over a series of behavioural episodes involving the (probable) manufacture and discard of bifaces by hominids on the River Axe and River Blackwater floodplains and surrounding valley slopes. This interpretation argues that the sub-samples are not only stratigraphically distinct in the Broom sedimentary sequence, but are also chronologically-distinct — i.e. they represent a series of hominid visits to the river valley that are separated in time over the several millennia during which the Broom sediments accumulated (following the broad trends evident in the OSL geochronology and other sedimentological evidence from Broom (chapter 3)):

Hominid activity (biface discard) > entrainment into fluvial system > deposition > time interval (unspecified) > hominid activity (biface discard) > entrainment into fluvial system > deposition > time interval (unspecified) > …

2. General stability in biface manufacturing techniques over a single behavioural episode involving the (probable) manufacture and discard of bifaces by hominids on the River Axe and River Blackwater floodplain and surrounding valley slopes. This interpretation argues that although the sub-samples are stratigraphically distinct in the Broom sedimentary sequence, they are *not* chronologically distinct — i.e. they represent a 'single' hominid visit/occupation of the River Valley. The bifaces were gradually entrained into the fluvial system and deposited into the Broom sediments over several millennia (following the broad trends evident in the OSL geochronology and other sedimentological evidence (chapter 3)).

It should be apparent that these alternative interpretations provide a rather different view of hominid behaviour with respect to stone tool production. The first argues for general stability in stone tool production over multiple generations by hominid groups that may be unrelated (at least in terms of knowledge transmission). The second argues for short-term stability, but makes no assumptions about the potential for change and flexibility in stone tool technology over long time-spans. Evaluation of these alternative models is therefore important (and difficult) and is undertaken both in the next section (which explores the evidence for spatial patterning in these data) and in the next chapter (which applies models of fluvial systems to the issue of assemblage formation and chronological models). Finally, it is also stressed (and this point will be returned to in the conclusion to this chapter), that these models are discussing stone tools and possible technological 'uniformity', and not necessarily behavioural uniformity.

6. SPATIAL ORIGINS OF THE ASSEMBLAGES

Alongside the issue of change through time, a key question concerned whether there was evidence for changes in the biface assemblage in space — in other words, whether different types of artefacts were manufactured and/or discarded in different parts of the fluvial landscape. This is a critical question when investigating the archaeology and behaviour of early hominids, as it focuses upon the question of whether their behavioural repertoire incorporated a version of 'cultural geography' (Binford 1987) — the 'mapping' of specific tasks and activities to selected and varied locations in their landscapes. It should be emphasised that this approach assumes that behavioural variability can be detected through patterns in stone tool assemblages. As with the previous analysis, the division of the assemblage into spatial sub-units sought to test whether:

1. There were significant differences in the typological composition of the biface component in each of the sub-units.
2. There were significant differences in the technological aspects (e.g. raw material type and form) of the biface component in each of the sub-units.

The sub-division of the assemblage into two spatial sub-units was based upon the modelled biface transport distances (Section 3). The sub-300m sample included bifaces with modelled transport distances of less than 300m (89%, n=843); while the 300m+ sample includes bifaces with modelled transport distances of more than 300m (11%, n=108). This sub-division supported the distribution of the full assemblage (Figure 137), which suggested a concentration of material from a location(s) within *c.* 300m of the Broom sediments, with smaller numbers of bifaces scattered across the landscape, at greater distances from the Broom deposits. The sub-300m sample is described here as an on-site patch, while the 300m+ sample is described as an off-site scatter, following the terminology of Foley (1981). The analysis was therefore testing whether the bifaces from a small, spatially-delimited catchment source displayed significantly different attributes to material that was scattered over a wider source area.

This spatial sub-division makes no assumptions as to any chronological associations between the two sample units. The analysis is concerned with the presence (if any) of typological/technological trends associated with the deposition of bifaces in different locations and different contexts (repetitive deposition of artefacts in a 'single' location versus the sporadic deposition single artefacts in multiple, unique locations) in a fluvial landscape.

Comparison of the typological and technological characteristics of the two sub-units indicates little significant variation, either from each other, or the overall assemblage pattern (Section 3). The sub-300m sample showed clear similarities with the overall assemblage (as might be expected, given that it represents a large proportion of the assemblage):

- Biface typology is dominated by cordate/ovate forms (29%, n=242), with significant numbers of cordate (20%, n=166) and pointed (11%, n=90) forms. There are small numbers of cleavers, ficrons and flat-butted cordates. The cordate/ovate types (42%, n=91) also dominated the asymmetrical (lop-sided) sub-sample (n=217), with significant numbers of cordates (21%, n=46). There are relatively few pointed forms (5%, n=11). Cordate/ovate (30%, n=50) and cordate (20%, n=32) forms also dominated the plano-convex biface sub-sample (n=164).
- Blank forms (Figure 161) were predominantly unidentified (61%, n=511), although those that were positively identified indicated a mixture of cobbles (39%, n=130) and flakes (55%, n=184).
- Raw material types (Figure 162) were dominated by medium-grained chert (47%, n=400), with smaller quantities of fine (29%, n=242) and coarse-grained chert (19%, n=156) and flint (5%, n=42).
- Tip types are dominated by irregular rounded (44%, n=375), rounded (14%, n=120) and ogee points (10%, n=86), although the previous comments regarding potential damage and alteration of biface tips during fluvial transport should be recalled. There are six (<1%) examples of tranchet tips.
- Butt types (Figure 163) were dominated by trimmed flat (55%, n=467) and trimmed (19%, n=160) types.

- Biface weight (Figure 159) was clustered between 100g and 600g (69%, n=375), with a total weight range of 2390g.
- Biface edges (Figure 164) were dominated by straight and sinuous profiles (96%, n=808), with the sample sub-dividing as follows: double straight edges (47%, n=396); straight/sinuous edges (27%, n=229); and double sinuous edges (22%, n=183). This overall pattern is replicated on asymmetrical (lop-sided) bifaces (n=217): double straight edges (52%, n=113); straight/sinuous edges (28%, n=60); and double sinuous edges (17%, n=36).

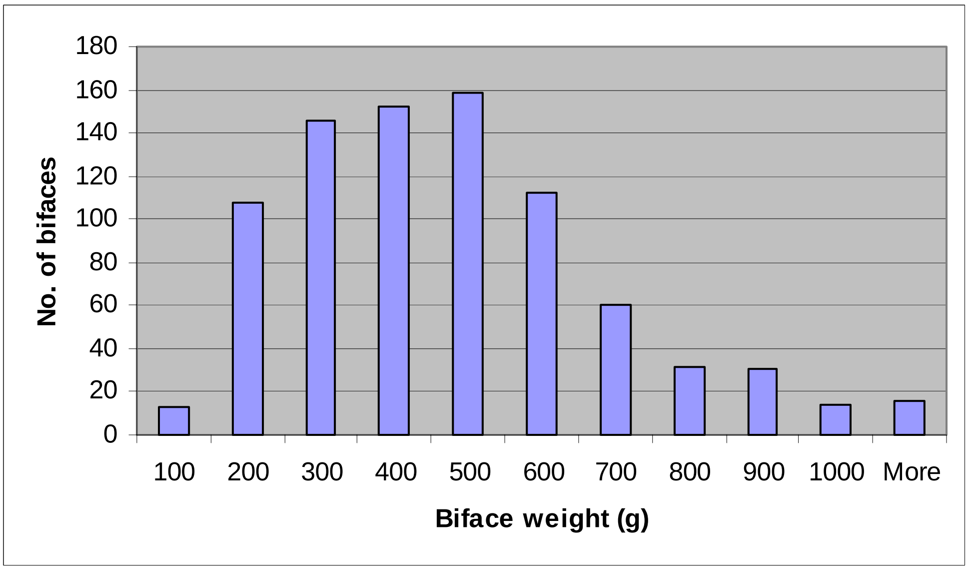

Figure 159: biface weight distribution (sub-300m sample)

The 300m+ sample also shows numerous similarities with both the overall assemblage and the sub-300m sample:

- The primary biface type is the cordate/ovate form (23%, n=25), but it is not as dominant as in either the sub-300m sample or the overall assemblage. There are also small numbers of all the major categories: cordate forms (15%, n=16); pointed forms (13%, n=14); sub-cordate/cordate (10%, n=11); sub-cordate/ovate (9%, n=10); ovate forms (8%, n=9); pointed/sub-cordate (6%, n=7); and sub-cordate (5%, n=5). There are also very small numbers of cleavers, ficrons and flat-butted cordates. Cordate/ovate, cordate and sub-cordate/ovate bifaces make up the very small asymmetrical (lop-sided) sub-sample (n=10). Cordate/ovate (40%, n=6) forms dominate the small plano-convex biface sub-sample (n=15), with very small numbers of the other main types.
- Blank forms (Figure 161) were predominantly unidentified (70%, n=76), although those that were positively identified indicated a mixture of cobbles (47%, n=15) and flakes (53%, n=17).
- Raw material types (Figure 162) were dominated by medium-grained chert (47%, n=51), with smaller quantities of fine (21%, n=23) and coarse-grained chert (19%, n=21) and flint (12%, n=13).
- Tip types are dominated by irregular rounded (49%, n=53), rounded (18%, n=19) and ogee points (10%, n=11), although the previous comments regarding potential damage and alteration of biface tips during fluvial transport should be recalled. There are three (3%) examples of tranchet tips.
- Butt types (Figure 163) were dominated by trimmed flat (51%, n=55) and trimmed (32%, n=30) types.
- Biface weight (Figure 160) was clustered between 100g and 400g (61%, n=66). The total weight range is 927g.
- Biface edges (Figure 164) were dominated by straight and sinuous profiles (95%, n=515), with the sample sub-dividing as follows: double straight edges (49%, n=53); straight/sinuous edges (22%, n=24); and double sinuous edges (20%, n=22). This overall pattern is generally replicated on

asymmetrical (lop-sided) bifaces, although the sample size is too small (n=10) to discuss this in greater detail.

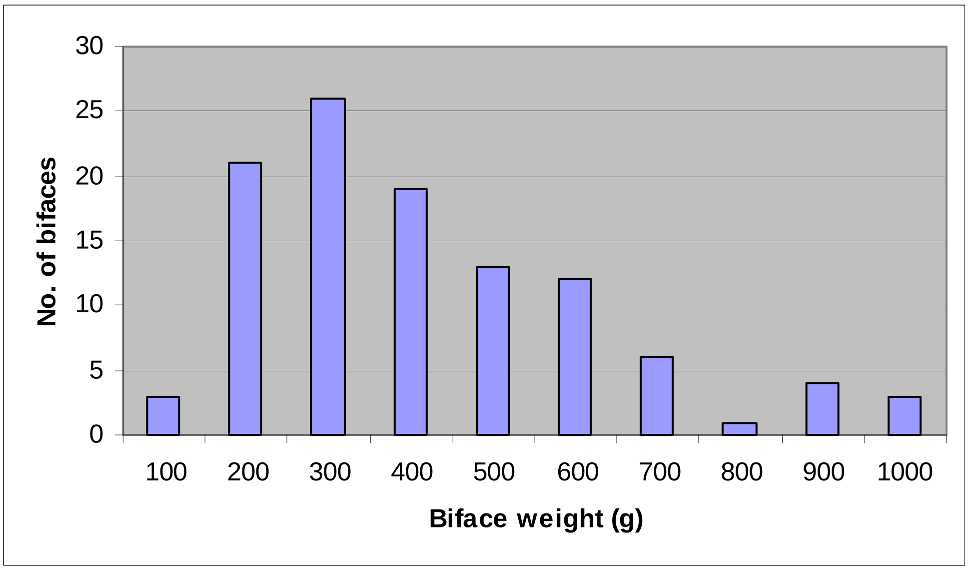

Figure 160: biface weight distribution (300m+ sample)

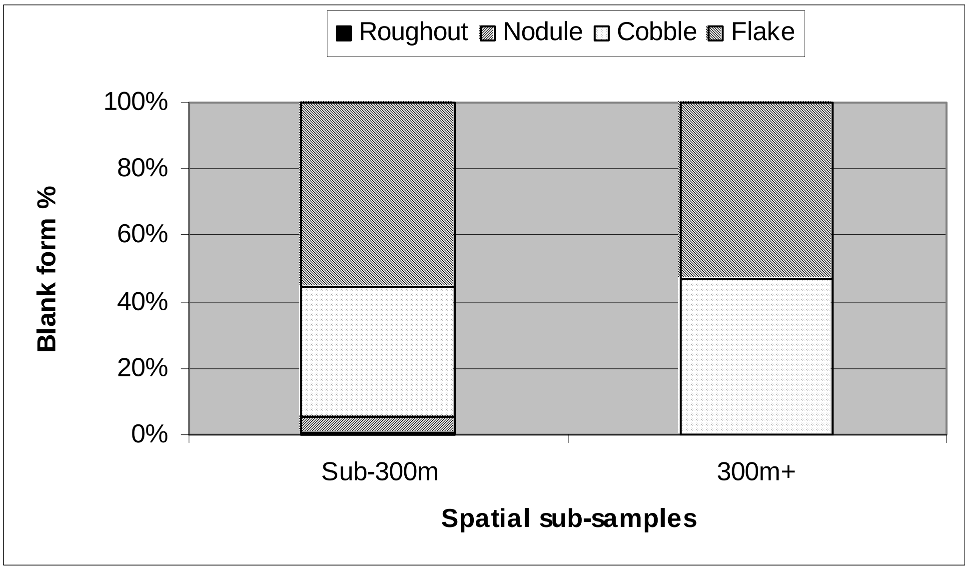

Figure 161: blank form distribution, by spatial sub-sample

The patterns evident in the two sub-samples suggest that there are no significant variations in the typological and technological composition of the biface assemblages distributed across the Axe valley landscape. Specifically, the following points are stressed:

1. There are no major changes in the pattern of bifaces types in the two samples, although the cordate/ovate form is more dominant in the sub-300m sample than in the 300m+ sample. Nonetheless, the same range of types is represented in both samples.
2. There are no major variations in the patterns in raw material usage (primarily medium-grained chert), blank forms preference (both cobbles and flakes are common), tip types (irregular rounded — but recall comments regarding fluvial damage to biface tips), butt types (trimmed flat and trimmed types) and edge types (double straight, straight/sinuous, and double sinuous profiles) in either sample.

3. The low level usage of flint in both samples suggests that this raw material was not abundantly available from any location within the Axe Valley environment around Broom (this again assumes that flint would have been a preferred material when it was 'easily' obtainable). However (as also noted in the previous section), it is worth emphasising that flint may not have been a highly sought after raw material, given that fine-grained chert materials were readily available and possessed a similar range of flaking properties.
4. Smaller artefacts (as measured by weight) were more common in the 300m+ sample. This pattern may suggest the quality and/or size of available raw materials in certain locations of the Axe Valley landscape, or a tendency for the discard (and use?) of smaller bifaces away from the major catchment zone (or to look at it the other way on, the discard of heavier bifaces in the major catchment zone). The data possibly suggests differential behaviour over the landscape, although there is not extensive support for this hypothesis from other data patterns in the assemblage.
5. Cleavers, ficrons and flat-butted cordates occur in both samples, suggesting no clear link between these distinctive types and different locations in the landscape. Tranchet tips also occur in both samples.

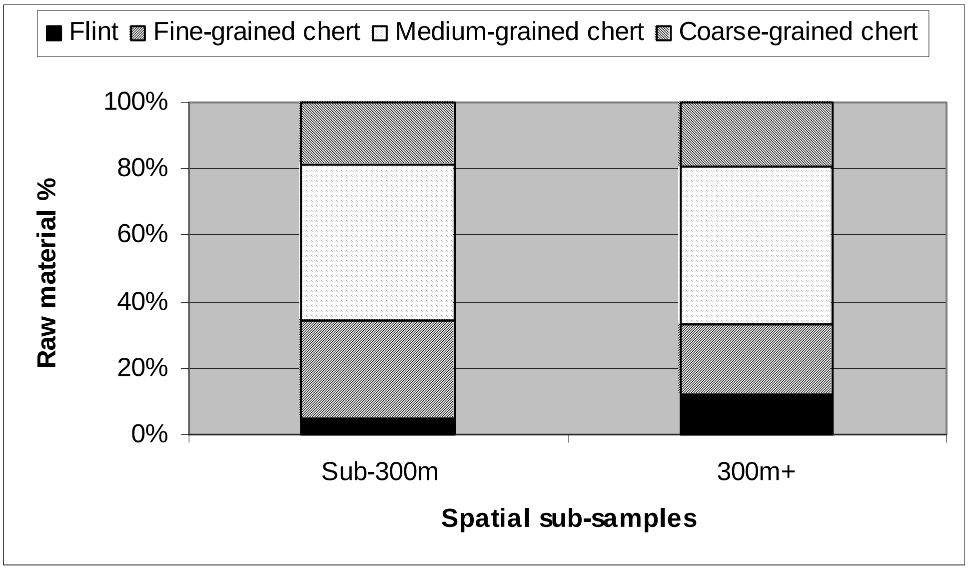

Figure 162: raw material distribution, by spatial sub-sample

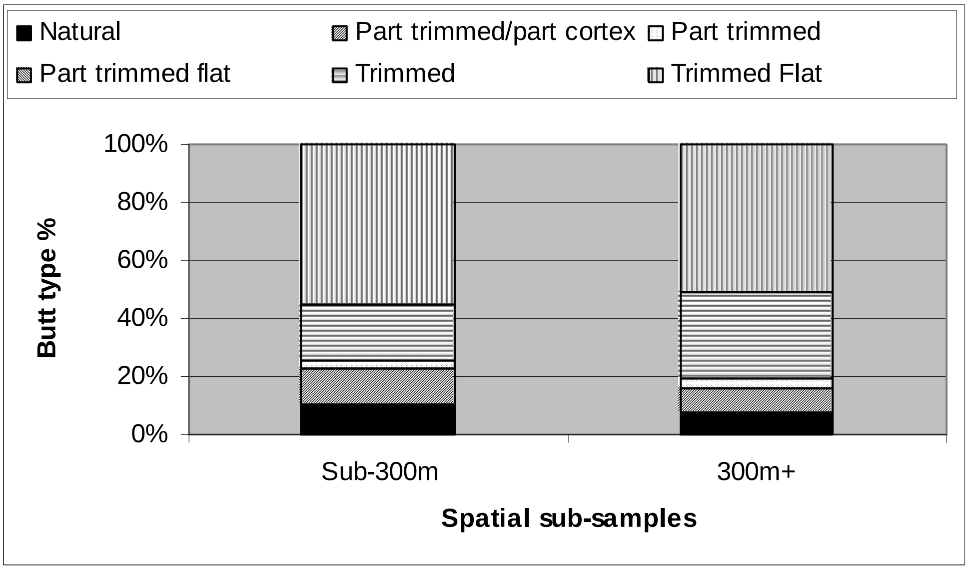

Figure 163: butt type distribution, by spatial sub-sample

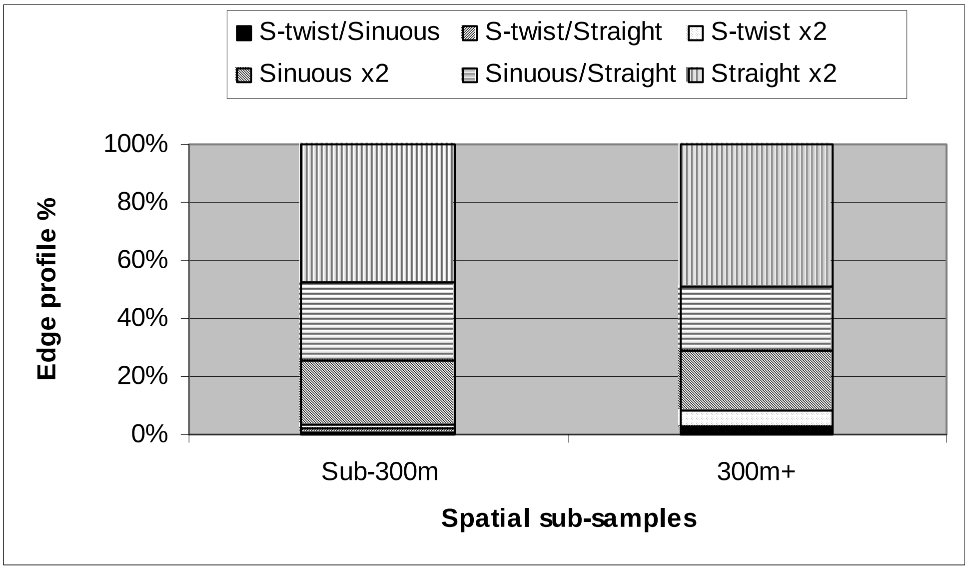

Figure 164: edge profile distribution, by spatial sub-sample

6. Plano-convex and asymmetrical (lop-sided) bifaces demonstrate a similar range of types in both samples, and in all cases, cordate/ovate forms are the prominent biface type.

In conclusion therefore, the data suggest a generally homogenous pattern with respect to the inter-sample technological and typological characteristics of the bifaces discarded in a 'single' on-site location close to the Broom sediments, and those bifaces discarded off-site across a wider area of the Axe Valley landscape. Two potential interpretations are suggested:

1. There is no stone tool evidence supporting a Binfordian model of cultural geography (Binford 1987), as there is no suggestion that different activities (requiring specific biface types) were undertaken in specific areas of the landscape. In particular, the pattern of biface types might be expected to differ markedly between the large, spatially-localised sample (on-site patch) and the smaller, spatially-dispersed sample (off-site scatter). It should be stressed however, that if behavioural variability and flexibility is not reflected in stone tool technology, then it is not possible to assess claims for a cultural geography using this type of approach.
2. However, if either or both of the two samples represent a palimpsest of material that accumulated over decades or centuries, then it can be argued that original spatial patterning in the data (which might be supportive of a cultural geography) is blurred due to over-printing (e.g. activity x is undertaken at location y, followed subsequently by activity y at location y, resulting in a 'mixed' assemblage at location y). However, we would argue that this interpretation is partially disputed by the evidence from the stratigraphical samples, which suggest that there is not distinctive inter-sample variation through time, only further examples of intra-sample variability (see also Section 7).

These patterns and data-sets also raise a number of additional issues:

1. The reason behind the apparent existence of a small source area for *at least c.* 840 of the Broom bifaces remains unclear. It is possible therefore that the location was favourable due to unknown factors such as a river crossing point for animals and/or hominids, or a favourable foraging/gathering/hunting location, which resulted in hominids being repeatedly attracted to the location and discarding the stone tools associated with a range of subsistence activities. Under such a model, the bifaces from the wider landscape represent the residue from the occasional activities that were undertaken in these less attractive areas of the landscape (e.g. the product of chance resource encounters).

2. The assemblages reveal extensive intra-sample variability (in biface form, tip and butt types, raw material usage, blank form preference, and edge profiles), at least according to modern archaeological classification methods. Yet, there is little or no inter-sample variation. The absence of inter-sample variability in space suggests that the intra-sample variation is not due to functional requirements (i.e. type x is made to do task y) nor that there were clear links between specific types and set tasks (if this was the case, one would expect to see greater differences in the composition of the high density (on-site patch) and low density (off-site scatter) samples. Rather, it suggests that there is a general absence of enforced standardisation onto the process of biface manufacture, which is also suggested by the extensive intra-sample variation in raw material usage, blank form types and other elements of manufacture.

The data therefore suggests that there is little evidence for a cultural geography being practised in and around the Axe Valley environment (or at least not one that is represented by the stone tool record). Nonetheless, there does appear to be evidence for an 'on-site'/'off-site' patterning in the spatial distribution of the discarded artefacts, with probable evidence for repetitive visits to a specific locale. This represents currently unknown factors (we suggest the location of key environmental resources as a strong possibility), but of greatest interest is the apparent lack of standardisation in the stone tools discarded, both at this locale and across the wider landscape.

Having demonstrated a spatial patterning in the distribution of bifaces in the Axe Valley, a key question concerns whether that type of patterning is typical of fluvial secondary context assemblages. Examination of other secondary context assemblages allows an assessment of or whether different assemblages reveal different patterns, reflecting wider variations in landscape behaviours. A comparison was therefore undertaken with the Lower Palaeolithic site of Dunbridge (Section 6.1), with particular focus on the issues of assemblage formation and the spatial signatures of the biface component of the assemblage.

6.1 Dunbridge Lower Palaeolithic assemblage

The Dunbridge gravel pits lie to the west of the river Test, immediately below its confluence with the tributary river Dun. The gravel deposit rises away from the river, reaching over 40m OD. The gravel pits have predominantly exploited the lower deposits adjacent to the river, cutting into the northern edge of the gravel and facing the river Dun. The workings have exposed the largest collection of Palaeolithic artefacts from a single locality in Hampshire, and there are further low-level pits on the eastern edge of the gravel deposit at Kimbridge (Bridgland & Harding 1987: 50).

The gravels at Dunbridge were extensively worked during the first quarter of the 20th century. Collections were made by William Dale (1912a, 1918), a local Southampton-based antiquarian, and there are also references to the site by Sturge (1912) and R.A. Smith (1926). Roe (1968a: 96) listed 1021 artefacts, including 953 bifaces (93.3%). The ratio of bifaces to non-biface artefacts in the extant assemblage is thus similar to that from Broom. The remainder of the Dunbridge assemblage includes 14 roughouts, 3 cores, 16 retouched flakes, 24 unretouched flakes, 8 miscellaneous pieces, and 3 Levallois flakes. A watching brief was undertaken during the 1990's at the Kimbridge Farm pit (adjacent to the old Dunbridge site), by Phil Harding of Wessex Archaeology. This work produced a far lower ratio of bifaces to other collected artefacts. The composition of Roe's assemblage undoubtedly reflects selective collection during the early part of the 20th century, although it is difficult to know whether this due to the labourers, the antiquarians or both.

Dale (1912a) described up to 7m of gravel at Dunbridge, overlying an irregular surface cut into clays and sands of the Woolwich and Reading Beds (Figure 165). Dale also suggested that palaeoliths with different states of preservation had originated from different stratigraphic levels in the gravel. It was proposed that the sharp, white implements from the upper deposit were of a 'later character' than those from the lower beds (Dale 1918). The sub-division of the gravel deposit was based on colour: a lower, dark red gravel, a middle yellow-brown gravel and an upper white gravel. Dale subsequently modified this interpretation and suggested that the gravel of two periods was present. In this later view, an upper, paler deposit was separated from a lower, darker aggradation by an iron pan horizon. Bridgland & Harding (1987: 50) suggest that the middle and lower units of Dale's earlier, tripartite division had been combined into the lower, darker aggradation of the later interpretation. Dale's (1912a, 1918) observations suggested the possibility that different Lower Palaeolithic industries existed in stratigraphic superposition at Dunbridge. Following these claims Roe (1981) examined the range of material from the site and was able to identify the white material described by Dale.

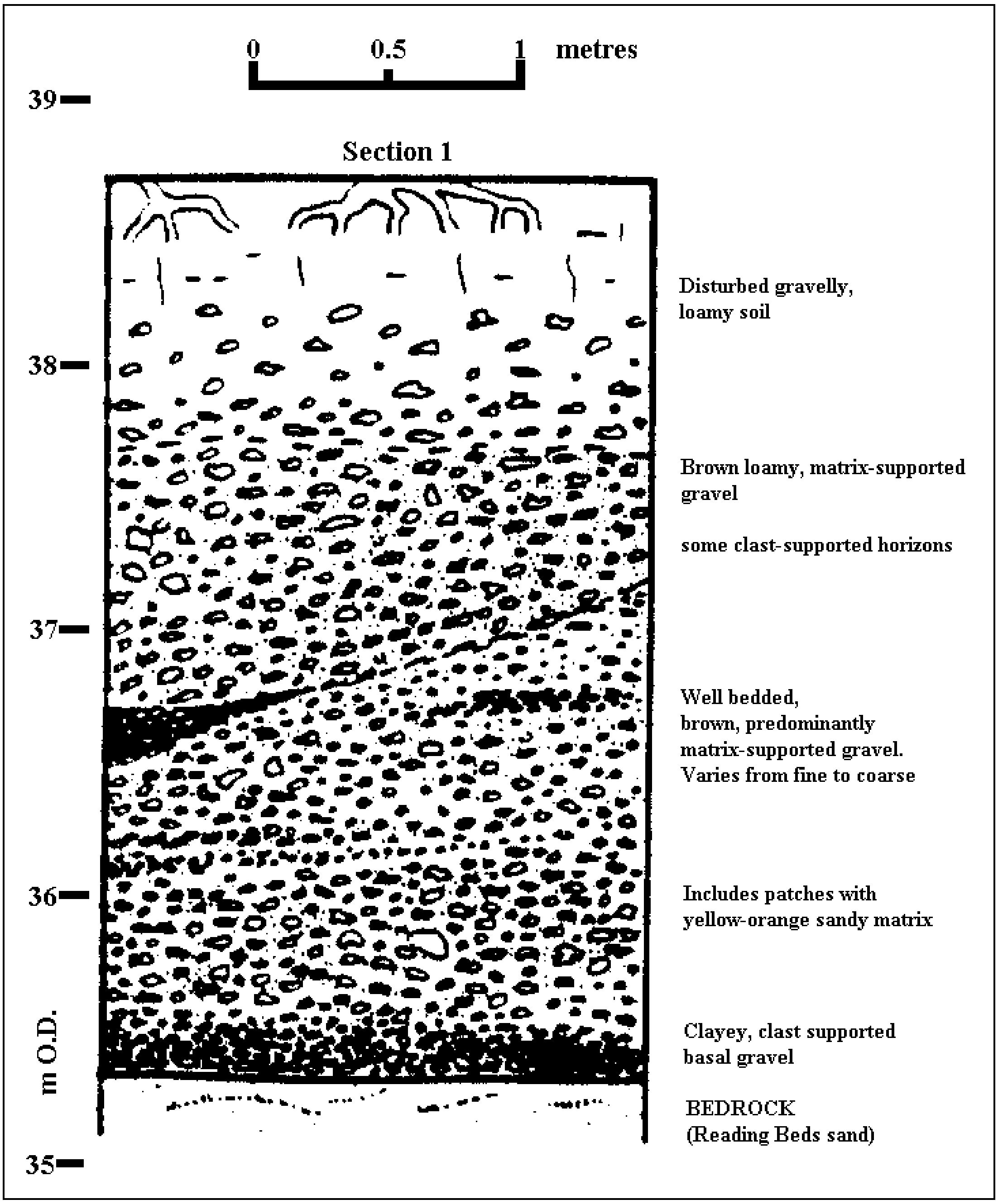

Figure 165: section from the Lower Palaeolithic site at Dunbridge (after Bridgland & Harding 1987: figure 5)

Dale (1912b) recognised separate 100 and 150 foot gravels at Dunbridge and Kimbridge. Although geological mapping indicated a single spread of gravel, the geological memoir (White 1912) recognised two levels. White (*ibid.*) described an upper Belbins stage (21m above river level) and a lower Mottisfont stage (12m above the river), both yielding Palaeolithic materials. White assigned the Dunbridge gravel to the Belbins stage and the Kimbridge gravel to the Mottisfont stage. He also disputed Dale's (1912a, 1912b) claims that the Dunbridge deposits might have a sub-glacial origin.

Bridgland & Harding (1987: 51) excavated three sections at the old Dunbridge workings in 1986. They noted that the deposits were of a brown, ferruginously stained appearance and were unable to subdivide the gravel into upper white and lower darker units. The single iron pan horizon could also not be identified. White patinated flints were recorded in the upper layers of sections 2 and 3, but they were also observed from lower down in section 3.

In 1991, four sections were recorded at the Kimbridge Farm site (Bridgland & Harding 1993). A distinction was drawn here between lower, well-bedded, generally unbleached gravel, and an upper, poorly bedded or unbedded, generally bleached gravel. The bleached and unbleached gravels were typically separated by a persistent iron / manganese pan, although the pan did not necessarily coincide with the top of the well-bedded gravel. This distinction, not apparent in the 1986 sections, may support Dale's (1912a, 1918) stratigraphic claims (Bridgland & Harding 1993: 8–9).

The Dunbridge assemblage therefore appears to provide highly comparable lines of enquiry to Broom, with respect to the claims for stratigraphically-distinct assemblages (deposited at different heights in the sedimentary sequence) and 'upper' and 'lower' sedimentary gravel units. However, the difficulties encountered by Bridgland & Harding (1987, 1993) in the division of the sediments and the general absence of documentary evidence pertaining to artefact collection and provenance, mitigates against a stratigraphically-driven analysis of the assemblage. Focus was therefore placed on abrasion modelling of the biface component of the assemblage, with a view towards reconstructing the artefacts' spatial catchment and models of landscape archaeology.

6.1.1 Dunbridge Biface Abrasion

A sample of 166 bifaces from the Dunbridge assemblage were analysed and compared to the experimental abrasion development data set. The biface sample comprises of those artefacts held by Winchester (Hyde Street) Museum, Southampton (God's House Tower) Museum and the Hampshire County Museum Stores (Chilcombe House, Winchester). All artefacts were manufactured in flint. During the course of this analysis it was not possible to identify any of the 'sharp, white patinated' artefacts described by Dale (1912a). The sampled artefacts all displayed some degree of iron-staining and signs of fluvial transportation damage.

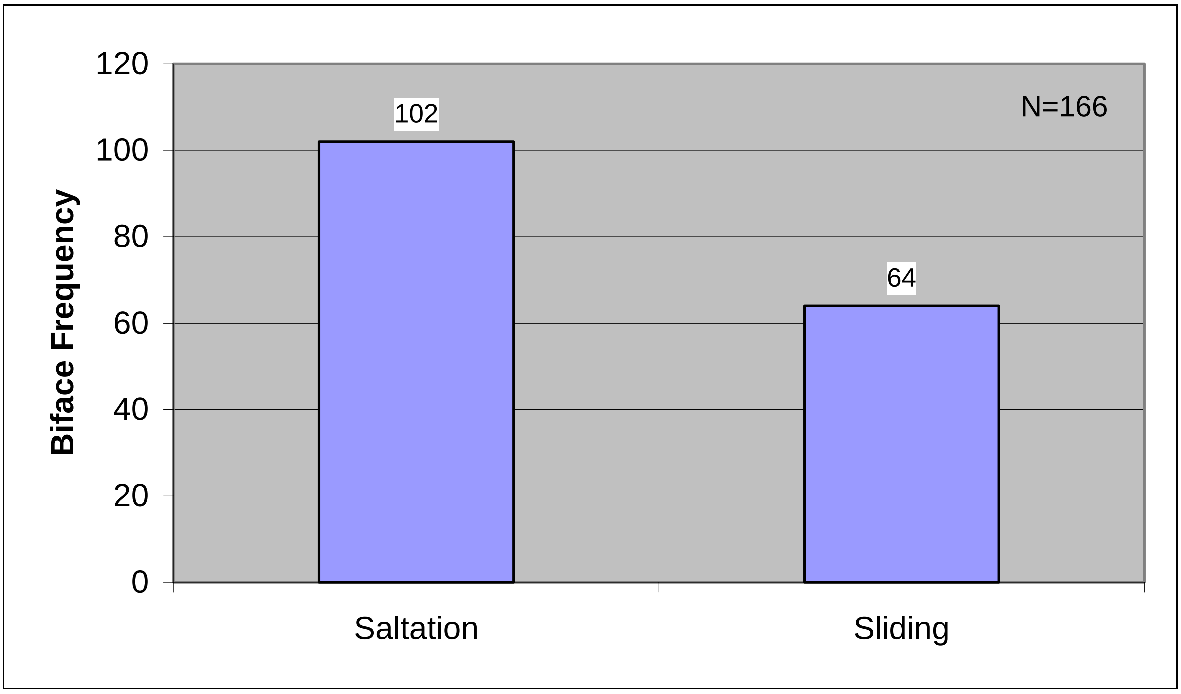

Figure 166: occurrences of saltation and sliding movement within the Dunbridge biface sample

Of the 166 Dunbridge bifaces examined, 102 showed arête and edge damage patterns indicative of saltation transportation regimes, while the remaining 64 artefacts displayed sliding damage patterns (Figure 166). The two transportation regime populations are discussed separately below.

1. The Dunbridge saltation sample: Figure 167 shows a breakdown of the Dunbridge saltation sample at intervals of 100m. It can be seen that, as in the Broom population, there is a notable peak in artefact frequency distribution that can be seen around the 200–300m range.

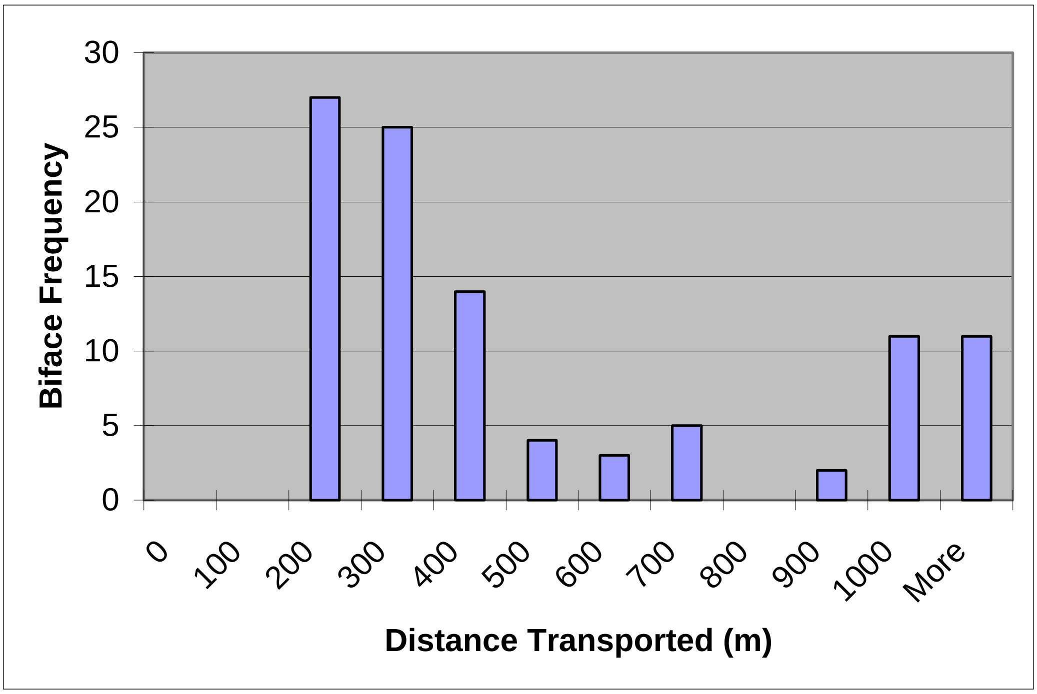

Figure 167: Dunbridge biface sample, transported by saltation

The Dunbridge saltation population does not contain any artefacts from the immediate vicinity, all examined bifaces appeared to have been transported for distances of 200m or more and a greater proportion of the population has been transported significantly further.

2. The Dunbridge sliding sample: Figure 168 shows a breakdown of the bifaces in the Dunbridge sample that showed evidence of fluvial transportation via sliding motion. Unfortunately experimental modelling of sliding damage development could only be documented up to a distance of 250m. The Dunbridge sliding sample has predominantly sustained more damage than the flint experimental sliding data set. It can be postulated therefore that these Dunbridge bifaces have slid for distances greater than 250m. Constraints in the experimental data set prohibit the modelling of the specific distances that this additional damage pertains to. As with the saltation sub-sample, there is no evidence that any of the bifaces transported by sliding originated from the immediate vicinity of the Dunbridge pits.

In general however, the Dunbridge biface sample shows a higher proportion of highly transported material than the Broom assemblage. The two assemblages are therefore compared in more detail below (Figure 169–Figure 170), with respect to the transportation characteristics of the bifaces, the fluvial catchments for the two sites, and their implications for models of hominid landscape behaviour.

Due to the substantial differences in assemblage size, the two data sets are compared on a percentage basis, facilitating a more representative evaluation of the transportation trends present than a raw data count would allow. A comparison of the components of each assemblage that show evidence of transportation via primarily saltation motion, reveals that both the Broom and Dunbridge samples are characterised by concentrations of bifaces which have travelled approximately 200–300m from their original point of discard (Figure 169). However, the dominance of this distance category is much more pronounced within the Broom population (84% (n=498) compared to 51% (n=52) in the Dunbridge sample). In contrast, the Dunbridge population is characterised by a greater % of more heavily abraded bifaces (49% (n=50) compared to 16% (n=94) from Broom), whose abrasion damage signatures are indicative of longer transportation distances.

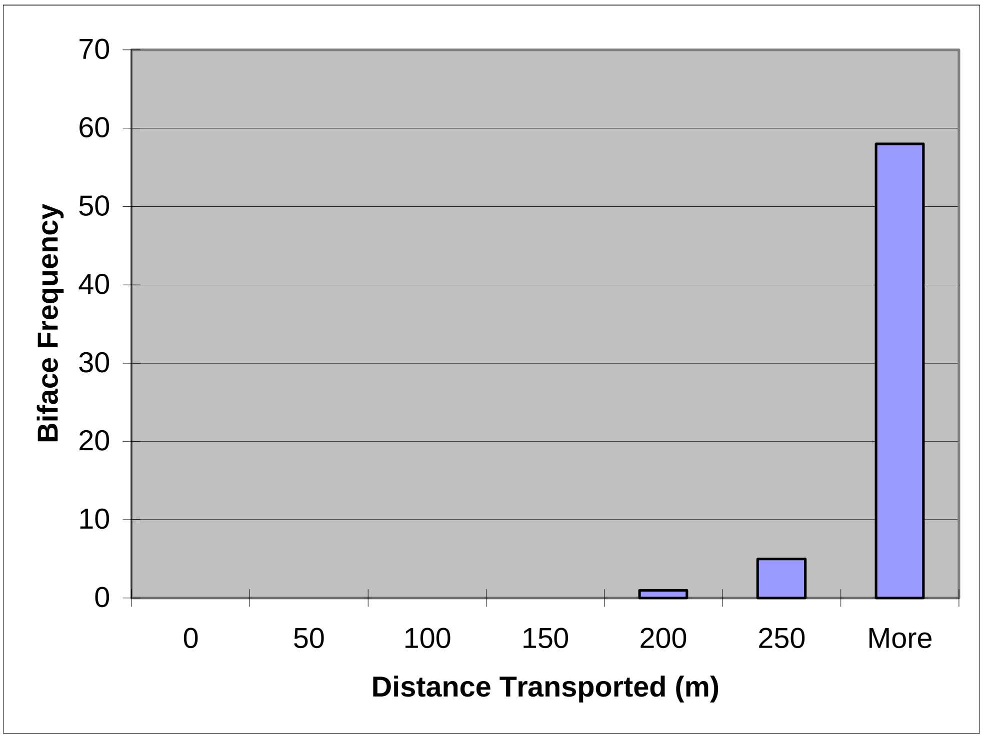

Figure 168: Dunbridge biface sample, transported by sliding

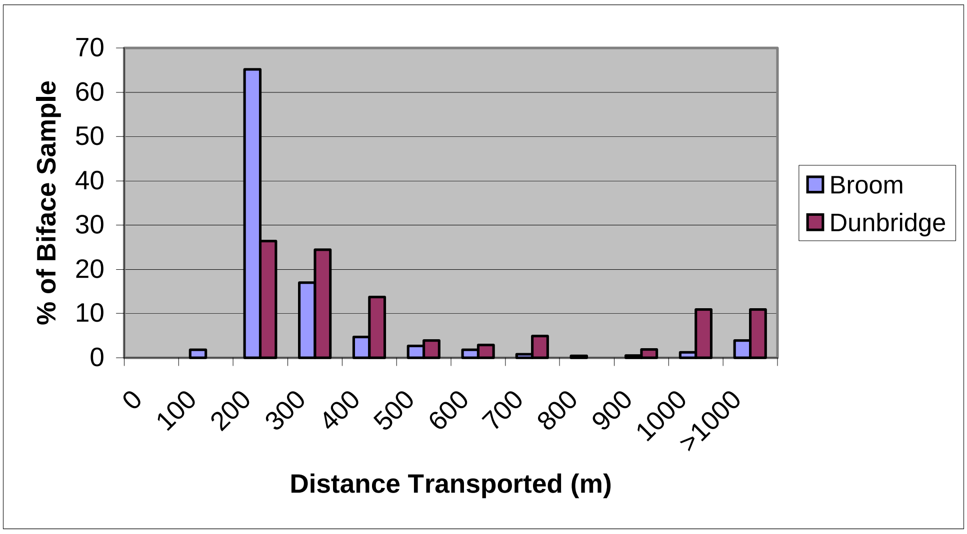

Figure 169: comparison of Broom and Dunbridge bifaces transported through saltation

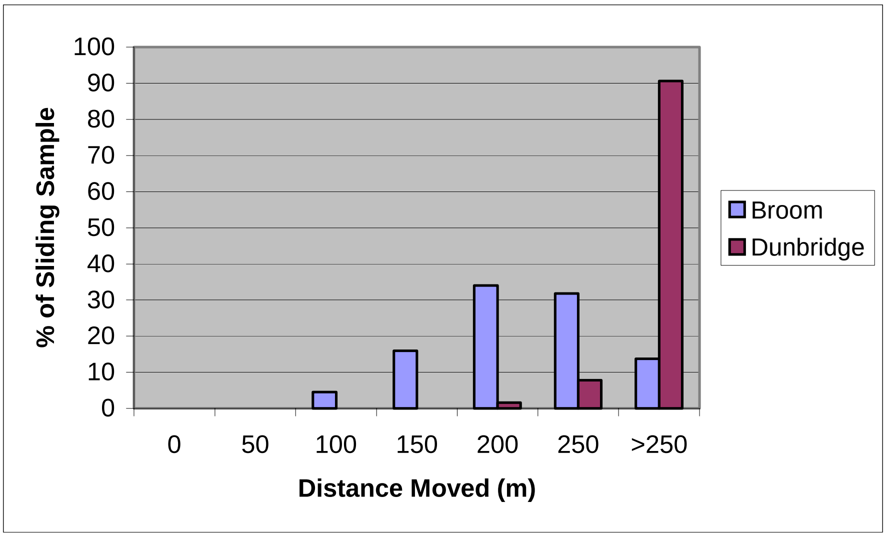

Figure 170: comparison of Broom and Dunbridge bifaces transported through sliding

The comparison of the bifaces transported primarily by sliding, also suggested that the Broom sample was characterised by a higher proportion of locally-derived (defined here as sub-200m) bifaces (55%, n=24). In contrast, the Dunbridge material had a very small component of locally-derived material (2%, n=1), with the vast majority of the bifaces characterised by damage signatures indicative of transportation greater than 250m (Figure 170).

In conclusion, the data from Broom suggested a predominance of locally-derived material in the assemblage. Very small quantities of the sampled bifaces suggested transportation distances greater than 500m. With respect to hominid activity in the Axe Valley, these data suggest repeated visits (rather than a 'single' occupation) to a spatially discrete locality, in the vicinity of the Broom pits. Although the attractions of this locality cannot be proven, the probabilities include mobile resources (animal species), static resources (water, lithic raw materials), and landscape logistics (e.g. river crossings and ease of movement). The data also indicate sporadic activity distributed more widely across the landscape. The inter-sample homogeneity of the assemblages suggests that similar behaviours were conducted throughout the Axe Valley landscape. Finally, the intra-sample technological variation suggests that the spatially discrete locality was not a task-specific site, and there is no evidence for the existence of cultural geography as defined by Binford (1987).

The Dunbridge data indicates partial similarities with Broom (approximately half of the sampled bifaces are locally derived from with 200–300m of the modern pits), but there is also evidence of a wider artefact catchment area. These data would suggest a combination of wide-ranging behaviour over the River Test landscape and intensive activity at a spatially discrete locality in the vicinity of Dunbridge, although the absence of clear stratigraphic provenancing for the artefacts make it difficult to say whether this reflects a series of visits or a single phase of occupation. Given the location of the Dunbridge sediments at the geological interface between Upper Cretaceous chalk to the north and Tertiary sands and clays, the latter pattern may reflect the acquisition of high quality raw material (flint nodules as opposed to river cobbles — White 1998b) from chalk outcrops. The concentrated deposition at Dunbridge of bifaces from across this wide catchment area is probably due to geological and fluvial geomorphological factors. Specifically, the restrictive impact of chalk bedrock on river terrace development (chalk river valleys are narrow and lack long terrace staircase sequences) and fluvial migration (Bridgland 1985; Hosfield 2001). These factors may have resulted in the extensive spatial re-working of the artefacts in the chalk river Test valley, prior to their deposition at Dunbridge in fan gravels/preserved terrace deposits. The deposition of the fan gravels and preservation of terrace deposits are associated with the interface of bedrock chalk and bedrock sands and clays, and the resulting changes in fluvial system behaviour (this point is discussed at greater length in the following chapter).

This comparison of derived data sets has therefore indicated general similarities, with both sites indicating concentrated hominid activity in the local vicinity. They also both demonstrate that hominid activity was not limited to 'sites' and reveal their exploitation of the wider fluvial landscape. It should be stressed that the landscape has often been ignored in traditional interpretations of these assemblages. Most importantly, this work has demonstrated the potential for inter-site comparisons and the investigation of off-site patterns in hominid behaviour across fragmented Palaeolithic fluvial landscapes.

7. ASSEMBLAGE CHARACTERISATION & CONCLUSIONS

The Broom assemblage can be characterised in terms of its technological and typological characteristics, alongside the evidence for patterning through time and in space:

1. The following discussion of technological and typological patterning in the Broom assemblage stresses intra- and inter-sample trends. Intra-sample patterning refers to trends within an individual sample, which could be the overall assemblage sample (n=977) or the below-datum sample (n=52). Inter-sample patterning refers to comparisons between individual samples. The following discussion is predominantly concerned with the biface element of the assemblage, given the high proportion of these artefacts and their greater potential for informative patterning.

   The assemblage shows considerable intra-sample variation in all of the major categories (biface type, raw materials, blank form, tip and butt types, edge profiles, and size (weight)). Although in many of these categories, there was a dominant type (e.g. cordate/ovate bifaces, medium-grained chert, irregular rounded tips, trimmed flat butts, and bifaces between 100–500g), the range of other types indicate considerable variation in technological practise and the end products of knapping activity. These patterns do not suggest strongly imposed standardisation with respect to the production of artefacts. This is also supported by the absence of inter-sample variation (discussed further below), evident in the stratigraphic sub-samples and the spatial sub-samples.

   There is a strong preference for the production of straight edges, suggesting that the knappers' were concerned with the production of good cutting edges on the bifaces. This is further supported by the dominance of trimmed or trimmed flat butts, suggesting the production of bifaces with fully circumferential cutting edges. The dominance of straight edges for all the major biface types at Broom further suggests that efficient cutting edges were required, regardless of the overall biface form (it is possible that the different combinations of cutting edges and biface forms might have afforded a wide range of task-related ergonomic tools).

   In contrast to the claims made by C.E. Bean, asymmetrical (lop-sided) biface forms do not dominant the assemblage (Bean claimed that this type 4 represented *c.* 50% of his collection). No evidence has been found to support Bean's claim that the asymmetrical bifaces were produced on side-struck flakes (and 12 of the asymmetrical bifaces were shown to have been produced on cobbles). Nonetheless, these forms are relatively common (19.5%, n=125), occurring on all raw material types. This implies that the asymmetry was not a consequence of raw material type. A wide range of biface types are represented on these asymmetrical forms, suggesting either that the asymmetry was an unintentional product of the knapping process (and that biface form was significant); or vice-versa (that the asymmetry was an intended end goal, and was considered to be more important than biface form). It is currently not possible to evaluate one interpretation over the other, although the dominance of straight edges on these forms suggests that they may have been no less functional than the 'symmetrical' bifaces.

   The non-biface assemblage is dominated by retouched flake tools. Given the collection history at the site, it seems likely that this dominance of the retouched flake tools and unifaces over non-retouched débitage is a factor of their high degree of working and therefore unambiguous artefact status. The continued recovery of flakes in the 1980's (by C.P. Green) and the 2000's (by Hosfield & Chambers) also suggests that the débitage component in the Bean collection is highly under-represented. It is therefore not possible to reconstruct knapping behaviour in the Axe Valley.

However, the presence of non-biface stone tools indicates that activities beyond those traditionally associated with biface use (e.g. butchering large animals) were being conducted within the demonstrated fluvial catchment area.

2. Division of the Broom biface assemblage into stratigraphic sub-samples was based primarily on the Bean archive and the previous work of Green (1988). Although it yielded relatively small samples (due to the number of accurately provenanced bifaces in the Bean archive), the samples suggested generally robust patterning. All three sub-samples were characterised by intra-sample variation that was similar to that of the overall assemblage sample (see point 1 above). However, there was very little inter-sample variation, suggesting little change through time in hominid behaviour (as represented by stone tools). In this respect, Broom is notably different to Swanscombe, where fundamentally different stone tool industries (Acheulean and Clactonian) lie in stratigraphic superposition within a single MIS-cycle (Conway *et al.* 1996; Wymer 1999). The OSL dates for the Broom sediments (see module 2) suggest that this time-span *could* represent as much as 20,000 years, raising the possible issue of each sub-sample representing a palimpsest. However, the compositional similarity of the three stratigraphic samples suggests that the intra-sample variability is not due to time-averaged over-printing, since it would require the same sequence of over-printing to occur three times, a scenario for which there is no analogue.

   It is acknowledged that the similarity of the above datum sample (broadly associated with the upper gravels) and the datum sample (associated with the middle beds) may be due to the artefacts ultimately recovered from the upper unit having been eroded out of the finer-grained and less resistant sediments of the middle beds, prior to and during the deposition of the upper gravels (Green pers. comm.). However, such a process does not explain the similarities between the artefacts of the middle beds and the lower gravels, and it is also not supported by the physical condition of the above datum sample artefacts, which did not display evidence of more intensive transportation and re-working when compared to the datum sample.

   Indeed, the modelled abrasion data for the three sub-samples shows a very similar pattern (the majority of the material appears to be derived from a local source catchment), suggesting that the spatial foci of hominid behaviour in the River Axe landscape (as represented by biface discard) remained consistent through time. The physical condition of the majority of the bifaces (e.g. edge damage) suggested that they were primarily transported and deposited in the coarse-grained gravels which occur throughout the Broom sedimentary sequence (including the Middle Beds), rather than being discarded *in situ* in the fine-grained sediments, as suggested by C.E. Bean.
   As c. 85% of the assemblage could not be stratigraphically provenanced, it is possible that there is greater inter-sample variation at Broom which cannot be demonstrated. However, on the basis of the current analysis, there is very little evidence for inter-sample variation. It is also possible that the lack of inter-sample variation is due to the three samples being stratigraphically separated in the Broom sediments, but originating from a 'single', homogeneous occupation. We would argue however, that this hypothesis requires a complex model of episodic artefact supply into the fluvial system (either as a result of fluvial erosion of floodplain sediments or sediment movement from valley slopes). Further discussion of these issues is introduced in the next chapter.

3. Division of the Broom biface assemblage into spatial sub-samples was based on the artefact abrasion modelling work of Chambers (in prep). The samples suggested robust patterning, with a large concentration of bifaces derived from within a few hundred metres of the Broom pits. The remainder of the bifaces were derived from a wider source area, although there was very little material that could be demonstrated to have been transported from further than *c.* 1km upstream. These samples are described as on-site and off-site material respectively, although the terms are not strictly used in the Foley (1981) tradition. Both samples are characterised by intra-sample variation that is similar to that of the overall assemblage (see point 1 above). There was also (as with the stratigraphic samples) very little inter-sample variation, suggesting little spatial variation in hominid behaviour (as represented by stone tools). This would suggest an absence of a cultural geography (e.g. the existence of task-specific sites, the creation of taskscapes or the spatial

differentiation of landscapes) (Binford 1980, 1987; Ingold 1993; Gamble 1999). In contrast, in so far as can be demonstrated by biface manufacturing techniques and discard patterns, there appears to be a high degree of behavioural homogeneity across the modelled landscape.

The apparent intra-sample variability in the on-site sample could be argued to result from over-printing and the generation of a palimpsest assemblage over an extensive time-span. However, we would argue that the patterning in the stratigraphic samples (of intra-sample variability and inter-sample similarity over time) *suggests* that this is not the case and that the intra-sample represents relatively short-term trends in technological practice. It is of course difficult to independently assess whether the on-site sample (and the off-site sample) represents a 'single' occupation or repeated visits to the landscape over a long period of time. However, the stratigraphic range of the artefacts in the Broom sediments suggests that the latter rather than the former is the case, supporting an over-arching model of behavioural homogeneity in time as well as space.

In conclusion, this analysis of the secondary context archaeological assemblage from the Broom Lower Palaeolithic locality archaeology has highlighted a series of important archaeological applications:

1. That it is possible to extract meaningful archaeological information from derived, secondary context data sets, with respect to behavioural homogeneity/heterogeneity in space and time.
2. That assessments of the spatial and temporal origins of Palaeolithic artefacts in derived contexts can be made.
3. That it is possible to compare landscape archaeologies associated with separate secondary context Palaeolithic assemblages.

The following chapter continues to develop all of these themes, exploring wider issues of fluvial system behaviour, assemblage formation and their implications for the interpretation of archaeological data.

CHAPTER 5

THE TRANSPORT HISTORIES OF STONE TOOL ASSEMBLAGES OCCURRING WITHIN SECONDARY CONTEXT, FLUVIAL AGGREGATE DEPOSITS

1. INTRODUCTION

The previous two chapters introduced the Lower Palaeolithic locality of Broom, reviewed the geoarchaeological fluvial sedimentary context and explored spatio-temporal patterns evident in the secondary context stone tool assemblage. In doing so, the discussion addressed a fundamental issue associated with stone tool assemblages that occur in secondary context deposits: are they homogeneous or heterogeneous? In other words, do the lithic assemblages consist of artefacts which, prior to their incorporation within the secondary context deposits, were related or unrelated? Of course this notion of relatedness prior to fluvial transport and deposition refers both to the spatial and temporal dimensions, between which there may be considerable differences. For example, an assemblage may have been fluvially derived from a single locality, but accumulated there as a result of repeated hominid/human visits over many years. Such an assemblage would be time-averaged (Stern 1993), but associated with a spatially discrete 3-dimensional area. By contrast, an assemblage may have been derived from a 20 km long river valley landscape, but the artefacts accumulated in the valley during a short two week occupation in late spring. In this case, the assemblage is space-averaged, but is associated with a temporally-discrete phase. These discussions are highlighting a key problem: what is the structure and patterning of early prehistoric human behaviour in space and time, as represented in derived, secondary context assemblages, and how can archaeologists assess it?

This chapter therefore introduces and evaluates the range of data that may be utilised in an assessment of the homogeneity and/or heterogeneity of these secondary context archaeological assemblages. Emphasis is placed upon the artefact as an unusually-shaped clast (Chambers in prep), and the possible behaviours of artefacts during the formation of secondary context assemblages in fluvial deposits are investigated with respect to extant models of clast entrainment, transportation and deposition. The chapter therefore draws heavily upon physical engineering and physical geography research. It also reviews the Broom assemblage analysis (Chapter 4) to assess the value of three data sets (physical, stratigraphic, and morphological/technological) in assessing the potential homogeneity and/or heterogeneity of generic, secondary context assemblages. Finally, the role of experimental fieldwork is assessed, and the integration of the former with laboratory research and theoretical modelling is highlighted.

Overall, the report assesses the role of taphonomic investigations in the interpretation of secondary context assemblages, with particular reference to future research agendas and the investigation of non- or poorly documented, secondary context Palaeolithic assemblages. Specifically, the following themes are explored:

- Physical processes of clast entrainment, transportation and deposition.
- The relative importance of three data sources: the physical condition of stone tools; the morphology of stone tools; and the stratigraphic context of stone tools.
- The integration of laboratory research; theoretical modelling; and experimental archaeological fieldwork.

- The implications of taphonomic studies to the interpretation of stone tool assemblages occurring in secondary context deposits.

2. BROOM: A RE-ASSESSMENT

Chapters 3–4 presented a case study assessment of the Lower Palaeolithic locality of Broom, with respect to the palaeo-environmental framework (chapter 3) and the stone tool assemblage recovered from the secondary context fluvial deposits during the 20th century (chapter 4). This section provides a brief summary of these earlier assessments, and provides an overview with respect to the relative homogeneity and/or heterogeneity of the Broom assemblage. Fundamentally, this review highlights the importance of the Bean archive in the conclusions drawn, and assesses:

- The potential for assemblage assessment in the absence of a comprehensive documentary archive.
- Patterns in the artefact assemblage, lithological, and clast fabric data that may potentially be related to extant research in physical engineering and physical geography (Section 3), and experimental field archaeology (Section 4).
- The relative value of stratigraphic, morphological and physical condition data in the assessment of stone tool assemblage origins.

2.1 The Palaeo-environmental & Geochronological Framework

The sedimentary sequence at Broom was episodically deposited by a predominantly high-energy fluvial regime, over several thousand years:

1. The sedimentary sequence of coarse-grained gravels–fine-grained sediments–coarse-grained gravels suggests a cycle of a cold-climate river regime (probably multi-channel or braided), changing to a warm-climate regime (probably single-channel and meandering) before returning to a cold-climate pattern. The additional sedimentary evidence for short-term variations in the fluvial regimes highlights the potential importance of brief periods of climatic instability (and possible individual storm and flood events) in the deposition of the coarse-grained Broom sediments.
2. The clast fabric data suggest that the major source of the fluvial sediments at Broom was the River Axe, for both the upper and lower gravels, and probably the middle beds. It is also apparent that the River Blackwater (flowing broadly east-west) was a significant east bank tributary and confluenced with the River Axe in the area of Pratt's New Pit, *at least* during the period when the upper gravel sediments were deposited.
3. The optically stimulated luminescence (OSL) dating programme indicates a probable mid–late MIS-8 age for the Broom upper gravel and middle beds sediments (Table 26). However, it is clear from the stratigraphic reversals, error ranges, and the overall range of ages in the samples that at the current time it is not possible to estimate the duration of depositional events or hiatuses in fluvial activity at Broom on the basis of OSL dating.
4. The iron/manganese horizon evidence for localised landsurface development, especially in the lower gravels, suggests some significant hiatuses and periods of relative stability, although the lack of weathering evidence, cryoturbation features and cold-climate indicators such as ice wedge clasts (in what was a predominantly cold-climate environment), would suggest that the breaks in fluvial activity were not of considerable length.
5. The palynological work of Scaife suggests that during the deposition of the Middle Beds, the River Axe environment was characterised by grassland floodplains with scattered woods on the valley slopes.

2.2 Stone Tool Assemblage

The stone tool assemblage at Broom was predominantly derived from a local source (probably within a few hundred metres upstream of the deposits and probably associated with the River Axe rather than the

River Blackwater), although there is significant component of material derived from a wider catchment area. The temporal origins of the material are more difficult to assess:

1. Robust patterns in the physical condition data for the Broom assemblage indicate that a majority of the bifaces were derived from sources located within a few hundred metres upstream of the Broom deposits. The remainder of the bifaces were derived from a wider source area, although there was very little material that could be demonstrated to have been transported from further than *c.* 1km upstream. In terms of its spatial origins therefore, the Broom assemblage is predominantly homogeneous, although there is a small heterogeneous element.
2. Both the homogeneous and heterogeneous samples were characterised by intra-sample variability, of a similar type to the overall Broom assemblage (Chapter 4). However, the samples demonstrate very little inter-sample variability, which has been interpreted as indicating an absence of cultural geography (e.g. no evidence for task specific sites, taskscapes or the spatial differentiation of landscapes). The possible factors of over-printing and the resultant blurring of intra-sample variation in the 'on-site' sample have been considered. However, the absence of over-printing evidence in the stratigraphic samples (and the overarching pattern of intra-sample variability — see below) suggests that overprinting (the loss of individual behavioural signatures) has not been an important factor in the formation of these assemblages.
3. Assemblage patterns through time are more difficult to assess, reflecting the smaller sample sizes (only a proportion of the artefacts were assigned clear stratigraphic heights by Bean) and the difficulty in assessing the chronological framework of the Broom sediments. The employed division separated the sample by generic sedimentary units (lower gravels, middle beds, and upper gravels) and revealed little variation through time. All three of the sedimentary unit samples were characterised by intra-sample variation (again similar to that of the overall assemblage (Chapter 4), but very little inter-sample variation. In general, the samples suggested little change through time in hominid behaviour, with the current OSL samples suggesting a probable time span of *c.* 20–30,000 years (in other words, the overall assemblage is temporally heterogeneous).
4. It is possible, given the time span of the Broom sedimentary sequence, that each of the sedimentary unit samples represents a temporal palimpsest. However, the compositional similarity of the three samples suggests that they were not formed by over-printing (the blurring of a series of distinctive signatures from individual behavioural episodes), since it requires essentially the same sequence of over-printing to occur three times, a scenario for which there are no available analogues.
5. It is also possible that the absence of inter-sample variation is due to the three samples being stratigraphically separated in the Broom sediments, but originating from a 'single', relatively-short lived occupation. However, this hypothesis requires a relatively complex model of episodic artefact supply into the fluvial system (either as a result of intermittent fluvial erosion of floodplain sediments or sediment movement from valley slopes). A model of repeated visits to the Axe Valley landscape is preferred, suggesting behavioural homogeneity over time.
6. The similarity of the samples from the middle beds and the upper gravels may be due to the re-working of artefacts from the middle beds into the upper gravels, immediately prior to and during the deposition of the latter sedimentary unit. We feel that this is not supported either by the vertical distribution of artefacts throughout the body of the upper gravel, or the similarity in the physical condition of the artefact samples from the upper gravels and the middle beds. This interpretation also fails to explain the similarities between the middle beds and the lower gravels, since re-working from the latter into the former would have been very unlikely.

2.3 Assemblage Characterisation

In conclusion, the Broom secondary context assemblage is summarised as follows:

- Primarily spatially homogeneous: the majority of the artefacts appear to have been derived from a local source in the upstream Axe valley and re-worked into the Broom deposits. There is a smaller heterogeneous component, which has been derived from a number of sources distributed widely through the River Axe valley and (potentially) its tributaries.

- Primarily temporally heterogeneous: the distribution of the artefacts throughout the Broom sedimentary sequence suggests that they reflect hominid activity over a relatively long rather than a relatively short period (although the activities may have been highly episodic). At the same time, the distribution of material (e.g. the concentration of artefacts around the site datum and 1st floor levels) suggests that some periods of hominid activity may have been more intensive than others.
- With respect to hominid behaviour, the composition of the assemblage and its structural origins (in time and space) suggest behavioural homogeneity, as there is little evidence for change over time and strong evidence for repetitive visits to individual parts of the fluvial landscape.

2.4 Assessing the Broom assemblage

It should be clear from the above discussion that much of the assessment and interpretation of the Broom assemblage utilised the stratigraphic provenancing data recorded by C.E. Bean. Since this type of data is absent for many of the assemblages collected from other gravel deposits (e.g. Dunbridge and Wood Green in Hampshire (Westlake 1902; Dale 1912a, 1918; Bridgland & Harding 1987; Hosfield 1999, 2001; Chambers in prep.), a key question concerns the potential for interpretation of those types of deposits. The stratigraphic data is a key factor in evaluating the possibility of over-printing – i.e. the blurring of a series of individual (heterogeneous) behavioural signatures into a single (homogeneous) signature. In the absence of such data, it is still important to consider the spatial data (based on the physical condition of the artefacts) and assess whether the assemblages represent derivation from a homogeneous source area (e.g. derived 'on-site' material) or a heterogeneous scatter (e.g. 'off-site' material). These data inform with respect to landscape behaviour (e.g. cultural geography or encounter-based scavenging, to take two extreme cases). With respect to the problem of over-printing, compositional differences between the 'on-site' and 'off-site' samples may provide an indication of assemblage variability and possible assemblage blurring. In general however, in the evaluation of assemblages without stratigraphic provenancing data, attention should be focused on the spatial origins of the assemblage and its potential implications for the interpretation of landscape behaviours.

With respect to the three categories of data stressed in the assessment of the Broom assemblage, the key types are stratigraphic (artefact provenancing) and physical condition/abrasion. Their applications are relatively self-evident, enabling the assessment of the temporal (stratigraphic) and spatial (physical condition/abrasion) origins of secondary context assemblages, with respect to their relative homogeneity and/or heterogeneity. However, the role of morphological data in the assessment of assemblage homogeneity/heterogeneity in space and time is less immediately apparent. The most obvious application of these data (and technological data) is with respect to the interpretation of hominid behaviour (e.g. tool making traditions), but technological homogeneity (e.g. a dominance of ovate bifaces) does not necessarily equal homogeneity in time and space. However, there are nonetheless a series of morphological aspects that may be related to issues of site formation (entrainment, transportation and deposition):

- Shape and weight: specifically, the impact of clast/particle form and weight upon processes of entrainment, transportation and deposition. These factors are discussed below (Section 3) with respect to recent and current research in the fields of physical engineering and physical geography.
- Artefact type: a key factor concerns the robusticity of flake material. The presence of flake débitage in secondary context assemblages could be taken as evidence for minimal transportation of the assemblage. However, initial experimental work (Section 4) suggests that this assumption may be in need of review.

Finally, the analysis of the Broom sediments and assemblage has indicated a series of patterns in the artefact assemblage, site lithology and clast fabric data that require wider consideration with respect to existing models of clast and fluvial system behaviour (Section 3) and experimental observations (Section 4):

- The sedimentary sequence demonstrates a range of different flow regimes, primarily shifting between cold-climate, high energy and warm-climate, lower energy systems. Although the majority of artefacts show evidence (e.g. edge damage) of transportation in coarse-grained bed-load systems (i.e. gravel-bed rivers), the interpretation of artefact abrasion data must consider whether (and if so, how) artefacts behave differently under varying flow regimes.

- The pollen data indicates a grassed floodplain environment, at least during the deposition of the clays and sands in the Middle Beds. How would this impact upon river erosion processes, by which artefacts discarded upon the floodplain were entrained in the fluvial system, transported and re-deposited along with the Broom sediments. Would a shift to cold-climate conditions with reduced vegetation coverage have resulted in a greater frequency of floodplain erosion, artefact entrainment and re-deposition?
- The issues of channel migration and erosion processes (introduced above) are fundamental for assessing any claims that the Broom artefacts represent a single occupation site, whose material was gradually incorporated into the fluvial system over several thousands of years (point 5 in Section 2.2. above).
- Clast fabric data from the Broom sedimentary sequence indicates the probable confluence of the Axe and Blackwater rivers in the vicinity of the Broom pits. What impact would the rivers' confluence have had upon processes of sediment deposition and patterns of clast transport and deposition?

3. MODELS OF CLAST TRANSPORTATION

There has been extensive recent research into the processes and mechanics of sediment entrainment, transportation and deposition, both in the fields of physical engineering and physical geography (Einstein 1942; Murphy & Hooshiari 1982; van Rijn 1984; Wiberg & Smith 1985; Hassan *et al.* 1991, 1992; Church & Hassan 1992; Sekine & Kikkawa 1992; Wilcock 1997, 2001; Nino & Garcia 1998; Martin & Church 2000; Ham & Church 2000; Lee *et al.* 2000, 2002; Hassan & Church 2001; Lewin & Brewer 2002; Dancey *et al.* 2002; Hunziker & Jaeggi 2002; Graf & Cellino 2002; Malmaeus & Hassan 2002; Yang & Lim 2003; Sumer *et al.* 2003; Crossley *et al.* 2003). This research has explored transportation types and mechanisms (e.g. suspension and saltation), bed-loads, step lengths, individual particle movement, grain sorting and channel dynamics. However, much of this research relies upon specific system variables (e.g. flow discharge, mean sediment concentration, water flow depth, bed slope and specific densities (for water, sediment, and water/sediment mixtures) which are unknowable for geoarchaeological secondary contexts. These and other variables are typically utilised within mathematical modelling approaches, as the basis for generating specific observations. Specific models are of limited application to secondary context archaeological assemblages, as the required variables cannot be known. This is even the case for sites with comprehensive documentary archives and/or surviving sedimentary sections (e.g. Broom), due to problems of data resolution. Nonetheless, while the models cannot be specifically applied, this research has identified important generic trends in clast transport. These can be applied to the interpretation of secondary context archaeological assemblages and are discussed in more detail below:

1. Transport in gravel-bed rivers is highly variable, in both the spatial and temporal dimensions (Hassan & Church 2001: 813). Flume and field studies have revealed considerable variability in the relationships between hydraulic parameters and sediment transport rates (Gomez & Church 1989). Consequently, predicting general sediment transport rates in gravel-bed rivers has remained extremely difficult, as the movement of clasts is governed by a large number of sedimentological, geomorphic and hydraulic variables (Malmaeus & Hassan 2002). Indeed, Malmaeus & Hassan (2002) have argued that given the complexity of bed-load movement in gravel-bed rivers, the movement of individual particles appears to be a statistically random phenomenon. What is clear from an archaeological perspective therefore, is the need to emphasise general trends and attempt to only identify robust patterns.

2. The transport of clasts in fluvial systems involves entrainment (the incorporation of the clasts within the active system) and transport:

    - Particle entrainment occurs when the forces exerted by the flowing water overcome particle inertia (Malmaeus & Hassan 2002: 83). In addition to the fundamental effects of flow velocity, a range of other factors have been identified as affecting the probability of particle entrainment (and movement) during an individual flow event. These include particle size, the proximity of neighbouring particles, and relative elevation (Malmaeus & Hassan 2002); bed sheer stress, grain size and bed surface armouring (Hunziker & Jaeggi 2002); and particle size geometry, channel turbulence and channel velocity gradients (Muste 2002). It should be immediately apparent that in an archaeological context, few (if any) of these factors can be known for an artefact or artefact(s). Moreover, the objective in the analysis of secondary context assemblages concerns the duration of transport (including step lengths and burial phases) rather than the specific process of entrainment. An example of the importance of archaeologically-invisible variables is demonstrated by Hunziker & Jaeggi (2002) with respect to the classical assumption that finer grains may be more mobile than coarser particles:

"Mobility of grains is governed by flow conditions, which are often characterised by the bed shear stress and grain size. According to the classic sediment transport theories which indicate that the critical shear stress for initiation of motion is dependent on the grain size, finer grains are more mobile than coarser ones. This conclusion however can be drawn only if the material is uniform and the grains are surrounded by identical ones…for a bed mixture containing a wide range of grain sizes at the surface, the fine grains are shielded by the coarser ones, whereas the coarser are more exposed to the flow than if surrounded by identically coarse grains. The consequence is that shielding and stronger exposure almost compensate for differences in grain size and that mobility is nearly the same."

(Hunziker & Jaeggi 2002: 1061–1062)

- Once entrained, the transportation of clasts can occur through a range of mechanisms: suspension and bed-load transport (rolling, saltation and sliding). While the mechanisms of bed-load transport have been extensively discussed, suspended transport of clasts has received relatively little attention. Muste (2002) has highlighted many of the complexities associated with this type of transport:

  "Suspended-sediment transport in alluvial channels comprises an especially complex two-phase flow. It potentially includes difficulties attributable to sediment concentration and velocity gradients across the flow depth, non-homogenous open-channel turbulence, the irregularity of sediment particle geometry and the simultaneous presence of a range of particle sizes."

  (Muste 2002: 65)

  These complexities may go some way to explaining why the relationship between suspended particles and the fluid medium has so far not been adequately explained. Experiments have commonly relied upon flume data, and have all focused on sand or very small (sub-3 mm) gravel particles (e.g. Samaga *et al.* 1986; Sumer *et al.* 1996; Best *et al.* 1997 — see Muste (2002: Table 1) for a comprehensive list). This extant research reflects the prime concerns of the researchers in modelling suspended transport of small particles such as sands (civil engineering) or pollutants (hydrology). It is therefore not currently possible to physically model suspension of archaeologically-sized particles (e.g. bifaces or even flakes), while the extant mathematical models of the initiation of particle suspension require a wider range of variables than can be recorded from archaeological fluvial contexts. Finally, Muste (2002) emphasised that particle interaction during suspended flow will be affected by the size and character of the neighbouring particles. Once again, this would be very difficult to determine for assemblages of artefacts recovered from Pleistocene river gravels, regardless of whether field sections remain available for re-examination or not.

- In contrast to suspended load, there has been extensive modelling of bed-load transport, both in the field and the laboratory (Einstein 1942; Bagnold 1980; Murphy & Hooshiari

1982; van Rijn 1984; Wiberg & Smith 1985; Hassan *et al.* 1991, 1992; Sekine & Kikkawa 1992; Wilcock 1997, 2001; Niño & García 1998; Martin & Church 2000; Lee *et al.* 2000, 2002; Malmaeus & Hassan 2002; Hunziker & Jaeggi 2002; Sumer *et al.* 2003). In general, bed-load transport in fluvial channels consists of the movement of individual particles. Transportation distances (step lengths) are commonly small (e.g. sub-100m in the experiments of Hassan *et al.* (1991, 1992) and the bed is only partially mobilised (Malmaeus & Hassan 2002). Although bed material in gravel rivers is normally widely graded and therefore highly variable, at the bed surface alluvial channels demonstrate self-stabilising tendencies. These tendencies result in the formation of armor layers (Hunziker & Jaeggi 2002).

Armor layers form as a result of bed erosion, as smaller clasts are eroded from the surface, leaving a concentration of coarse particles at the bed surface. The armor prevents further bed erosion, as the surface armoring and cobble structures limit sediment availability and require relatively high discharges to loosen any part of the surface layer and initiate the movement of larger particles (Hassan & Church 2001; Hunziker & Jaeggi 2002). These processes were demonstrated by Hassan & Church (2001) in experiments at Harris Creek, near Lumby, in British Columbia, Canada. Harris Creek is highly seasonal, due to annual snowmelt discharges. The study reach included a bar head and midsection covered by cobble-pebble size clasts with small pebbles and sand in the voids between and beneath them. It was demonstrated that the movement of coarse gravel (+64 mm) was very sporadic throughout a variety of seasonal flow conditions. From an archaeological perspective, this indicates that the transport of biface-sized material can be highly episodic, dependent not only upon the magnitude of flow but also upon local bed conditions.

- Research into bed-load transport has also indicated that the relationship between particle size and travel distances in fluvial channels is highly complex. Einstein (1942) argued that there is no relationship between transported distances and particle size, while Takayama (1965, cited in Church & Hassan (1992)) claimed that during individual floods, observed travel distances decreased with grain size. However, Hassan & Church (1992) suggest that Takayama's (1965) data displayed only weak trends, and also cited extensive other research supporting the conclusions of Einstein (1942). Church & Hassan (1992) argued that differential movement of a fixed size range of clasts may reflect unique circumstances, such as the propensity for small stones to be trapped by other clasts, regardless of the magnitude of flow:

"The movement of small stones appears to depend mainly on the relative efficiency of trapping in the bed whereas the movement of large stones depends mainly on size."

(Church & Hassan 1992: 301)

By contrast, large particles tend not to be trapped, and their travel distance depends mainly on size and inertia (*ibid*: 302). These observations are echoed by Malmaeus & Hassan (2002), who noted that:

"No straightforward relationship between distance of movement and particle size is evident; for particles of the same size some stones moved long distances whereas others of the same size moved very short distances…[there is a suggestion that] *larger particles are apt to move shorter distances."*

(Malmaeus & Hassan 2002: 89)

In general therefore, travel distances appear to be influenced by the size of the tracers in relation to the characteristic size of the bed material, rather than by the size of the tracers *per se*. his conclusion runs contrary to expectations that small particles move further as they require less energy to become entrained, and emphasises the increased likelihood of small particles to become trapped during their journey downstream. This research has implications for the archaeological interpretations of fluvially-modified sites, with particular reference to the assessment of transported and non-transported components (e.g. Schick 1986; Schick & Toth 1993).

Comparison of simulation experiments with data from the Harris Creek field experiments (Hassan & Church 2001; Malmaeus & Hassan 2002) suggested that particle transport distances tended to decrease as particle density increased, due to increased particle interaction. This has potential implications for the interaction of archaeological materials deposited in high density patches (e.g. *in situ* knapping scatters). Although the original scatter densities of flake material recovered from secondary contexts cannot be known, these data are recorded in field experiments and the tendency of flakes to behave in the manner outlined above can be tested (Section 4).

- Clast transport may be influenced by shape. The role of grain shape has not received much attention (e.g. Church & Hassan 1992; Wilcock 1997). However, it was explored by Schmidt & Ergenzinger (1992; Schmidt 1994). 960 concrete tracers (500g and 1000g) of different shapes (rod, ellipsoid, ball and plate) were emplaced in the Lainbach River, Southern Bavaria. During and after two moderate flood events, tracer recovery indicated that the entrainment frequency of plates was as little as half that of the other tracer shapes, while the mean displacement length was *c.* 3 times shorter than for the other shape classes. In morphological terms, archaeological flakes can be regarded as plates, and this research therefore raises interesting questions with respect to the potential for differential entrainment and transport of flake and core tools. It is noticeable that during the extreme floods (of 100 year magnitude) on the Lainbach River in the summer of 1990, the plate tracers were transported the greatest distances, although the very small sample size (n=62, 6.5%) makes it difficult to place much significance to this pattern.

In conclusion, research in fluvial engineering and physical geography highlights 5 important issues for the evaluation of archaeological assemblages in secondary contexts:

1. Given the wide range of micro-scale variables and their invisibility in the archaeological record, it is impossible to apply specific models of clast entrainment and transport to the interpretation of archaeological assemblages. Instead, only the broadest trends and principles can be applied to the interpretation of archaeological data:
2. There is no overarching relationship between particle size and transport distances. E.g. Small particles do not necessarily move further than large particles, and vice-versa.
3. Step lengths tend to be small (e.g. sub-100m), due to localised 'trapping' of particles in transit, and can be separated by periods of burial and/or stabilization.
4. Entrainment and transport of particles is influenced by a wide range of factors, including flow velocities, size and density of neighbouring particles, elevation and armoring, to name but a few. Two particles on the same gravel bar cannot therefore be expected to behave in the same way during the same flood event.
5. Therefore, even when dealing with a large archaeological assemblage, the material must be analysed on an artefact by artefact basis, with respect to their transport histories.

4. EXPERIMENTAL ARCHAEOLOGICAL DATA

This section primarily reports upon the Afon Ystwyth Experimental Archaeology Project (2000–2003), undertaken by the authors (Hosfield & Chambers 2002a, 2004). The project explored a series of processes relating to the taphonomic assessment of stone tool assemblages occurring in secondary contexts:

1. Processes of stone tool transportation, modification and deposition within a fluvial system, with respect to core tools (bifaces) and flake material.
2. Process of stone tool modification and burial within fine-grained sedimentary systems (including aeolian silt), with respect to core tools (bifaces) and flake material.
3. Processes of short-term change in river system morphology.

The project was carried out on the Afon Ystwyth in mid-Wales, at two study sites: Llanilar (SN 628754) and Grogwynian Reach, Llanafan (SN 709719). The sites were selected due to:

- The absence of indigenous Palaeolithic material — there are no records of Palaeolithic artefacts having been recovered from the Afon Ystwyth valley.
- The suitability of the sites for tracer recovery, as illustrated by the previous research of Harding *et al.* (1987; Macklin 1995).
- The rapid shifting of the Afon Ystwyth channel at Llanafan (Grogwynian Reach), associated with developing bars and active transport of bed materials (Harding *et al.* 1987: 116).
- The contrast between the sites, supporting the investigation of a range of different processes. The Llanafan (Grogwynian Reach) site boasts a dynamic floodplain environment, with regular changes in river channel morphology, sediment distribution, and floodplain vegetation coverage. In comparison, the Llanilar site is subject to relatively little morphological change, partially due to stabilising engineering works undertaken since the 1960's.
- Existing topographic surveys of the Llanafan (Grogwynian Reach) site's floodplain and channels, undertaken by the Institute of Geography and Earth Sciences, University of Wales, Aberystwyth.
- A river bed-load dominated by Palaeozoic shales and gritstones, which aided the recovery of tracers produced in exotic raw materials (flint and chert).

The Llanilar study site was previously utilised in the experimental archaeology programme conducted by Harding *et al.* (1987; Macklin 1995) during the 1980's (Figure 171). However, since the 1980's this specific section of the Afon Ystwyth has undergone additional artificial straightening[2] (Figure 172), with the inclusion of a weir to control river discharge. The length of the experimental reach was therefore restricted to approximately 300m between the point of emplacement (a modern bridge) and the top of the weir. This stretch of the Ystwyth is dominated by a major point bar on the south bank (Figure 173), while a number of small, ephemeral point and midstream bars appear during periods of low water levels (Figure 174).

The Llanafan study site (Grogwynian Reach) has not been previously used for experimental archaeology, but is an excellent example of a meandering, gravel-bed river system (Figure 175). The site is dominated by a single channel, and includes a major point bar on the northern side of the channel (Figure 175). There are a number of smaller point bar and midstream bar features which have appeared during periods of low river levels between 2000 and 2003 (Figure 175 & Figure 176). Many of these bar structures have been modified during the 3 year period of the experimental programme. There has also been extensive bank undercutting and erosion between 2000 and 2003 (Figure 177).

[2] Several sections of the Afon Ystwyth in the vicinity of the Llanilar site have been artificially straightened in a number of separate engineering projects since the 1960's, although at the time of Harding *et al.*'s (1987) work, channel straightening had occurred without bank protection works.

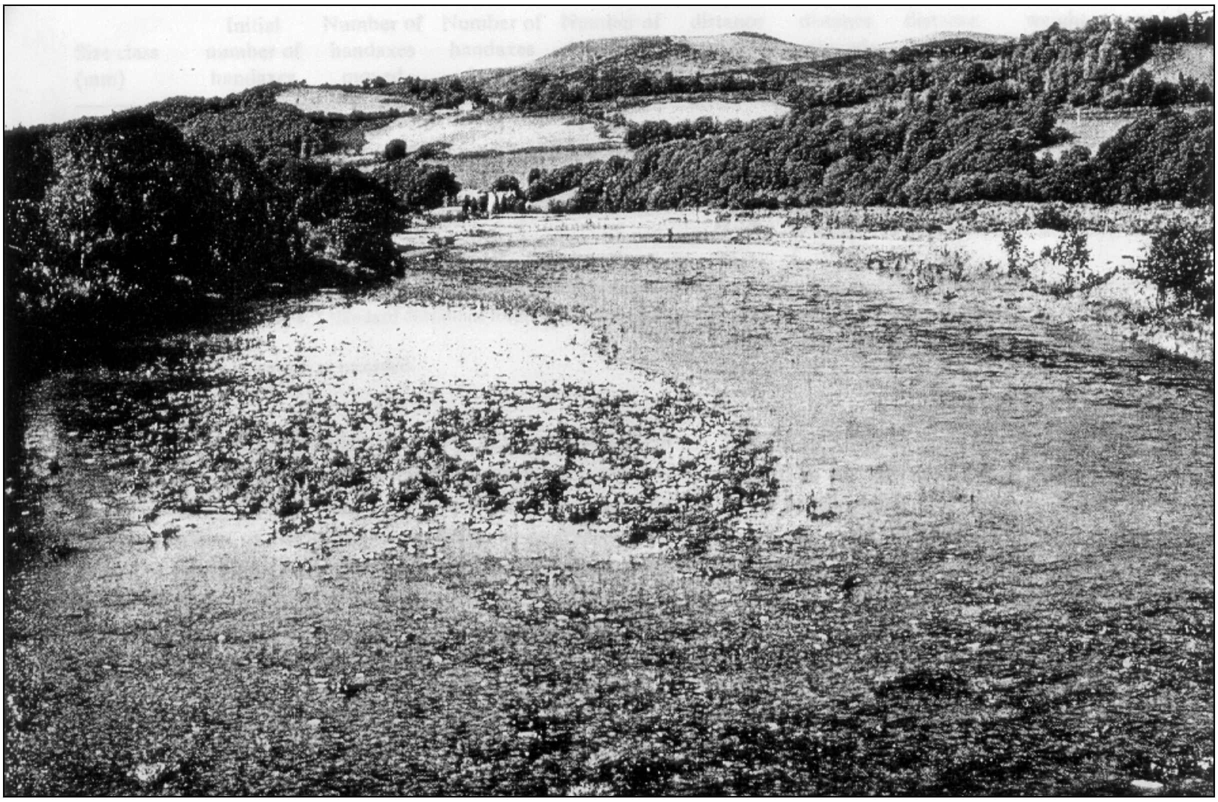

Figure 171: Afon Ystwyth at Llanilar, c. *1983 (Harding et al. 1987: Figure 1)*

Figure 172: Afon Ystwyth at Llanilar, January 2001

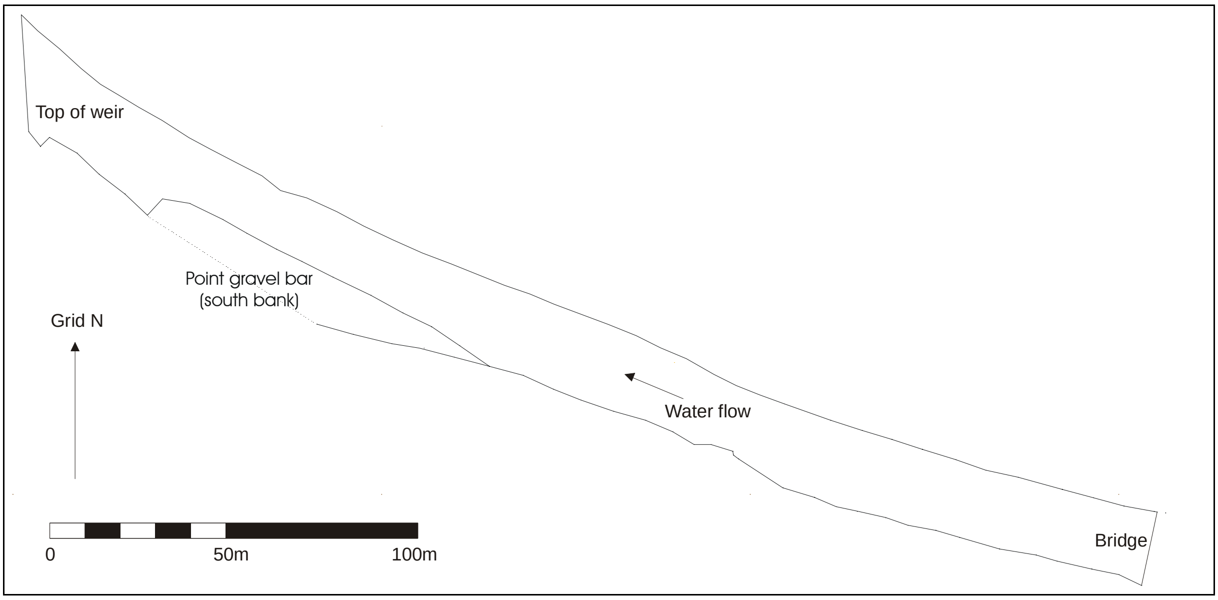

Figure 173: Llanilar study site at the time of current experiments (2000–-2003)

Figure 174: Afon Ystwyth at Llanilar, July 2003. Note the low river levels and the exposed point and midstream bars.

In general, the Afon Ystwyth sandy gravel clasts fall into the *c.* 16–32 mm median grain size category, although material up to 0.40m diameter has been observed to move during floods. Finer sedimentary units exist as bar tail deposits, as discontinuous sand bodies on bar tops, and on the floodplain surface. The gravels are predominantly derived from local Palaeozoic shales and gritstones, with a high proportion of disc- and blade-shaped clasts (Harding *et al.* 1987: 116).

There are clearly marked contrasts between the experimental conditions and those that prevailed during certain (if not all of the) periods of the Middle Pleistocene. Harding *et al.* (1987: 116) emphasised the following:

- The steepness of the gradient at the Llanilar study site (4m km^{-1}). It is recognised here that this contrasts markedly with the gradients of lowland river systems (e.g. the lower reaches of the Thames, Solent and Bytham rivers).
- The size and discharge of the Afon Ystwyth are different to those of the larger Middle Pleistocene systems (e.g. Thames, Solent and Bytham rivers).
- The bed material lithology is different. This is recognised here as an important factor. However, the key concern here is with the patterns and associations of abrasion development (e.g. the association of different patterns of abrasion with different transportation regimes — see chapter 4), rather than specific rates of abrasion development (*c.f.* Hosfield 1999). Along with issues of step lengths, it is suggested that the variations in bed material lithology (and the production of artefacts in exotic raw materials) are not of great significance.
- The storm-rainfall dominated river regime is different. We recognise the validity of this statement, but do raise issue with its relevance, given the immense time depth of the Middle Pleistocene and the potential for an almost infinite variety of river regimes to have existed at different periods.

In general, we follow Harding *et al.* (1987) with respect to the suitability of the Afon Ystwyth for the experimental programme reported here:

"This actively developing coarse-sediment reach does provide an accessible natural gravel-river environment where the movement and modification of bifaces can be observed, taking place alongside the transport of appropriately sized natural materials in an eroding and depositing river."

(Harding *et al.* 1987: 116)

21 individual experiments were undertaken between September 2000 and July 2003. These can be summarised as follows:

- Biface tracer experiments (Llanilar). Replica bifaces were emplaced across the Afon Ystwyth channel and recovered (where possible) after entrainment.
- Biface tracer experiments (Llanafan, Grogwynian Reach). Replica bifaces were emplaced on the vegetated floodplain, point bars and midstream bars and recovered (where possible) after transportation and/or modification by aerial and sub-aerial processes.
- Flake tracer experiments (Llanafan). Replica flake scatters (both knapped *in situ* and pre-knapped) were emplaced on the vegetated floodplain and point bars and recovered (where possible) after transportation and/or modification by aerial and sub-aerial processes.

Figure 175: view south across the Afon Ystwyth at Llanafan (Grogwynian Reach), January 2002. Note the extensive point bar on the north bank of the meander bend (the photograph is taken from the north) and the midstream bar at the upstream end of the visible channel (flow is to the west).

Figure 176: view south across the Afon Ystwyth at Llanafan (Grogwynian Reach), July 2003. Note that the low water levels and the transformation of the midstream bar in Figure 175 into a point bar on the southern bank (the photograph is taken from the north).

Figure 177: bank erosion at Llanafan (Grogwynian Reach), July 2003

4.1 Biface tracer experiments

Bifaces were emplaced at both sites, to pursue contrasting experimental goals:

- Llanilar biface tracer experiments. Bifaces were emplaced with the primary objective of studying the development of physical abrasion characteristics (arête widths, micro-flaking and percussion cones) in relation to the distances over which the artefacts were transported. Step length data was therefore a key secondary objective of the experiments. Bifaces were recorded prior to emplacement, with recorded data including morphology, technology and physical condition. Bifaces were emplaced either as new surface clasts (surface method) or by replacing an existing clast of comparable dimensions (replacement method), following the principle of scaling the tracer to the median of the bed-load (Church & Hassan 1992). A combination of the surface and replacement methods were employed to investigate the claims of: Church & Hassan (1992), that the probability of particle movement for exposed clasts is inversely related to its size; and of Malmaeus & Hassan (2002), that elevated particles are likely to start moving before embedded ones. Unfortunately, at the current time the recovered sample size has been too small to assess the model of Malmaeus & Hassan (2002).

All artefact positions were surveyed and the orientation and dip of the bifaces was recorded. A total of 49 bifaces were emplaced at the site (20 in January 2001, 5 in January 2002, 14 in December 2002 and 10 in March 2002). The Afon Ystwyth was prospected for transported bifaces in March, June, August and October 2002, and March and July 2003. At the time of writing, 10 (20.4%) have been recovered. This recovery rate compares poorly with the 45% achieved by Harding *et al.* (1987), although the Foot and Mouth epidemic in 2001 restricted access to the study site between January and December 2001, a period when up to 20 bifaces may have been available for recovery.

- Llanafan (Grogwynian Reach) biface tracer experiments. Bifaces were emplaced with the primary objective of studying the tendency of bifaces for entrainment and transportation or *in situ* burial. Biface morphology, technology and physical condition were recorded prior to emplacement, as with the Llanilar samples. The artefacts were emplaced either as new surface clasts or as replacement clasts, and their positions were surveyed. The orientation and dip of the bifaces was recorded. A total of 34 bifaces were emplaced at two sites. The first site was an area of semi-stable floodplain, consisting of exposed riverine sediment (including point bars) and vegetated floodplain. 25 bifaces were emplaced at this site (8 in September 2000, 16 in December 2001 and 1 in April 2002). The second site was a point/ midstream bar (depending on river water levels), lying at the eastern (upstream) end of the study site. 9 bifaces were emplaced at this site in June 2002. The floodplain was prospected for bifaces in January and December 2001, January, March, April, June, August, October and December 2002, and March and July 2003. At the time of writing, 10 (29.4%) have been recovered. This ratio compares favourably with that from Llanilar, but it is stressed that 6 of these bifaces had not been subject to any fluvial transportation.

In the discussion of the experiments at Llanilar and Llanafan, Afon Ystwyth flow and discharge rates are not highlighted here. It is emphasised that as associations between tracer transport episodes and individual high flow events could not be demonstrated (partially due to the recording intervals), specific discharge data was of limited importance. Furthermore, such data represent a process variable which cannot be determined with respect to Palaeolithic secondary context assemblages.

4.1.1 Llanilar Results

The 10 recovered bifaces were transported a range of distances, between 0.21m and 326.88m (Table 43). There was no clear relationship between size (using weight as a size index) and distance transported, although the general trend was towards a positive rather than a negative relationship ($r^2 = 0.3147$; $r=0.56$). This is supported by Einstein (1942) and Church & Hassan (1992), who also argued that there was no clear relationship between clast size and transport distances. The current Llanilar experimental results contrasted with Harding *et al.* (1987: 117) who argued for a significant negative relationship between distances transported and the biface length and weight, using stepwise multiple regression. We suggest that these data should be treated cautiously however, since they are heavily dependent upon the vagaries of artefact recovery, and the number and severity of flooding events associated with each entrainment period.

Biface #	Weight (g)	Emplacement Date	Recovery Date	Linear Distance (m)
6	567	22/01/2002	30/03/2002	137.70
7	332	22/01/2002	30/03/2002	0.40
19	502	19/01/2001	07/06/2002	326.88
18	638	22/01/2002	03/10/2002	131.76
95	473	14/12/2002	15/03/2003	194.97
27	279	14/03/2003	13/07/2003	0.21
29	189	14/03/2003	13/07/2003	0.46
30	546	14/03/2003	13/07/2003	6.51
35	298	14/03/2003	13/07/2003	6.78
36	406	14/03/2003	13/07/2003	0.31

Table 43: biface transport distances and weight data (Llanilar site)

However, it is notable that bifaces 6 and 7 were both emplaced (January 2002, using the clast replacement method) and recovered (March 2002) at the same time, and yet showed markedly different transportation histories. Biface 6 was transported 137.70m, while biface 7 moved just 0.40m downstream from its point of emplacement. Biface 7 had been buried by other transported clasts (Figure 178) and underwent minimal transport. It is impossible to assess whether it may have been entrained during subsequent flood events, although the data indicates the potential for material to be buried *in situ* — in other words, material is not inevitably transported shortly after entry into the system. In this respect, the current study supported by the comments of Harding *et al.* (1987):

"The axes behave in the same way as the local mobile sediment: if placed on an active gravel bar they may move and become buried, but if placed in slacker water they will not. In an environment of dynamic bedforms, transport is an episodic process involving a phase of movement, and then a prolonged phase of burial which be followed by renewed transport if those sediments are re-eroded again."

(Harding *et al.* 1987: 118)

Bifaces 6 and 7 therefore demonstrate the observations of Malmaeus & Hassan (2002) that:

"Given the complexity of bedload movement in gravel-bed rivers, the movement of individual particles appears to be a statistically random phenomenon."

(Malmaeus & Hassan 2002: 95)

With respect to biface burial, it is possible that a significant proportion of the unrecovered bifaces are currently buried within the experimental site. This is based partly on the evidence for biface burial (both at the Llanilar and Llanafan sites) and localised armoring development on the channel bed at Llanilar (Figure 179), but also by the absence of any evidence for bifaces accumulating at the downstream end of the experimental site. In such circumstances, the evidence would suggest that burial rather than river bed exposure and/or transportation is the predominant state for the experimental biface (following the conclusions of Harding *et al.* (1987) and the observations of Malmaeus & Hassan (2002). However, it is stressed that this conclusion is tentative, and that the removal of the unrecovered bifaces from the system (either through human interference or extremely high energy flooding events that transported the bifaces past the weir) should not be discounted.

The condition of the artefacts after transportation highlighted some interesting contrasts with the laboratory experiments of Chambers (in prep.). The transported bifaces displayed evidence of abrasion development, although the quantities of arête abrasion tended to be lower than the modelled quantities generated by Chambers' laboratory experiments for the demonstrated transported distances (Table 44). It is suggested that this contrast may reflect the presence of fluvial silt and algae growth on the biface surfaces and on the surrounding clasts within the channel. The growth of algae on the bifaces tended to occur rapidly (within 2 months of the emplacement of the bifaces within the channel during the spring of 2002) and it is suggested that these coverings (on both the clasts and the bifaces) may have reduced the impact of clast collisions and other mechanisms of abrasion development (particularly edge micro-flaking). There was no evidence of micro-flaking development on the biface edges (except for that relating to the original manufacturing processes). However, it is also stressed that other factors (e.g. contrasting flow velocities and suspended transportation) are probably of significance with respect to the differing abrasion development patterns seen in the field and these laboratory specimens.

By contrast however, the bifaces subjected to minimal movement (bifaces 7, 27, 29, 30, 35 and 36) all displayed greater quantities of arête abrasion than the modelled values generated in Chambers' laboratory experiments for the demonstrated (non-) transport distances. Combined with the evidence for localised *in situ* burial (e.g. biface 7), these bifaces are probably demonstrating the effects of abrasion damage sustained either during the process of burial or through bombardment to exposed surfaces by mobile particles, during episodes of partial burial. However, it should be stressed that issues of data accuracy do exist when recording arête widths < 0.1mm, and indeed that the majority of archaeological bifaces occurring in secondary contexts display arête abrasion values in excess of this threshold.

Figure 178: biface #7, Afon Ystwyth, Llanilar site (March 2002)

Biface #	Distance (linear (m)	Min. arête width (mm)	Max. arête width (mm)	Transport regime	Modelled distance (m)
6	137.70	0.03	0.09	Saltation	125-150
7	0.40	0.02	0.08	Saltation	100-125
18	131.76	0.03	0.10	Saltation	150
19	326.88	0.03	0.10	Saltation	125-150
27	0.12	0.01	0.06	Saltation	100
29	0.46	0.01	0.03	Saltation	30-40
30	6.51	0.01	0.08	Saltation	80
35	6.78	0.01	0.03	Saltation	40
36	0.31	0.04	0.2	Saltation	100-125
95	194.97	0.01	0.05	Saltation	90-100

Table 44: biface abrasion (field experiment data from Llanilar and laboratory flume data (Chambers in prep.)

Incipient cones of percussion, the result of direct impacts with other lithic materials (probably caused by artefact-clast collisions) were prominent on bifaces 6 and 19, and were present to a smaller extent on bifaces 95 and 18. They were not present on bifaces 7, 27, 29, 30 and 35. Biface 36 did not display any evidence of incipient percussion cones. However, given its manufacture in coarse-grained chert, the detection of these features would only be possible in the most extreme cases. Within fluvial environments, incipient cones of percussion may be regarded as being the result of either a mobile biface impacting upon the stationary bed clasts, or alternatively these cones may occur as the biface is stationery and struck by smaller (and therefore mobile) particles. The restriction of incipient percussion cones to the Llanilar bifaces transported over 100m may suggest however that their development is more commonly associated with active transport.

In general, the key conclusions from the Llanilar biface experiments are as follows:

- Bifaces have a tendency for both *in situ* burial and transportation.
- The tendency of an individual biface for burial or transportation relates not only to flow velocity (i.e. flood magnitude) but also to the local river bed morphology, as highlighted by Malmaeus & Hassan (2002), Hassan & Church (2002) and Hunziker & Jaeggi (2002). The potential for archaeological material to behave as clasts was also illustrated by Harding *et al.* (1987) during the earlier archaeological tracer experiments on the Afon Ystwyth.

- Bifaces may be subject to abrasion development while in phases of partial burial, as well as during periods of active transportation.
- The development of diagnostic transport features (e.g. edge micro-flaking and incipient percussion cones) may be hindered in fluvial environments with a significant vegetation (algae) component.

Figure 179: channel armoring at the Llanilar site. The coarse clast armor layer has been removed from the centre of the photograph during the recovery of biface #7 (compare with Figure 178).

4.1.2 Llanafan Results

12 bifaces were recovered from Llanafan, of which 6 showed no evidence of fluvial transportation. There was also no supporting evidence for fluvial activity (e.g. local clast orientations, silt[3] introduction or vegetation modification and/or transportation) within their vicinity. These bifaces (numbers 60, 62, 64, 69, 70 and 71) are therefore excluded from the following discussion.

The 6 entrained bifaces were transported a range of distances, between 2.42m and 35.67m (Table 45). There was no clear relationship between size (using weight as a size index) and distance transported, following Einstein (1942) and Church & Hassan (1992), although the general trend was towards a negative relationship ($r^2 = 0.3138$; $r = -0.56$). This partially supported Harding *et al.* (1987: 117) who argued for a significant negative relationship between distances transported and the biface long (A) axis and weight, using stepwise multiple regression (although this was based on work at the Llanilar site). We again suggest that these data should be treated cautiously however, since they are heavily dependent upon the vagaries of artefact recovery, and the number and severity of flooding events associated with each entrainment period.

[3] There is a wide range of fine-grained sediment types present on the Afon Ystwyth floodplain. These include silts, fine and coarse-grained sands, and fine granules. 'Silt' is employed in this report as a generic term for this material, although it is not being used *sensu stricto*.

The transportation distances appear to demonstrate relatively short step lengths (e.g. a *maximum* of 19.41m for biface 6[4]), although it is possible that some or all of the unrecovered bifaces were transported over much longer distances and would therefore have demonstrated longer and/or higher frequency step lengths had they been recorded. With respect to the recovered bifaces, these apparently short step lengths may be due to the absence of armoring on the gravel bar sites, which increases the potential for sediment re-working, burial of clasts (and artefacts), and the disruption of transport through local clasts traps.

Biface #	Weight (g)	Emplacement Date	Recovery Date	Linear Distance (m)
6	567	29/09/2000	19/01/2001	19.41
14	921	29/09/2000	19/01/2001	2.42
65	651	30/11/2001	15/07/2003	33.36
72	805	30/03/2002	14/12/2002	11.39
74	416	30/03/2002	14/12/2002	6.83
76	274	30/03/2002	15/03/2003	35.67

Table 45: biface transport distances and weight data (Llanafan site)

It is possible that a significant proportion of the unrecovered bifaces are currently buried within the experimental site. This is based partly on the evidence for biface burial at the Llanilar site, but also from bifaces 65 and 68 at the Llanafan site. Biface 65 was emplaced in November 2001, and was not relocated for 20 months despite site survey at two monthly periods over this interval. During this period there was substantial evidence for bar form modification and sediment transport (Figure 180), and it was presumed that the biface had probably been buried. The biface was recovered in July 2003 (Figure 183), *c.* 30m downstream in a small overflow channel on the floodplain. The relatively small transport distance makes it unlikely that the artefact had been exposed to surface movement throughout the 20 months (which included 2 winter flood seasons) and therefore indicates the potential for substantial periods of burial and the re-erosion of artefacts in response to the local dynamics of sediment transport.

Biface 68 was emplaced in November 2001, adjacent to scatter 4 (see below), and was regularly re-identified until March 2003. The biface was not transported but it gradually became covered by the surrounding silt sediments. It was unclear whether this was caused by the introduction of silt material into the vicinity or due to the effect of gravity and the weight of the biface (Figure 181–Figure 182). Ultimately the biface was completely buried between March and July 2003, and has yet to be re-located. Although the circumstances of burial were specific, it is argued that similar processes may occur in other fine-grained sediment environments (e.g. bar tail deposits and discontinuous sand bodies on bar tops, as well as floodplain surfaces).

The condition of the artefacts after transportation highlighted some interesting contrasts with the laboratory experiments of Chambers (in prep.). The transported bifaces displayed evidence of abrasion development, although the quantities of arête abrasion were greater than the modelled quantities generated by Chambers' laboratory experiments for the demonstrated transported distances (Table 46). There was evidence of transport-related micro-flaking development on the edges of biface 72, although in general it is absent. Incipient cones of percussion were present on the dorsal and ventral surfaces of bifaces 72, 74 and 76. In contrast with the Llanilar data, incipient percussion cones are present on bifaces transported over sub-100m distances, suggesting that they may also develop during non-mobile phases of fluvial entrainment. Combined with the evidence for localised *in situ* burial and interaction with local, mobile bed-load (e.g. biface 65, 72 and 74), all of these bifaces are probably demonstrating the effects of damage sustained either during the process of burial or through bombardment to exposed surfaces by mobile particles, during episodes of partial burial (Figure 184 & Figure 185). However, it should again be stressed that issues of data accuracy do exist when recording arête widths < 0.1mm, and indeed that the

[4] Potentially, biface 6 could have been transported over multiple phases — e.g. 3 step lengths of *c.* 6.4m each, although this could not be demonstrated due to the nature of the experimental equipment.

majority of archaeological bifaces occurring in secondary contexts display arête abrasion values in excess of this threshold.

Figure 180: floodplain overflow channel, Llanilar, Afon Ystwyth (January 2002). Note the transported sediment and vegetation flotsam and jetsam.

Biface #	**Distance (linear (m)**	**Min. arête width (mm)**	**Max. arête width (mm)**	**Transport regime**	**Modelled distance (m)**
6	19.41	0.02	0.04	Saltation	80
14	2.42	0.02	0.04	Saltation	70
65	33.36	0.01	0.08	Saltation	90-100
72	11.39	0.03	0.20	Saltation	125-150
74	6.83	0.03	0.20	Saltation	175
76	35.67	0.03	0.10	Saltation	125-150

Table 46: biface abrasion (field experiment data from Llanafan and laboratory flume data (Chambers in prep.)

In general, the key conclusions from the Llanafan biface experiments are as follows:

- Bifaces have a tendency for both *in situ* burial and transportation.
- Bifaces demonstrated potential for burial within fine-grained floodplain and bar form sediments.
- Transportation distances (and therefore step lengths) tend to be relatively short (this assumes that the majority of unrecovered bifaces were buried rather than transported downstream of the study area).
- Bifaces may be subject to abrasion development and related damage while in phases of partial burial, as well as during periods of active transportation.
- The development of incipient percussion cones may occur over short distances.

Figure 181: biface #68, emplaced at Llanafan, Afon Ystwyth (November 2001)

Figure 182: biface #68, becoming buried in fine-grained silt sediments, Llanafan, Afon Ystwyth (December 2002)

Figure 183: biface #65, recovered in July 2003, Llanafan, Afon Ystwyth

Figure 184: biface #72, Llanafan, Afon Ystwyth (October 2002)

Figure 185: biface #74, Llanafan, Afon Ystwyth (December 2002)

4.2 Flake tracer experiments

Flake scatters were emplaced at the Llanafan (Grogwynian Reach) site, to explore the transformation of flake materials as a consequence of fluvial disturbance and other aerial and sub-aerial processes. A total of 13 scatters were emplaced, of which 4 were knapped *in situ*, and 9 were pre-knapped and emplaced to mimic the spatial density of a scatter knapped *in situ*. Scatters were pre-knapped as it enabled the recording of flake weight and the a, b and c-axes. It also facilitated material identification and recovery. As the main focus of the experiments was flake movement, it was considered to be more important to record accurate size data than to create 'authentic' knapping scatters. Two flake dimensions (the a and b-axes) were recorded for the *in situ* knapped scatters. The orientation and dip of all flakes were recorded after the scatters were emplaced. 3 scatters were emplaced at Llanafan site two (the point/midstream bar at the upstream (eastern) end of the site), with the remaining 10 scatters emplaced at Llanafan site one (the semi-stable floodplain). The floodplain was prospected for flakes in January and December 2001, January, March, April, June, August, October and December 2002, and March and July 2003. Flakes were recovered from 11 of the scatters, with two scatters providing no returns (Table 47). Two scatters were fully re-excavated (scatter 3 was excavated in April 2002 and scatter 4 was excavated in July 2003).

4.2.1 Results

The results from the flake experiments are only summarised here, reflecting the quantity of data generated by the flake experiments. The most informative data on flake transport was recorded from scatters 7, 8, 10, 11 and 12. In all of these cases, there was no clear relationship between flake size (using weight as an index of size) and distance transported (illustrated here for scatters 12 in Figure 186; Einstein 1942; Church & Hassan 1992). However, it has been argued that clast dimensions and shapes rather than weight are a more significant factor with respect to transport distances (Wilcock 1997). It is notable however that there is also no evidence for a clear relationship (either positive or negative) between flake size (using a-axis x b-axis area as an index of size) and distance transported, illustrated again for scatter 12 (Figure 187). It is therefore argued that trends within the size class distribution of flake material (e.g. the predominance of small or large artefacts), cannot be taken as an indicator of the relative proximity (or not) of the artefact source(s) to the secondary context assemblage.

Scatter	Material recovered?	Emplacement	1st recovery	2nd recovery	3rd recovery
1	Yes	September 2000	January 2001	November 2001	April 2002
2	Yes[5]	September 2000	-	-	-
3	Yes	November 2001	March 2002	April 2002 (excavation)	-
4	Yes	November 2001	July 2003 (excavation)	-	-
5	No	January 2002	-	-	-
6	Yes	April 2002	June 2002	August 2002	October 2002
7	Yes	June 2002	October 2002	-	-
8	Yes	June 2002	August 2002	October 2002	-
9	Yes	June 2002	October 2002	-	-
10	Yes	August 2002	October 2002	-	-
11	Yes	August 2002	October 2002	December 2002	March 2003
12	Yes	August 2002	October 2002	December 2002	March 2003
13	No	October 2002	-	-	-

Table 47: flake scatter emplacement and recovery, Llanafan, Afon Ystwyth

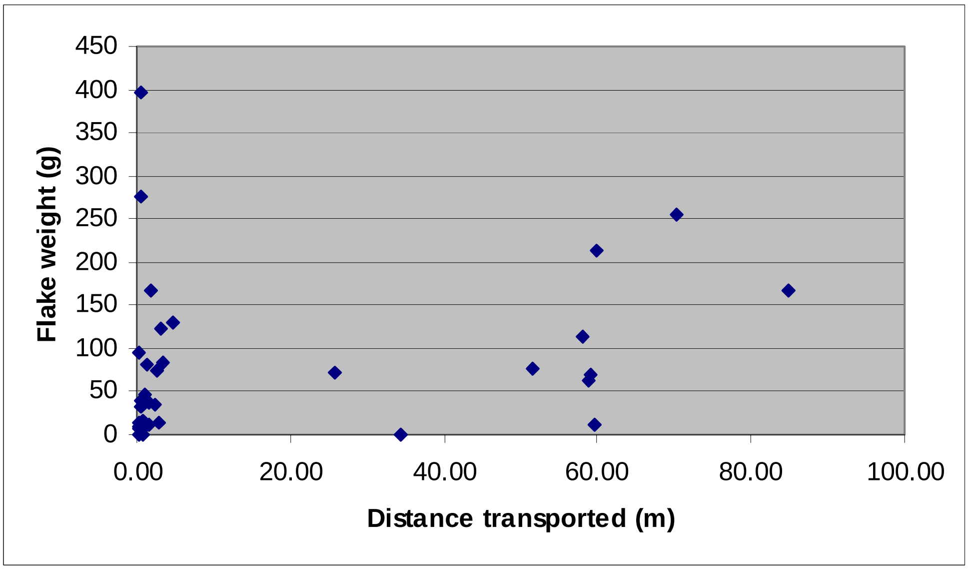

Figure 186: flake transport distances (August 2002/March 2003) vs flake weight (Scatter #12)

Flakes have been transported over a wide range of distances (Table 48), and it is apparent from flake scatters 11 and 12 that flakes survive transportation over a *minimum* of 80m with little or no evidence of substantial damage. Breakages tended to be minor (Figure 188), although it is suggested that more substantial breakages may occur over longer transportation phases. However, there was evidence of micro-flaking on a large proportion of the recovered flakes (Table 49; Figure 189). Chambers' flume research (in prep; Chapter 4) has related the development of micro-flaking to saltation transport, and this suggests that these flakes were probably transported in this manner. However, given the poor current understanding of suspended load transport (Muste 2002), this is a preliminary conclusion and it highlights the need for future modelling of flake transportation.

Most of the micro-flaking scars displayed on the transported flakes are small (sub-5 mm in all dimensions) and it is therefore highly unlikely that these micro-flakes would be recovered archaeologically. However, in

[5] Scatter 2 was not fluvially displaced throughout the period of the experiments and has been left *in situ* to explore longer-term processes of bioturbation and aeolian winnowing upon flake material.

those circumstances where such flakes were recovered from secondary context fluvial sediments, their presence should not be taken as an automatic indicator for *in situ* knapping activity.

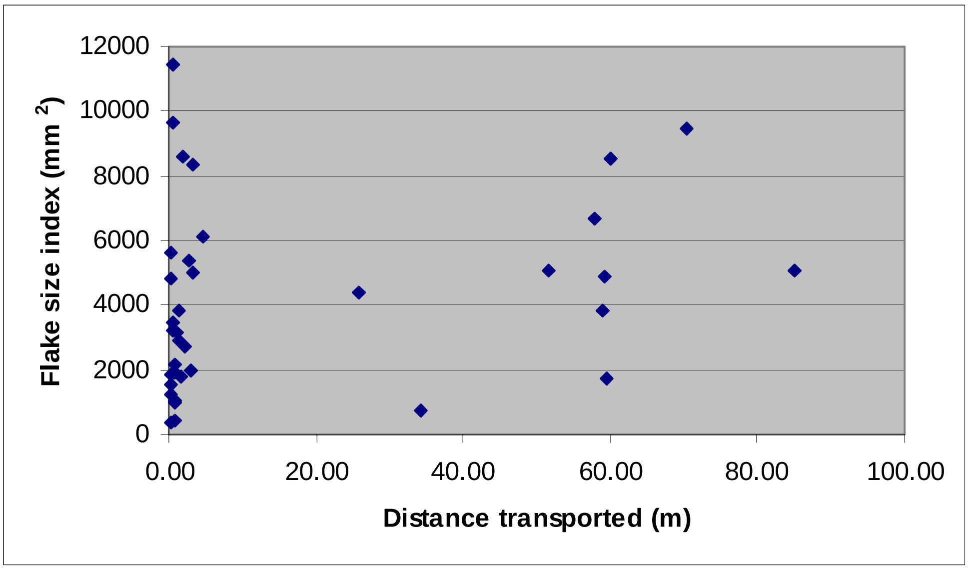

Figure 187: flake transport distances (August 2002/March 2003) vs flake size index (Scatter #12)

In some instances (Figure 190) the products of edge flaking through transport damage are larger (over 1.5 cm in at least one dimension), highlighting not only the potential for transport to modify the shape of flakes, but also for the products of these modifications to be mistakenly regarded as the results of hominid knapping activity. It should also be noted, that sustained episodes of micro-flaking produce scar patterns on flake edges that are reminiscent of intentional retouch (Figure 191). There is a single example of flake modification resulting in an artefact which could be classified as a flaked flake/notch (Ashton *et al.* 1991; Figure 192A & B).

Scatter	Transport distances (m)	
	Minimum	Maximum
1	0.46	16.33
3	0.15	2.88
6	0.05	34.53
7	0.09	1.57
8	0.48	21.52
10	1.32	29.34
11	0.07	82.34
12	0.14	84.95

Table 48: minimum and maximum flake transport distances, Afon Ystwyth, Llanafan

Scatter	# of flakes recovered	Broken flakes		Micro-flaking	
		n	%	n	%
8	21	3	14%	14	67%
10	26	1	4%	18	69%
11	13	1	8%	11	85%
12	10	2	20%	9	90%

Table 49: micro-flaking and breakage for 4 experimental scatters, Afon Ystwyth, Llanafan

Figure 188: scatter #8, flake #29. Note the small breakage on the top-right corner of the exposed face.

Figure 189: scatter #12, flake #22. Note the micro-flaking along the distal edge.

Figure 190: scatter #11, flake #20. Note the micro-flake scar (approximate dimensions 18 mm x 12 mm).

Figure 191: scatter #12, flake #30. Note the developing micro-flaking scar patterns, which if intensified through further transportation processes could ultimately be suggestive of intentional retouch.

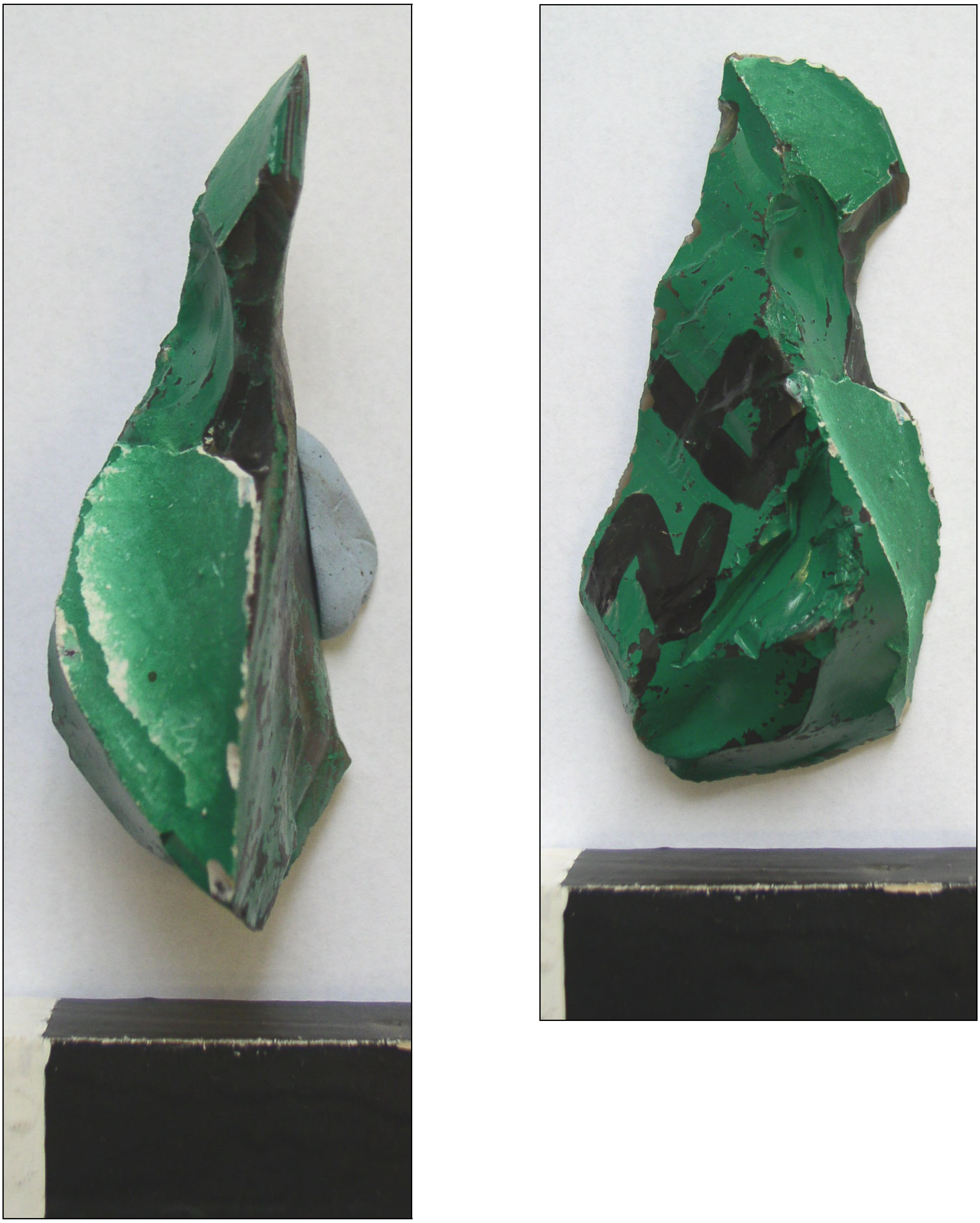

Figure 192A & B: scatter #10, flake #26. Note the 'notch' to the distal right edge.

The recovery of flakes in multiple phases indicated a gradual downstream dispersal of flake material from the original scatters. This is particularly evident for scatters 8, 11 and 12 (e.g. Figure 193 & Figure 194), where the flakes were dispersed less than 5m downstream during the first 2-month experimental period (Figure 193). In contrast, during the subsequent phases flakes were dispersed over much wider areas (Figure 194). Although these patterns could be interpreted through changes in flow velocities and water levels, it is significant that during the period August–October 2002, scatter 8 flakes underwent secondary dispersal over a 20m downstream catchment (scatter 8 flakes were primarily dispersed over an 8m downstream catchment during the period June–August 2002). In contrast, scatter 11 and 12 flakes were primarily dispersed over 2.5m and 5m downstream catchments over the same period (August–October 2002). This suggests that freshly knapped (emplaced) flake scatters display relative structural stability, prior to and during their initial dispersal through fluvial processes. This stability appears to be due to the spatial density of flakes within the scatters, resulting in high levels of flake interaction during entrainment and relatively short transport distances, as suggested by Malmaeus & Hassan (2002) and Hassan & Church (2001). This internal stability may be a partial factor in the high degree of preservation displayed by archaeological material in low energy sedimentary environments such as the Boxgrove beach (Roberts & Parfitt 1988) and the Hoxne lake shore (Singer *et al.* 1993).

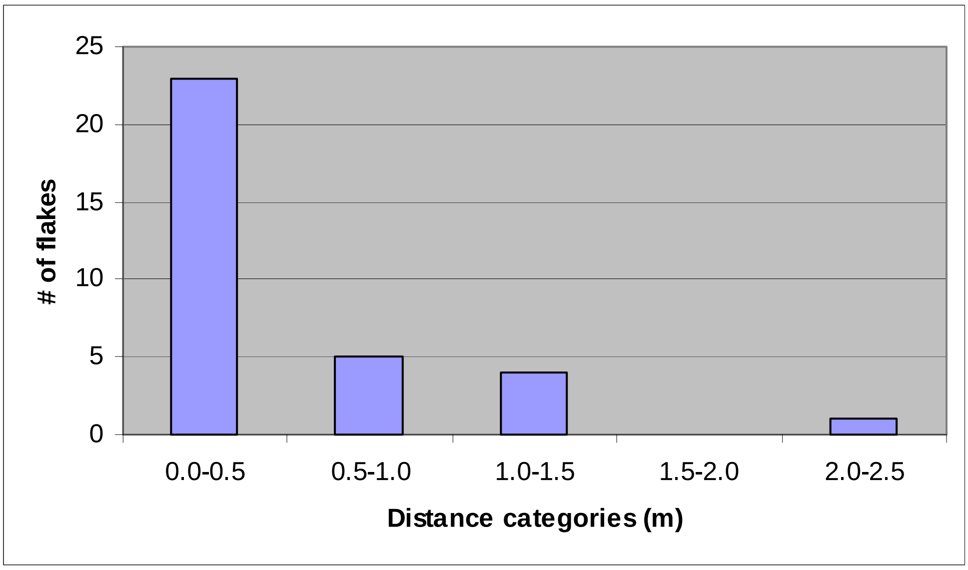

Figure 193: flake transport distances (scatter #11) — August/October 2002 (phase 1)

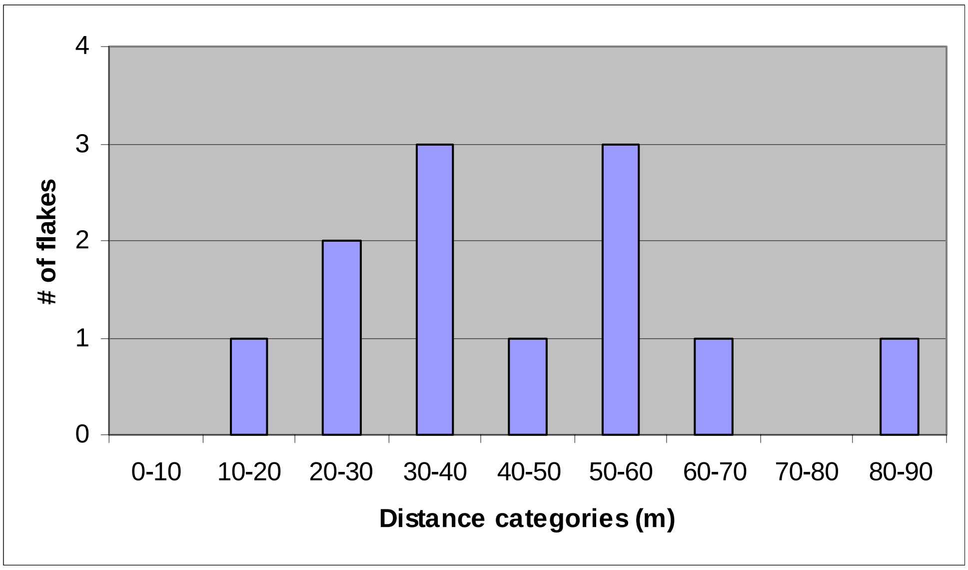

Figure 194: flake transport distances (scatter #11) — October/December 2002 (phase 2)

Overall, these data *suggest* that primary dispersal of flake scatters may be relatively limited, followed by more expansive secondary and tertiary dispersals (although the importance of flow velocities and local variations in gravel bar and channel bed morphologies are not discounted). This model for flake scatter dispersal and transportation indicates that the spatial density of flakes recovered in secondary context sedimentary units may provide an indicator of whether the original scatter has undergone limited or more extensive downstream dispersal.

While there does appear to be a degree of patterning related to phases of dispersal, it was also evident that flake dispersal patterns were influenced by the local morphology of the floodplain (Figure 195). Both smaller and larger flakes were trapped by local clast configurations, both on the submerged channel beds and on gravel bar surfaces, and also by local clusters of vegetation. It is currently difficult to assess whether these trapped flakes tend to be subsequently buried in these traps, or are winnowed out by subsequent flow and transported further downstream. However, the demonstrated tendency for flakes to be dispersed downstream over time suggests that the latter, rather than the former, is the case. In general therefore, while local channel and gravel bar morphology will influence short-term patterns in flake distribution, they will not prevent the widespread downstream dispersal of flake artefacts over the long term.

Figure 195: flake scatter #11, Llanafan, Afon Ystwyth. Note the trapping of small flakes between larger clasts

Scatters 8 and 10, and 11 and 12 were emplaced as pairs to investigate the potential spatial integration of knapped materials from behaviourally-separate episodes. Scatters 11 and 12 were emplaced at the same time (August 2002), while scatters 8 (June 2002) and 10 (August 2002) were separated by a two month period. In the case of scatters 11 and 12, material was spatially differentiated during the initial dispersal phase (Figure 196). However, during the secondary and tertiary dispersal phases, material from the two scatters became fully spatially intermingled (Figure 197).

In the case of scatters 8 and 10, a slightly different distribution pattern was seen. Prior to the emplacement of scatter 10 in August 2002, scatter 8 had already undergone an initial phase of displacement over short distances (Figure 198). Between August and October however, material from both scatters was fully intermingled (Figure 199). The more widespread initial dispersal of scatter 10 (compared to scatter 8) probably reflects seasonal flow variations, combined with its emplacement at the edge of the point bar site (i.e. the role of local topographic factors). In general however, it was clear from both scatter pairs that after initial phases of dispersal, it was not possible to differentiate flake material from separate scatters on the basis of their spatial distribution. This has clear implications for the interpretation of archaeological flake material recovered from secondary contexts, namely that the recovered spatial association of such material cannot be taken as a direct indicator of genuine associations and discrete knapping episodes. These experiments have demonstrated that material from unassociated behavioural episodes can quickly become compressed, and appear to represent the residue from an apparently single phase of knapping activity.

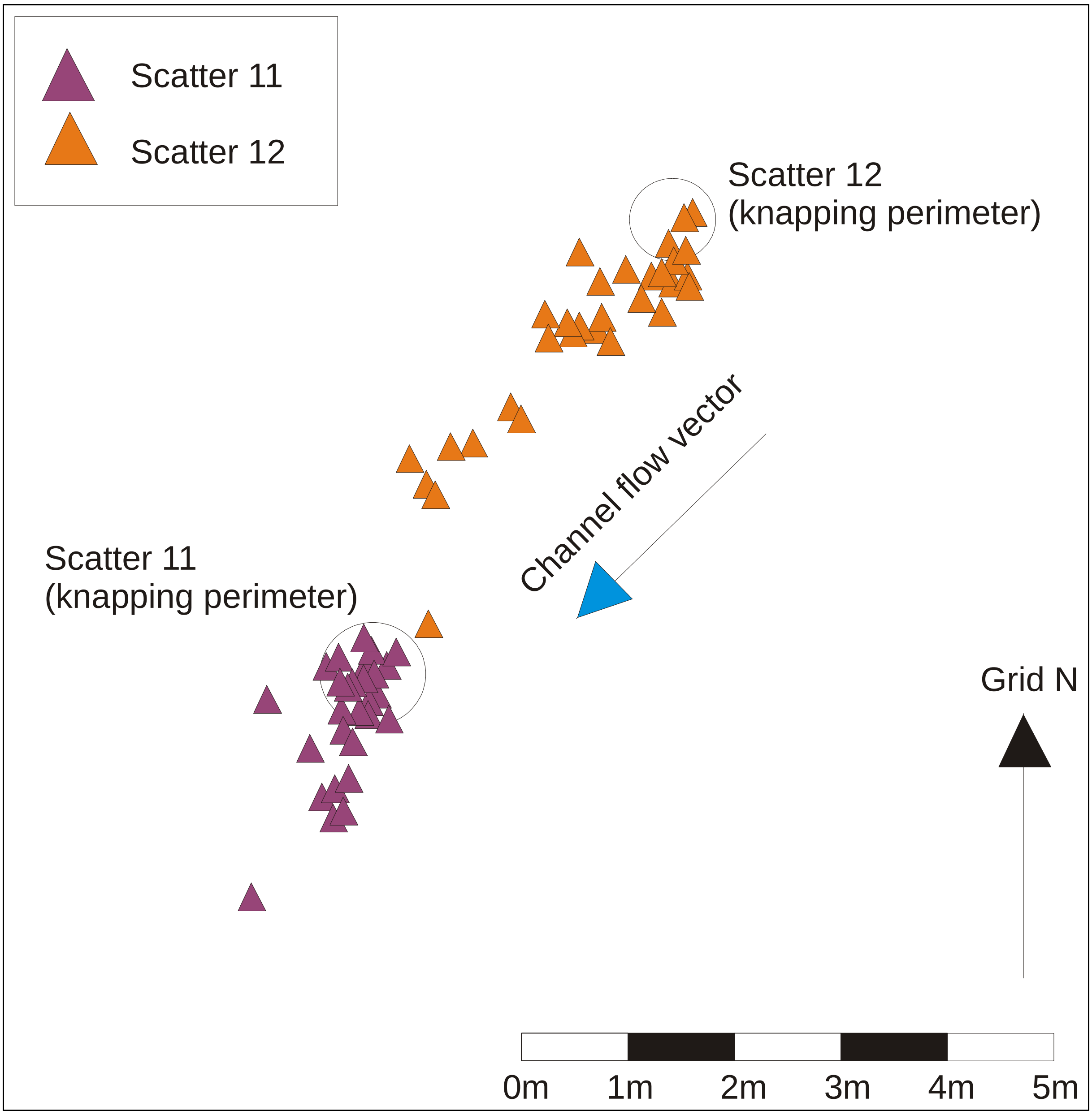

Figure 196: spatial distribution of scatter #11 and #12 flakes after initial fluvial dispersal

Analysis of flake (long axis) orientation after transport episodes indicated only relatively weak diagnostic patterning (e.g. there was relatively weak evidence for primary and secondary orientation axes). This contrasts markedly with the evidence from the clast fabric analysis of the Broom sediments (see Module 2), and may be due to the localised 'trapping' of flakes between larger clasts which results in 'random' long axis orientation patterns.

In a number of cases it was not possible to analyse flake orientation patterns after secondary and tertiary dispersal events, due to the very small sample sizes recovered. These include the secondary and tertiary dispersals of scatter 12 (n=6 and n=4 respectively), and the secondary and tertiary dispersals of scatter 1 (n=6 and n=4 respectively).

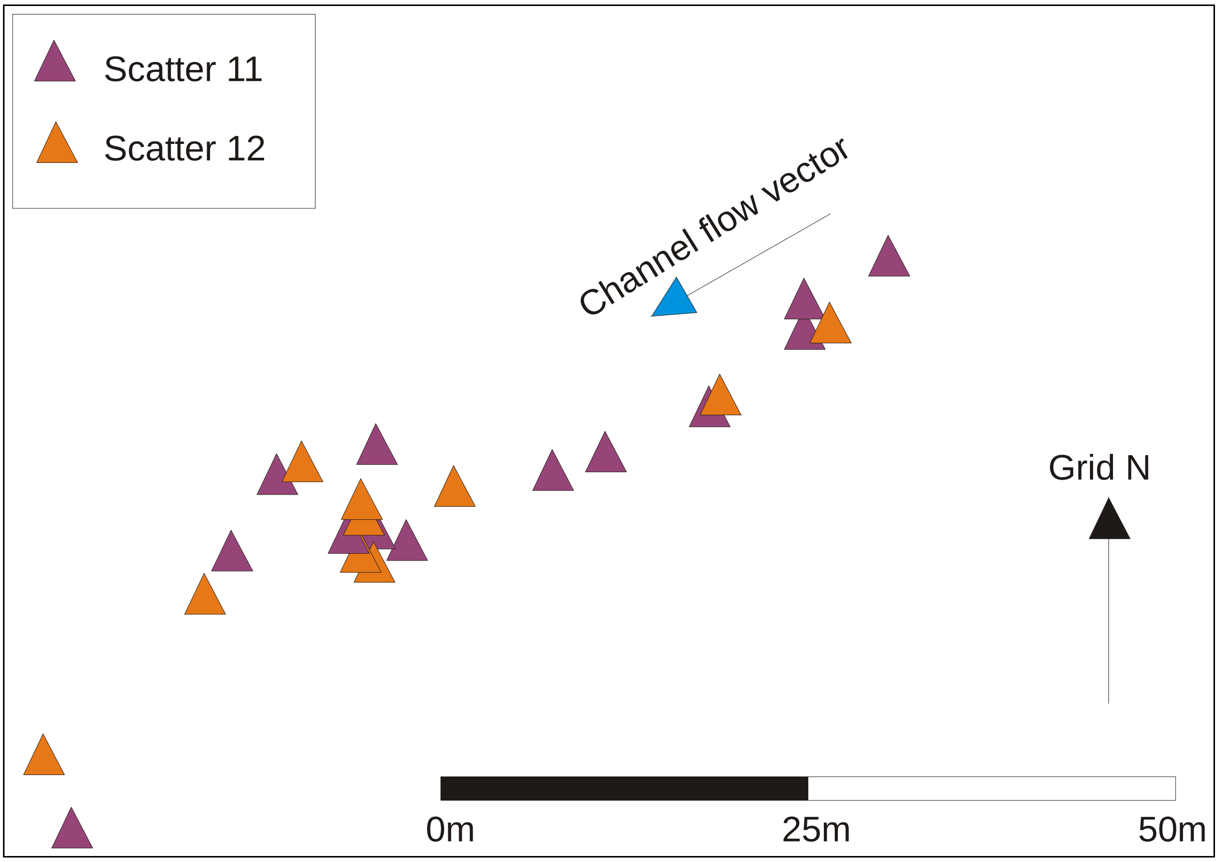

Figure 197: spatial distribution of scatter #11 and #12 flakes after secondary fluvial dispersal

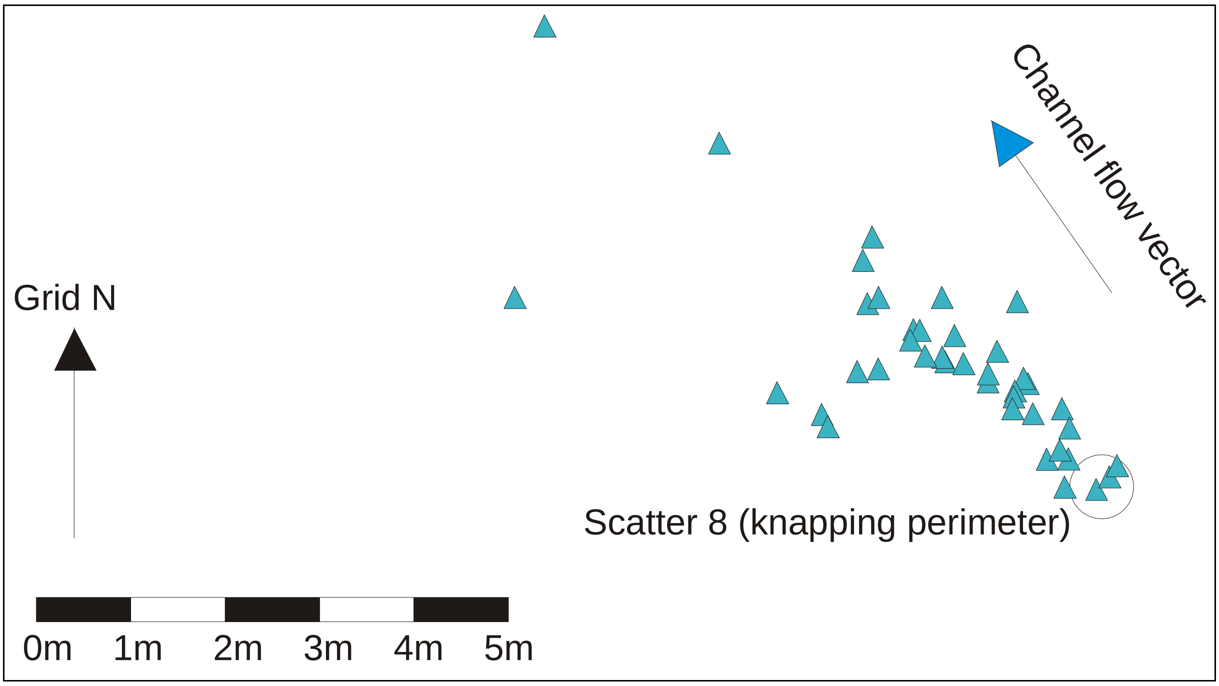

Figure 198: spatial distribution of scatter #8 flakes after primary fluvial dispersal

The primary dispersal of scatter 11 (n=30; Figure 200) suggests a primary axis of NNE–SSW, with a possible E–W secondary axis. However, flake long axes were also distributed in a range of other orientations. The primary and secondary axes show a partial correlation with the local flow vector (233°), suggesting that flake deposition after transport may occur as the long axis is aligned at right angles to flow. Unfortunately, the sample size is too small to sub-divide the sample by clast shape (prolate, oblate, blade and equant) and investigate this issue further (this is the case with all of the transported scatter data reported here). The secondary dispersal of scatter 11 (n=11) shows some similarities with the primary dispersal (Figure 201), with a primary axis of *c.* NE–SW and a secondary axis of WNW–ESE. However, the sample size is too small to place great significance on this data.

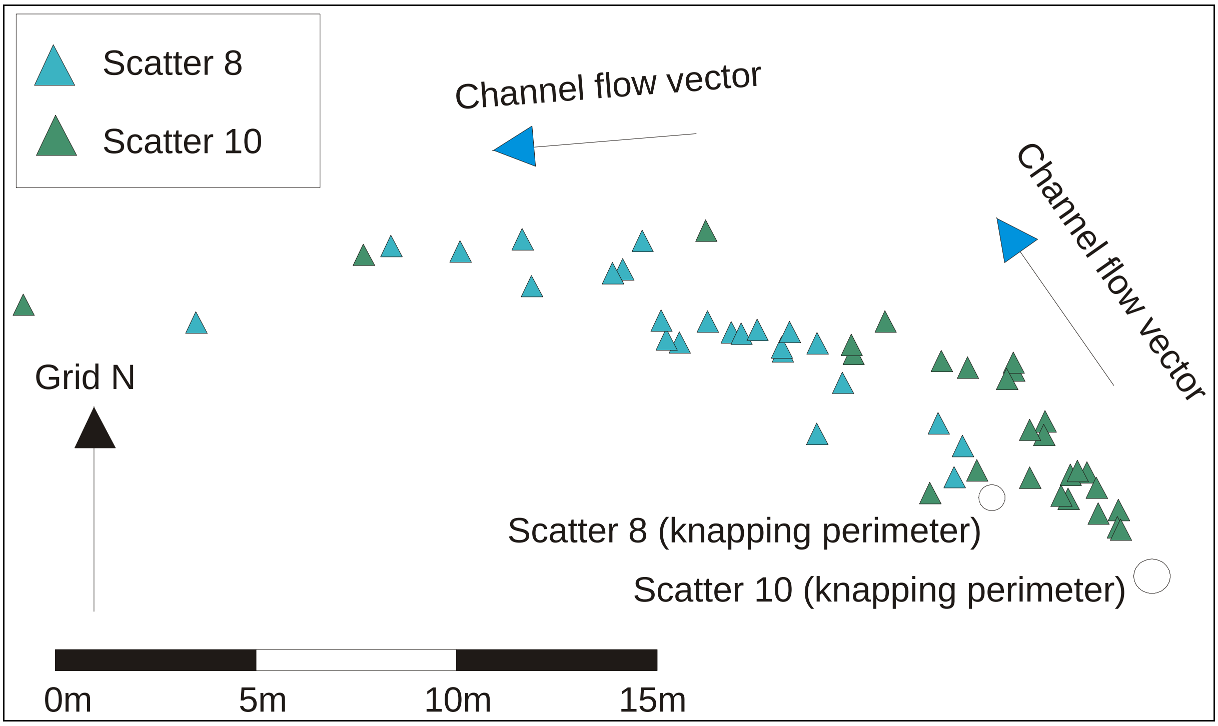

Figure 199: spatial distribution of scatter #8 and #10 flakes after secondary fluvial dispersal

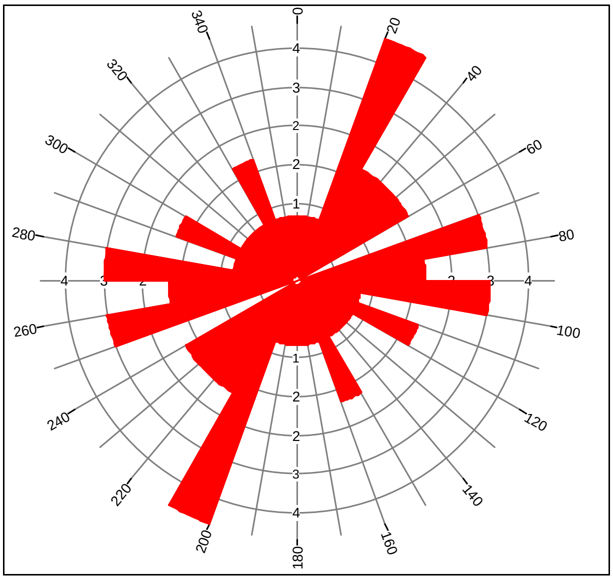

Figure 200: flake orientation (scatter 11, 1st dispersal). N=30.

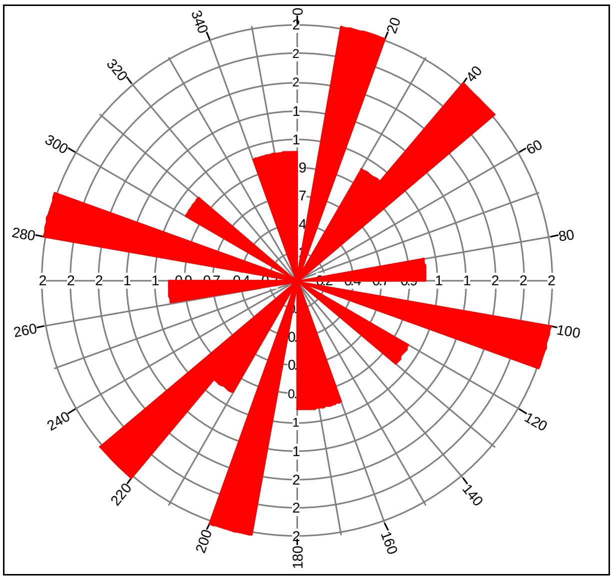

Figure 201: flake orientation (scatter 11, 2nd dispersal). N=11.

The primary dispersal of scatter 12 (n=32) shows no clear patterning with respect to a primary or secondary axis, although a WSW–ENE primary axis and NW–SE secondary axis is suggested (Figure 202). This shows some links with the local flow vector (233°), although in general, the data suggest that the localised trapping of flakes may be an additional major factor in the orientation of transported flakes. This is also the case with the primary dispersal of scatter 10, which shows no clear evidence of a primary or secondary axis.

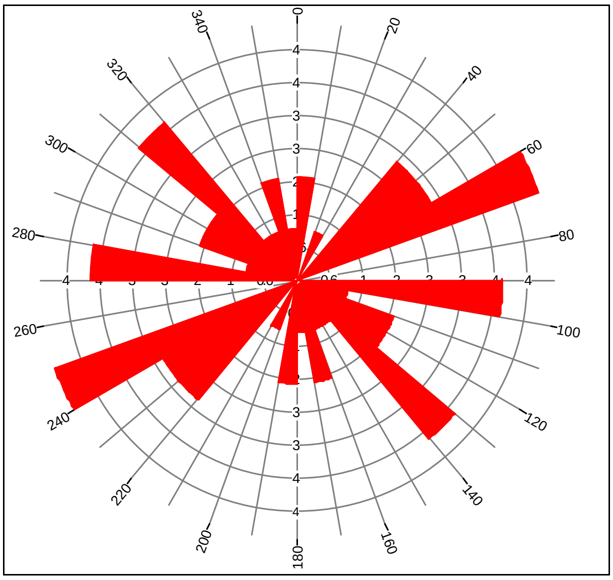

Figure 202: flake orientation (scatter 12, 1st dispersal). N=32.

In contrast, the primary dispersal of scatter 8 (n=38; Figure 203) displayed a clear primary (WSW–ENE) and secondary (NNE–SSW). These data show strong correlation with the local flow vector (339°), suggesting that in this case local flow was an important factor in the orientation of the transported flakes. The secondary dispersal of scatter 8 (n=23; Figure 204) also displayed a clear primary axis (NNE–SSW), although this axis demonstrated no clear association with the local flow vector (339°).

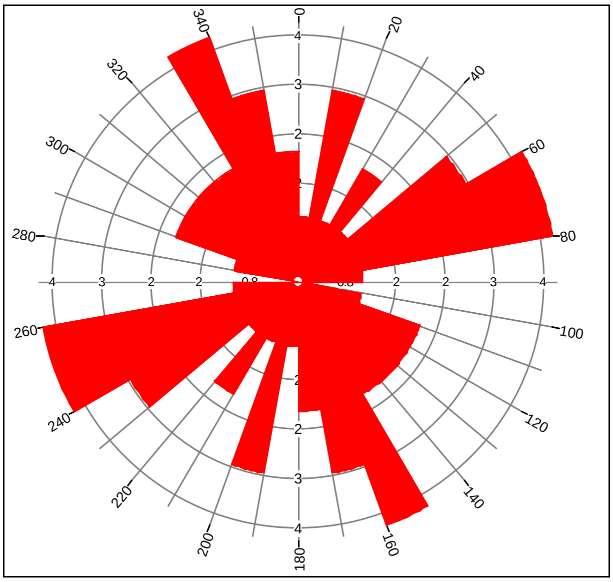

Figure 203: flake orientation (scatter 8, 1st dispersal). N=38.

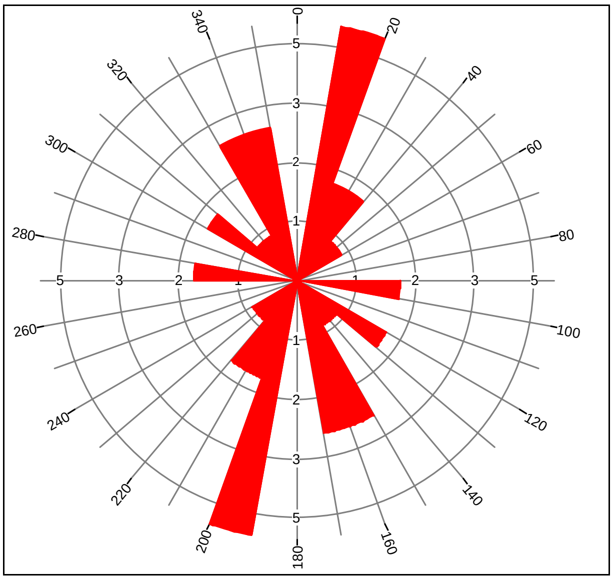

Figure 204: flake orientation (scatter 8, 2nd dispersal). N=23.

In general however, the flake fabric data suggested that flake orientation is not inevitably aligned with respect to local flow conditions, and that local trapping of flakes by larger clasts can play an important role in the alignment of transported artefacts.

Overall, the key conclusions from the Llanafan flake experiments are as follows:

- Flake scatters demonstrate a degree of structural integrity, with flakes being transported short distances (generally sub-10m) in the initial phases of fluvial dispersal.
- However, flakes are transported significant distances during subsequent dispersal phases (demonstrated minimum of 80m).
- Flakes are damaged during transport episodes, but while this damage may modify the specific morphology of individual flakes (see below), it does not modify them beyond the point of recognition as anthropogenic flakes.

- High percentages of the transported flakes display varying degrees of edge micro-flaking. As transportation distances and the quantities of micro-flaking increase, it is suggested that the micro-flaking can increasingly come to resemble intentional retouch.
- Flake material from separate scatters (knapped in relatively close spatial proximity) tends to become spatially indistinguishable during fluvial dispersal.

4.3 Floodplain morphology study

A photographic archive was recorded between May 2000 and July 2003, documenting the evolution of the Afon Ystwyth floodplain at the Llanafan (Grogwynian Reach) site (Figure 205–Figure 214). Specific focus was placed upon the development of floodplain vegetation and bar development at the two sites in Grogwynian Reach. Photographs of these sites are included for May 2000 (Figure 205), January 2001 (Figure 206–Figure 207), November 2001 (Figure 208–Figure 209), December 2002 (Figure 210–Figure 211) and July 2003 (Figure 212–Figure 213). All of the photographs were taken from the north, overlooking the Llanafan site. A photographic archive was not developed for the Llanilar site, as this reach of the Afon Ystwyth has been artificially engineered and discussions of fluvial development will therefore only focus on the Llanafan site (Grogwynian Reach).

Figure 205: Afon Ystwyth at Llanafan (Grogwynian Reach). May 2000. Note the midstream gravel bar in the bottom left of the photograph.

Figure 206: Afon Ystwyth at Llanafan (Grogwynian Reach). January 2000. Note the complex of midstream gravel bars in the left of the photograph.

Figure 207: Afon Ystwyth at Llanafan (Grogwynian Reach). January 2001. Note the midstream gravel bar in the centre of the photograph.

Figure 208: Afon Ystwyth at Llanafan (Grogwynian Reach). November 2001. Note the fragmentation of the midstream gravel bar complex, and the presence of semi-permanent vegetation on the 'dry' gravel bars above the water level.

Figure 209: Afon Ystwyth at Llanafan (Grogwynian Reach). November 2001. Note the fragmentation of the point gravel bar to the south of the main channel.

Figure 210: Afon Ystwyth at Llanafan (Grogwynian Reach). December 2002. Note the extensive midstream gravel bar.

Figure 211: Afon Ystwyth at Llanafan (Grogwynian Reach). December 2002. Note the point and midstream gravel bars to the north of the main channel.

Figure 212: Afon Ystwyth at Llanafan (Grogwynian Reach). July 2003. Note the extensive point gravel bar, the established vegetation in the stable parts of the bar, and the relatively narrow channel.

Figure 213: Afon Ystwyth at Llanafan (Grogwynian Reach). July 2003. Note the extensive point bars on both sides of the relatively narrow channel, and the contrasts in vegetation coverage across the floodplain to the south of the main channel.

Figure 214: bank erosion on the Afon Ystwyth, Llanafan (January 2002)

4.3.1 Results

The enclosed photographs of the Llanafan (Grogwynian Reach) study site (Figure 205–Figure 214) indicate five key trends in the development of the Afon Ystwyth channel and floodplain system between May 2000 and July 2003:

- Variations in bar type. This is primarily apparent in the barforms at the upstream end of the Llanafan study site (Figure 206, Figure 208, Figure 210, & Figure 212). In response to changes in water levels, the barform varies between a point bar complex, recorded in July 2003 (Figure 212), and a complex of midstream barforms intersected by minor channels in January 2001 (Figure 206), November 2001 (Figure 208), and December 2002 (Figure 210). The midstream barforms display varying levels of fragmentation in response to specific water levels (e.g. Figure 208), and this is also evident in the fragmentation of the point barform at the downstream end of the study site, during November 2001 (Figure 209).

- Variations in bar presence. This is primarily apparent in the barforms at the downstream end of the Llanafan study site (Figure 205, Figure 207, Figure 209, Figure 211, & Figure 213). A midstream barform is clearly apparent in May 2000 (Figure 205), January 2001 (Figure 207), and December 2002 (Figure 211), but is absent in November 2001 (Figure 209) and July 2003 (Figure 213). This is apparently due to variations in channel width and depth, water levels and (possibly) sediment transport.

- Vegetation development. At the micro-scale, this is most comprehensively documented in the barforms at the upstream end of the Llanafan study site, but it is also evident on the major point bar complex to the north of the channel. The patterns in the locations of semi-stable vegetation provide a 'negative' image of the position of the 'overflow' channels that fragment the barforms during periods of high water levels (e.g. Figure 208, Figure 209, Figure 210, & Figure 212). The presence of vegetation also indicates relatively highly elevated sections of the barforms, which are clearly rarely inundated by flooding. The presence of this semi-stable vegetation therefore indicates that, over relatively short periods (e.g. the 3 years of this study), the location of 'overflow' channels and the fragmentation of barforms follows repetitive patterns in response to high level flows and flooding events.

  Over slightly longer time-spans, the distribution of vegetation on the floodplain to the south of the main channel indicates shifting patterns in the distribution of the main channel (Figure 209 & Figure 213). From east to west, the transition from vegetation (grasses and shrubs) to bare gravel and silt, to partial vegetation (shrubs and some grasses) suggests the relatively recent existence of a major palaeochannel flowing from north to south across the floodplain.

- Variations in channel types and locations. The major channel of the Afon Ystwyth shows considerable variation in width between periods of low and high flow (e.g. Figure 209 & Figure 213). There is also an extensive development of multiple channels associated with the barform complex at the upstream end of the study site (e.g. Figure 208 & Figure 210). Finally, during periods of extremely high flows (e.g. November/December 2001), there is evidence of 'overflow' channels fragmenting the floodplain to the north of the main channel (Figure 209).

- Erosion. This is less apparent in the main photographic archive (due to the scale of the photographs), but there is extensive evidence of bank erosion at the downstream end of the study site (Figure 177 & Figure 214). It has not been possible to accurately measure the quantities of bank erosion that have occurred (due to difficulties of access), although the undercutting of the fence lines has provided a relative measure of erosion rates in this part of the Llanafan site.

The photographic archive has therefore indicated a number of trends in the evolution of the Afon Ystwyth floodplain at Llanafan. Variations in barforms and channel morphology would inevitably impact upon the local micro-conditions controlling clast entrainment, transport and deposition. However, the short-time scales of this study limit the data with respect to investigating floodplain erosion rates (through channel migration) which are pertinent to the issues of hominid 'site' erosion and the supply of artefacts into a fluvial system. To explore these issues, data is included here from a range of Welsh sites in the region of the Afon Ystwyth study sites (Macklin *et al.* 2002). These studies have highlighted four key trends:

- Floodplain change. Johnstone *et al.* (2002) explored the evolution of the Dyfi river terraces and palaeochannels during the Late Pleistocene, a period when glaciation supplied the Dyfi and other valleys with abundant supplies of coarse sediment. Detailed mapping of the Dyfi valley (Figure 215 & Figure 216) reveals the large numbers of palaeochannels formed by the river over the course of the Holocene. Although some of these palaeochannels may have been occupied simultaneously by the river (during the first half of the Holocene the river was braided), this mapping indicates the potential for extensive channel migration over relatively short periods.

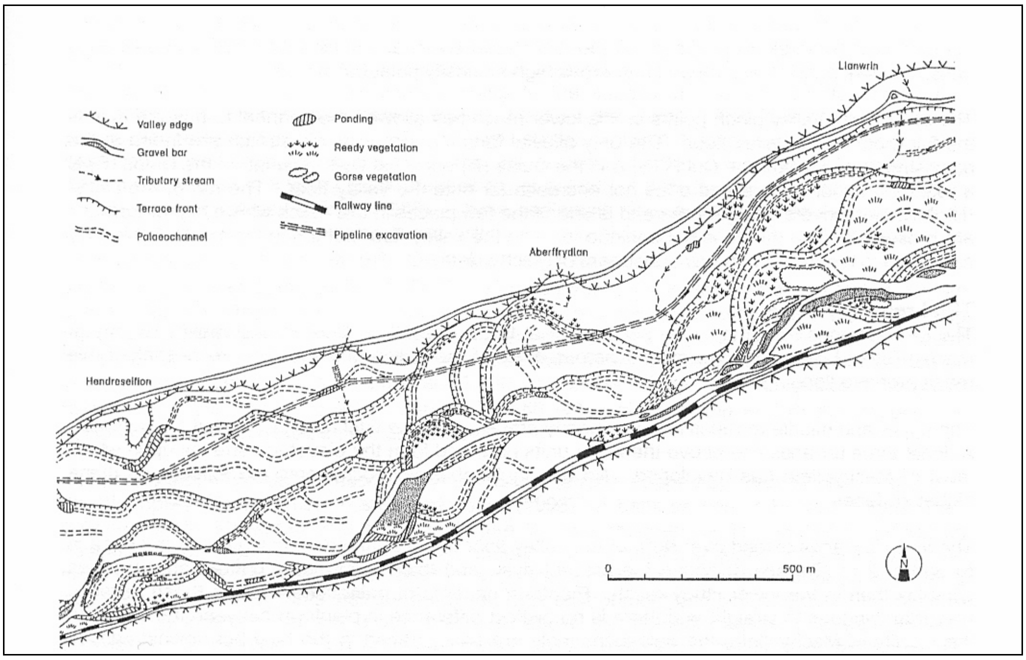

Figure 215: river terraces and palaeochannels in the lower reach of the Dyfi, mid-Wales (Johnstone et al. 2002: Figure 5)

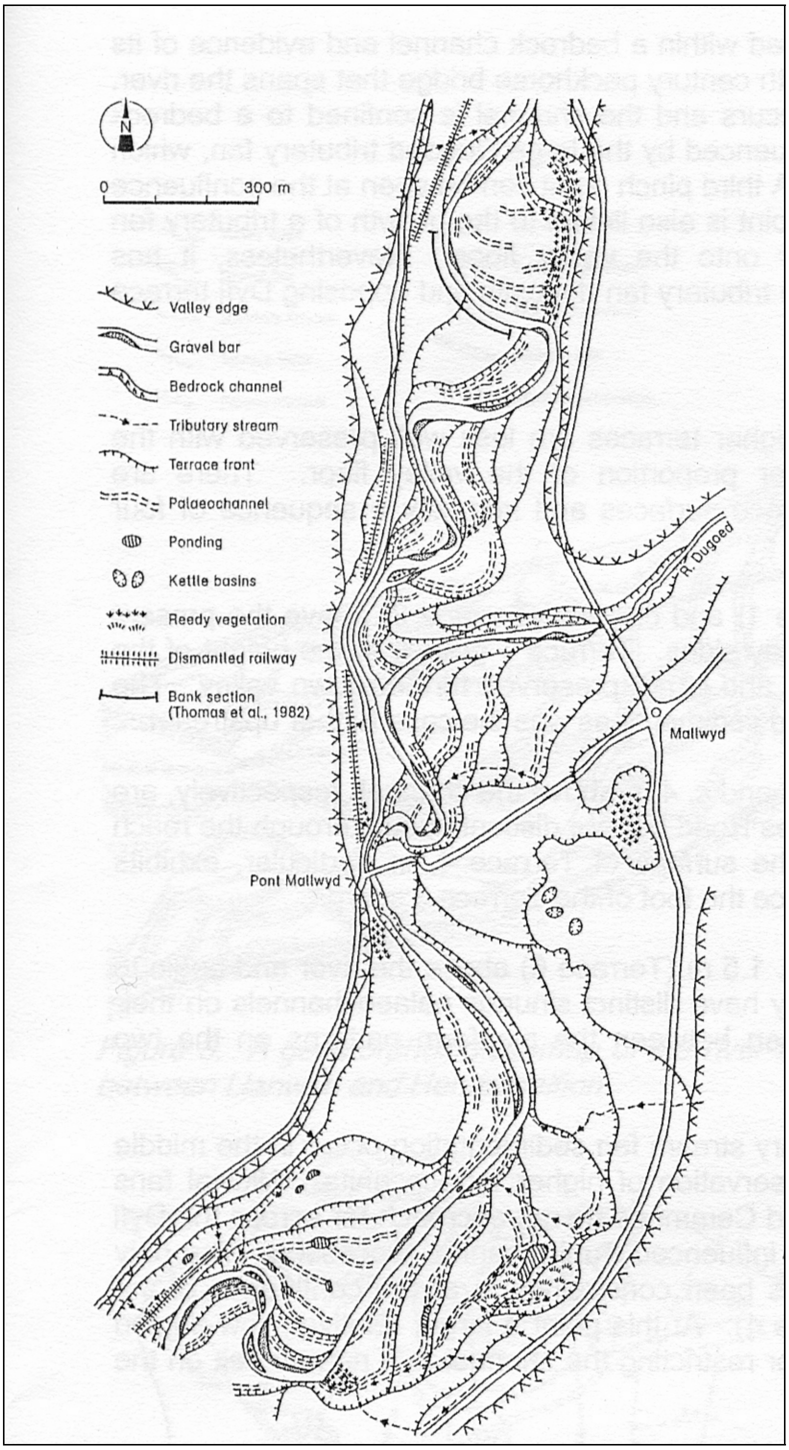

Figure 216: river terraces and palaeochannels in the upper reach of the Dyfi, mid-Wales (Johnstone et al. 2002: Figure 3)

- Vegetation and river channel stability. Gittins *et al.* (2002) explored changes in exposed river sediment (ESR) on three Welsh rivers (the Dyfi, Ystwyth and Rheidol) between 1890 and 1992. A reduction in exposed riverine sediment since the first half of the 20th century was documented, and was demonstrated to not be a result of coarse-grained gravels (> 2 mm) being flushed out of the catchment. By contrast, the reduction in sediment was demonstrated to be due to vegetation growth on bar surfaces. For example, in the Rheidol valley (Figure 217) the vegetated area on active and formerly active bar surfaces was 4 times greater that the amount of exposed sediment within the river in 1992. Although the causes for these processes were primarily anthropogenic (*ibid*: 55–56), the impacts of such vegetation growth (increasing bar and bank stability) are important to the understanding of relative rates of floodplain change during periods of varying vegetation cover in the Pleistocene.

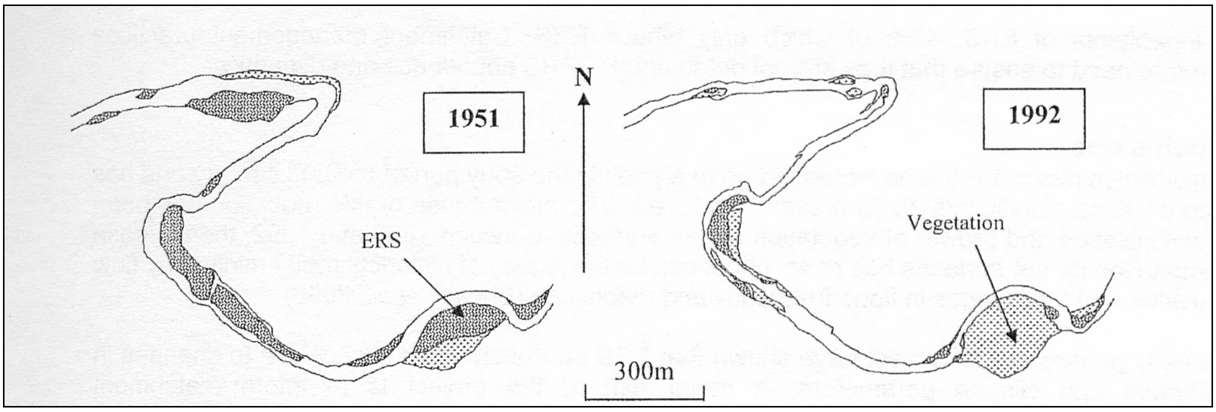

Figure 217: exposed riverine sediment reduction on the Afon Rheidol east of Capel Bangor between 1951 and 1992 (Gittins et al. 2002: Figure 7)

- Sediment transport. Brewer *et al.*'s (2000) study of sediment dynamics on Welsh rivers demonstrated that coarse-grained, gravel-sized material (> 2 mm) only moved a few 10s of metres during flood events. These comparatively short step lengths support the experimental results from the Afon Ystwyth and suggest that archaeological artefacts may have been transported through a series of transport/burial cycles (at least during phases of interglacial climate), with the majority of entrainment time being spent in a state of burial. This raises a key issue with respect to how much (if any) abrasion development occurs during periods of artefact burial.
- Channel change and bank erosion. Brewer *et al.* (2002) explored rates of channel change and bank erosion on the Afon Rheidol at the Felin Rhiwarthen and Lovesgrove meanders. Since these changes reflect both environmental (flood frequency and magnitude) and anthropogenic (metal mining and flow regulation) factors, specific rates (e.g. of bank erosion) are not of great relevance, although the magnitude of the maximum per annum erosion rates (e.g. between 1.4 and 7.9 m yr^{-1} at Lovesgrove) indicate the potential for relatively rapid erosion and channel change (Figure 218) under an interglacial climatic regime. Of greater interest is the observation that fine-grained sediments (silts and clays) form cohesive banks that are difficult to erode, whereas coarser-grained sediments (sands and gravels) form non-cohesive banks that erode more easily. These observations potentially suggest interesting patterns with respect to variable erosion rates (and therefore channel change) in different sedimentary regimes.

In general, these data emphasise longer time scales (ranging from 100 years to the entire Holocene) and provide evidence for relatively rapid processes of erosion, channel migration and floodplain evolution (albeit during an interglacial climatic regime). With respect to the erosion of primary context deposits, the entrainment of artefacts, and the formation of secondary context assemblages, these data suggest that individual 'sites' would probably be eroded rapidly over a short period rather than sporadically over millennia.

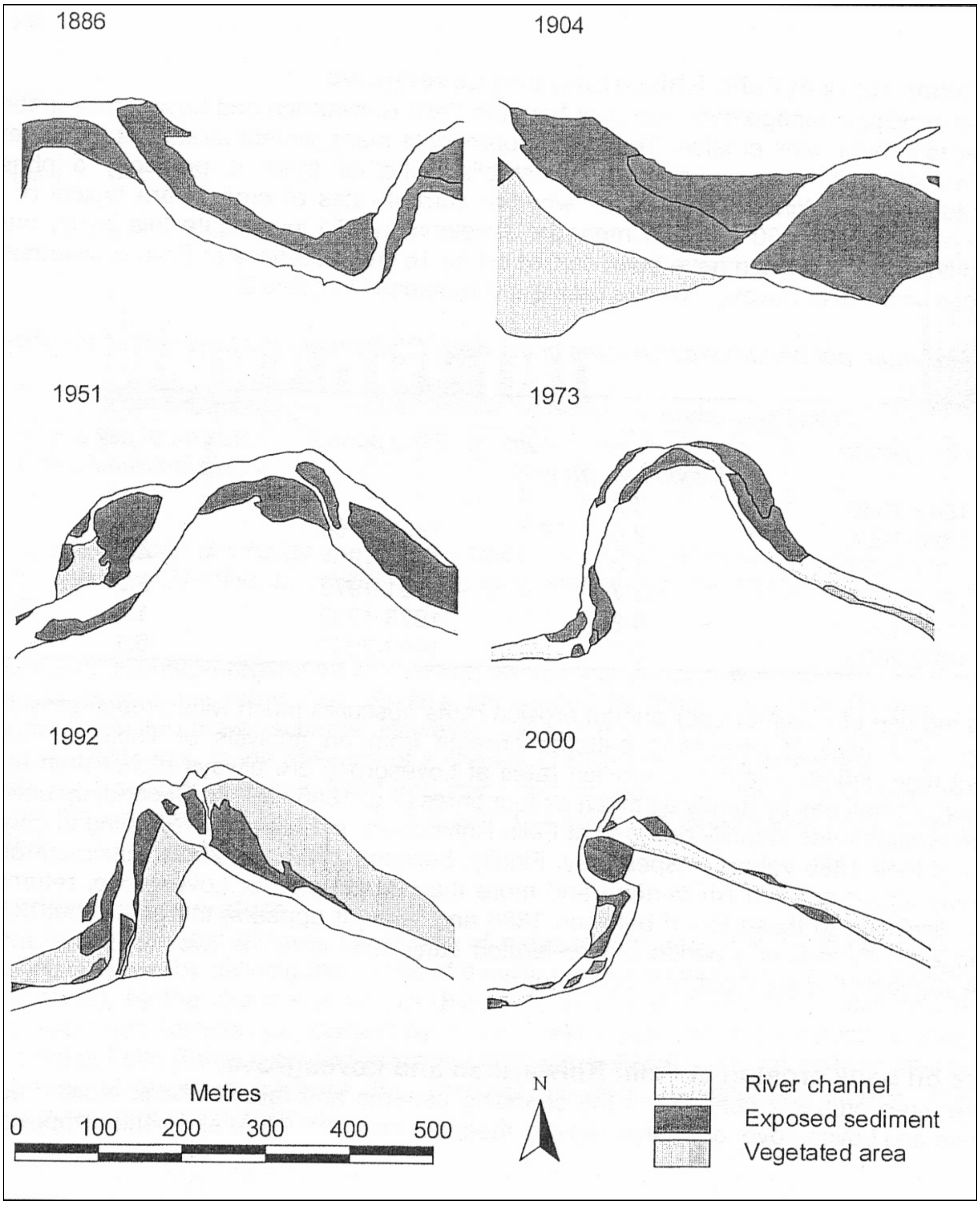

Figure 218: channel change on the Afon Rheidol at Lovesgrove between 1886 and 2000 (Brewer et al. 2002: Figure 3)

5. MODELLING ARTEFACT TRANSFORMATION

The following discussion draws upon the analysis of the Broom artefact assemblage (Chapter 5), the experimental fieldwork of Hosfield & Chambers (2002a; this chapter), the experimental laboratory work of Chambers (in prep; Chapter 4) and extant research in fluvial engineering (this chapter). The conclusions are not intended to apply to every secondary context Palaeolithic assemblage, but they do highlight two key factors for the interpretation of transported artefacts occurring within secondary context assemblages:

- The laboratory and field experiments of Chambers (in prep.) and Hosfield & Chambers (2002a) have highlighted a series of diagnostic indicators for artefact transport in gravel-bed river environments. These are arête abrasion (Figure 219), edge micro-flaking (Figure 220), and incipient percussion cones (Figure 221) on bifaces and flakes. The presence of all, or some, of these indicators can be taken as evidence that the artefact has been subject to fluvial transport. Chambers (in prep.) has highlighted five key variables:

- Arête abrasion does not develop in a uniform manner. This was demonstrated by the recording of 12 arête values on each face of the artefact, with each face divided into 6 zones (2 values per zone).
- The pattern of differential arête abrasion development can be used to indicate the type(s) of bed-load transport to which an artefact has been subjected (e.g. saltation and sliding).
- Biface morphology (cross-section profile) influences the mode of transportation. For example, plano-convex bifaces show a tendency to slide on the planar face.
- The development of edge damage (micro-flaking) only occurs during saltation transport.
- The presence of high, outlying arête abrasion values does not appear to be directly related to active transport. It is therefore hypothesised that archaeological occurrences of high, outlier values on bifaces relate to periods of partial burial, which leave exposed areas of the biface prone to intensive abrasion through collision with mobile clasts.

Figure 219: experimental biface displaying arête abrasion development

This research is fundamental to modelling the spatial origins of fluvially transported artefacts (as illustrated in the Broom case study of the previous chapter). However, the robusticity of the model would be improved by expansion of the experimental programme, with specific reference to:

- The burial of artefacts and the demonstrated development of associated damage.

- The modification of flake artefacts within a flume experimental environment.

It is clear however, that at a micro-scale, the entrainment, transport and deposition of artefacts is a stochastic process, due to variations in bed-form conditions (e.g. particle density and neighbouring particle proximity, particle elevation, armoring, and flow turbulence). Unfortunately, local geomorphological conditions cannot be known for archaeological materials. It is therefore stressed that the application of experimental transport data should seek to identify robust, over-arching patterns within secondary context archaeological assemblages.

Figure 220 experimental biface displaying micro-flaking edge damage

- The field experiments of Hosfield & Chambers (*et al.* 2000; 2002a) and Harding *et al.* (1987) combined with extant clast transport research have indicated the importance of relatively short step lengths and significant periods of burial. This has been demonstrated both for the gravel-bed rivers of mid-Wales (Hosfield & Chambers 2002a, 2004; Harding *et al.* 1987; Brewer *et al.* 2000), the Nahal Hebron in the Negev Desert and the Nahal Og in the Judean Desert (Hassan *et al.* 1991), and Harris Creek in British Columbia (Hassan & Church 2001). The demonstration of similar patterns in a variety of fluvial and climatic contexts would appear to indicate that these patterns of short step length and significant burial phases are a universal phenomenon. It therefore seems highly probable that similar patterns of clast dispersal would have occurred in the rivers of north-western Europe during the climatically-variable Middle Pleistocene. These data further emphasise the episodic nature of artefact transportation, and highlight the potential time depth that may exist between hominid discard, initial artefact entrainment within the fluvial system, and terminal deposition within the secondary context.

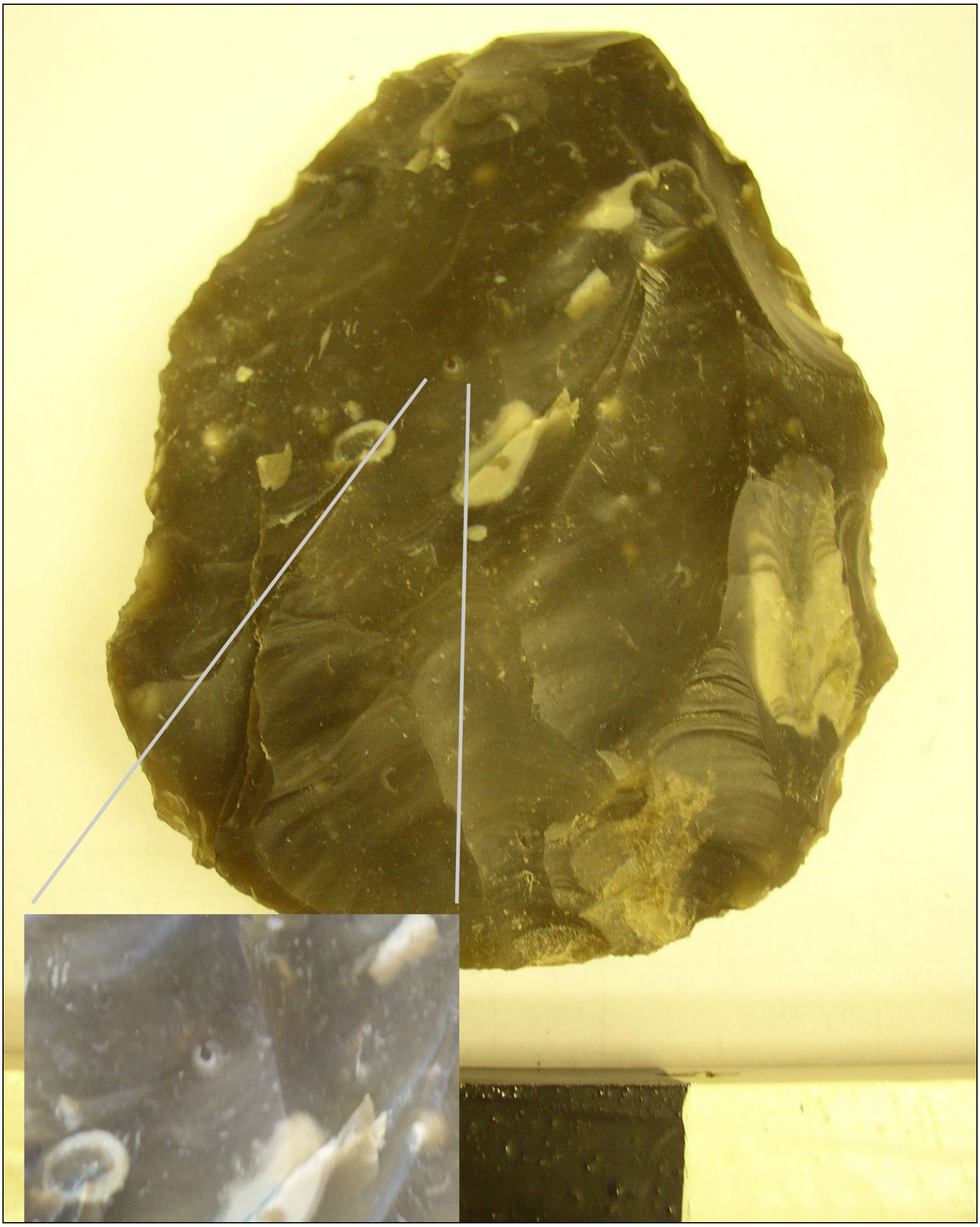

Figure 221: incipient percussion cones on experimental biface #6 (one of the cones is located in the centre of the inset)

These patterns reinforce the need (emphasised above) for continuing experimental and modelling research addressing the issues of:

- The duration of artefact burial phases.

- Abrasion development during phases of artefact burial, with particular reference to the identification of diagnostic abrasion signatures.

It is also stressed that the river systems utilised in modern experimental studies are all broadly acting under a global, interglacial climate, although some (e.g. Harris Creek) are strongly influenced by regional, cold-climate processes (annual snowmelt). We acknowledge that the processes of clast entrainment and transport in extreme cold-climate fluvial regimes remain poorly understood at the current time, due to an absence of suitable analogues. It is suggested here that in extreme, high energy fluvial conditions, associated with glacial meltwaters, particles may have been more prone to suspended load transport. Unfortunately, modelling suspended load currently presents major experimental problems, including the replication of flow velocities strong enough to induce suspension of large particles (bifaces) and the danger to flume equipment from large particles travelling at high velocities. Since suspended load artefacts sustain damage through their collisions with other suspended particles, key factors would appear to be flow velocity and the grain size distribution of the suspended load. From an archaeological perspective it is nigh on impossible to evaluate either of these variables for a specific assemblage.

6. SECONDARY CONTEXT ASSEMBLAGE FORMATION

The previous section discussed the experimental evidence for artefact transportation in fluvial systems, as recorded on the artefacts themselves. These data are important, given the widespread documentation of "waterworn" artefacts in Palaeolithic assemblages recovered from fluvial secondary contexts over the last 150 years (e.g. Evans 1872; Wymer 1968; 1999; Roe 1981). Despite this documentation however, there remains a considerable conundrum with respect to the formation of these assemblages:

"At sites where dense concentrations[6] of palaeoliths are found within river gravels, such as many of the sites in the Solent Area (e.g. Romsey, Hants; Bournemouth, Dorset; Dunbridge, Hants; Wood Green, Hants) it can be assumed that they have not travelled far from their place of discard. Some will be in relatively fresh condition, although rolling along river beds at times of spate soon dulls the edges of flint artefacts."

(Wessex Archaeology 1993a: 12)

However, recent examinations of both large and small secondary context assemblages have indicated that much of the material is relatively heavily abraded. This has been demonstrated for the assemblages from Dunbridge (Hosfield 1999, 2001; Chambers in prep.), Kimbridge (Chambers in prep.), Belbin's Pit, Romsey (Chambers in prep.) and Wood Green (Hosfield 1999, 2001) in Hampshire. There are two alternative explanations for these conflicting interpretations:

1. The material has been derived from local places of discard, with the short transport distances offering little opportunity for the widespread dispersal of the artefacts, resulting in the 'dense concentrations'. This interpretation must therefore assume that abrasion develops extremely rapidly over these short transportation distances.

However, the experimental evidence discussed above offers little support for the assumption that artefact abrasion of the magnitude seen in secondary context assemblages develops rapidly, leading into the second explanation:

2. The material has been derived from a mixture of local and distant places of discard, with the longer transport distances offering opportunities for a slower development of artefact abrasion and deposition over a wider catchment (i.e. apparently reducing the possibility of 'dense concentrations' being retained). The experimental evidence discussed above supports this model

[6] We stress that the term 'dense concentrations' is a relative one, and that even at these sites, the artefacts represent only a minor component of the sedimentary material. As an example, the Broom sites yielded *c.* 1,800 artefacts, but in February 1935, Pratt's Old Pit was producing 60 tons of gravel per day, and C.E. Bean estimated that 150 tons of gravel was yielding just six implements.

of longer transport distances and slower abrasion development. However, this interpretation leaves us with a key issue to resolve: what is the mechanism or mechanisms behind the formation of these 'dense' artefact concentrations? This question is critical to our understanding of archaeological secondary contexts.

6.1 Geomorphological models

Large-scale fluvial geomorphological processes would appear to be the most plausible solution to this question. In other words, the concentration of artefacts within fluvial secondary context deposits (where the artefacts show traces of fluvial transport) is due to the operation of natural formation processes. Three examples of these processes are included here to illustrate possible site formation mechanisms (there is some overlap between these categories, reflecting the fact that they cannot be considered in isolation).

6.1.1 Regional bedrock controls.

This model was presented by Hosfield (2001) and is therefore only summarised here. It stresses the fluvial bedrock of the Solent River basin and its impact upon river rejuvenation behaviour and terrace preservation conditions. Allen & Gibbard (1993: 520–521) observed the unidirectional migration of the Solent River and its major tributaries, including the Test and Avon rivers. Within the core of the Solent Basin, the Solent River and the lower reaches of its tributaries flowed predominantly over Tertiary clays and sands, in wide, shallow valleys. During episodes of downcutting (related to climatic cycles, sea-level rise and fall, and isostatic uplift) the rivers moved laterally, incising into the bedrock rather than the recently deposited gravel aggradations (Figure 222). The initial direction of this lateral river migration was determined by factors including local hydrology, slope of land, and topographical aspect. In contrast, towards the margins of the Solent Basin where rivers flowed over chalk bedrock, the valleys were narrow with steep sides. This pattern is evident for the Frome, upstream of Dorchester, and for the Test and Avon rivers to the north of Romsey, where they all flow over chalk. In these circumstances, Allen & Gibbard (*ibid.*) argued that the rivers would retain their original channel positions during downcutting events, as it was easier to erode former gravel accumulations than to cut a wider valley in the resistant chalk (Figure 223). The resultant valley patterns, lacking long terrace sequences, have been observed by Bridgland (1985: 29–30) for other chalk bedrock rivers in southern England.

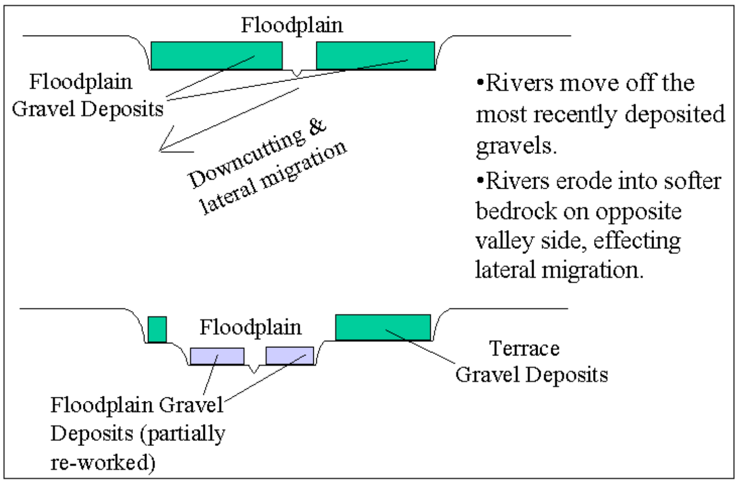

Figure 222: river rejuvenation behaviour and terrace preservation potential on Tertiary bedrock (Hosfield 2001: Figure 7)

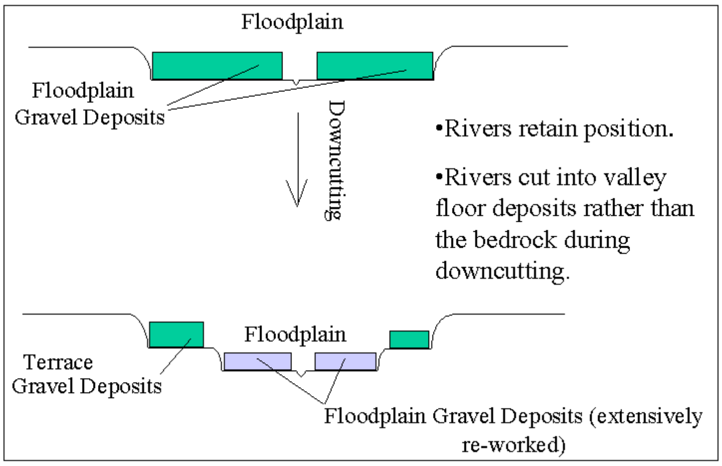

Figure 223: river rejuvenation behaviour and terrace preservation potential on Chalk bedrock (Hosfield 2001: Figure 8)

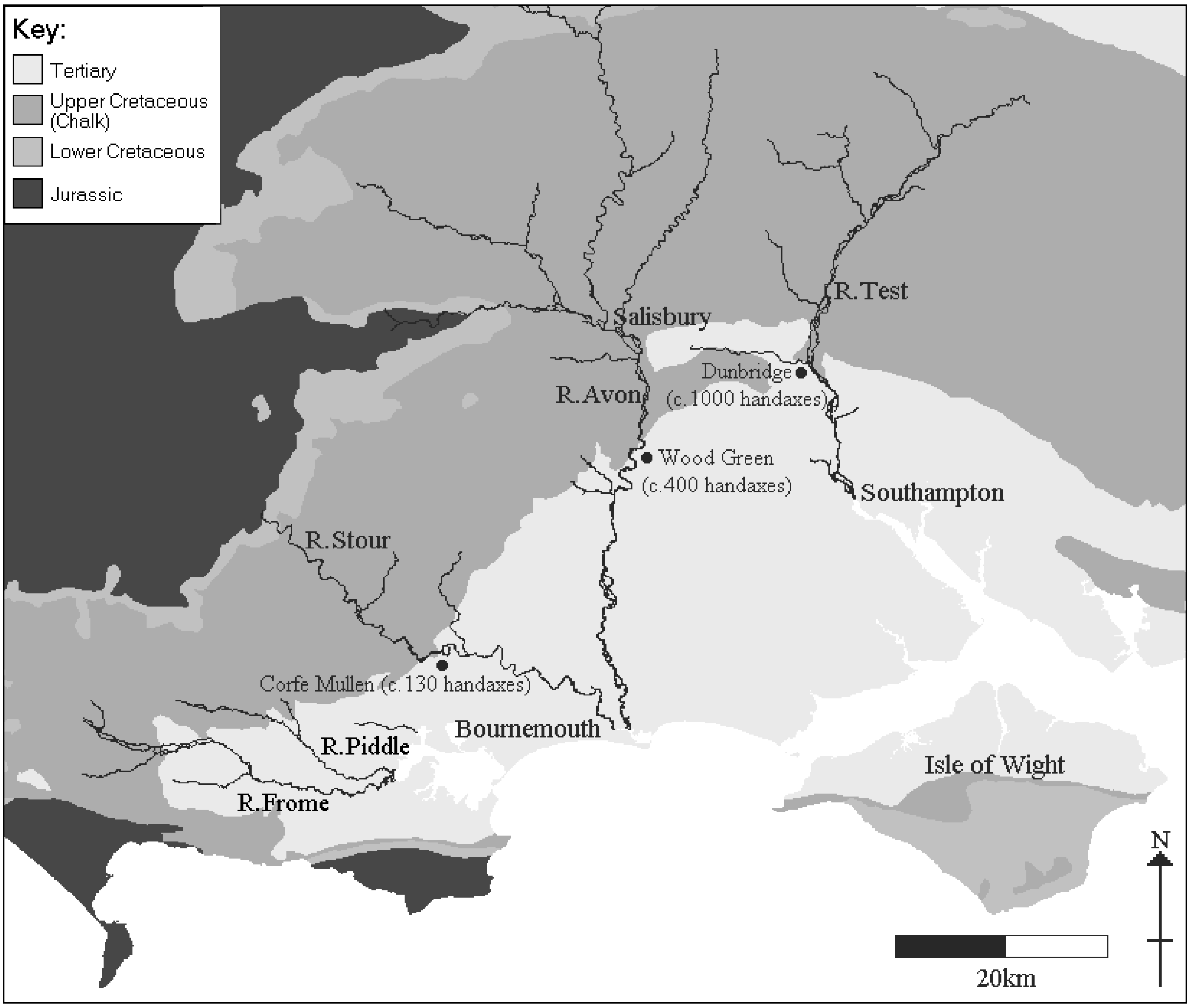

Figure 224: pre-Quaternary bedrock geology and selected Lower Palaeolithic findspots in the Solent River Basin (Hosfield 2001: Figure 10)

It is argued that the consequence of these bedrock-controlled processes is extensive sediment erosion in rivers flowing over chalk. Consequently, there is restricted development of floodplain deposits (potential terraces sediments), with sediments (clasts and artefacts) re-worked down the valley in a series of depositional/erosional episodes. These episodes presumably occur both between and during glacial/interglacial cycles, at micro (individual flooding) and macro (river rejuvenation and downcutting) scales. However, upon flowing from chalk to tertiary sand and clay bedrock (Figure 224), there is a transformation in the rivers' regime of erosion and deposition. Due to the channel's lateral migration behaviour, there is greater potential for the preservation of floodplain/terrace deposits. Sediments (clasts and artefacts) are therefore likely to be deposited and preserved as floodplain/terrace deposits, rather than undergo a further series of deposition/erosion episodes.

The archaeology of the Solent Basin supports this geological model of regional bedrock controls. The findspots of Dunbridge, Wood Green and Corfe Mullen (all producing at least 100 bifaces) are located immediately downstream of the transition from chalk to tertiary bedrock (Figure 224), suggesting that these assemblages were formed by the dumping out of sediments (clasts and artefacts) at these points in the rivers' reaches, and associated with the change in valley form and river behaviour.

6.1.2 Regional fluvial geomorphology.

This has links with the first model, but is essentially emphasising the generic role of major landforms upon fluvial depositional activity and the creation of local sedimentary traps as represented by fan gravels (Boggs 1987; Miall 1996). These influential landforms include the zones of transition from a constricted to unconstricted valley (e.g. as in the Solent River basin example above), areas in proximity to the junctions between tributary and major streams, and sudden changes in stream gradient (Miall 1996: 245). These are discussed by Miall (*ibid.*) with respect to the development of alluvial fan gravels, while Boggs (1987) also highlights outwash fans associated with melting glaciers. The key issue is that these geomorphological factors all influence fluvial behaviour and can be associated with major episodes of sedimentation (the deposition of alluvial or outwash fan gravels). As alluvial fan gravels produce highly diagnostic sedimentary signatures (Miall 1996), it should be possible to evaluate the potential impact of these processes upon the formation of secondary context assemblages.

6.1.3 Local fluvial geomorphology.

This final example emphasises the role of local geomorphological features and conditions, following their emphasis with respect to the processes of entrainment (e.g. Malmaeus & Hassan 2002; Hunziker & Jaeggi 2002). In this case, the focus is upon local geomorphological conditions which can result in repetitive sediment deposition in a spatially restricted area. Examples could include meandering rivers of high sinuousity (resulting in the development of extensive point bar features on inner bends (Miall 1996), the formation of major braided river bars (Nichols 1999), the local development of braidplains (*ibid.*), and the impact of contemporary river confluences (resulting in a highly local loss of river competence and the development of extensive bar features).

Although the duration and impact of these types of fluvial features has been well discussed with respect to historical time (e.g. Macklin *et al.* 2002), their significance over geological time is poorly understood, not least because of the difficulties of identification. They are therefore simply highlighted here as potential mechanisms by which transported material from disparate sources may be deposited, and preserved, in association within fluvial sedimentary units.

6.2 Site formation through time

Due to the history of collection associated with many of Britain's secondary context Palaeolithic assemblages (e.g. Roe 1981), it is often difficult to assess how densely concentrated the artefacts were in time (as represented by the vertical sedimentary sequences). In many cases, stratigraphic provenance data were not recorded, and in some cases spatial provenance was limited to the accuracy of parishes. Moreover, the question of temporal distribution is complicated by two key factors:

- Is it likely that floodplain 'sites' will be fluvially eroded rapidly or gradually? This has obvious implications for the supply of artefacts into the fluvial system, and for the chronology of their subsequent deposition. The data from the mid-Wales study rivers (Macklin *et al.* 2002), although providing a geographically restricted sample, suggests that erosion over historical (e.g. 10^1 and 10^2 years) rather than geological time (10^3 and 10^4 years) is more likely. This is based on historical mapping of floodplain and channel change, and the C^{14} dating of floodplain and terrace palaeochannels. Over Palaeolithic and Middle Pleistocene timeframes, these data therefore suggest that the erosion of sites is essentially a 'contemporary' process, rather than over tens of thousands of years. As these study rivers are interglacial fluvial systems, it is argued that under glacial conditions fluvial erosion rates would be even faster (reflecting the paucity of vegetation coverage).

- It has been demonstrated that artefacts within the same system will undergo different regimes of burial and transport. Is it likely that two artefacts, entering the system within 100 years of one another, will be deposited 10,000 years apart (the temporal magnitude of the Broom sedimentary sequence)? Based on the rates of erosion and channel change discussed above, this would appear to be unfeasible. It is accepted that artefacts may be deposited 10^1 or 10^2 years apart (due to localised variations in burial, transport, and barform preservation/erosion), but it is stressed that these timescales will appear 'contemporary' in light of current levels of geochronological resolution when dealing with Pleistocene sedimentary units.

In general therefore, when interpreting a dense artefact concentration of clearly transported material (e.g. Dunbridge) it is argued that once the artefacts were entrained within the fluvial system, they underwent the majority of their reworking over historical time-spans. This reflects demonstrated rates of channel migration and fluvial erosion, which indicate that the residues of human activity episodes (e.g. butchery sites on the floodplain) would be vulnerable to erosion and initial entrainment over decades rather than millennia. These data also suggest that individual channels only remain active over decadal rather than millennial timescales, implying that *recovered* artefacts must have been reworked relatively rapidly.

7. CONCLUSIONS

This chapter has sought to assess the relative homogeneity and/or heterogeneity in space and time of Palaeolithic stone tool assemblages occurring in secondary context aggregate deposits, with particular reference to:

- Physical processes of clast entrainment, transportation and deposition.
- The relative importance of three data sources: the physical condition of stone tools; the morphology of stone tools; and the stratigraphic context of stone tools.
- The integration of laboratory research; theoretical modelling; and experimental archaeological fieldwork.
- The implications of taphonomic studies to the interpretation of stone tool assemblages occurring in secondary context deposits.

7.1 Clast entrainment, transportation and deposition

Extant research in fluvial engineering and physical geography has indicated the highly variable nature of clast transport at the micro-scale, reflecting localised stream bed conditions. However, the research also indicates some robust trends of considerable importance to the interpretation of transported, secondary context assemblages — principally, the absence of any clear relationship between clast size and transport distances, and the tendency for short step lengths and long burial phases. The clast size/transport distance relationship data stresses the stochastic nature of clast transport and highlights the importance of interpreting derived assemblages on an artefact by artefact basis. The short step length/long burial phase data promotes caution in the interpretation of abrasion data as an index of transport distance and an indicator of catchment source areas. Consequently, as with the interpretation of the Broom and Dunbridge data (Chapter 4), focus is placed on highly robust patterns, rather than on high resolution trends. Finally, the identification of these trends has also highlighted the importance of further experimental research with respect to the duration of burial phases and the potential for abrasion development during periods of burial and partial burial.

7.2 Assessing stone tool assemblage data

With respect to the spatial homogeneity/heterogeneity of derived stone tool assemblages, artefacts' physical condition data is obviously of prime importance. However, the work of Chambers (in prep.; Chapter 4) has indicated the importance of the *état physique* approach, emphasising zonal arête abrasion, edge damage micro-flaking, incipient cones of percussion, and the role of artefact morphology (e.g. cross-section profiles) in transportation. In an ideal world, field data from the associated sedimentary units (e.g. grain size, bed-forms, clast and artefact fabric data) would be informative with respect to reconstructing transport histories, fluvial regimes, and therefore the spatial origins of the material. Unfortunately, given the fragmentary nature of fluvial sedimentary sequences and the highly variable nature of entrainment and transportation (see above), such an approach would involve an unacceptable level of generalisation. Moreover, for nearly all extant assemblages, sedimentary field data of the type referred to above was not recorded. Therefore, modelling the spatial component of secondary context assemblages must focus upon the *état physique* of individual artefacts.

In cases where stratigraphic provenancing data are available, this information is important for an initial, crude assessment of the temporal homogeneity/heterogeneity of derived stone tool assemblages (e.g. whether the artefacts were deposited in a single 'horizon' or throughout a sedimentary sequence). However, to make a detailed assessment requires a high resolution analysis of the preserved sedimentary sequence. This includes the geochronological framework (e.g. the duration of depositional events and sedimentary hiatuses (Chapters 2–3), and micro and macro-changes in the sedimentary sequence (represented by grain size distributions, sediment types, and bedforms). On a wider scale, understanding of 'site' formation processes are vital, with respect to the coarse-resolution chronologies of the initial entrainment of the artefacts (e.g. through floodplain 'site' erosion over historical rather than geological time-spans), and the depositional environment(s). Unfortunately, these data are often unavailable for extant assemblages, although the methodology is applicable to well-documented assemblages such as Swanscombe and Broom.

With respect to morphological data, the evidence from fluvial engineering research indicates that artefact size and dimensions cannot be used as an indicator of transport distances. However, this section has indicated the value of other elements of artefact morphology in the detailed assessment of transport history (e.g. the uses of cross-section profiles in Chambers' (in prep.) transport modelling methodology).

7.3 Integrating laboratory, field and desktop research

Correlation of Chamber's (in prep; Chapter 4) experimental flume research with the experimental fieldwork of Hosfield & Chambers (2002a, 2004; this chapter) has highlighted some robust patterns, most notably the rates and patterning associated with the development of arête abrasion on bifacial artefacts. The experimental research has also drawn clear links with the extant fluvial engineering research literature, through the stressing of local variations in field conditions (e.g. bed morphology) which have impacted upon individual clast transport behaviour.

However, it has been apparent from the field experiments that non-laboratory results will inevitably be more variable, reflecting the wider range of variable conditions, and in some cases unpredictable (e.g. the apparent role of algae in retarding abrasion and edge damage (micro-flaking) development). In contrast, the laboratory has provided tighter controls on experimental conditions and yielded data that is currently unknowable for field experiments (e.g. the mechanism of transport). The integration of the laboratory and field experimental research has therefore highlighted the need for further research, improved tracer recovery (magnetic tracers), improved data logging techniques (radio tracers) and the greater integration of archaeological and fluvial geomorphological research.

7.4 Taphonomy and secondary context assemblages

The demonstration of artefact transport patterns and damage development inevitably raises the problem of explaining the formation of large artefact assemblages within secondary contexts. It is clear that artefacts recovered from a single site have very often been transported a wide range of distances (based on the *état physique* of extant artefacts), while experimental fieldwork has demonstrated that materials from a single source will be dispersed over an increasingly wide area over time. The problem is therefore clear: derived artefacts originate from a wide range of sources, yet are ultimately deposited in a single sedimentary location. Why does this happen?

We suggest that fluvial geomorphological processes are the critical factor. Although hominid involvement is (inevitably) a required starting condition (e.g. the bifaces must be discarded in a valley for large concentrations to be formed downstream), it is fluvial processes and landforms that produce localised sedimentary traps within which fluvial material and entrained artefacts are deposited, after a wide range of transport histories. The significant geomorphological processes are argued to include river confluences (resulting in localised loss of stream competence and therefore extensive depositional activity), the impact of bedrock types and valley forms upon fluvial behaviour (sediment re-working and river incision), and local depositional environments (e.g. braidplains and large-scale barforms).

In conclusion, it is clear that secondary context assemblages are the product of artefact transportation and deposition. With respect to the homogeneity and/or heterogeneity of these assemblages, investigations must therefore consider the nature of clast transport within fluvial systems, the *état physique* of individual artefacts, and the taphonomic processes responsible for the deposition of sediments and artefacts in specific locations within fluvial landscapes. Through these approaches it is possible to begin to understand the nature of artefact discard and hominid behaviour within the contemporary fluvial landscapes of the Pleistocene.

CHAPTER 6

THE PALAEOENVIRONMENTAL POTENTIAL OF ARCHAEOLOGICAL SECONDARY CONTEXTS

1. INTRODUCTION

The preceding two chapters have been primarily concerned with the lithic component of archaeological data from fluvial secondary contexts. However, the evidence from many British Pleistocene sites indicates that fluvial sediments are capable of yielding a wide range of palaeoenvironmental data (Briggs *et al.* 1985, 1990; Keen 1990; Bridgland 1994; Preece 1995; Conway *et al.* 1996; Howard *et al.* 1999; West 1999; Roe 2001; Schreve 2001a; *et al.* 2002; & Bridgland 2002). The focus of this chapter is therefore an assessment of the potential for the palaeoenvironmental reconstruction of Middle Pleistocene fluvial landscapes from secondary context data sets. This assessment is not simply an identification of the main categories of biological data and a highlighting of their potential applications (previously and comprehensively documented elsewhere, e.g. Lowe & Walker 1997; Evans & O'Connor 1999; Dincauze 2000), although these issues are summarised here. The key theme addressed in this chapter concerns the spatio-temporal resolution of these palaeoenvironmental data sets and the mapping of them against the varying scales of early human behaviour in time (e.g. an afternoon's knapping activity, a seasonal settlement, or ten generations of sustained occupation) and space (e.g. throughout regional river systems, around a river estuary, or within the micro-environment of a floodplain backwater). This highlights the fundamental question of whether palaeoenvironmental reconstructions are *relevant* to the discussion of hominid behaviour or whether spatio-temporal associations between these data sets (biological and 'archaeological'[7]) simply cannot be demonstrated for secondary contexts.

The chapter does not focus upon a specific case study locality (unlike chapters 2 and 4), since the goal is to assess the generic potential of these data sets. A initial review of the extant literature (e.g. Keen 1990; Bridgland 1994; Preece 1995; Lowe & Walker 1997; Evans & O'Connor 1999; West *et al.* 1999; Coope 2001; Schreve 2001a, 2001b, & Thomas 2001, *et al.* 2002; Thomas 2001) indicates the major (vertebrates, coleoptera, non-marine molluscs, ostracods, and pollen) and minor (chironomids and testate amoebae) categories of biological evidence that can occur within fine-grained and organic deposits, sandwiched within fluvial sedimentary sequences (the archaeological secondary contexts of this project). The overall significance of these data for palaeoenvironmental reconstruction and as Pleistocene biostratigraphical markers is reviewed in Section 2. The relative potential of the different data sources is also assessed on the basis of their frequency of occurrence in the geoarchaeological record and the logistics of sampling and sample processing (Section 3). The modelling of the data's spatio-temporal resolutions (Section 4) stresses the physiological behaviour of the floral and faunal species, issues of secondary context site formation (also discussed in Chapters 2, 5, and 7), scales of hominid behaviour and the current range of research questions prevalent in Palaeolithic studies (e.g. models of colonisation and occupation; land-use and subsistence behaviour; 'single' behavioural episodes).

It is recognised that in many instances the occurrence of biological data is more often associated with fine-grained, temperate climate sediments (e.g. at Purfleet (Schreve *et al.* 2002)) than with coarse-grained, cold climate sediments. Nonetheless, it is stressed that all of these deposits fall under the definition of secondary contexts as outlined in the original project design:

[7] 'Archaeological' is used here to refer to the cultural debris of hominid activity (e.g. stone tool technology).

"For the purposes of this project, ***secondary contexts*** *are defined as fluvial aggregate deposits situated on river terrace and river floodplain landforms. These deposits incorporate gravels, sands, silts and clays. These fluvial aggregate deposits in secondary contexts are hereafter referred to as secondary contexts."*

(Hosfield 2002: 3)

Specifically therefore, this assessment of the potential of palaeoenvironmental data from archaeological secondary contexts explores four themes:

- The identification of biological data sources with the potential for reconstructing riverine palaeo-environments.
- The relative potential of the different data sources, based on the frequency of their occurrence within the geoarchaeological record and the logistics of sampling and sample processing.
- The spatio-temporal resolution of the different biological data sources, mapped against different scales of hominid behaviour.
- The relationships between palaeoenvironmental data and the current questions prevalent in studies of Pleistocene hominids.

2. BIOLOGICAL DATA SOURCES

Biological data sources cover a wide range of types, including vertebrates, coleoptera, non-marine molluscs, ostracods, pollen, chironomids, and testate amoebae (e.g. Stuart 1982; Keen 1990; Bridgland 1994; Preece 1995; Lowe & Walker 1997; Evans & O'Connor 1999; West *et al.* 1999; Coope 2001; Schreve 2001a, 2001b, & Thomas 2001, *et al.* 2002; Thomas 2001). These are summarised here in turn.

2.1 Vertebrates

Vertebrate fossils are a diverse data set, encompassing the remains of large (macrofauna) and small (microfauna) mammals, birds, fish and reptiles. In comparison with other lines of palaeoenvironmental evidence, vertebrate remains are the most durable, with preservation possible in all but the most acidic soils. As such, vertebrate remains have been recovered from a variety of Quaternary contexts, including cave sediments, lacustrine and marine sediments, fluvial sediments (in particular river terrace sequences), and peat bogs (Lowe & Walker 1997).

The depositional environment inevitably influences the way in which palaeoenvironmental data are extracted from vertebrate assemblages. In low energy settings, such as lacustrine sediments, there is a greater possibility of micro-fossil material (e.g. fish and amphibians) being preserved, which are considered to be highly representative of the local environmental conditions. While the remains of larger mammals can also be recovered from lacustrine settings, these are most likely to represent animals that have drowned after becoming trapped in the lake bed (Coope & Lister 1987). In contrast, higher energy contexts, such as fluvial deposits, can represent a more diverse bio-spatial catchment, although fish and amphibian remains are still generally considered to represent the immediate environmental conditions, and can often dominate assemblages. Large mammal remains are relatively common, though often as single bones rather than articulated skeletons, and their physical condition can provide an indication of their taphonomic history (Shipman 1981). Small mammal remains are common within a range of Pleistocene sediments. Waterside species can provide valuable palaeoenvironmental data of local significance, although Mayhew (1977) has suggested that their population numbers can be artificially inflated by predator accumulation of their remains. Finally, their rapid evolution during the Quaternary promotes their usage as biostratigraphical markers.

Due to the diversity of vertebrate data, the palaeoenvironmental reconstructive potential of each of the main classes of vertebrate remains will be considered in turn:

2.1.1 Mammalian Evidence

Mammalian remains are of prime palaeoenvironmental and biostratigraphic significance due to the rapid turnover of many mammalian lineages (the origination and extinction of species) and the quantifiable evolutionary trends exhibited by many of these lineages during the Pleistocene (Lister 1992; Schreve & Thomas 2001). Additionally, mammalian evidence can be used to track the repeated climatic changes that affected Europe during the Pleistocene:

"The intensive and repeated environmental changes that affected Europe during this period led to major disruptions in the geographical distributions of mammalian species, thereby providing the potential for each successive climatic cycle during the late Middle Pleistocene to give rise to a different suite of mammals"

(Schreve 2001b: 1693)

Inferences about palaeoclimate are based on the known distributions of extant species, and their climatic and habitat preferences and tolerances. For example, during the Last (Ipswichian) Interglacial species such as *Hippopotamus amphibius, Emys orbicularis* (pond tortoise) and *Crocidura* cf. *suaveolens* (lesser white-toothed shrew) were all present in southern Britain. Currently the hippopotamus is known only in tropical Africa, the pond tortoise in the Mediterranean and southeast Europe and the lesser white-toothed shrew from southern Europe (Stuart 1979), hence the presence of these species in Britain during the Last Interglacial suggests that the climate was warmer then than it is today.

As the life spans and associated climatic and environmental sensitivities of large and small mammals operate on very different scales (and therefore data resolutions) mammalian assemblages are commonly divided on size grounds.

1. Large Mammals: large mammals, identified to species level, will provide relatively gross information about regional climate and habitat (Dincauze 2000). Generally, large mammals are more tolerant of environmental change and require less locally specialised habitats than small mammals. The ranges of large mammals typically cover much larger geographical areas than those of small mammals, and may encompass several micro-habitats, leading to the generation of much more generalised palaeoenvironmental reconstructions.

   The reproductive cycles of large mammals are much slower than those of small mammals, and are therefore correspondingly slower to demonstrate evolutionary diversity. However, large mammals can also be used provide information about the age of the site they were recovered from. Certain species, referred to as 'indicator species', are known to only be present in certain locations (e.g. Britain) at certain times. For example, within Britain, the cave bear species *Ursus spelaeus* and *Dama dama clactoniana*, a large subspecies of fallow deer, are unique to the first post-Anglian interglacial (Schreve 2001b).

   From a taphonomic perspective the bones of large mammals are more likely to survive fluvial transportation than those of small mammals. However, while this increased survival potential means they are perhaps more likely to be recovered, it can also mean that this recovery may take place some distance from the location (and therefore the habitat and environment) where the animal lived and died. And as with all sources of palaeoenvironmental data, serious consideration must be given to the depositional context and associated degree of derivation large mammal assemblages have been subjected to.

2. Small Mammals: small mammal remains (e.g. Sutcliffe & Kowalski 1976), in particular those of rodents, are commonly recovered from Pleistocene sites and are regarded as providing palaeoenvironmental data at a higher resolution than that obtained from large mammals. The environmental tolerances of small mammals are much lower than those of large mammals, therefore small mammal remains can be utilised in local palaeoenvironmental reconstructions. Small mammal remains are also unaffected by human or large carnivore predation and therefore assemblages are considered to be more representative of environmental and climatic factors than

those of larger mammals.

Due to their size and perceived fragility, small mammal remains do not survive fluvial transportation, and generally therefore when they are recovered from Pleistocene contexts they are not considered to have travelled far from their original (death) location. Species lists of small mammals recovered from a site can therefore provide a means of determining what local environmental condition(s) and habitat(s) prevailed.

2.1.2 Birds, Fish & Reptiles

Bird bones are extremely fragile, and do not survive well in either fluvial or lacustrine deposits. Their remains are not commonly recovered from Pleistocene contexts and this may simply reflect their fragility, or rather a historical research bias towards mammalian remains. Where present, and identifiable to species level, avian fossils can assist in broad palaeo-environmental reconstructions on the basis of the presence of 'warm' or 'cold' climate species (Lowe & Walker 1997). Fish remains are also extremely fragile, though when recovered from aquatic Pleistocene sites they can provide detailed palaeoenvironmental information, as the species recovered provide an indication of both aquatic temperature and flow conditions. Herpetofaunal (reptilian) remains have not commonly been recovered from Pleistocene contexts, due to the dominance of fluvial sediments. The nature of the depositional environment greatly affects the herpetofauna, and few European reptilian (or amphibian) species are associated with large rivers, suggesting that Quaternary fluvial sediments are unlikely to preserve herpetofauna.

2.1.3 Summary of vertebrate remains

This brief review highlights the biological diversity and different data resolutions preserved in vertebrate remains. As a general rule of thumb, the larger the vertebrate the coarser the palaeoenvironmental data that they preserve. There has been an increasing realisation that rather than relying on single proxy lines of evidence, for example large mammals, palaeoenvironmental reconstructions and biostratigraphies are more robust when they incorporate multi-proxy lines of evidence. Each class of vertebrate remains represents a different biological scale of resolution, and by combining the environment(s) indicated by as many classes of data as are available, reconstructions are more likely to be representative of the mosaic nature of genuine environments.

2.1.4 Multi Proxy approaches and MAZ

A multi-proxy approach also enhances the robusticity of biostratigraphic interpretations. The development of distinctive suites of chronologically discrete animals by Schreve (1997, 2001a, 2001b, 2002), rather than a reliance on the presence or absence of single indicator species, has enhanced the applicability and resolution of mammalian biostratigraphy.

Mammalian biostratigraphy has long been applied to Pleistocene assemblages. The extensive climatic and geographical changes which occurred in Britain during the Pleistocene would have had a major impact on faunal migratory behaviour. Potentially, each successive climatic cycle within the Middle Pleistocene could have generated a different and unique suite of mammals. Early biostratigraphies (e.g. Currant 1989; Sutcliffe 1976) demonstrated that the mammalian record preserved evidence of three post-Anglian interglacials, more cycles of climatic change than had been previously acknowledged within the original terrestrial sequences of Britain as proposed by the Geological Society (Mitchell *et al.* 1973).

During the 1990's the marine oxygen isotope record confirmed the biostratigraphic observation that the degree of cyclical climatic change undergone during the Quaternary was greater than had transitionally been acknowledged. Terrestrial evidence for four post-Anglian interglacials within the British sequence is now widely accepted (Bowen *et al.* 1989) and the correlations between the MIS record and the terrestrial record continues to be enhanced, particularly through analysis of fluvial terrace sequences (e.g. Bridgland *et al.* 1989; Maddy *et al.* 1991, 1995; Bridgland 1994). These terrace sequences, in particular those of the Thames which are well dated and fossil-rich, provide a chronological framework within which to apply relative dating techniques such as the identification of chronologically discrete faunal suites.

Examination of mammalian assemblages recovered from the Thames terrace deposits by Schreve (2001b) has led to the identification of three distinctive temperate-climate assemblages, referred to as mammalian assemblage zones (MAZ's) and believed to correspond with three discrete climatic cycles between the Anglian glaciation (MIS-12) and the Ipswichian Interglacial (MIS-5e). It is suggested that these MAZ's correspond with marine isotope stages 11 (the Swanscombe MAZ), 9 (the Purfleet MAZ) and 7 (the Ponds Farm/Sandy Lane (Aveley) MAZ) — Figure 225.

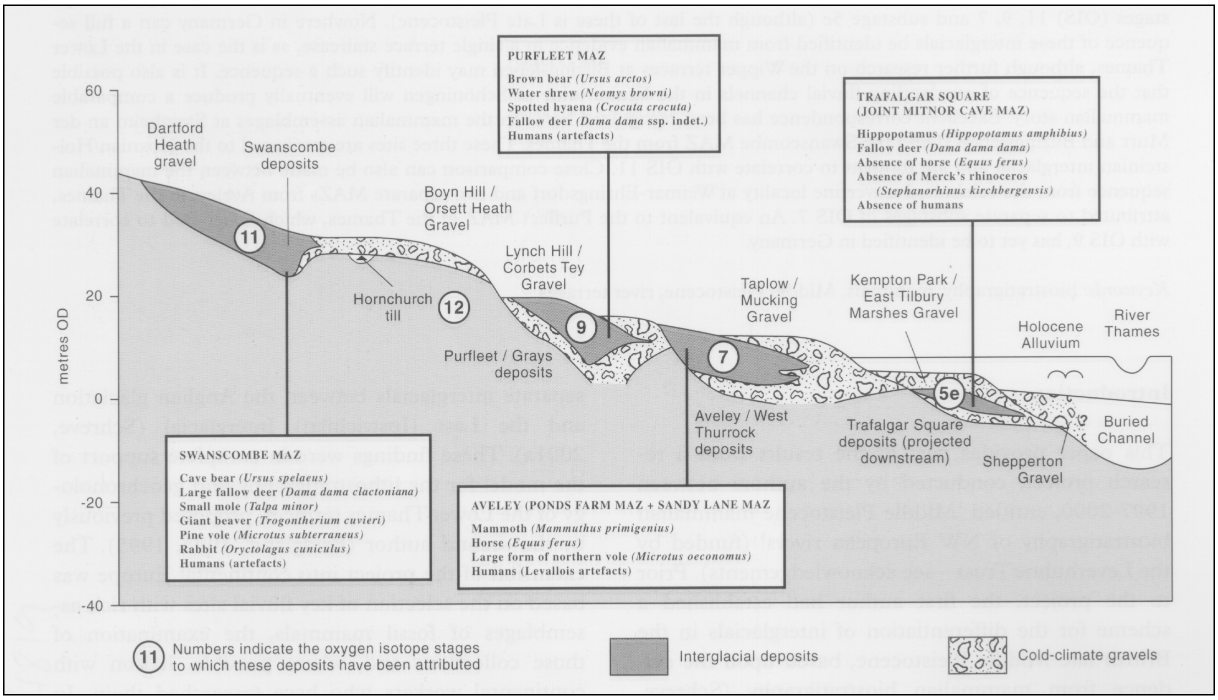

Figure 225: selected mammalian assemblage characteristics and their attribution to MAZs (Schreve & Bridgland 2002: Figure 1)

Each of the MAZ's has been identified on the basis of a series of consistent multi-species correlations. Each of these mammal assemblage zones can therefore be clearly separated from each other and from assemblages of the Last Interglacial. They represent a move a way from previous reliance on single 'indicator' species and are therefore a more robust modelling technique, less prone to excavation- or recovery-related distortions. The recognition that discrete MAZ's can be identified for each interglacial provides a means of independently dating faunal assemblages from sites outside of the Thames terrace sequence in which they were originally identified. This wider applicability of the MAZ's has been demonstrated by Schreve & Bridgland (2002) in a recent analysis of key German fluvial assemblages. Correlation between the British and German sequences had previously proved problematic, as the German fluvial sequence is not preserved in the classic staircase formation of the Thames terraces, but rather fluvial gravels are instead preserved as isolated remnants. Schreve & Bridgland's (*ibid.*) examination of the faunal assemblages recovered from key German localities such as Steinheim, Bilzingsleben and Thüringen showed strong similarities with the MAZ's identified within the Thames. This correlation indicates that these faunal groupings are both robust and widely applicable within similar latitudes. In addition to providing corroboration to the MAZ methodological groupings, this study has also facilitated independent dating of highly significant German Pleistocene localities, for example on the basis of excellent correlation with the Swanscombe MAZ both Steinheim an der Murr and Bilzingsleben II have been attributed to MIS-11, the Hoxnian/Holsteinian interglacial (*ibid.*).

Detailed analyses of the faunal assemblages from Swanscombe and Aveley (both located in the Lower Thames valley) by Schreve (2001b) have shown that the mammalian record can be used to identify environmental and climatic oscillations within single interglacial events. Despite their differences in age (Swanscombe is assigned to MIS-11, and Aveley to MIS-7), both sites and therefore both interglacial stages, show consistencies in their patterns of environmental progression (*ibid*.). An example of this progression is outlined below with reference to Swanscombe.

The Swanscombe sequence clearly represents the first post-Anglian temperate event, but has also been the subject of debate regarding the actual number of climatic events preserved (King & Oakley 1936; Evans 1971; Mullenders, in Wymer 1974; Hubbard 1982; Conway *et al*. 1996). Bridgland (1994) considers that the entire Swanscombe sequence represents a single interglacial (MIS-11), a view supported by both shell aminostratigraphy (Bowen *et al*. 1989) and mammalian evidence (Schreve 2001b). However, within this single interglacial, a series of five small-scale, intra-stage climatic oscillations can be identified. This includes three temperate events, delineated by cold phases as indicated by depositional hiatuses or lithology (*ibid*.). During the first depositional break multi-proxy evidence suggests sea levels low enough to reconnect Britain to the Continent and this is reflected in a marked faunal change above and below this horizon.

The Lower Gravel and Lower Loam are considered to represent the earliest warm episode (Phase I) within MIS-11, with mammalian fauna indicating fully temperate, mixed or deciduous woodland and open grassland habitats. *Dama dama clactoniana,* a woodland indicator species, dominates during this phase of the interglacial (Schreve 2001b). The sequence then preserves evidence of a significant hiatus in fluvial deposition, low sea levels and Continental reconnection (Zeuner 1959; Conway 1969). Within the Lower Middle Gravel the fauna is of the 'Rhenish' type and has been considered to indicate fluvial exchange between the Thames and the Rhine. The fauna of the Lower and Upper Middle Gravels is associated with the second warm phase (Phase II) and indicates temperate conditions, but of a more open nature. This is attested to by the pronounced decrease in woodland indicator species such as fallow deer, coupled with an increase in open species such as *Equus ferus* (horse) (Schreve 2001b). The Phase II deposits are followed by the cold climate Upper Sands (Phase IIIb). The fauna from temperate Phase III remain unknown at this time. In summary therefore, the Swanscombe sequence was laid down during a single interglacial, correlated to MIS-11. Both lithostratigraphic and mammalian evidence indicate multiple temperate events. Mammalian evidence indicates the change between Phase I and Phase II to more open conditions, perhaps reflecting increasingly continental climatic conditions brought about by the marine transgression.

It can therefore be demonstrated (Schreve 2001b) that not only does mammalian evidence allow the distinction between different interglacials during the Middle Pleistocene, they can also be used to distinguish environmental and climatic oscillations within them. The interglacials of MIS-11 (Swanscombe) and MIS-7 (Aveley) both demonstrate fully temperate, wooded conditions, followed by a period of temperate, open grassland habitats. At both locations two (possibly three) distinct warm episodes can be recognised, though it currently remains unclear whether some of these phases should be considered as amalgamations (*ibid*.). Mammalian evidence can therefore be demonstrated to display intra-stage variability, and can be utilised as a proxy chronology.

2.1.5 Conclusions

Mammal assemblage zones provide a detailed means of correlating the faunal assemblages from multiple sites. As they rely on the conglomeration of multiple mammalian species (both large and small) they provide a more robust set of climatic and chronological indicators than single indicator species. It can be demonstrated that the discrete MAZ's identified were present not only within the Thames valley (e.g. Schreve 2001a) and other major British river systems (Bridgland & Schreve 2001) but they can also be identified within continental Europe (Schreve & Bridgland 2002). As these discrete assemblages have been demonstrated for each interglacial (Schreve 2001a), their wider European presence can therefore provide a means of correlation and an independent dating technique (e.g. Koenigswald & van Kolfschoten 1996). Finally, mammalian evidence, as demonstrated by Schreve (2001b) can also be utilised to examine the terrestrial record for evidence of the small scale climatic oscillations present in the MIS record, potentially providing independent chronological schemes.

2.2 Coleoptera

Coleoptera (beetles) are one of the most diverse groups of macroscopic invertebrates occurring in Quaternary deposits (Lowe & Walker 1997: 192; Evans & O'Connor 1999: 140). They are the most important of the insect orders, with over 300,000 known species, of which 3,800 occur in Britain alone (Lowe & Walker 1997: 192). They occupy all of the planet's biomes except for the sea (although some do occur within the inter-tidal zone), and can be found in the vast majority of freshwater and terrestrial ecological niches (Evans & O'Connor 1999: 140). Fortunately, several aspects of coleoptera aid their usage in palaeoenvironmental research (Lowe & Walker 1997; Evans & O'Connor 1999; Coope 2001):

- Beetles, like other insect species, have remained morphologically constant throughout the last two million years of the Quaternary period (Lowe & Walker 1997: 194–195; Coope 2001: 1718).
- Evidence from living and fossil beetle assemblages suggests that the ecological preferences of the majority of species also underwent relatively little change during the Quaternary. This is indicated in Britain by the similarity of warm-adapted insect assemblages from different interglacials, widely separated in time (Lowe & Walker 1997: 195). Indirect geological and palaeobotanical evidence also suggests that the majority of fossil beetle species were associated with similar types of environments to those that they occupy in the present (*ibid*: 195). Therefore, the coleoptera appear to demonstrate physiological stability during the Quaternary (*ibid*: 195; Coope 2001: 1718).
- The complexity of the fossil enables identification to the level of the species (Coope 2001: 1718). Dead beetles disintegrate into the component parts of the exoskeleton: the head, thorax, elytra (wing cases), legs and abdominal sclerites. The first three of these are both robust enough for common preservation and variable enough to enable identification to a high degree (Evans & O'Connor 1999: 140).
- Many species of beetle are stenoptic, showing marked preferences for very restricted environmental niches or conditions (Lowe & Walker 1997: 192; Evans & O'Connor 1999: 140).
- Beetle species change their geographical ranges on a large scale and extremely rapidly in response to environmental changes, especially those of the thermal climatic (Lowe & Walker 1997: 192; Coope 2001: 1718).
- They are not readily eroded from one deposit and re-deposited in another. This is due to the fact that the fossil insect cuticle is readily attacked and destroyed by bacteria and fungae, and so coleoptera are rarely found as derived fossils (Coope 2001: 1718).

The classical application of coleopteran fossils has been in the fields of palaeoenvironmental and palaeoecological reconstruction, with particular emphasis upon climatic change (Lowe & Walker 1997: 196–199; Evans & O'Connor 1999: 141; Schreve & Thomas 2001: 1580). The morphological and physiological stability of beetles enables the present day ecological requirements and preferences of different species to be used in palaeoenvironmental reconstructions. However, there are exceptions to the rule of morphological and physiological stability. *Hypnoides rivularis* (Gyll) has its modern southern limit across Fennoscandia at about 60°N, yet occurs in several British sites (including the Lateglacial Windermere Interstadial) in association with temperate species (Lowe & Walker 1997: 195). In such cases, it is possible that the species has changed its ecological tolerances and could therefore be misleading as a palaeoenvironmental indicator if and when found in isolation. The importance of examining the association of species within the total assemblage is therefore stressed, not least because of the varying mobility of different beetle species. Some taxa are relatively sedentary and therefore provide small-scale data, while others are highly mobile and may therefore be incorporated into alien assemblages (Evans & O'Connor 1999: 140).

Overall however it is clear that for many species, their geographical ranges correspond with well-defined climatic zones and especially with summer temperature thresholds. Those species with narrower (stenotherms) rather than broader (eurytherms) ranges of climatic tolerance are inevitably more important in palaeoclimatic research as they enable more precise climatic inferences to be made (Lowe & Walker 1997: 196). The use of beetles as climatic proxies is not without difficulties however, since it can never be definitively established that a species has colonised the entire climatic range for which it is suited, or that past distributions were wholly in equilibrium with the prevailing climatic conditions. Coope (1977) however has argued that the speed and scale of changes in species' geographical distributions (in response to climatic change) during the Quaternary indicates that coleoptera were able to colonise new, available habitats extremely quickly. Therefore, where species' range limits coincide with climatic boundaries, the relationship has been used to derive quantitative palaeotemperature estimates.

A second major problem concerns the potential for fossil assemblages to contain species representing a variety of different climatic ranges. Coope (1987) has shown that British assemblages may consist of species falling into eight different categories, ranging from Southern European to Eastern Asiatic. The conversion of these complex assemblages into palaeoclimatic information has relied primarily upon two methods:

- The range overlap method. The modern geographical distributions of the assemblage species are plotted, and the zone of overlap between them is identified. Modern climatic data from within the zone are then used to reconstruct the palaeoclimate. This method works best with large numbers of stenothermic species, but also faces some major problems. It is possible that a species does not occupy its full potential geographical range, and that some taxa may only temporarily co-exist during transitional phases of adaptation to new climatic conditions. This latter problem can result in ephemeral fossil mixes, which have no modern analogue (non-analogue assemblages). It is particularly relevant in the interpretation of fossil insect assemblages from sediments that accumulated during an episode of abrupt climatic change (reflecting the rapid response times of insects to climatic conditions). It is therefore vital to be able to distinguish between temporary and stable associations of beetles (Lowe & Walker 1997: 197).
- The mutual climatic range (MCR) method. This approach plots the climatic parameters for each beetle species in the assemblage, utilising modern distribution maps and meteorological data. The climatic parameters (temperature of the warmest and coldest months and an index of seasonality) provide a best fit estimate of the mutual climatic conditions within which the mix of fossils existed. As previously, the method is most successful for assemblages with large numbers of stenothermic species. By ignoring geographical ranges (which are often too broad and ignore a range of other factors), this method can reduce complex geographical ranges to simple climatic summaries, reflecting the fact that the diverse geographical locations occupied by a species are often linked by common climatic characteristics. It also does not matter if the species doesn't occupy its full (potential) geographical range, so long as some of the boundaries are reached (Lowe & Walker 1997: 197–198). The MCR method has been extensively applied to the study of the last-glacial/interglacial transition (Ponel & Coope 1990; Lemdahl 1991; Walker *et al.* 1993).

More recently, Coope (2001) has argued for the use of coleopteran fossils as biostratigraphical indicators. This application is supported by the potential for species-level identification, the large numbers of species and the possibility for stochastic fossil faunas, the rapidity and scale of their geographical ranges (resulting in highly contrasting glacial and interglacial assemblages), and the rarity of fossil derivation (see above for further discussion of all of these points).

Coope's (2001) analysis of coleopteran assemblages from southern Britain and their role in the biostratigraphy of marine isotope stages 5 and 7e is briefly described here. The analysis highlighted coleoptera assemblages from 14 different interglacial sites, all of which were post-Hoxnian in date (Aveley, Sandy Lane Quarry, Essex; Bobbitshole, Suffolk; Deeping St James, Lincolnshire; Elsing BGS borehole, Norfolk; Histon Road, Cambridge; Itteringham, Norfolk; Marsworth, Buckinghamshire; Shropham, Norfolk; Stanton Harcourt, Oxfordshire; Stoke Goldington, Buckinghamshire; Strensham, Worcestershire; Tattershall Thorpe, Lincolnshire; Trafalgar Square, London; and Woolpack Farm, Cambridgeshire). All 14 assemblages had broadly similar implications for the local environment, indicating fairly open country, with deciduous woodland at some distance from the sedimentary site. The sites were typically pools or abandoned floodplain channels, with abundant, lush grass or reed vegetation.

The 14 assemblages were divided by Coope into two groups: group A included highly characteristic assemblages that were attributed to the Ipswichian interglacial (on stratigraphic and other independent palaeontological grounds), and specifically to MIS-5e and the early part of the interglacial (the *Pinus-Quercetum mixum-Corylus* pollen zone Ip II of West (1977)); while group B included assemblages from deposits that pre-dated the Ipswichian interglacial and which have been assigned to MIS-7. The group B assemblages are markedly different from those of group A. The exotic species from group A are missing in the group B assemblages (most notably the dung beetles), while two characteristic group B species (*Oxytelus gibbulus* and *Stomodes gyrosicollis*) are absent from the group A assemblages. These two species act as useful, but not unique biostratigraphical markers. Overall therefore, these coleopteran assemblages have assisted in the distinction of MIS-5e and MIS-7 deposits, although further work (particularly with respect to the beetle faunas of the late Ipswichian) is required.

2.3 Molluscs (non-marine)

Non-marine molluscs are some of the most common fossils remains recovered from terrestrial Quaternary sediments (Lowe & Walker 1997: 202; Figure 226). The two key classes are the Gastrapoda (snails, or univalves) and the Bivalvia (mussels and clams). After early taxonomic work in the 18th and 19th centuries, molluscs began to be utilised as palaeoclimatic indicators and for dating geological events, in the late 19th and 20th centuries. Compared to other terrestrial and freshwater fossil groups, molluscs boast a number of advantages (Lowe & Walker 1997: 203; Evans & O'Connor 1999: 141):

- Specimens have a high degree of taxonomic resolution and can nearly always be identified to species, supporting detailed palaeoenvironmental interpretation (Lowe & Walker 1997: 203).
- Shells occur in oxidised sediments that typically lack other fossil remains such as pollen or coleoptera (Lowe & Walker 1997: 203).
- Specimens are large enough to be recognised in the field, enabling a general appreciation of the palaeoecology to be gained on site. This can assist in the development and implementation of sampling strategies for other fossil groups (Lowe & Walker 1997: 203).
- The present day ecology and geographical distribution of molluscs is extremely well understood, indicating that molluscs often occur in distinctive species associations that reflect particular habitats (Lowe & Walker 1997: 203; Evans & O'Connor 1999: 141).
- Molluscs are characterised by rapid generation times and population turnover rates, which combined with their sensitivity to local changes in the physical and chemical environment, makes them valuable indicators of micro-scale environmental change (Lowe & Walker 1997: 203; Evans & O'Connor 1999: 141).

- However, molluscs (which are preserved as their shells) are composed of calcium carbonate, and are therefore only well preserved in alkaline conditions (Evans & O'Connor 1999: 141).

The predominant application of mollusc shells has been in the reconstructions of palaeohabitats and the study of environmental change (e.g. Kerney 1968; Sparks & West 1970). These approaches have emphasised the respective division of freshwater and terrestrial species into groups that demonstrate common habitat preferences (Lowe & Walker 1997: 205):

- Freshwater molluscs:
    - 'Slum' group: individuals tolerant of poor water conditions, ephemeral or stagnant pools, and considerable changes in water temperature (e.g. the water snail *Lymnaea truncatula*).
    - 'Catholic' group: molluscs that tolerate a wide range of habitats, except for the worst slum conditions (e.g. *Lymnaea peregra*).
    - Ditch group: species found in ditches with clean or slowly moving water, and abundant growth of aquatic plants (e.g. *Valvata cristata*).
    - Moving water group: molluscs found in larger bodies of water, including moving streams and large ponds where water is stirred by current and wind (e.g. *Valvata piscinalis*).

- Land molluscs:
  - Marsh species (e.g. *Vallonia pulchella*).
  - Dry land species (e.g. *Pupilla muscorum*).
  - *Vallonia* species: indicate open, un-wooded land surfaces.
  - Woodland species.

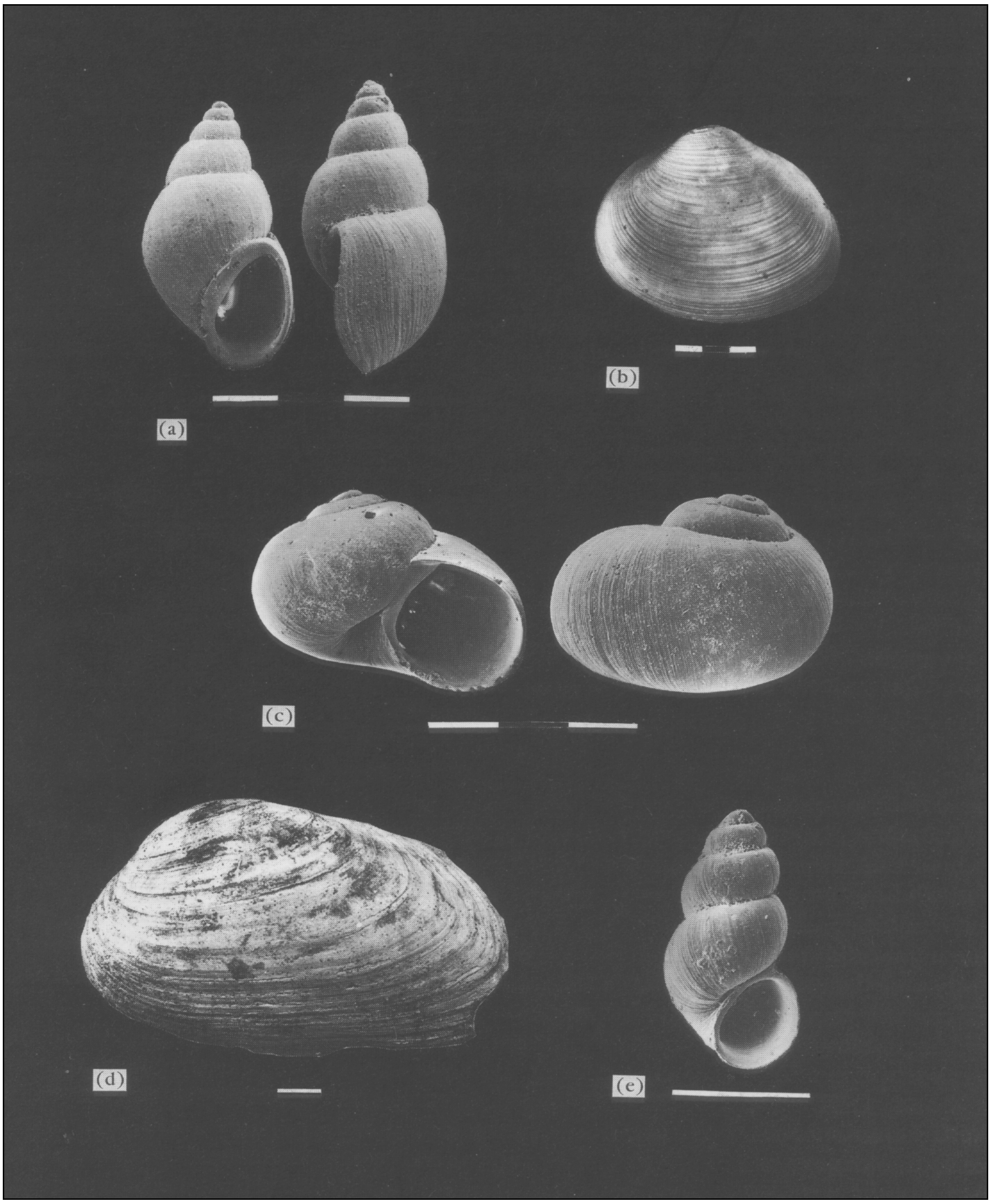

Figure 226: characteristic molluscs from the Little Oakley sands & silts (Bridgland 1994: 308)

Studies of environmental change have indicated that the primary influence upon molluscan assemblage variability during the late Quaternary was local habitat conditions. For the land taxa, the degree and type of vegetation cover was especially critical, and these molluscs could also indicate whether land conditions were dry or marshy. In contrast, the freshwater assemblages indicated rates of movement and the degree of oxygenation of water bodies (Lowe & Walker 1997: 206). Although the initial work in palaeoclimatic reconstruction focused upon indicator species (e.g. Kerney 1968; Sparks & West 1970), more recent approaches (e.g. Rousseau 1991) have developed transfer functions based on training sets of modern molluscan assemblages and their relationships with modern climatic variables (Lowe & Walker 1997: 207).

More recently, attention has been turned to the potential of molluscan assemblages as biostratigraphical indicators (Preece 2001; Keen 2001). Preece (2001) for example has argued that the view of a single-interglacial Cromerian is a huge over-simplification, and that molluscan and vertebrate evidence suggests there may be as many of five distinct stages conflated into the Cromerian Complex. For the late Middle Pleistocene Keen (2001) has developed a non-marine molluscan biostratigraphy, which was comparable with mammalian, coleopteran and lithostratigraphic evidence, although it is at odds with extant pollen biostratigraphies. The biostratigraphy distinguishes the Ipswichian interglacial (MIS-5e) from the MIS-7 interglacial on the basis of the presence/absence of taxa now exotic to the UK, including *Belgrandia marginata* and *Corbicula fluminalis*. The faunas utilised by Keen were from fluvial deposits with similar facies, thus making the assemblages directly comparable with one another. Although flood-formed fluvial assemblages consist of species from multiple ecological niches in the river and floodplain (causing some interpretive problems), this homogenising of molluscs from different environments enables the comparison of faunas of the same or different ages.

The interglacial fluvial assemblages consisted primarily of very similar sets of species that were forced out of the UK in each cold stage and returned in each interglacial. Critical for the biostratigraphical scheme however, was the extinction of small numbers of species during the Middle Pleistocene. This enabled individual temperate stages to be characterised by a combination of species extinctions and the presence/absence of species (Keen 2001: 1658). Fluvial faunas for sub-stage 5e revealed a number of distinctive features:

- Molluscan taxa consisted largely of species that are present in southern Britain today, combined with a small number of exotic species, the most important of which is *B. marginata*.
- The assemblages commonly occur with mammal fauna containing *Hippopotamus amphibious*, a diagnostic species of sub-stage 5e.
- The assemblages also occur in association with a diagnostic coleopteran fauna, whose non-British elements have a predominantly Mediterranean distribution today.
- Plant macrofossils are indicative of summer temperatures 4°C higher than today.
- In general, the presence of *B. marginata* appears to be biostratigraphically significant and indicates an MIS-5e age.

In comparison, the MIS-7 faunas indicate a number of contrasts:

- The presence of *C. fluminalis* (although in association with Ipswichian-type pollen) appears to indicate MIS-7 age for sites in the Upper Thames, the Warwickshire/ Worcestershire Avon and the upper reaches of the Wash drainage.
- However, this pattern is more complicated in the Wash margins and the Lower Thames, where it is suggested that stage 7 faunas feature both species (*C. fluminalis* and *B. marginata*), at least in some areas. Keen (2001) suggests three possible explanations for this pattern:
    - That there was a biogeographical boundary across the Thames, between the Thames and the Avon, and between the upper and lower reaches of the Wash. However, this seems highly unlikely given the uniformity of modern faunas in the southern half of Britain today.
    - That faunas with *C. fluminalis* and *B. marginata* together, and with only *C. fluminalis* represent separate sub-stages of MIS-7. This is a possibility (and is potentially supported by the recent work of Schreve (2001a) at Aveley), but cannot be definitively evaluated at the current time.
    - That *B. marginata* occurs as a result of re-working from earlier deposits, in certain favourable circumstances (this is the explanation supported by Keen (2001)).
- The stage 7 faunas are also characterised by the last appearance of *P. clessini* prior to its extinction.

- Overall therefore, the presence/absence of *P. clessini*, *C. fluminalis* and *B. marginata* give a clear biostratigraphic signature to the stage 7 deposits and faunas.

In contrast with the stage 5e and 7 faunas, the stage 9 and 11 faunas cannot be comprehensively characterised, primarily due to the small number of sites. However, the three stage 11 sites which have yielded fluvial faunas are highly distinctive, containing the so-called "Rhenish Fauna" (named for its supported connection with the Rhine during stage 11) which includes *B. marginata* and *C. fluminalis*, and other exotic fauna (*T. serratiliniformis*, *V. naticina* and *U. crassus*). In fact, the major molluscan biostratigraphic index for stage 11 is the terrestrial assemblage (found at Beeches Pit, Suffolk and Hitchin, Hertfordshire), although unfortunately this highly distinctive terrestrial fauna has not yet been found at enough sites to be confirmed as a biostratigraphic marker.

Overall therefore, Keen's (2001) biostratigraphic analysis of molluscan faunas indicated that:

- Fluvial deposits can be divided on the basis of their included molluscan faunas, so long as deposits from the warmest parts of each interglacial, and from similar facies, are compared.
- Sub-stage 5e faunas are easily identified, stage 7 faunas are more difficult to characterise, while stage 9 and stage 11 sites are too poorly known (despite the stage 11 "Rhenish" fauna).
- The molluscan sequence tentatively divides into four groups that match the four temperate stages of the marine isotope stage record.
- While pollen lacks the resolution to distinguish between temperate stages (e.g. "Ipswichian" pollen appears to be found in both MIS-5e and 7 and "Hoxnian" pollen in MIS-9 and 11), these stages can be separated using molluscan, mammalian and coleopteran biostratigraphies.

2.4 Ostracods

Ostracods are small, marine and freshwater crustaceans (Evans & O'Connor 1999: 144). The bulk of ostracod research has focused upon marine species, although there has recently been an increasing interest in the occurrence and ecological preferences of brackish and freshwater species (Lowe & Walker 1997: 212). Although there is a well documented fossil record (the first fossil ostracod was described in 1813) and some species have highly restricted ecological preferences (Lowe & Walker 1997: 212; Evans & O'Connor 1999: 144), there are several problems influencing ostracod analyses:

- The classification of modern ostracods is predominantly based on the soft body parts, yet these features are rarely preserved in the fossil form. Taxonomic classification is therefore based on the carapace (the outer shell, which fossilises relatively easily), but this limits the comparison of modern and fossil forms (Lowe & Walker 1997: 212–213).
- The distributions of living ostracod communities are governed by a wide range of factors, including physical parameters (water temperature, salinity and the nature of the substrate) and biological parameters (food chains and natural associations). Unfortunately, it is difficult to cite any one factor as being universally dominant (Lowe & Walker 1997: 212).
- Terrestrial ostracods typically possess thinner carapaces than the marine species, and can be easily destroyed by mechanical breakdown and chemical corrosion (Lowe & Walker 1997: 214).

Prior to the 1970's ostracods (marine and freshwater) were little used in Quaternary studies, with the main exception being their use in the distinction of non-marine and marine sedimentary facies (Griffiths 2001: 1743). The majority of recent ostracod research however has focused upon marine specimens (e.g. Whatley 1993). Although studies of terrestrial ostracods have been limited, there has been a growing use of freshwater ostracods as palaeoenvironmental proxies since the 1970's (Griffiths 2001: 1743). Recently, the use of transfer functions has related species distributions to variations in substrates, salinity, oxygen/anoxia and temperature. The ability of ostracods to immigrate rapidly into ponds after cold/temperate climate transitions also indicates their potential use as palaeoclimate indicators (Lowe & Walker 1997: 214).

Roe (2001) recovered ten ostracod species for borehole EH1 at East Hyde, Essex. Freshwater species dominated the assemblages of the basal gravels and sands, with high proportions of the plant-associated species *Scottia browniana* (Jones). Freshwater species decline in the overlying organic beds, with an accompanying increase in brackish water species (e.g. *C. torosa*). Above unit 3b, there were very few ostracod valves, predominantly juveniles of *C. torosa*. Overall, the East Hyde assemblages suggest a slow-flowing, well vegetated stretch of river, with restricted access to the sea. Over time, flooding or gradual sea level rise introduced deeper, more saline waters, accompanied by a more vigorous flow regime (Roe 2001: 1613).

Finally, the last few years has seen new interest in the potential of freshwater ostracods as biostratigraphic markers in the European Quaternary (Griffiths 2001). This research has highlighted patterns of ostracod speciation, migration and lineage extinction. Griffiths (*ibid*: 1744) has highlighted several highly ornate forms (e.g. *I. quinculminata*), which are robust indicators of the Hoxnian (*sensu lato*) and the Cromerian (*sensu lato*). As with most organisms, ostracod species richness follows distinct gradients. Although these are not currently fully understood, there are clearly more species per unit area in the east and south-east of Europe than in the north-west (*ibid*: 1745). The ostracods are able dispersers, with many species producing desiccation resistant eggs or having diapausing life-history stages. These are transported by other organisms (birds, fish, amphibians, and water bugs), hydrology and possibly aerial plankton. Parthenogenetic taxa are also able to establish new populations from single individuals, giving them the potential for rapid colonisation. Although ostracod colonisation processes are random, their dispersal strategies allow them to rapidly invade newly created or ephemeral habitats and to "track" their preferred environmental and climatic optima (*ibid*: 1745–1746).

It appears that most ostracods have "preferred" climatic and environmental optima, and that they "track" these back and forth across landscapes as conditions fluctuate over time. This process is particularly noticeable in the UK because of its periodic isolation from the rest of Europe, and it results in characteristically interglacial ostracod faunas:

- MIS-11 and MIS-9 faunas are extremely similar to those of modern central Europe.
- MIS-5e faunas are much more similar to those of modern UK and the Low Countries.

In general, the advantages of ostracod species as ecological and biostratigraphic markers have been greatly enhanced by recent research that has resolved many of the most problematic issues: identification, taxonomy and systematics; and the fauna of western and central Europe.

2.5 Pollen

Pollen analysis (or pollen stratigraphy) is the most widely adopted technique used for the reconstruction of Quaternary environments (Lowe & Walker 1997: 163). It involves the extraction, identification and counting of the pollen grains and spores that are incorporated and fossilised within archaeological sediments. The study of pollen has a long history within modern archaeology, and it is clear that the technique has a wide range of advantages and disadvantages (Evans & O'Connor 1999: 134). The key advantages are as follows:

- There is an extremely well-established methodology for the recovery and representation of pollen data, emphasising the importance of local and regional pollen assemblage zones (Lowe & Walker 1997: 167–169).
- Lacustrine sequences provide long, high resolution pollen sequences (Thomas 2001: 1621).
- Degraded grains (see also below) commonly indicate secondary deposition, evident in the structural modification of the exine surfaces (which occurs through re-working). Deteriorated pollen diagrams can therefore provide useful corroborative information with regards to redeposited pollen (Lowe & Walker 1997: 172).
- Despite the many problems and difficulties associated with the interpretation of pollen data (see below), the value of this data is clearly indicated by:

> *"the remarkable degree of consistency in the large number of pollen-based research publications that have appeared in the Quaternary literature in recent years".*
>
> (Lowe & Walker 1997: 173)

Nonetheless, these problems and difficulties should be stressed here:

- Not all plants produce the same amounts of pollen, although this can be corrected for by the application of scaling and weighting factors to original pollen counts (Lowe & Walker 1997: 169).
- Pollen identification is hindered by a degree of taxonomic imprecision.
- Within almost any polleniferous deposit, there is likely to be a combination: of local pollen derived from the contemporary vegetation close the point of deposition; regional pollen transported over long-distances by air and water; and a residual component of re-worked pollen of various different ages (Evans & O'Connor 1999: 70–71). Evans & O'Connor (1999: 70) also stress that the processes of fluvial flooding and transport offer a mechanism by which pollen taxa not normally widely dispersed are transported over potentially large distances.
- The variable nature of pollen deposition can create considerable complications in the fossil record. Factors include the differential settling velocities of pollen in lakes and ponds, the disturbance of sediments by currents and/or burrowing organisms, and the occurrence of reworked pollen (Lowe & Walker 1997: 171). Streams and rivers can derive pollen from eroding soils and peats which may be centuries or millennia older than the contemporary, freshly deposited pollen, although patterns in exine deterioration can be used to distinguish primary and secondary pollen (Evans & O'Connor 1999: 70).
- Fossil pollen grain deterioration results from physical, chemical and biological attacks on the exine. Experimental research has indicated that grains and spores vary in their responses to oxidation and corrosion, and that this variability is partly attributable to the depositional environment. In other words, some pollen types tend to be under-represented and others over-represented in the fossil record (Lowe & Walker 1997: 172).
- It is now generally recognised that many former plant communities have no modern analogues (Lowe & Walker 1997: 172). This highlights the issue of how far pollen assemblages can be related to plant communities, and how valid are the palaeoenvironmental and palaeoclimatic inferences that are made on the basis of pollen data.
- With respect to the biostratigraphical value of pollen in Quaternary studies, it has become apparent that pollen sequences from two or more interglacials can be comparable, recording similar patterns of vegetation development (Thomas 2001: 1622).
- Finally, the fragmentary nature of many terrestrial pollen records, combined with the issue of local vegetation variability, means that single-proxy palynological schemes are difficult to apply (Schreve & Thomas 2001: 1579).

The classical focus of pollen studies has been in the reconstruction and tracing of local and regional vegetation developments. At the local level, pollen records from peat and lake cores underpin the identification of ecosystem histories, while in coastal regions pollen is used to track sea-level change, as marine transgressions and regressions are reflected by changes between saltmarsh, terrestrial, and freshwater plant communities. At the regional and extra-regional levels, pollen data enables large-scale vegetation patterns to be established and the history of individual species and entire assemblages to be tracked through time. Finally, where sufficient numbers of well-dated pollen sites exist, space-time reconstructions of palaeo-vegetation change through time can be developed, showing changes in vegetation composition and distribution (Lowe & Walker 1997: 173).

Pollen data is also used to reconstruct Quaternary climates, although increasing awareness of the complexities of pollen taphonomy (see above), and the differential migratory responses of plants (especially trees) to climate change, has highlighted the dangers of using indicator species as a basis for making palaeoclimatic inferences. More recently therefore, focus has been placed on the development of pollen response surfaces, which provide a quantitative measure of the dependence of broad-scale vegetation patterns upon climate (Lowe & Walker 1997: 175).

Thomas (2001) has recently assessed the problems and potential associated with the development of a pollen biostratigraphy for the British Quaternary. This work is grounded in the pioneering work of Pike & Goodwin (1953) and West (1956, 1957), who argued that the various warm stages of the Pleistocene were apparently characterised by different patterns of vegetation development. Pollen (and macroscopic plant remains) therefore became the basis for the reconstruction of regional vegetation histories, and three Middle and Late Pleistocene interglacials (the Cromerian, Hoxnian and Ipswichian) were recognised (Mitchell *et al.* 1973. However, it has since been demonstrated that pollen sequences for different interglacials can be comparable, a realisation that has been partially due to the oxygen isotope record's demonstrated that the pollen-based glacial/interglacial scheme was an over-simplification (Thomas 2001: 1622). It is now clear for example, that pollen records with a 'Hoxnian' signature can originate from more than one interglacial.

Therefore, with respect to the pollen record and its overall potential as a biostratigraphical marker, Thomas (2001: 1625) has highlighted a series of key current issues:

- It is critical to recognise biostratigraphical signals that are significant at regional and not just local levels, if palynology is to be used to identify and distinguish interglacials. In this respect, regional variations in taxa abundance (e.g. the abundance of *Carpinus* in East Anglia and its scarcity in the Midlands) may be of considerable value.
- Boreal forest pollen assemblages from early or late interglacial sub-stages show strong similarities between different interglacials, and may indeed by undiagnostic.
- High resolution lacustrine sites are extremely difficult to link into established stratigraphical frameworks (e.g. the river terrace sequences), although these links may be achieved through the use of other proxies (e.g. mammals and molluscs).
- A large proportion of UK Middle and Upper Pleistocene palynological sequences are from fluvial contexts. Unfortunately, the polleniferous fluvial and estuarine sites are unlikely to yield sufficient length of record, or quality of resolution, to enable the distinction of interglacials with similar pollen signatures.

2.6 Plant macro-fossils

The distinction between plant macro and microfossils is made on the basis that macrofossils are visible to the naked eye. Plant macrofossils can potentially survive in a variety of depositional environments, though they are most commonly recovered from lacustrine, fluvial and peat deposits where anaerobic conditions prevail. Nonetheless, the preservation of plant macrofossils is highly variable and the occurrence of plant macrofossils within Quaternary deposits is best described as sporadic. For example, many polleniferous deposits do not contain plant macrofossils, and where they do occur it may only be at very low densities. However, where plant macrofossils are preserved it is usually possible to identify them, to species level.

Where plant macrofossils are preserved they are usually locally derived. This makes them useful in local palaeoenvironmental and ecological reconstructions (e.g. Watts 1978) but of limited value in wider, regional analyses. At a local scale, macrofossil remains can be valuably employed to clarify the local distributions of species generally over-represented in pollen diagrams such as *Pinus*.

As the preservation and ease of identification of plant macrofossils is highly variable, perhaps the best application of this dataset is in conjunction with pollen analyses to produce detailed reconstructions of Quaternary vegetation patterns:

"when used in conjunction, therefore, plant macrofossil analysis and pollen analysis offer a more secure basis for palaeoecological inference than either technique used in isolation"

(Lowe & Walker 1997: 189)

2.9 Other sources of data

Lowe & Walker (1997: Chapter 4) highlight a range of other biological data types, including chironomidae, diatoms, foraminifera, marine micro-flora and micro-fauna, chrysophytes, cladocera, coral polyps, fungal remains, and testate amoebae. None of these categories of biological evidence are discussed further here, as they all represent environments and/or sediments which are not incorporated within the secondary contexts that are the focus of this work.

3. POTENTIAL OF BIOLOGICAL DATA SOURCES

This assessment is based on a range of factors, including the sampling logistics for each of the major data categories, the preservation potential within different sediment types, and an analysis of their occurrence within a sample set of secondary context archaeological deposits, as documented by Bridgland (1994) for the Quaternary of the Thames.

3.1 Sampling logistics

3.1.1 Mammals

Considerable care should be taken in the excavation of bone-bearing deposits, reflecting the variety of conditions in which bones can be found. Mapping, surveying, field descriptions, sketches and photography should precede the removal of bone fragments from the sediment matrix. In some cases it is possible to remove larger bones by hand, which should be left to dry out prior to cleaning with brush or water. It many cases however, bones (even those quite heavily mineralised) are brittle, and treatment with a penetrative plastic solution (e.g. polyvinyl acetate in toluene) may be necessary prior to removal of the matrix. If the bones are wet, especially those that are markedly decalcified, an emulsion of the plastic solution may be necessary, so that the strengthening material will penetrate the bone fibres. Very small bones and teeth (e.g. those of rodents) can usually only be recovered through sieving or screening of the sediment matrix, following the removal of the larger bones by hand (Lowe & Walker 1997: 228).

3.1.2 Coleoptera and other insect remains

Typically, flotation techniques are required for the extraction of fossil insect remains from sediment matrix. Following Lowe & Walker (1997: 192), disaggregation of the sediment using water or sodium carbonate solution breaks the sediment down into slurry. After sieving (300 μm), the residues remaining in the sieves are mixed with kerosene, after which water is then added enabling the insect remains (along with plant macro-fossils if these are present in the sediment) to float to the surface. The floating fraction is decanted, washed and sorted in alcohol, prior to microscopic collection and identification.

3.1.3 Non-marine (and marine) molluscs

Molluscan remains can be collected by hand from open sections in the field. However, they are best extracted under laboratory conditions as hand-picking of individual shells inevitably results in samples that are bias towards larger specimens. Following Lowe & Walker (1997: 203–204), bulk samples from sections or cores should be air dried and immersed in water, with a small quantity of a dispersive agent (e.g. H_2O_2 (Hydrogen Peroxide) or NaOH (Sodium Hydroxide)) being added if there is organic material present. The 'froth' (which contains the snails) is decanted through a 0.5 mm sieve and the process is repeated several times until no more snails are present in the froth, at which point the residual slurry is poured into a second 0.5 mm sieve. Both sieves are dried and the residues passed through another set of sieves (1 mm, 710 μm and 2411 μm) for ease of sorting, after which molluscan remains are removed by hand and/or brush under microscopic conditions.

3.1.4 Ostracods

Ostracods are commonly collected from lacustrine and marine sediments, under laboratory conditions. Following Lowe & Walker (1997: 212), deposits are typically disaggregated in water (although occasionally hydrogen peroxide may be required), sieved and dried. Ostracod carapaces and valves can be picked out by hand, using a very fine brush, under microscopic conditions.

3.1.5 Pollen

Samples containing fossil pollen can be taken from cores, or from sections exposed in river banks, cliffs, road cuttings and building excavations. Samples must be sealed air-tight and are usually kept in a cool store (at *c.* 1–3°C) to prevent desiccation and microbial attack. This also protects the samples from contamination by pollen circulating in the atmosphere (especially during the pollen and spore production seasons). In the laboratory, following sediment dispersal, sieving and/or chemical flotation (density separation), samples should be chemically treated in a variety of ways to remove as much of the sediment matrix as possible. Lignins and cellulose can be reduced in volume, if not entirely removed, by oxidation and acetolysis. Minerogenic sediments may be removed by either digestion in hydrofluoric acid, or be separated off by differential centrifugation or by floating the organic detritus (including pollens) out of the matrix using a 'heavy liquid'. Carbonates and calcareous sediments are treated with hydrochloric acid. The residues containing the pollens and spores may then be stained with an organic dye (e.g. safranin) which enhances the surface detail of some grains, prior to microscopic identification and counting of the grains and spores (Lowe & Walker 1997: 165).

3.2 Preservation Potential and Sediment Types

Evans & O'Connor (1999: 80–81) provide a valuable summary of soil and sediment types, depositional environments and their associated environmental indicators (summarised here in Table 50). Table 50 indicates, unsurprisingly, that anoxic environments (whether acidic or basic) provide favourable preservation conditions for the widest range of biological evidence (bone, insects, pollen, macroscopic plant remains, wood, and charcoal). However, such peats and organic sediments are relatively rare within Pleistocene secondary contexts (although certainly not unknown), and are also unfavourable to the preservation of molluscs and ostracods. It is clear that acid (favouring soil pollen, charcoal, and phytoliths preservation), basic (favouring bone, molluscs, charcoal, and ostracods) and neutral (promoting charcoal and sometimes bone and shell preservation) oxic environments are more widely distributed, although their preservation potential is less all-encompassing with respect to the different biological data categories.

Depositional environment	**Main soil/sediment type**	**Some typical situations**	**Environmental indicators**
Acid, pH usually < 5.5, oxic	Podsols & other leached soils	Heathlands, upland moors, some river gravels	Soil pollen, charcoal, phytoliths
Basic, pH usually > 7.0, oxic	Rendsinas, lake marls, tufa, alluvium & shell-sand	Chalk & limestone areas, valley bottoms, karst, machair	Molluscs, bones, charcoal, ostracods
Neutral, pH 5.5-7.0, oxic	Brownearths & gleys, river gravels	Clay vales & other lowland plains	Charcoal, sometimes bone & shell
Acid or basic, anoxic	Peats & organic deposits (e.g. lake sediments)	Urban sites, wetlands, river floodplains	Insects, macroscopic plant remains, pollen, bone, wood, charcoal

Table 50: soil & sediment types, depositional environments and environmental indicators (Evans & O'Connor 1999: 80)

3.3 Case Study

Although the previous discussions provided a general background to variable preservation conditions, it provided relatively little specific detail with respect to the fluvial sediments that are the focus of this report. By contrast, Bridgland's (1994) synthesis of the Quaternary of the Thames provided an excellent resource for assessing the relative abundance of different biological data within fluvial secondary contexts. The presence/absence of different biological data categories at each of 39 sites was documented, along with the main sediment types recorded at each site (Table 52). Although it is clear that the preservation of different data categories can be strongly influenced by soil and sediment types (Section 3.2 above), the 39 sites cover a wide range of geographical localities (Figure 227) and this minimises (without wholly removing) the effects of localised preservational biases.

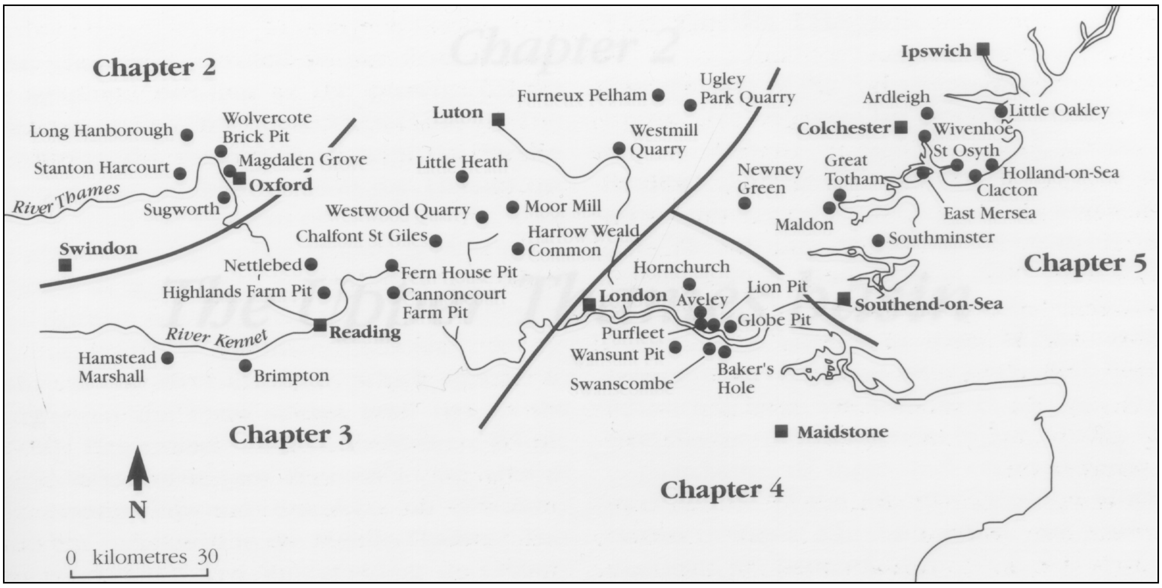

Figure 227: Thames Quaternary sites (Bridgland 1994: Figure 1.4)

The presence/absence of the data categories are summarised in Table 51, and indicate that the most common categories of biological evidence recovered from the Thames Quaternary sites are large mammals (20%), molluscs (primarily non-marine species, 16%) and pollen (15%; Figure 228). Small mammals (10%), ostracods (10%), coleoptera (8%) and plant macro-fossils (12%) are also relatively common, while birds, fish, amphibians and reptiles were only rarely recovered.

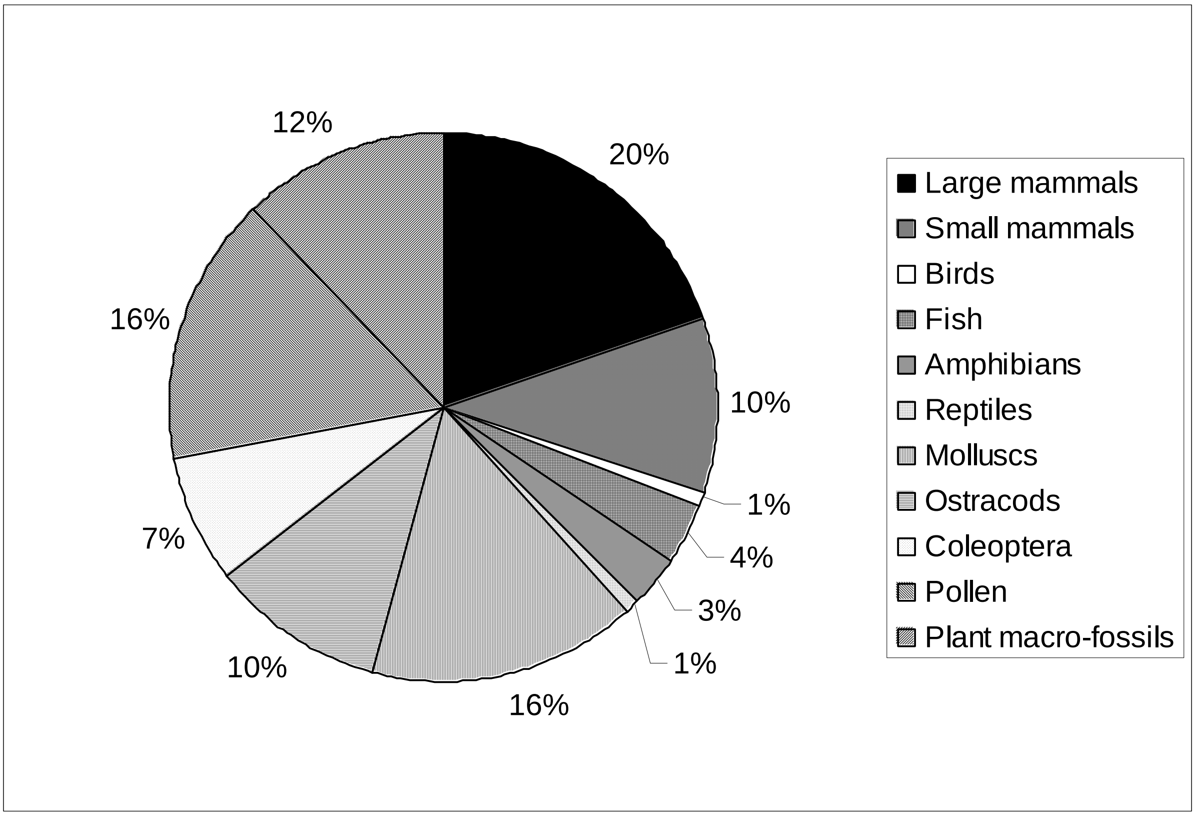

Figure 228: biological data recovered from 39 Thames Quaternary sites (after Bridgland 1994)

Data Type	Present	Absent
Large mammals	21	18
Small mammals	11	28
Birds	1	38
Fish	4	35
Amphibians	3	36
Reptiles	1	38
Molluscs	17	22
Ostracods	11	28
Coleoptera	8	31
Pollen	16	23
Plant macro-fossils	13	26

Table 51: occurrence of biological data types in 39 Thames Quaternary sites (after Bridgland 1994)

It is clear from the review that the recovery of certain categories of biological data correlates to specific sediments and deposits. For example, pollen, plant macro-fossils and insects (e.g. coleoptera) were predominantly recovered from organic deposits and other fine-grained, low energy sediments (e.g. pollen has been recovered from the Swanscombe lower loams (Bridgland 1994: 193–218), laminated silts, sands and clays at Purfleet (*ibid*: 218–228), and (along with plant macro-fossils) from the organic silty-clays at Wivenhoe gravel pit (*ibid*: 313–317). Small mammals and other small vertebrates (e.g. birds, fish, amphibians and reptiles) were also typically recovered from organic and fine-grained deposits (e.g. organic clays and silts at Great Totham), reflecting their vulnerability to physical and chemical destruction in higher energy fluvial deposits.

By contrast, only mammalian fauna (typically large mammals) and molluscs were recovered from the coarser-grained (and higher energy) fluvial gravels sediments, and in many of these cases, the molluscs were actually recovered from silt and sand lenses within those gravels. This is particularly well illustrated at the Long Hanborough gravel pit, where non-marine mollusc assemblages were sampled from distinctive silt and fine-sand lenses within the gravel unit *(ibid*: 49–58; Figure 229). By contrast, mammalian fauna has often been recovered from gravel units, such as the Stanton Harcourt gravel, which yielded a cold-climate assemblage including *Mammuthus primigenius*, *Coelodonta antiquitatis*, *Bison priscus* and *Equus ferus* (*ibid*: 65–79).

Rather unsurprisingly, it is those sites consisting only of fluvial gravel sediments (e.g. Harrow Weald Common, Chalfont St Giles Brick Pit, and Ferneux Pelham Gravel Pit) that most typically yield no biological evidence. However, it cannot be taken as a simple relationship, and it is noticeable that some sites including organic sediments (e.g. Priest's Hill, Nettlebed) have produced relatively little biological data, emphasising the importance of the local depositional environment and soil chemistry.

A specific assessment of the relationships between biological data and sediment types is presented for ten sites that have yielded a wide range of biological data (Table 53): Great Totham (Loft's Farm Pit), Clacton, Cudmore Grove (East Mersea), Little Oakley, Swanscombe (Barnfield Pit), Purfleet, Globe Pit (Little Thurrock), Aveley (Sandy Lane), Wolvercote, and Stanton Harcourt (*ibid.*). It is immediately apparent that silts, clays and sands tend to preserve the widest range of biological data, while gravels typically preserve only large mammals (the absence of smaller vertebrates reflects taphonomy and sampling processes) and molluscs.

In summary, it is clear that the recovery of the different categories of biological evidence reflects a combination of several factors: soil and sediment chemistry; the depositional environments (e.g. high and low energy settings); the preservation of organic and/or fine-grained sediments within fluvial sequences; and the nature of the archaeological sampling. Given these variables, it should be clear that the potential range of biological data will vary considerably, but a case study synthesis of Bridgland (1994) does suggest that large mammal fauna and molluscs may be the most commonly encountered types of data within purely coarse-grained, fluvial gravel deposits and sequences. Naturally, the presence of finer-grained and organic sediments within those sequences will potentially increase the range of biological data, although regional soil conditions can still limit the available evidence, as at Broom (Chapter 2).

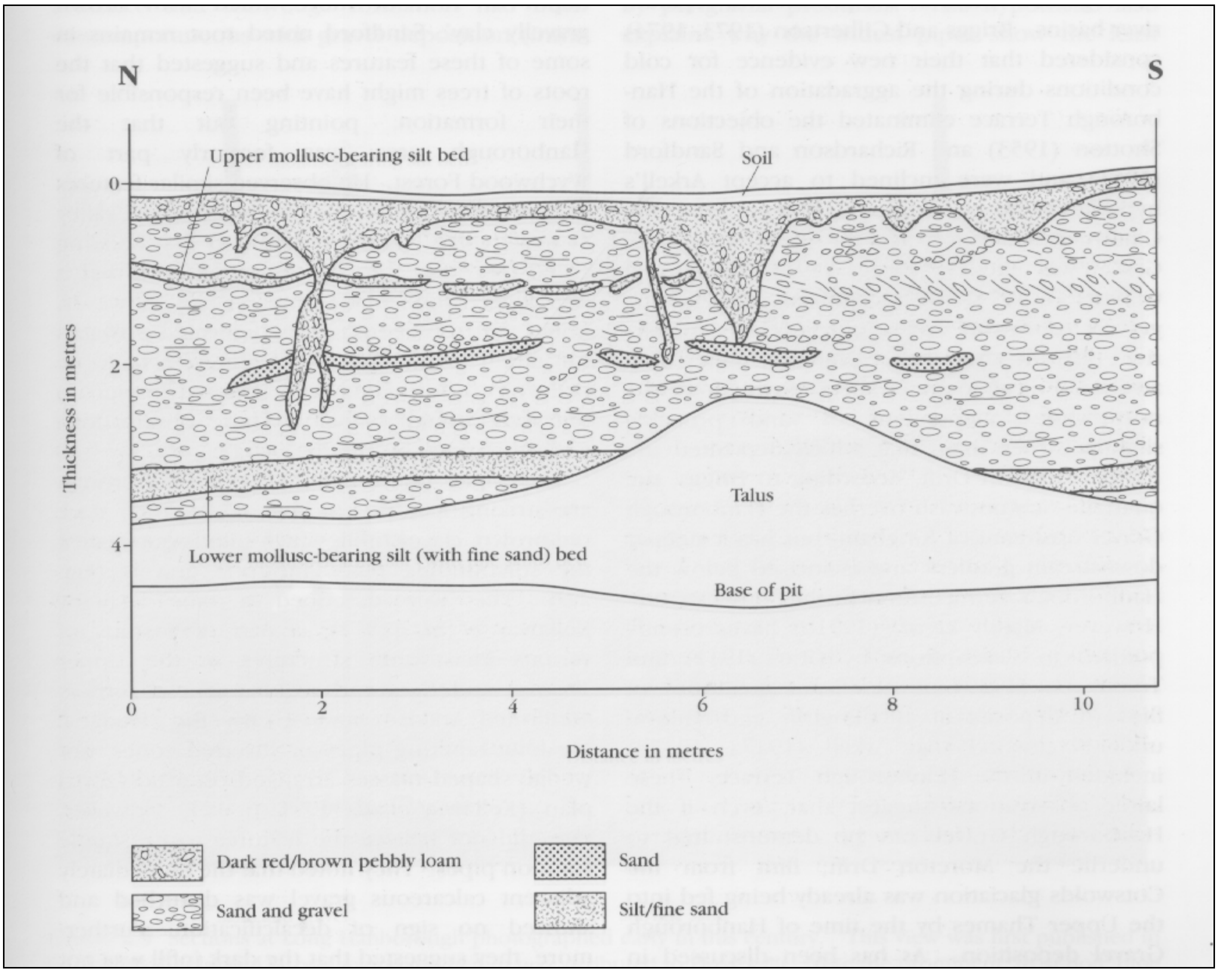

Figure 229: Long Hanborough Gravel Pit (East Face). Note the mollusc-bearing silt beds (Bridgland 1994: Figure 2.8)

Site	Sediment types	Vertebrates										
		Large mammals	Small mammals	Birds	Fish	Amphibians	Reptiles	Molluscs	Ostracods	Coleoptera	Pollen	Plant macro-fossils
Sugworth Road Cutting	Gravels, sands, silts & clays	YES	YES	NO	NO	NO	NO	YES	YES	YES	YES	YES
Long Hanborough Gravel Pit	Gravels (incl. silt & sand lenses)	YES	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO
Wolvercote Channel	Gravels, sandy-gravels, silty-clays & peats	YES	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES
Stanton Harcourt Gravel Pit	Gravels, sands, silts & organic sediments	YES	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES
Magdalen Grove	Gravels & silty-sands	YES	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO
Little Heath	Gravels, sands & clays	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Harrow Weald Common	Gravels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Priest's Hill, Nettlebed	Gravels & interglacial organics	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO
Chalfont St Giles Brick Pit	Gravels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Ferneux Pelham Gravel Pit	Sandy-gravel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Westwood Quarry	Gravels (incl. clay-enriched & iron-stained horizon)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Westmill Quarry	Tills, gravels & sands	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO
Moor Hill Quarry	Till, gravels & glacio-lacustrine sediments	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Ugley Park Quarry	Till, gravels & sands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Highlands Farm Pit	Gravels	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Cannoncourt Farm Pit	Gravels & sands	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fern House Gravel Pit	Gravels	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Site	Sediment types	Vertebrates										
		Large mammals	Small mammals	Birds	Fish	Amphibians	Reptiles	Molluscs	Ostracods	Coleoptera	Pollen	Plant macro-fossils
Brimpton Gravel Pit	Gravels, sands, silts & organic muds	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES
Hornchurch Railway Cutting	Till & gravels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Wansunt Pit, Dartford Heath	Gravels, silts & clays	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Swanscombe (Barnfield Pit)	Gravels, sands & loams	YES	YES	NO	NO	NO	NO	YES	NO	NO	YES	YES
Purfleet (Bluelands, Greenlands, ESSO & Botany Pits)	Gravels, brickearths & coombe deposits	YES	YES	NO	NO	NO	NO	YES	YES	NO	YES	YES
Globe Pit, Little Thurrock	Gravels & brickearths	YES	YES	NO	NO	NO	NO	YES	YES	NO	YES	YES
Lion Pit, Tramway Cutting (West Thurrock)	Gravels, sands, silts & silty-clays	YES	NO	NO	NO	NO	NO	YES	YES	NO	YES	NO
Aveley, Sandy Lane Quarry	Sands, silty-clays & peaty-clays	YES	YES	NO	YES	NO	NO	YES	YES	YES	YES	YES
Northfleet (Ebbsfleet Valley): Baker's Hole Complex	Gravels & fine-grained sediments	YES	YES	NO	NO	NO	NO	YES	NO	NO	NO	NO
Newney Green Quarry	Till, outwash gravels & cover-sands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Ardleigh (Martells Quarry)	Gravels & organic sediments	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES
Little Oakley	Gravels & channel sediments	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	NO
Wivenhoe Gravel Pit	Gravels & organic silty-clays	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES
St. Osyth Gravel Pit	Ice-sheet outwash sediments & gravels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Holland-on-Sea Cliff	Ice-sheet outwash sediments & gravels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Site	**Sediment types**	**Vertebrates**										
		Large mammals	Small mammals	Birds	Fish	Amphibians	Reptiles	Molluscs	Ostracods	Coleoptera	Pollen	Plant macro-fossils
Holland-on-Sea Cliff	Ice-sheet outwash sediments & gravels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Clacton	Gravels, sands & clays (channel-fill sediments)	YES	YES	NO	NO	NO	NO	YES	YES	NO	YES	YES
Cudmore Grove, East Mersea	Gravels & channel-fill estuarine sediments	YES	YES	YES	YES	YES	NO	YES	YES	NO	YES	YES
Southminster, Goldsands Road	Sandy-gravels, sands & clayey-sands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Maldon Railway Cutting	Tills, gravels & sandy-silts	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
East Mersea Restaurant Site	Gravels, sandy-silts & clay-silts	YES	YES	NO	NO	NO	NO	YES	YES	NO	NO	NO
East Mersea Hippopotamus Site	Gravel & silts (incl. sand & gravel stringers)	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Great Totham (Lofts Farm Pit)	Gravels, silts & organic clays	YES	YES	NO	YES	YES	NO	YES	YES	YES	YES	YES

Table 52: presence/absence of biological data types for 39 Quaternary sites from the Thames (after Bridgland 1994)

Data types	**Sediment type**					
	Gravels	Sand	Silt	Clay	Peat	Loams
Large mammals	YES	YES	YES	YES	NO	YES
Small mammals	NO	YES	YES	YES	NO	YES
Fish	NO	YES	YES	YES	NO	NO
Birds	NO	NO	NO	YES	NO	NO
Reptiles	NO	YES	YES	NO	NO	NO
Amphibians	NO	YES	YES	YES	NO	NO
Molluscs	YES	YES	YES	YES	NO	YES
Ostracods	NO	YES	YES	YES	NO	YES
Coleoptera	NO	NO	YES	YES	YES	NO
Pollen	?[8]	YES	YES	YES	YES	NO
Plant macro-fossils	NO	NO	YES	YES	YES	NO

Table 53: occurrence of biological data in different sediment types, from the sites of Great Totham (Loft's Farm Pit), Clacton, Cudmore Grove (East Mersea), Little Oakley, Swanscombe (Barnfield Pit), Purfleet, Globe Pit (Little Thurrock), Aveley (Sandy Lane), Wolvercote and Stanton Harcourt (after Bridgland 1994)

4. SPATIO-TEMPORAL RESOLUTION OF BIOLOGICAL DATA

The review of the key biological data sources (Section 2) indicated two contrasting scalar approaches to the issue of reconstructing fluvial palaeoenvironments:

- High resolution reconstruction, based on biological material that is highly sensitive to palaeoclimatic change and other aspects of palaeoenvironmental variation (e.g. coleoptera and molluscs).

- Low resolution reconstruction, based on biological material that is less sensitive to palaeoclimatic change and other aspects of palaeoenvironmental variation (e.g. large mammal fauna and pollen).

These scalar differences function at both spatial and temporal scales. For example, not only do beetles and molluscs change their geographical ranges rapidly in response to environmental change (high resolution spatial data) but they also have rapid generation times and population turnover rates, thus providing high resolution temporal data.

However, with respect to palaeoenvironmental reconstructions, the robusticity of biological data and their susceptibility to destruction during fluvial transport is also a critical factor. Thus molluscs, beetles, ostracods and small mammals tend to be preserved in close proximity to their death environment and provide valuable data for local habitat reconstruction. By contrast, large mammals and pollen are far more susceptible to long range transport and are therefore often only reliable as indicators of regional and sub-regional palaeoenvironments.

Most importantly, it is clear from the previous discussions of biological data types (Section 2) and their occurrence within the geoarchaeological record (Section 3), that many types of evidence occur most commonly within sediments that often yield *in situ* archaeology and would therefore be described as archaeological primary contexts. Classic examples include the Swanscombe lower loam, where a thin horizon (thought to represent a sub-aerial surface) contains conjoinable flint flakes (Bridgland 1994: 206); and the gravel/clay interface at the Clacton golf course site, which yielded mint and conjoinable artefacts (Bridgland 1994: 342); while primary context archaeology is also associated with fine-grained and organic sediments at several other British Lower Palaeolithic sites (e.g. Boxgrove (Roberts & Parfitt 1998), Beeches Pit (Gowlett & Hallos 2000), Barnham (Ashton *et al.* 2000a) and Elveden (Ashton *et al.* 2000b)). This clearly raises a number of important issues: principally whether such biological data should be discussed within an assessment of archaeological secondary contexts.

[8] This reflects the doubts expressed regarding the occurrence of pollen in the lower gravels at Swanscombe (Bridgland 1994: 197).

This project defined secondary contexts as the range of fluvial sediments (gravels, sands, silts, and clays) that are deposited within fluvial sedimentary sequences upon river terrace landforms. All of these sediments reflect fluvial processes, albeit at markedly different scales of magnitude and energy. If some of those sediments contained primary context archaeology (e.g. conjoinable knapping scatters within fine-grained silts), then the relevant sediments and the archaeology would be defined as being in primary context, as the archaeological materials had not been transported since they were discarded by hominids. Such archaeological 'sites' are therefore outside of the remit of this project. However, if the sedimentary sequence was as outlined below, how would it be defined?

(Top of sequence)
Fluvial gravels, containing re-worked, derived bifaces
—
Fluvial, organic clays, containing a coleoptera assemblage
—
Fluvial silts, containing a mollusc assemblage
—
Fluvial gravels, containing derived bifaces
(Base of sequence / bedrock surface)

Clearly, the gravels at the base and top of the sequence represent an archaeological secondary context, as the sediments and the archaeology (in this hypothetical example) demonstrate clear evidence of derivation (transportation and deposition) under high energy, fluvial conditions. The key question is whether the fine-grained silts and organic clays (and their biological contents) can be (or should be) associated with the gravels (and bifaces) as part of an archaeological secondary context? Moreover, if they are regarded as part of the same secondary context, then how can the material be related?

With regard to the first question, it is clear that the biological and archaeological data cannot be directly associated as they do not occur within the same sedimentary unit. However, Bridgland's (1994, 1995, 1996, 1998, 2000, 2001) climatically-driven, cyclical model of terrace formation does provide a framework within which these data can be bracketed: namely, the marine isotope stage (or stages) within which the sediments were deposited. The biological and archaeological data still cannot be directly related, but the materials represent un-associated examples of archaeological behaviour and palaeo-environmental conditions within the bracketed time-span of the sedimentary unit (an archaeological secondary context). We would therefore argue that all such data falls under the investigation of archaeological secondary contexts, and within the remit of this project. This therefore leads into our second question: can any links be drawn between the various categories of biological and archaeological data that occur within those secondary contexts? This is critically dependent upon the different minimum temporal and spatial scales that can be assigned to the data.

Based on the assessment of the different biological data types, we propose two classifications for their spatial and temporal resolution:

4.1 Spatial resolution

Macro-scale: large mammal fauna, pollen (the regional component) and arboreal macro-fossils (especially trunk material).
↑↓
Micro-scale: small mammals, small vertebrates, molluscs, ostracods, pollen (the on-site component), coleoptera, and plant macro-fossils.

In this context, macro-scale refers to a regional spatial unit, as represented by river system catchments. Will these can obviously vary in size (e.g. compare the River Thames with the River Axe), the key points are that the material has derived from a wide range of fluvial palaeohabitats and from a comparably-sized catchment to any derived archaeological artefacts. This latter point has obvious implications for the interpretation of hominid behaviour, and is returned to below. The incorporation of large mammal fauna, arboreal macro-fossils, and the regional component of pollen assemblages within the macro-scale group reflects the robusticity of this material and their potential for long distance transport by water (fauna and wood) and air and water (pollen). By contrast, micro-scale refers to 'site'-based spatial units. While it is impossible (and fruitless) to try and discuss specifically-sized spatial areas, these scales can be viewed as reflecting specific micro-habitats and landscapes (e.g. the Barnham channel and floodplain (Ashton *et al.* 2000a) or the Boxgrove landsurface (Roberts & Parfitt 1998)). These data support the high resolution reconstruction of individual palaeohabitats, which may or may not contain the archaeological evidence of hominid behaviour. The inclusion of small mammals, small vertebrates, molluscs, ostracods, coleoptera, pollen (the on-site component) and plant macro-fossils reflects the general fragility of this material and the taphonomy of their deposition (Section 2).

4.2 Temporal resolution

Macro-scales: large mammal fauna.
↑↓
Intermediate scales: pollen, molluscs.
↑↓
Micro-scales: small mammals, small vertebrates, ostracods, pollen (on-site component), coleoptera, and plant macro-fossils.

In this context, macro-scales refer to marine isotope stages, or marine isotope sub-stages, reflecting the broader environmental tolerances of large mammal species, low turnover rates and generation times, and the relatively coarse biostratigraphical signatures of large mammal associations (Schreve 2001a, 2001b). Moreover, the presence within high energy fluvial contexts and varied physical conditions of large mammal fauna indicates their ability to withstand extensive re-working and derivation. The occurrence of large mammal fauna within a specific fluvial sediment (especially coarse-grained gravels) is therefore not a high resolution temporal indicator (i.e. death did not necessarily occur immediately prior to the deposition of the sediment). This contrasts markedly with the fragile micro-fauna (e.g. coleoptera, ostracods, small mammals and other small vertebrates), whose intact preservation tends to indicate a short time period (and limited transport and derivation) between death and the sedimentary accumulation event.

The classification of pollen and molluscs within the intermediate group reflects a range of factors. For pollen, the robusticity of the material indicates its potential for surviving re-working episodes, and ultimately being deposited in pollen assemblages where the 'fresh' pollen is centuries or even millennia younger. In the case of molluscs, their apparent occurrence within coarser-grained gravel and sand deposits (e.g. Bridgland 1994) suggests a degree of robusticity and the potential to survive re-working episodes within high energy contexts.

These classifications are clearly intended as guidance rather than a hard rule. For example, certain elements of large mammal fauna are far more robust than others (e.g. limb bones compared to cranial material), while small mammal fauna may be preserved over several phases of derivation and re-working in exceptional circumstances. However, the physical conditions of this material (e.g. fauna, shells, pollen exine) can often be employed as an indicator of atypical levels of derivation and re-working in time and space.

Overall therefore, macro-scale (as defined above) palaeoenvironmental reconstructions are primarily dependent upon large mammal faunal assemblages within secondary contexts. These species associations have been widely employed to reconstruct broad-scale environments and climatic conditions. For example, in the Aveley (Sandy Lane) mammal assemblage zone (MAZ) the predominance of species such as woolly mammoth and horse suggests an open grassland environment, while decreasing numbers of straight-tusked elephant and Merck's rhinoceros suggest a reduction in woodland coverage (Schreve 2001b: 1701–1702). These reconstructions inevitably cover large spatial areas, reflecting the broad ecological tolerances of many large mammal species, the large ranges of individual species, and their wide geographical distributions (Schreve has traced her MAZ's into western and central Europe (Schreve & Bridgland 2002)). The reconstructions also span long time periods (e.g. MIS stages and sub-stages), reflecting the difficulties in assessing the time depth of derived fossils[9], and the relatively stable, non-ephemeral nature of large mammal communities. In effect therefore, these reconstructions are essentially time-averaged, and yield a reliable overview of the mammal fauna (associated with a specific terrace unit for example), although it must be remembered that it will not detect micro-variations in space and time. This has been demonstrated by Schreve (1997, 2001a, 2001b, & Bridgland 2002), whose development of mammal assemblage zones has documented the repetitive occurrence of distinctive faunal assemblages and species associations. These species associations minimise the dangers associated with the employment of single indicator species, which are particularly prevalent in secondary contexts subject to re-working.

Finally, it is stressed that when dealing with large mammal fauna, the potential role of hominids in the accumulation of the material needs to be acknowledged. However, the focus upon species associations and the range of other mechanisms leading to the accumulation of mammals within fluvial sediments (e.g. non-hominid carnivore predation, old age, disease, drowning) should limit the impact of hominid bias, although certain species may be over-represented.

Macro-scale palaeoenvironmental reconstructions can also make potential use of pollen assemblage zones from organic deposits within secondary context sequences, with specific reference to the reconstruction of regional vegetation development, palaeo-climatic conditions, and broad scale climatic change. However, in light of the major taphonomic complexities associated with pollen assemblages, and the typically low resolution, fragmented pollen sequences from fluvial secondary contexts (Thomas 2001), it is suggested here that regionally-derived pollen data from fine-grained deposits within fluvial secondary contexts will typically be strongly time and space-averaged. This is also true for arboreal macro-fossils occurring within both fine and coarse-grained fluvial sediments. Overall, these data may reveal broad patterns in palaeoclimate and regional vegetation types, although temporal trends in vegetation development will be difficult to detect. The nature of fluvial sequences and the problems of pollen taphonomy also highlight the dangers of utilising single indicator species to document palaeoclimatic change.

In contrast, micro-scale palaeoenvironmental reconstructions are primarily dependent upon a range of biological data (small vertebrates, molluscs, ostracods, coleoptera, pollen), from a wide range of coarse and fine-grained secondary contexts. These data can provide a wide range of extremely high resolution data, indicating local environmental conditions and short-term change (e.g. fish species can indicate aquatic temperature and flow conditions, beetle distributions vary in response to vegetation, substrate types, hydrology and/or micro-climate, while terrestrial mollusc species vary in response to vegetation cover and soil saturation levels). However, it is apparent from the extant literature that the time-spans associated with particular micro-habitat conditions and/or with climatic change are rarely explicitly stated (if they are known at all):

"Overall, the assemblages from East Hyde are typical of a slow-flowing, well-vegetated stretch of river which had restricted access to the sea. Through time*, flooding or gradual sea-level rise brought deeper, more saline waters to the site, accompanied by a more vigorous flow regime."*

(Roe 2001: 1613, our emphasis)

"Examination of the lithological and palaeontological evidence indicates that the Purfleet deposits were laid down by a river of substantial size, with water depths of at least 5m. There are indications of saline influence, although very muted, suggesting that the site lay only a short distance upstream from the inner end of the contemporary estuary. A gradual *freshening of the water is however indicated upwards through the profile."*

(Schreve *et al.* 2002: 1455, our emphasis)

[9] Interpretative caution is strongly recommended where a fossil shows evidence of extremely severe evidence of abrasion and fluvial modification (Schreve pers. comm.).

No criticism is intended of these authors, it is simply apparent that geochronological estimates of high resolution habitat change are extremely rare (see Roberts & Parfitt 1998 for an example). Unfortunately, from an archaeological perspective, drawing direct associations between specific palaeoenvironmental habitats and sets of archaeological debris is an extremely attractive goal. However, unless primary context archaeology is recovered from the sediments yielding the biological data, these associations cannot be made (and primary context archaeology is not the focus of this research).

It is stressed however that these high resolution biological data sources may be used within biostratigraphical models (e.g. Thomas 2001; Keen 2001; Preece 2001; Coope 2001). These may potentially assist in macro-scale palaeoenvironmental reconstructions, both through indicating broad palaeoclimatic patterns (e.g. the summer temperature contrasts between MIS-5e and MIS-7), and by facilitating comparisons with high resolution data from other sites. However, it is clear that there are still considerable biostratigraphical conflicts between the different categories of biological data, and the need for multi-proxy, rather than single-proxy, approaches is therefore stressed:

"A possible correlation of the Cassington sequence with the Upton Warren Interstadial Complex on the basis of the Mollusca…[is] refuted by the pollen [and] is also contradicted by the coleopteran fauna"

(Maddy *et al.* 1998: 228)

Having highlighted the spatio-temporal resolutions of the available biological data, the final goal concerns the mapping of hominid behaviours against the reconstructed palaeo-environments. Four types of hominid behaviour are identified, at two key scales:

- On-site activity (micro-scale behaviour). This primarily covers tool production and subsistence activities (e.g. carcass butchery), reflecting those activities that are most commonly recognised in the archaeological record (e.g. Roberts & Parfitt 1998; Ashton *et al.* 1998; Ashton *et al.* 2000; Gowlett & Hallos 2000). It is of course acknowledged that these activities do not represent the full range of hominid daily existence.
- Technological change (macro-scale behaviour). This relates to the appearance of new technological innovations in the archaeological record (e.g. the appearance of Levallois technology in late MIS-9 and early MIS-8) and/or changes in technological practise (e.g. the shift from Clactonian to Acheulean during MIS-11 and MIS-9 (White & Schreve 2000). It is recognised that technological change also occurs at the micro-scale (the scale of individual technological innovations), although this is extremely difficult to detect. White's (1998b) analysis of changing biface shape at Swanscombe in response to landscape transformation and variations in raw material supply clearly operates at the sub-marine isotope stage level, but it still does not reach micro-scales as defined here.
- Demographic change (macro-scale behaviour). Evidence of demographic change is difficult to detect and verify, even at macro-scales, during the Middle Pleistocene, although recent research utilising artefact densities as a population proxy (Hosfield 1999; Ashton & Lewis 2002) has begun to suggest the presence of robust patterns.
- Responses to climatic change and perception of environments (micro and macro-scale behaviours). It is suggested that hominid responses to environmental change (e.g. climatic, vegetational) are more likely to have operated at similar spatial and temporal scales to the large mammalian fauna, although their specific sensitivity to micro-changes (e.g. in flora and micro-fauna) remains an unknown factor.

A preliminary mapping of these behaviour types and scales against the palaeoenvironmental data is therefore proposed:

- On-site knapping and subsistence activities (micro-scale): where the archaeological debris of these behaviours is in primary context, they can be directly mapped against any micro-scale biological data within the same sedimentary unit (which as outlined above is likely to be multi-proxy and high resolution). However, we are not dealing with archaeological primary contexts. Where the archaeological debris is derived, not only is the behavioural information of lower resolution, but it also cannot be directly mapped against the biological data[10]. This is true whether the biological data occurs in the same sedimentary unit as the archaeology, or in other units within a secondary context sequence. The biological data and reconstructed (high resolution) habitats can be discussed with respect to the archaeology, but only as examples of the *types* of environments within which the hominid behaviour *may* have occurred. In a similar manner, macro-scale palaeoenvironmental data can also be mapped against these types of micro-scale archaeological debris, but only as an indicator of generic, rather than specific, environmental conditions (i.e. direct associations can obviously not be demonstrated, reflecting the time and space-averaged nature of both sets of data).

- Technological change (macro-scale): this is most commonly represented through changes in lithic technology at the marine isotope stage or sub-marine isotope stage level (e.g. Conway *et al.* 1996; White & Schreve 2000), and the data typically consists of time-averaged assemblages. As previously, these data cannot be directly mapped against high resolution biological evidence, due to the spatio-temporal contrasts. The latter data can only be employed as an example of the multiple possible habitats and environmental conditions that existed during the timespan over which the archaeology was deposited. However, the archaeology can be indirectly associated with the low resolution biological evidence, based on their complementary scales (both data sets are time and space-averaged palimpsests, encompassing regional and extra-regional space and marine isotope stage-time). The biological data provides a low resolution, large scale image of mammalian communities and palaeo-landscapes over defined time-spans (e.g. MIS-10 or MIS-11e), against which changes in hominid technology and behaviour can be tested at the MIS and sub-MIS scale:

  For example, in an extension of the hypothetical example represented above (and reproduced below), the lower gravels represent MIS-11c (older) and the upper gravels represent MIS-11a (younger):

  > Fluvial gravels (MIS-11a): derived, twisted ovate bifaces & straight-tusked elephant/woolly rhinoceros fauna
  > —
  > Fluvial, organic clays, containing coleoptera
  > —
  > Fluvial silts, containing molluscs
  > —
  > Fluvial gravels (MIS-11c): derived, pointed bifaces & horse/red deer fauna

  These gravels are exposed at multiple locations throughout a regional river catchment, and in all locations where bifaces are present, the MIS-11a bifaces are dominated by twisted ovates, while the MIS-11c bifaces are characterised by points. The MIS-11a fauna is dominated by straight-tusked elephant and woolly rhinoceros, while the MIS-11c fauna is characterised by horse and red deer. Both the fauna and the archaeology are space-averaged (the smallest definable analytical spatial unit is the river catchment, although bones and artefacts will have been transported over a range of different distances) and time-averaged (the smallest definable analytical temporal unit is the MIS sub-stage associated with the gravel deposits). A regional scale analysis therefore enables change in biface technology (from MIS-11c to MIS-11a, across the river catchment) to be tested against changes in large mammal fauna (from MIS-11c to MIS-11a, across the river catchment). In the above example, an association could potentially be made between the marked faunal and technological changes, if the analysis assumes that the respective sets of artefacts and fauna are associated with the individual sedimentary events (see Chapter 7 for further discussion of this issue).

[10] The physical condition of both faunal and lithic materials may indicate varying probabilities of association, but it is stressed that association still cannot be *demonstrated*.

- Demographic change (macro-scale): this has been recently demonstrated through MIS variations in artefact density, within fluvial secondary contexts (Ashton & Lewis 2002). As with the technological change data (see above), three key points are evident:

    - These palimpsest data sets cannot be directly mapped against high resolution biological evidence, due to the contrasts in the spatio-temporal scales.
    - The high resolution biological data can only be employed as an example of the multiple possible habitats and environmental conditions that existed during the timespan (MIS in the work of Ashton & Lewis (2002)) over which the fluvial secondary context archaeology was deposited.
    - The archaeology can be indirectly associated with the low resolution biological evidence, utilising their shared time and space-averaged palimpsest structures. The low resolution biological data (defined by MIS-units) provides an environmental framework against which changes in hominid demography can be tested. Such possible connections (e.g. between technology, hunting strategies, social structures, environments and biota) have been more fully explored by Ashton & Lewis (2002).

- Responses to climatic change and perception of environments (micro- and macro-scale): this aspect of hominid behaviour is intended to highlight elements of Palaeolithic societies which are typically ignored in favour of tool making and subsistence activities. The premise is relatively simple: that as another social mammal, hominids may well have perceived and reacted to environmental and climatic change at broadly similar spatio-temporal scales to the large mammalian fauna. Since macro-scale data (e.g. Schreve's MAZ's) provides a range of data regarding mammalian distributions at the MIS and MIS sub-stage scales, it is argued that hominids could potentially be mapped against these patterns to explore trends in Palaeolithic occupation and migration (e.g. the apparent abandonment of Britain during MIS-6). Finally, it is noted that hominids may also have been sensitive to the high resolution environmental and climatic changes evident in micro-flora and fauna, although the scalar contrasts between micro-scale palaeoenvironmental data and secondary context archaeology do not permit the direct investigation of this potential relationship.

The above discussion highlighted issues of data scales and their implications for the applications and potential of palaeoenvironmental data within assessments of archaeological secondary contexts. The final section briefly expands this theme with respect to current research questions in British Palaeolithic studies.

5. PALAEOENVIRONMENTAL DATA, PALAEOLITHIC QUESTIONS & CONCLUSIONS

A brief review of the extant literature regarding current British Palaeolithic research suggests a core of key themes to which the interrogation of archaeological secondary contexts is relevant:

- The earliest occupation of 'Britain' during the Pleistocene (e.g. Roberts *et al.* 1995; Roebroeks 1996, & van Kolfschoten 1995; Roberts & Parfitt 1998; Wymer 1999; Rose *et al.* 2001).
- Patterns of colonisation and demography during the late Middle Pleistocene (e.g. Hosfield 1999; White & Schreve 2000; Ashton & Lewis 2002).
- Palaeolithic technology and hominid behavioural repertoires (e.g. Roberts & Parfitt 1998; White 1998a, 1998b; Gamble 1999; Wenban-Smith 1998, *et al.* 2000; White 2000, & Schreve 2000).
- The geochronological frameworks of the Middle and Late Pleistocene (e.g. Maddy *et al.* 1998; Bridgland 1998, 2000, 2001; Maddy *et al.* 2001; Schreve 2001a, 2001b; Bridgland & Schreve 2001; Current & Jacobi 2001; Preece 2001; Coope 2001; Keen 2001; Schreve & Bridgland 2002; Schreve *et al.* 2002).

With respect to these key themes and archaeological secondary contexts, where and how can the palaeoenvironmental data resource be applied? This review of the resource has indicated that the data covers a wide range of spatial and temporal scales, from stenoptic beetles to continent-ranging mammoths. These data scales mirror the variable and wide-ranging resolutions evident in archaeological material from the Middle and Late Pleistocene. The applications of palaeoenvironmental data therefore range from high resolution, small-scale and multi-proxy reconstructions of micro-habitats and local environments (e.g. Roe 2001; Schreve *et al.* 2002), to the low resolution, large scale mammal assemblage zones of Schreve (1997, 2001a, 2001b). In the case of the earliest occupation and geochronological frameworks themes outlined above, the applications of the palaeoenvironmental data are easily defined:

- Earliest occupation theme: linking biostratigraphically significant species (or assemblages of species) to the occurrence of otherwise undated archaeological materials within MIS and sub-MIS-scale secondary archaeological contexts. This has been previously demonstrated for primary context sites (e.g. the presence of *Stephanorhinus hundsheimensis*, *Ursus deningeri*, and *Arvicola terrestris cantiana* in the archaeological sediments at Boxgrove (Roberts & Parfitt 1998)) but could also potentially be applied to archaeological secondary contexts.

- Geochronological frameworks theme: linking biostratigraphical models to existing frameworks (e.g. absolute dating and/or terrace stratigraphy models). While it is clear that different schemes are sometimes contradictory (e.g. mammalian and coleoptera data are currently at variance with pollen biostratigraphies (Keen 2001)), these biostratigraphical approaches offer multi-proxy data and potential sub-MIS stage resolution (e.g. Schreve 2001a).

However, the application of these data to themes 2 (colonisation and demography) and 3 (technology and behaviour) is more difficult to identify. This is primarily due to the significant contrasts between the spatio-temporal scales of the various data sets. As discussed in Section 4, it is suggested here that the direct applications of high resolution palaeoenvironmental data are limited with respect to secondary context archaeology. While the derived archaeological data provide valuable time-averaged insights into technology and demography, the cultural debris cannot be demonstrably associated with the reconstructed habitats. In other words, while the archaeology provides direct evidence of hominid presence (within coarse timescales), that presence cannot be related to specific local habitats and environments. Those environments can only be presented as examples of the range of environments and habitats that were present, and which may or may not have been encountered by hominids. This last issue is specifically highlighted, since it is often not made explicit within multi-proxy investigations of Quaternary sequences.

However, low resolution palaeoenvironmental data can be indirectly linked at the scalar level with secondary context archaeology. This reflects their comparable scales of magnitude (e.g. river system catchments incorporating derived artefacts and fluvially transported mammal remains into time-averaged fluvial sedimentary sequences). These data are inevitably low in resolution and coarse-scale, but provide robust indications of broad trends, both in hominid technology and mammal/tree species distributions, although it is stressed that this data mapping does *not* assume that encounters between hominids and specific flora/fauna associations occurred. Such data are nonetheless extremely valuable as they can be employed to test multi-MIS changes in hominid demography, extra-regional colonisation, and technology, and explore potential relationships between hominid behaviour and the environment. They therefore highlight the importance of both regional data sets and macro-analysis approaches.

In conclusion, this module initially highlighted four goals:

- The identification of biological data sources with the potential for reconstructing fluvial palaeoenvironments: these currently cover a wide range, primarily vertebrates (including large and small mammals, fish, amphibians and birds), molluscs (non-marine), ostracods, coleoptera, pollen, and plant macro-fossils. It is also apparent however that new sources of palaeoenvironmental data are becoming available, reflecting new technological and methodological developments. These include Cladocera (a freshwater crustacean (the water flea)), Chironomids (non-biting midges), and testate amoebae (Evans & O'Connor 1999: 145; Charman 2001).

- The relative potential of the different data sources: based on the relative fragility of the different materials and their variable survival potential during re-working episodes, it was apparent that mammals and molluscs are more likely to be recovered from archaeological secondary contexts than any other type of palaeoenvironmental data. This reflects their greater durability and assumes (Chapter 2) that high energy sediments (e.g. fluvial gravels) constitute the bulk of the deposits within these secondary contexts. However, it is also clear that where fine-grained and organic sediments are preserved, a wide range of biological data may be recovered (although taphonomic factors are still important). Finally, it was clear that local sedimentary regime variations were of greater significance than sampling strategies with regard to the diversity of biological data recovered.

- The spatio-temporal resolution of the different biological data sources: it was clear that these varied markedly, and that secondary context archaeology cannot be directly mapped against high resolution palaeoenvironmental reconstructions. It is argued here however that secondary context archaeology and low resolution palaeoenvironmental data occur at similar scales of magnitude, and can be employed to generate comparable, low resolution models of different aspects of the Pleistocene environment.

- Relationships between palaeoenvironmental data and the current questions prevalent in studies of Pleistocene hominids: it is stressed that these relationships must be made explicit (irrespective of the specific questions), since there are fundamental scalar contrasts between the archaeological and biological data.

CHAPTER 7

THE POTENTIAL OF THE SECONDARY CONTEXT ARCHAEOLOGICAL RESOURCE

1. INTRODUCTION

The previous chapters assessed the temporal (Chapters 2, 3 & 6) and spatial (Chapters 4, 5 & 6) structure of the secondary context archaeological resource recovered from fluvial sedimentary sequences. These assessments correlated extant research (Chapters 2, 5 & 6) and reported new case study investigations (Chapters 3, 4 & 5). These assessments provide the platform from which the fundamental theme of this research project can be explored: what is the potential of the secondary context archaeological resource for the reconstruction of human/hominid behaviour during the early prehistoric periods (primarily the Lower, Middle and Upper Palaeolithic)?

Sections 2 and 3 address the spatial and temporal structures of the secondary context archaeological resource, with particular reference to the formation of artefact assemblages and their spatial and geochronological resolution. Building upon these models, Section 4 establishes analytical frameworks applicable to the secondary context archaeological resource and identifies the different spatio-temporal analytical scales that can be explored through these data. Section 5 maps these frameworks and analytical scales against extant archaeological research questions, and where relevant, tests whether these questions can be re-examined from alternative spatio-temporal perspectives. Finally, the potential and value of the secondary context archaeological resource is proposed (Section 6).

Specifically, the chapter explores four themes:

- The geo-chronological resolution of the archaeological resource and the relative importance of sedimentary, artefactual and palaeoenvironmental data.
- The spatial resolution of the archaeological resource, the relative importance of sedimentary and artefactual data, and the role of experimental archaeology and modern analogues.
- The analytical frameworks associated with the secondary context archaeological research, and their applicability to extant research questions and the varying spatio-temporal scales of hominid behaviour.
- The value of the secondary context archaeological resource, with specific reference to the range of available data and their spatio-temporal scales, their relevance to current research themes, and the current state of geoarchaeological methodologies.

2. PALIMPSESTS IN TIME

The geochronological resolution of the secondary context archaeological resource is concerned both with the fluvial activity that deposited a specific sedimentary unit (e.g. gravel or sand unit), and with the chronological catchment of the archaeological material. In other words, for how long were the recovered artefacts accumulating in the landscape prior to their incorporation with the fluvial sediments? This is clearly a multi-faceted problem, and the approach proposed here for its resolution incorporates geomorphological models, sedimentary data, artefactual material and palaeoenvironmental fossil evidence.

2.1 Fluvial activity across the glacial/interglacial cycle

The initial review of extant geomorphological models (Chapter 1) highlighted four issues of critical relevance to an assessment of the secondary context archaeological resource:

- A significant proportion of the fluvial activity that occurred during the Middle and Late Pleistocene is not preserved within the sedimentary record, due to subsequent, high energy erosional processes (e.g. Gibbard & Lewin 2002). This is especially applicable to the fine-grained sediments deposited under interglacial climatic regimes, but is also relevant with respect to the small-scale sedimentary features (both fine- and coarse-grained) that were formed in response to the high frequency, low magnitude climatic oscillations occurring within individual MI stages (see below).
- The majority of preserved fluvial activity occurs in association with the major glacial/interglacial climatic transitions of the Middle and Late Pleistocene). This reflects both the climatic instability of these phases (e.g. Bridgland 2000; Maddy *et al.* 2001; Vandenberghe 1995), and the high magnitude of these climatic oscillations, which results in the critical response thresholds of the majority of fluvial systems being exceeded and the formation of large-scale sedimentary features.
- River system response to the lower magnitude climatic oscillations (e.g. associated with stadial and interstadial events occurring *within* glacial phases) are variable, depending upon the specific threshold conditions of individual systems (Vandenberghe 2002). Moreover, the sedimentary units and erosional structures resulting from these episodes are typically vulnerable to subsequent erosion during the major transitional climatic phases (see above).
- River system responses to specific climatic change vary markedly between different rivers and between different zones (e.g. upland, lowland) of the same system (Howard & Macklin 1999).

Despite the availability of high resolution ice-core records of climate change (e.g. Anklin *et al.* 1993; Petit *et al.* 1999), it is clear that it is not possible to map the fluvial sedimentary archive against these climatic records, due to the discontinuous nature of the sedimentary record. Moreover, it is clear from optically stimulated luminescence dating of fluvial sediments (e.g. Chapter 3; Rhodes 2003), that it is not currently possible to develop high resolution sub-marine isotope stage (MIS) geochronologies for individual sedimentary episodes from the Middle Pleistocene.

Establishment of the geochronological resolution for archaeological secondary context sediments was therefore dependent upon Lateglacial and Lateglacial/Holocene transition models of fluvial systems, where high resolution radiocarbon chronologies could be established. Evidence from a wide range of studies suggested that the maximum time-spans associated with fluvial sedimentation activity (the deposition of individual units), incision and erosion were of a magnitude of 10^2 or 10^3 years (i.e. a few hundred or at most a few thousand years). It is also stressed that these estimates do not assume continuous activity, but rather represent the current limitations of geochronological dating techniques and the problems of correlating climatic and fluvial evolution. For example, Rose *et al.* (1980: Table 12.1) estimated that the erosion of discontinuous gully channels on the River Gipping at Sproughton, Suffolk occurred between 11,300 and 11,000 years BP, while braided and meandering river sedimentation of sands and gravels occurred between 11,000 and 9,500 years BP (based on radiocarbon dates and ages inferred from a coleopteran assemblage). The key point is that these erosion and sedimentation events cannot be demonstrated to have occurred continuously. Indeed it is highly probable that incision and sedimentation only occurred episodically in response to high-energy discharge events (e.g. annual, nival-floods). However, current geochronological tools cannot provide finer-resolution dating, so the 300 and 1,500 year time-spans represent the highest achievable geochronological resolution with respect to the incision and aggradation events. In effect, these time intervals represent periods during which incision (11,300–11,000 years BP) and sedimentation (11,000–9,500 years BP) were the dominant fluvial processes.

In the case of Middle Pleistocene sequences, high resolution geochronological dating is currently unattainable, but the chronologies from Lateglacial/Holocene sequences suggest minimum chronological units (MCU's) of 10^2 and 10^3 years in magnitude, with respect to fluvial incision and sedimentation events. It is stressed that these MCU's relate to the preserved fragment of the fluvial sedimentary record, which is proposed here to *probably* date to the major glacial/interglacial transitions of the Middle and Late Pleistocene. Palaeoenvironmental and biological data can also play a role in the establishment of Middle Pleistocene geochronological frameworks, although the value of these data tends to be inversely proportional to the species' palaeoclimatic and palaeoenvironmental sensitivity, and proportional to their preservation potential. For example, while non-marine molluscan (e.g. Preece 2001; Keen 2001) and coleopteran (e.g. Coope 2001) assemblages tend to be indicative of highly specific environmental conditions and probably document very short time-spans (e.g. 10^1, 10^2 years), they are typically primarily associated with organic, fine-grained deposits. Such deposits have low preservation potential (they are commonly eroded and replaced with coarse-grained sediments). Moreover, estimating time-spans on the basis of vertical changes in species composition (taken as an indicator of changing environmental conditions) is extremely difficult. Prior to the Holocene for example, the pollen zones of the Quaternary interglacials still do not boast an absolute chronology. Finally, even where biological data encases sedimentary terrace unit(s) (e.g. pollen-bearing clay deposits at the top and bottom of a sand/gravel sequence), the presence of erosive contacts within the sequence would add the considerable problem of undated depositional hiatuses to any proposed chronology.

By contrast, large mammal faunas occur within coarse-grained deposits (e.g. gravels and sands, although they are commonly derived and reworked (see below)), and while these species are not sensitive indicators of specific environmental conditions, variations in species' associations have been demonstrated to equate with interglacial sub-stage climatic variability (Schreve 2001a). Unfortunately, such variations have yet to be demonstrated for glacial sub-stages, but this application of biological data is currently the most important with respect to geochronological frameworks.

Overall therefore, the geochronological resolution of the fluvial sedimentary sequences (containing the secondary context archaeology) is modelled on the basis of:

1. Models of terrace formation and fluvial activity, which suggest that the majority of the fluvial activity preserved within the sedimentary record occurred during major glacial/interglacial transitions.
2. Analogies with radiocarbon dated Lateglacial sequences, which suggest minimum chronological units of 10^2 and 10^3 years in magnitude.
3. A semi-floating geochronological framework: individual fluvial events are not absolutely dated, but sedimentary sequences can be dated at a marine isotope stage level of resolution through relevant dating techniques (optically stimulated luminescence and amino-acid ratio) and Bridgland's (2001) cyclical model of terrace formation.

However, it has long been recognised that artefacts occurring within fluvial secondary contexts may be considerably older than their encasing deposits (e.g. Wymer 1968, 1999). This research has sought to highlight the considerable potential variation in the magnitude of the chronological catchment associated with derived artefact assemblages. These variations reflect a combination of factors including:

- The river zone, reflecting the differential geomorphological behaviour and preservation potential of fluvial systems in their upland and lowland stretches (e.g. Howard & Macklin 1999).
- Regional and local geomorphological factors (e.g. bedrock type, valley form) which can impact upon the degree of sediment re-working.
- Local depositional factors (e.g. the depositional location of the artefact assemblage) which can impact upon the tendency of the material to undergo subsequent re-working.
- The chronological location of the sediment within the glacial/interglacial cycle, which can impact upon the vulnerability of the deposit to subsequent reworking.

All of these themes are considered further below, with particular focus upon the development of a provisional model for the incorporation of archaeological material within fluvial deposits over geological time.

2.2 The river zone

It is clear that river systems will behave differently in their various zones or stretches (Chapter 2), and that generic models of temporal fluvial activity (e.g. across an interglacial/glacial cycle) greatly oversimplify this complexity (see Howard & Macklin 1999 for further discussion of this issue). Although some research specifically identifies the fluvial systems that are being modelled (e.g. Gibbard & Lewin (2002) highlight interglacial fluvial sedimentation in the lowland Britain zone; while Bridgland (2000) is concerned with temperate latitude valley systems beyond the reach of the Pleistocene ice sheets), in many cases the focus of the models is not specifically stated. However, since the model of fluvial activity proposed here (Chapter 2) is grounded in the extant research of Vandenberghe (1993, 1995, 2002, 2003), Bridgland (1994, 1995, 1996, 1998, 2000, 2001), Maddy *et al.* (2001) and Gibbard & Lewin (2002), the river system zones investigated by those authors are identified as base-line types against which to examine variability in river behaviour (e.g. between the upland and lowland zones). As noted above, Gibbard & Lewin's (2002) model of interglacial fluvial sedimentation was developed by lowland British rivers, while Maddy *et al.* (2001) and Bridgland's (2000) models of terrace development were based primarily on the Thames Valley, also a lowland British river. The source data of the Vandenberghe (1993, 1995, 2002, 2003) models is less clear, but his inclusion of case studies from the Dinkel and Reusel valleys in the Netherlands (Vandenberghe 1993, 1995), and the Maas, Belgium/the Netherlands (Vandenberghe 1995, 2002); the Somme, France; the Scheldt, Belgium, and the Thames, England (Vandenberghe 2002) suggests that his models are again primarily based upon lowland river system data.

Following the terminology and classifications of Howard & Macklin (1999), this would suggest that our model of fluvial activity (Chapter 2 & Sections 2.5, this chapter) is primarily relevant to lowland and perimarine river systems. Howard & Macklin (1999) therefore highlight five factors of relevance to the magnitude of the chronological catchment and the potential re-working of archaeological material within different zones of a river system, during the Pleistocene:

- Within the upland systems, long-term terrace preservation can be prohibited, especially in narrow valleys.
- Within the upland systems, high magnitude flooding is capable of flushing the sedimentary fills from the valleys.
- Within the upland and piedmont systems, incision will result in the re-working of archaeological materials.
- Within the piedmont systems, wider valley floors can allow for the long-term preservation of terrace units.
- Within the lowland and perimarine zones, the river system stability and dominance of vertical accretion can result in the burial and preservation of archaeological materials.

It is of course difficult, if not impossible, to accurately quantify the impacts of these factors upon the chronological catchments of derived archaeological materials. However, on a qualitative scale it is apparent that the degree of re-working and the magnitude of the chronological catchment are likely to increase from the perimarine/lowland zones to the upland zone. This increase can be characterised both in terms of the proportion of archaeological materials that are re-worked, and in the duration of the chronological catchment. In the former case for example, if *n* artefacts are incorporated into narrow valley, upland river systems, then the majority of those artefacts are likely to be subject to intensive reworking through channel incision and the erosion of floodplain and low level terrace sediments (Figure 230). By contrast, if *n* artefacts are incorporated into a wide valley, lowland river systems, then there is a much greater probability for the majority of those artefacts to avoid re-working and be retained within the floodplain sediments which subsequently evolve into middle and high level terrace sediments (this is also dependent on their position across the floodplain — Section 2.4 below). In terms of the chronological catchment duration, the frequent absence of long-term terrace sequences in the upland zone increases the potential for chronological catchments dating over 100,000's of years, as artefacts are repeatedly vertically re-worked from one unpreserved floodplain to the next through incision and flooding. By contrast, where long-term terrace sequences are able to develop (e.g. as in the lowland Thames valley), the potential for repeated vertical re-working and chronological catchments spanning 100,000's years is greatly reduced (Figure 230). Moreover, the extensive vertical accretion in the lowland and perimarine zones (as a result of fine-grained flooding events, especially during the interglacial phases) increases the potential for the burial and long-term preservation of locally derived material upon the floodplain. These interpretations can, and should, be tested against field and artefact data, specifically the evidence for the presence/absence of preserved terrace landforms and sediments in different river zones, and the physical condition of the recovered artefacts which offer a relative indicator of the degree of re-working to which they have been subjected.

Finally, it is stressed that the considerable sea-level fluctuations of the Pleistocene and the impacts of glaciation will have potentially influenced the geographical distribution of the different river zones at different time periods during the Quaternary. This change is more difficult to document for the upland and piedmont zones, since the impacts of glacial erosion and glacio-isostasy upon physiography and basin relief, and the extensive erosion of upland sediments, severely complicate the identification of channel gradients and valley slope morphologies (Howard & Macklin 1999). In the lowland zones, river status would vary between lowland and perimarine types in response to sea-level rise and fall. The preservation of fine-grained perimarine (e.g. estuarine) sediments would clearly vary between the modern on-shore and off-shore zones. In the off-shore zones for example, sediments deposited during low-sea level stands would be extremely vulnerable to both fluvial erosion (e.g. during the next low-stand event) and to the fluctuating marine transgressions and regressions of the Pleistocene. In the on-shore zones, the sediments would be especially vulnerable to fluvial erosion, although isostatic uplift should reduce the potential threat from subsequent marine transgressions and regressions. In general however, since the major contrast in fluvial behaviour is between the upland/piedmont and lowland/perimarine zones, the impacts of sea-level change and glacial activity are not as dramatic as they could, although these processes should still be born in mind, especially when dealing with river systems in the north of England.

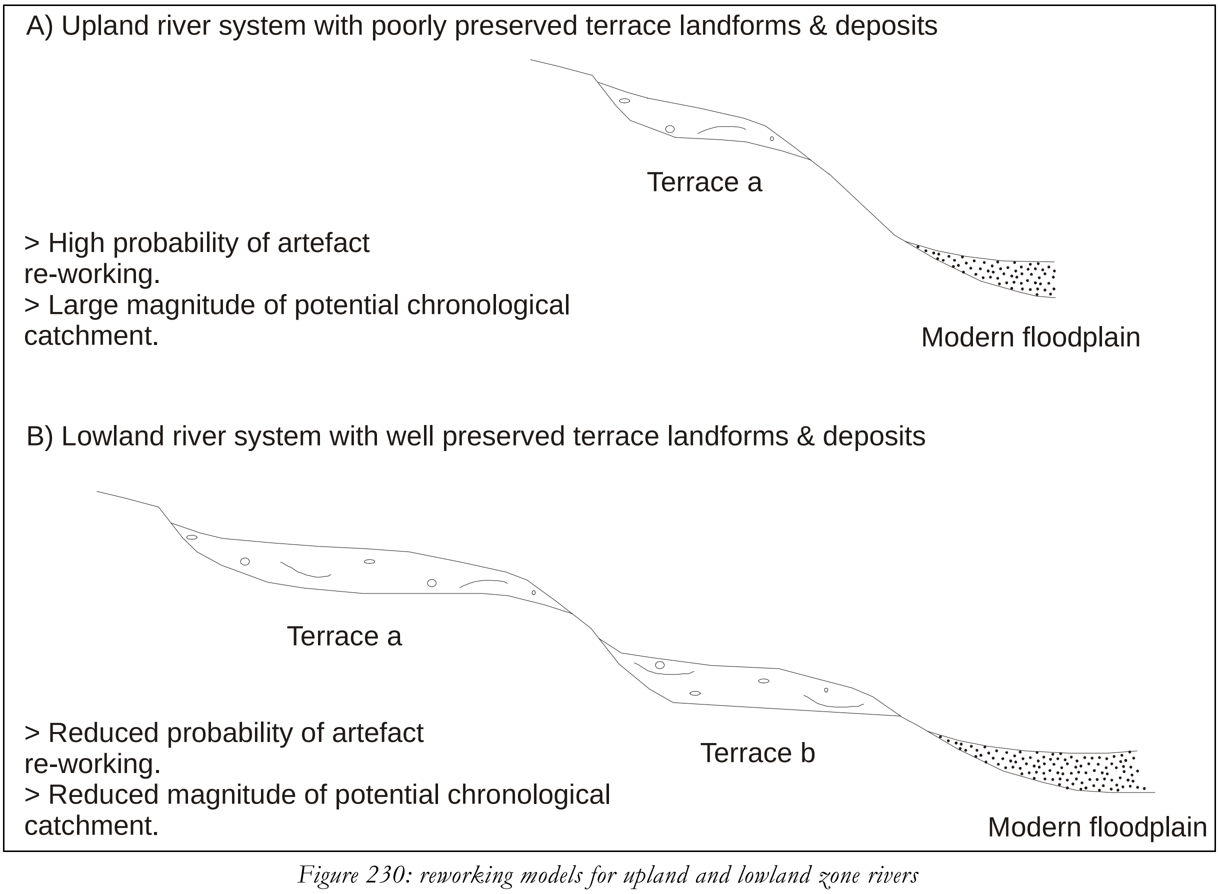

Figure 230: reworking models for upland and lowland zone rivers

2.3 Regional/local geomorphological factors

In many respects this theme explores similar issues to those outlined above. Of principle concern is the impact of regional and local geology upon fluvial behaviour. This was highlighted by Bridgland (1985) with respect to the terrace preservation associated with the rivers of the London Basin, and by Allen & Gibbard (1993) with respect to the rivers of the Solent Basin. Bridgland (1985: 31) observed that different patterns of terrace preservation could be related to the bedrock type, with major staircase sequences of terrace aggradations confined to areas of clayey bedrock. By contrast, sandy bedrock tended to be associated with the sporadic, but equal preservation of terraces on both sides of the valley, while terraces were largely absent in areas of chalk bedrock. In the Solent River basin, Allen & Gibbard (1993: 520–521) noted that the major staircase sequences of the Solent River (although only preserved on the northern valley side) were associated with Tertiary sands and clays, while the chalk bedrock on the fringes of the basin was associated with limited terrace preservation and narrow, steep valleys.

These patterns have highlighted the importance of bedrock type in influencing the pattern of terrace preservation. Bridgland has suggested that this reflects both the relative resistance to erosion of the bedrock type (this appears to be particularly important in the case of chalk) and the permeability of the bedrock:

- Relative resistance: rivers flowing over clay bedrock appear to move off their most recently deposited sands and gravels, and erode into the bedrock on the opposite valley side during downcutting phases. This process effects lateral migration of the river. By contrast, rivers flowing on chalk appear to remain entrenched in one position. When downcutting occurs these rivers cut into their own valley floor deposits rather than the bedrock. Lateral migration does not therefore occur.
- Permeability: Bridgland (1985: 29–30) also noted contrasting patterns of terrace preservation between areas of Tertiary clay (terrace staircases on one side of the valley) and unconsolidated sands (sporadic terraces on both sides of the valley). It has been argued that highly permeable sedimentary rocks (e.g. unconsolidated sands and gravels) can be surprisingly resistant to erosion because their permeability inhibits surface run-off. After initial unidirectional migration (e.g. to the south), clay-bedrock rivers are largely prevented from re-migrating north by the presence and resistance of permeable terrace sands and gravels, overlying the softer clays on that side of the valley. (It should also be noted that even when incision takes the channel below the level of the terrace deposits, the clay bedrock 'bluff' at the terrace edge is likely to be rapidly covered by slumped and soliflucted sands and gravels, which will continued to impede erosion of the northern valley side.) The river therefore tends to always migrate in same direction (e.g. southwards in this example), producing extensive terrace staircases on one side of the valley. In the case of sandy-bedrock rivers, there is little difference between the bedrock and the aggraded materials, so fluvial migration is bi-directional and terrace preservation occurs on both sides of the valley (Figure 231).

Overall, these patterns indicate that even within a particular river zone (e.g. the lowland zone of the Thames Basin), terrace preservation can vary markedly, ranging from terrace staircases to terrace-free gorges. It is also clear that the potential for re-working of archaeological materials will increase and decrease in response to these variations in terrace preservation. In other words, material recovered from low-level terraces within chalk-bedrock areas has the potential to have been heavily re-worked over multiple terrace-forming (and eroding) episodes, while materials recovered from low-level terraces at the base of long sequences are less likely to have been re-worked from top to bottom. However, the impact of this re-working upon the chronological catchments of the artefacts will also be partially influenced by the homogeneity or heterogeneity of the regional bedrock. For example, if a zone of chalk bedrock is relatively restricted (as are those underlying the Darent and Medway valleys in north Kent), then derived artefacts may be reworked downstream (due to floodplain sediment erosion and lack of terrace preservation) through the chalk bedrock gorge and re-deposited within the floodplain (preserved terrace sediments to be) over a relatively short time period. Under such circumstances, the chronological catchment would not necessarily be of a particularly large magnitude. By contrast, if the zone of chalk bedrock was relatively widespread (as is that underlying the upper part of the Test valley in north Hampshire), then derived artefacts might only be re-worked downstream (into sand/clay bedrock terrace sequences) over much longer time-spans. In these conditions, the chronological catchment might be of a considerably longer duration. Clearly these factors are important for the interpretation of derived artefact assemblages, and the concepts highlighted here should always be tested where possible against field and artefact data.

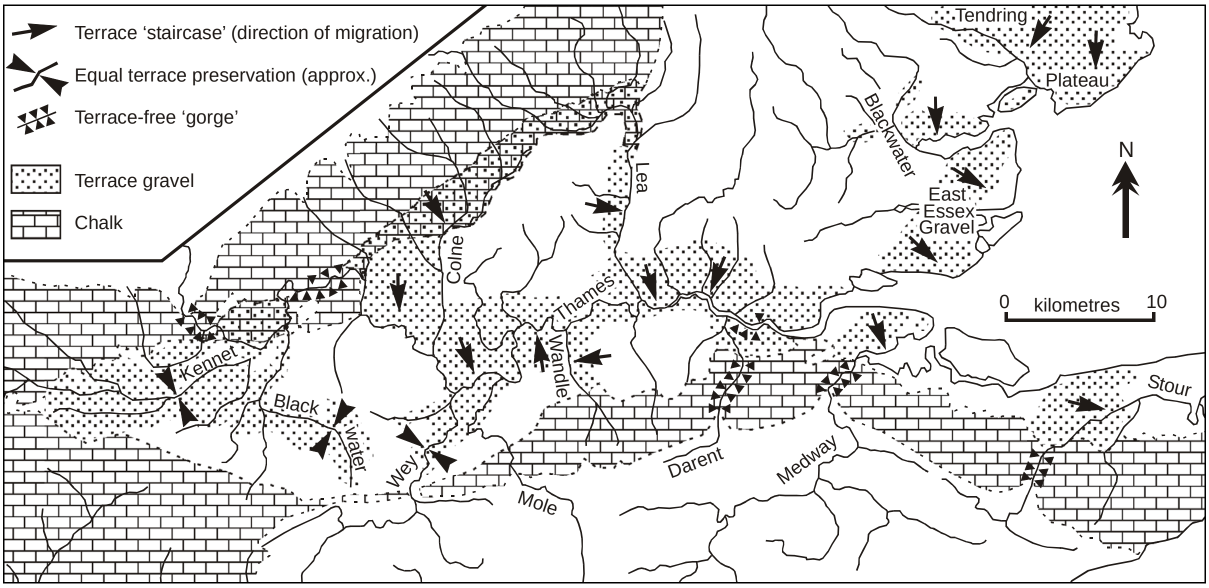

Figure 231: variable Pleistocene terrace preservation in southern English river systems (Bridgland 1985: Figure 1)

2.4 Local depositional factors

It is also stressed that the two-dimensional position of re-worked artefacts within a terrace unit can be significant with respect to the degree of potential re-working and the chronological catchment. For example, artefacts recovered from the margins of a former floodplain may be less likely to have been extensively re-worked than materials located nearer the middle of the former floodplain. This could reflect the courses adopted by the floodplain channel(s) or might also be a consequence of burial of the archaeology by slumping or the solifluction of slope deposits. However, it is currently difficult to assess this issue since it requires identification of the floodplain's extents and the contemporary valley slopes, the location of palaeochannels, and detailed information regarding the provenance of the artefacts (such information is often missing for older collections). Moreover, in many cases, the relevant sedimentary information is also unavailable due to limited preservation or, in the case of extant assemblages, quarrying away of the relevant sediments. Finally, it is noted that Gibbard & Lewin (2002) have suggested that floodplain re-working occurs rapidly under cold-climate regimes, suggesting that this factor may have been less significant over the long time-scales of the Pleistocene. Overall therefore, the issue of local variations in depositional environments (e.g. floodplain margins compared to channel margins) is acknowledged, and should be considered in those situations where the ancient floodplain environment can be adequately reconstructed.

2.5 Glacial/interglacial cycle

Of particular importance is the progression of fluvial behaviour over a glacial/interglacial cycle, following the model proposed here (Chapter 2) and Bridgland (1994, 1995, 1996, 1998, 2000, 2001), Maddy *et al.* (2001), Gibbard & Lewin (2002), and Vandenberghe (1993, 1995, 2002, 2003). It is proposed that the potential chronological catchment of a derived artefact assemblage will vary in magnitude, depending upon its chronological position within the interglacial cycle. For example, artefacts and sediments deposited immediately after the incision and cutting of a new floodplain are more likely to have been derived from the floodplain sediments of the higher terrace level, through which the river has recently incised. By contrast, artefacts and sediments deposited during the latest aggradation phases of a glacial/interglacial transition are more likely to have been reworked from the contemporary floodplain. The time-depths of these different chronological catchment can currently only be broadly estimated and differentiated in terms of temporal magnitudes (e.g. 10^2 compared to 10^5 years), reflecting the present lack of geochronological precision and the nature of the available data. Finally, it is emphasised that this classification deals in probabilities rather than absolutes, and is primarily intended as a heuristic device, and one that should ideally be further tested through field evidence and sediment modelling:

2.5.1 Phase 1A: the early glacial/interglacial transition (Figure 232A)

The river has recently incised a new floodplain surface, involving the reworking of considerable quantities of sediment from the older, higher floodplain (whose remaining sediments are now terrace deposits). Initial coarse-grained (gravel and sand) sedimentation across the braidplain during the aggradation phase is therefore likely to consist of materials (sediments and potentially archaeology) re-worked and sub-aerially eroded from the recently abandoned terrace level. Artefacts from the basal levels of the sediments, near the floodplain surface, are assumed to date to the earliest, initial phases of aggradation on stratigraphic grounds. They are therefore assigned a chronological catchment of 10^4 (10,000) and 10^5 (100,000) years, since they potentially date to a wide timespan covering the previous glacial/interglacial cycle. This chronological catchment should also be tested (where possible) against assessments of the physical condition of the artefacts (see Chapter 4–5 with respect to the physical transformation of lithic artefacts during fluvial transportation episodes). It is recognised that the stratigraphic interpretation described above should be confirmed where possible by field observations. For example, traces of subsequent erosive cut and fill activity removing earlier sediments would restrict the applicability of the stratigraphic model presented above.

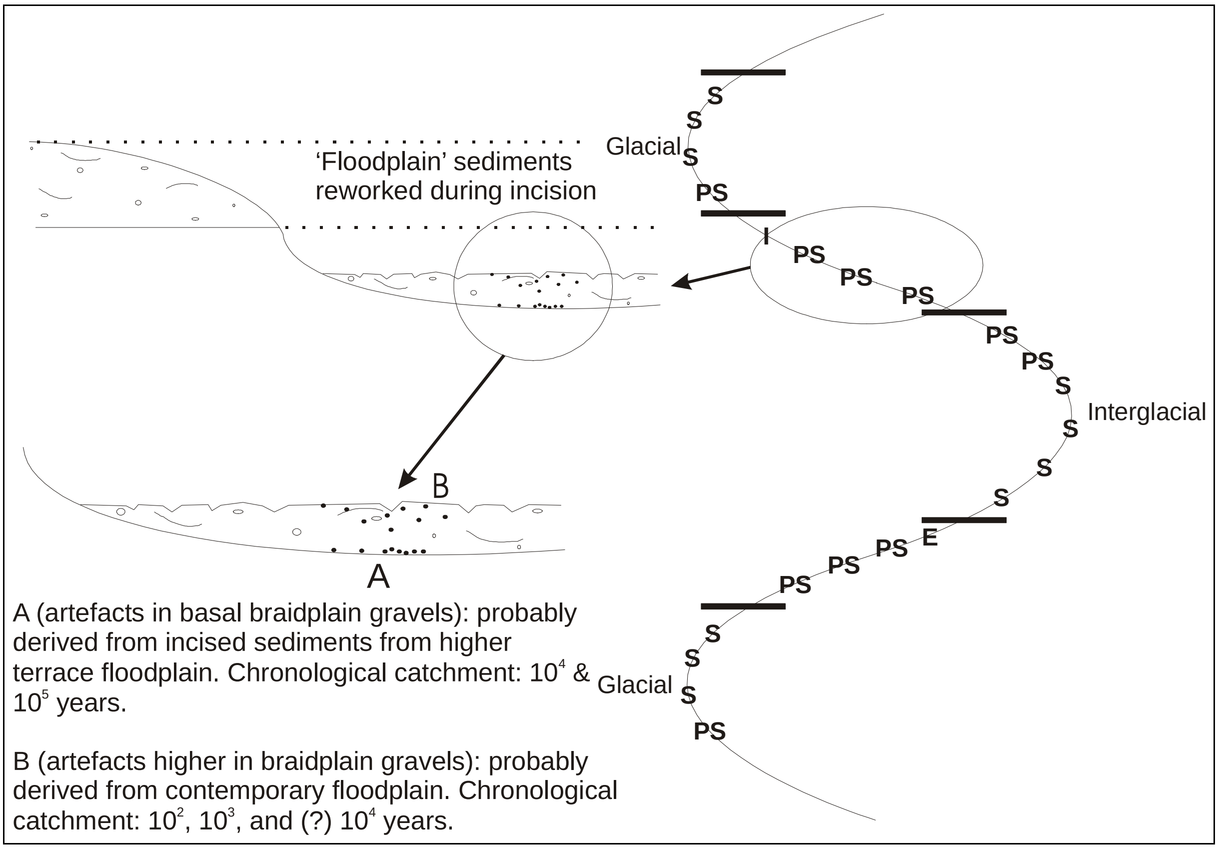

Figure 232: model of artefact reworking during the glacial/interglacial transition phase

2.5.2 Phase 1B: the later glacial/interglacial transition (Figure 232B)

The river system is undergoing a major phase of aggradation across the floodplain, involving the reworking of sediments supplied from both the floodplain surface and the marginal floodplain slopes. The continuing coarse-grained (sand and gravel) sedimentation across the braidplain is therefore likely to consist of sediments (and potentially archaeological materials) derived from the contemporary floodplain and adjacent landscape surfaces. Lithic and faunal artefacts from the upper levels of these sediments are considered to date to this later, continued phase of aggradation on the basis of stratigraphic principles. They are therefore assigned a chronological catchment of 10^2 (100), 10^3 (1,000), and possibly 10^4 (10,000) years, since they are primarily associated with the later aggradation phase of the glacial/interglacial transition. As previously, the model should be tested against the physical condition of the artefacts, whilst field evidence for depositional breaks (erosive contacts) in the sedimentary sequence would also support the model's emphasis on the later sedimentary events within the transitional climatic phase.

2.5.3 Phase 2: the early interglacial (Figure 233)

The river regime is stabilising the channel system inherited from the glacial/interglacial transition phase, combined with the vertical accretion of fine-grained sediments within abandoned channels and ex-braidplain depressions. The sediments are primarily supplied from the contemporary floodplain, while the relatively low energy nature of the fluvial system suggests that any archaeological materials have also been locally derived from the floodplain and channel complexes. Derived lithic and faunal materials from these sediments are therefore argued to date to this early interglacial phase, given the reduced ability of the river system to rework material from buried, coarse-grained sediments (see phases 1A and 1B above). The archaeology is therefore assigned a chronological catchment of 10^2 (100), 10^3 (1,000) years, and possibly 10^4 (10,000) years. The physical condition of the artefacts is particularly important in this case, since Chambers (pers. comm.) predicts differences between the *état physique* of artefacts subjected to coarse-grained and fine-grained sediment transport regimes.

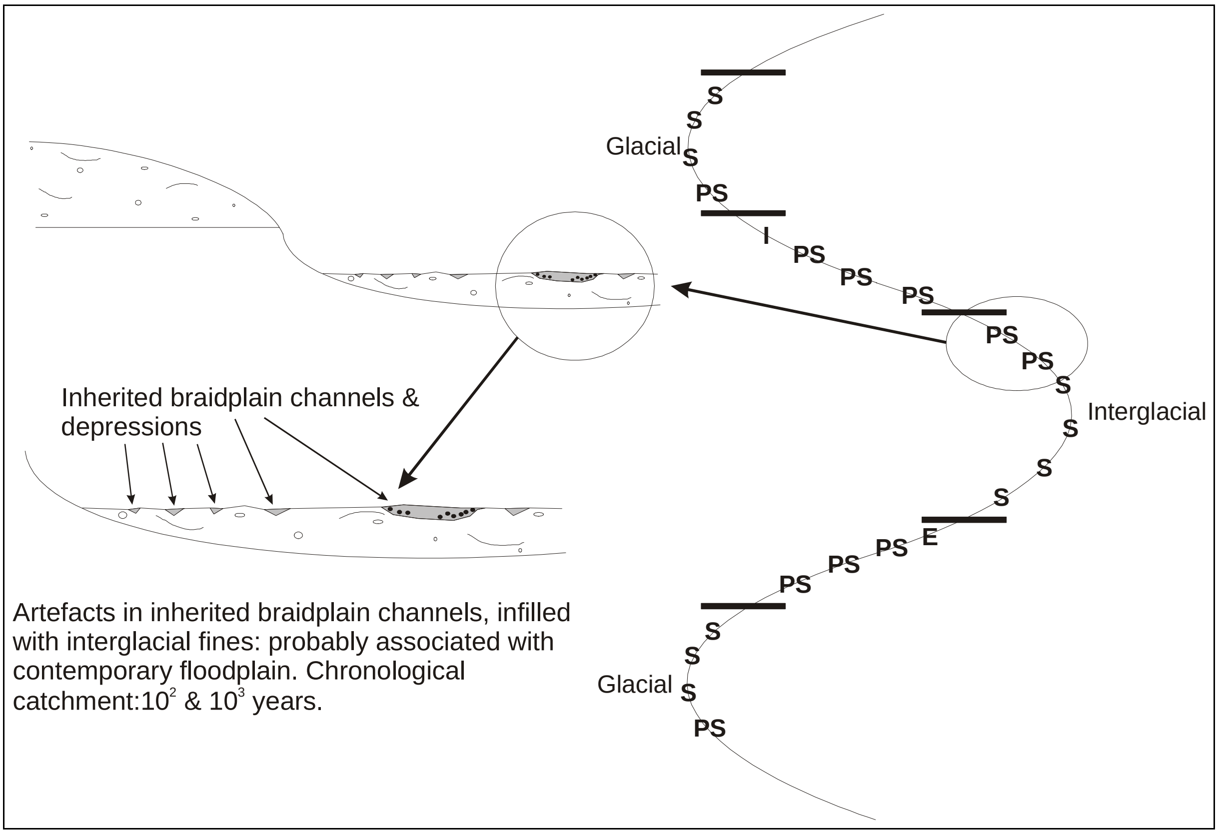

Figure 233: model of artefact re-working during the early interglacial phase

2.5.4 Phase 3A: the early interglacial/glacial transition (Figure 234A)

During the early phases of the interglacial/glacial transition, the high-energy river erodes extensively into the interglacial floodplain surface. This erosive activity reworks considerable quantities of fine-grained interglacial sediments and, potentially, older coarse-grained sediments from the previous glacial/interglacial transition. The succeeding aggradation phase of coarse-grained (gravel and sand) sedimentation across the braidplain is therefore likely to initially consist of older materials (sediments and potentially archaeology), re-worked from the contemporary floodplain. Artefacts (lithics and fauna) from the basal levels of the new sedimentary architecture, near the eroded floodplain surface, are assumed to date to the earliest, initial phases of this aggradation on stratigraphic grounds (as in phase 1A). They are therefore assigned a chronological catchment of 10^4 (10,000) and 10^5 (100,000) years, since they potentially date to a wide timespan covering the previous interglacial and glacial/interglacial transition. As emphasised above, the chronological catchment should be tested against the physical conditions of the artefacts (see Modules 4–5), while the stratigraphic interpretation should be confirmed where possible by field observations.

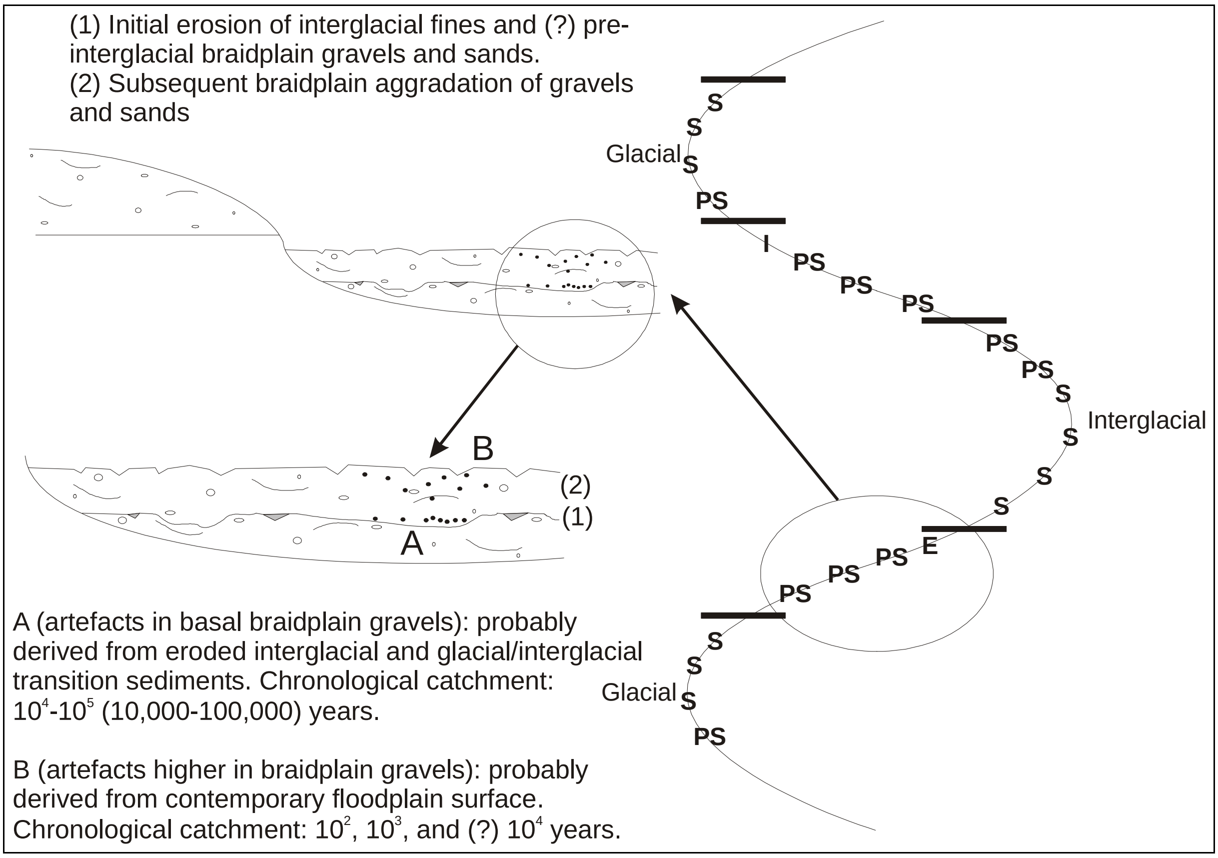

Figure 234: model of artefact re-working during the interglacial/glacial transition phase

2.5.5 Phase 3B: the late interglacial/glacial transition (Figure 234B)

The river system is undergoing a major phase of aggradation across the floodplain/braidplain, involving the reworking of sediments supplied from the braidplain surface and the marginal floodplain/valley slopes (as a result of vegetation degradation, freeze-thaw activity and soil instability). The continuing coarse-grained (sand and gravel) sedimentation across the braidplain is therefore likely to consist of sediments (and potentially archaeological materials) derived from the contemporary floodplain/braidplain and adjacent landscape surfaces. Lithic and faunal artefacts from the upper levels of the sediments are considered to date to this later, continued phase of aggradation on the basis of stratigraphic principles. They are therefore assigned a chronological catchment of 10^2 (100), 10^3 (1,000), and possibly 10^4 (10,000) years, since they are primarily associated with the later aggradation phase of the interglacial/glacial transition. As with the previous phases, the model should be tested against the physical condition of the artefacts, whilst field evidence for erosive breaks in the sedimentary sequence would also support the emphasis placed upon later sedimentary events within this transitional climatic phase.

Phase 4: the full glacial (Figure 235)

The river system is relatively stable during this phase, with annual nival-regime floods redistributing existing surface and near-surface coarse-grained sediments across the braidplain. The sporadic coarse-grained sedimentation across the braidplain is therefore likely to consist of sediments/archaeological materials derived from the surface and near-surface of the contemporary braidplain (redistribution of more deeply buried sediments is extremely limited due to permafrost). Lithic and faunal materials from the top layers of the sediments are therefore assumed to predominantly date to this glacial phase of limited aggradation, although there is also limited potential for the re-working of artefacts from the upper layer of sediments aggraded during the terminal phase of the interglacial/glacial transition. They are therefore assigned a chronological catchment of 10^3 (1,000) and 10^4 (10,000) years, since they are primarily associated with the glacial aggradation phase (although the speed of braidplain re-working suggests that only the terminal glacial phase may be directly represented in any preserved fluvial sediments). As previously, the model would be supported by artefacts' physical condition data and field evidence for erosive contacts in the upper part of the sedimentary record.

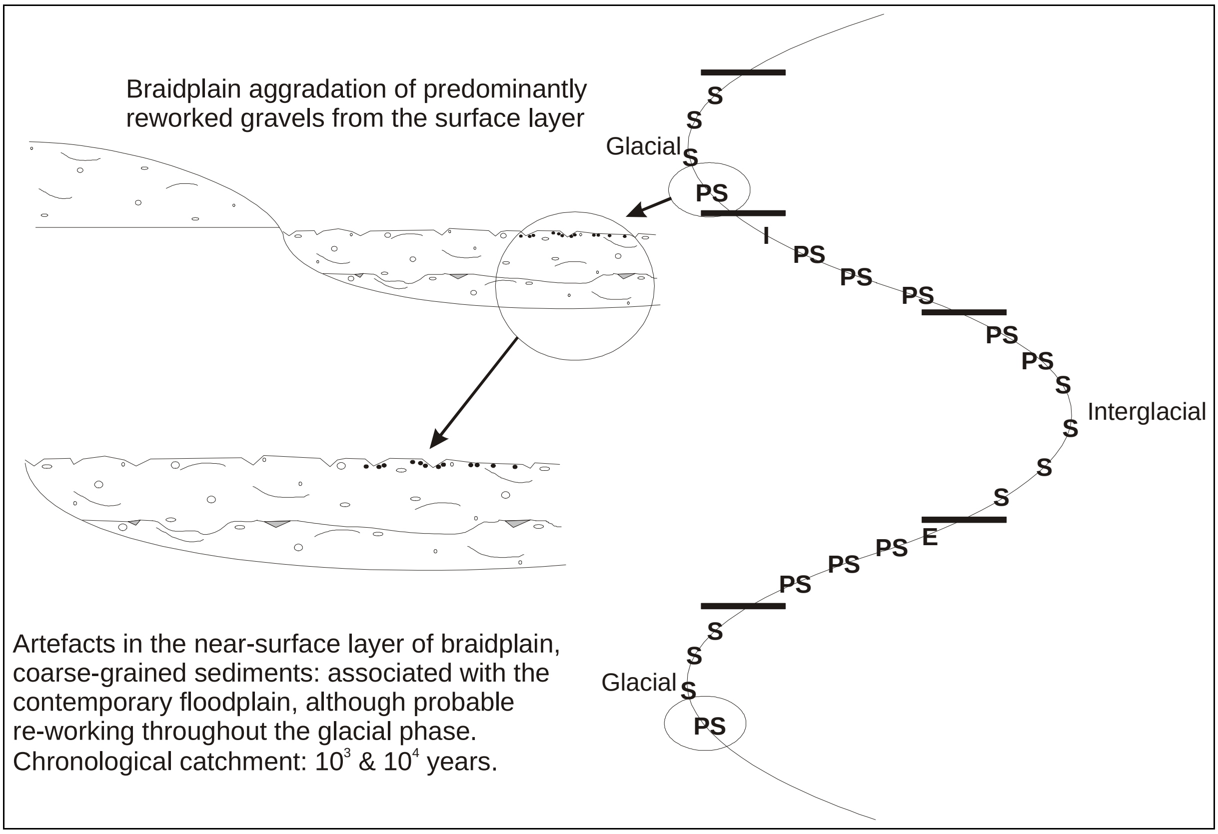

Figure 235: model of artefact re-working during the glacial phase

It is stressed that this is primarily a generic and exploratory framework, based on a current view of fluvial activity across the glacial/interglacial cycles of the Pleistocene (Vandenberghe 1993, 1995, 2002, 2003; Bridgland 1994, 1995, 1996, 1998, 2000, 2001; Maddy *et al.* 2001; Gibbard & Lewin 2002). Three specific points are also highlighted with respect to the model and its applications:

- The proposed chronological catchment estimates will also be influenced by the other factors identified above (river zones, regional/local geomorphology, and local depositional patterns). For example, all material in an upland river system is likely to have been subjected to greater temporal magnitudes of reworking than those proposed above, due to the tendency of such systems towards extensive reworking and flushing out of older sediments (e.g. Howard & Macklin 1999). This is considered further in Section 2.6 below.
- The proposed chronological catchment estimates are intended to describe the majority of any recovered assemblages, not the entirety. It is recognised that there may be temporal outliers, including material that has been re-worked over multiple glacial/interglacial cycles (this would be especially likely in upland fluvial zones — see above), and artefacts that were discarded on the contemporary landscape and derived over short timespans/distances prior to their incorporation within the sedimentary unit. However, it is argued that the physical condition of the material and the range of conditions in an assemblage should provide a valuable indicator of the presence of such outliers.
- It is recognised that the physical condition of artefacts is primarily an indicator of horizontal (i.e. down-channel) transportation distance, rather than vertical (i.e. between-terrace) transportation

distances. It is argued here that the former can certainly occur without the latter, and that considerable physical damage on an artefact is not necessarily an indicator of macro-scale chronological re-working between higher (older) and lower (younger) terraces. It is noted however that the same is not true for the reverse scenario. In other words, material that has been re-worked vertically will also have had to undergo a degree of horizontal transport. The challenge of modelling the potential for vertical re-working has been addressed throughout this section, and is summarised below.

2.6 Summary

Existing models of fluvial activity suggest that the highest, currently available geochronological resolution is in the order of 10^2 and 10^3 years in magnitude, with respect to individual fluvial sedimentary units and erosive events. Unfortunately, the chronological catchment of the derived archaeological materials occurring within these fluvial secondary contexts is much more variable, and encompasses a far wider potential time-span. It is clear that a number of factors influence the intensity of re-working and the magnitude of the potential chronological catchment, including the river zone (Section 2.2), regional and local geological factors (Section 2.3), and the final depositional position of the archaeology within the glacial/interglacial cycle (Section 2.5).

A provisional framework for the application and interpretation of these factors is proposed here:

- River zone: in those cases where a river is classified as an upland or piedmont system (following the definitions of Howard & Macklin (1999), with limited traces of terrace preservation and/or long-term sequences (based on field evidence and theoretical models where necessary), chronological catchments in the order of 10^5 years are proposed. These estimates can be reduced where there artefact typology provides a robust chronological marker, such as is the case with *bout coupé* bifaces (White & Jacobi 2002) and twisted ovates (White 1998a). However, it should be noted that there are relatively few examples of such chronologically-robust patterns in Palaeolithic artefact typology, while chronological typologies once considered robust (e.g. Roe 1981) have recently been overturned by new discoveries (e.g. Ashton *et al.* 1992; Roberts & Parfitt 1998). Finally, where the physical condition of secondary context specimens is suggestive of limited derivation and re-working, detailed field investigation of the sedimentary and depositional environment is recommended, *prior* to assumptions of a relatively brief chronological catchment.

- Regional and local geological factors (bedrock controls): in cases of lowland or perimarine systems influenced by chalk bedrock controls (resulting in limited terrace preservation), chronological catchments in the order of 10^5 years are again proposed. The above comments regarding the physical condition of the material and the presence of robust chronological marker artefacts are again applicable. It is also stressed that the extents of chalk-bedrock river systems should be assessed with respect to the potential downstream re-working of heavily re-worked artefacts over shorter and longer timespans (Section 2.3 above). Of particular importance is the re-working of heavily derived artefacts from gorge-style chalk-bedrock river valleys into terrace-staircase, Tertiary bedrock systems, as has been argued for the assemblages from Dunbridge and Wood Green in Hampshire (e.g. Hosfield 2001).

- Depositional origin within the interglacial/glacial fluvial cycle: in cases of lowland and perimarine systems with well-preserved terrace sequences, chronological catchments ranging in order of magnitude from 10^2 to 10^5 years are proposed. These vary on the basis of sub-cyclical variations in sedimentary and erosive activity, and the assignment of specific catchments to derived assemblages requires relatively detailed provenancing data with respect to the sedimentary sequence. There are currently no chronologically significant typological markers of sufficiently high resolution to influence these assignments, although as previously, the physical condition of the artefacts and detailed sedimentary evidence should be employed as an independent test of the model.

3. PALIMPSESTS IN SPACE

Assemblages of artefacts recovered from secondary context fluvial sediments immediately present the problem of whether, and how far, they have been transported. Where material is transported, these assemblages are inevitably spatial palimpsests, in other words consisting of artefacts that have been derived from a series of other places in the floodplain environment. The spatial resolution of the secondary context archaeological record is therefore concerned with determining the transportation history of these assemblages through the damage characteristics of individual artefacts, and identifying the minimum spatial resolution that can be applied to the interpretation of these data.

While the transportation of materials occurring in high energy fluvial sediments (typically consisting of gravels and coarse-grained sands) is easily demonstrated (based on the physical condition of the material, the absence of preserved spatial relationships, and the selective presence of specific artefact types), the situation is more problematic when dealing with archaeological materials in low energy fluvial sediments. These latter assemblages types receive relatively little attention here, since they represent a small proportion of the fluvial archaeological resource and have typically been regarded as primary context evidence (e.g. Singer *et al.* 1973) with respect to their interpretation. However, we would stress that even in low energy environments (e.g. fine-grained sands, silts, and clays), it is extremely unlikely that there has been no disturbance of the assemblages. Such disturbance could include the removal of the smallest débitage materials and the minor re-arrangement of spatial alignments and patterning (Schick 1986). It is therefore emphasised that even in these situations, the spatial associations demonstrated by the terminal locations of artefacts should not be immediately considered to be directly indicative of hominid discard activity, prior to assessments of artefact condition and orientation.

3.1 Assemblage and artefact transportation processes

The review of extant civil and hydraulic engineering literature (Chapter 5) has shown the relationships between particles and transportation distances to be highly complex. The movement potential of individual particles is affected by a variety of factors including their discard location within the channel or floodplain, their relative size and elevation in comparison to their neighbouring particles, and the characteristics of the contemporary fluvial environment. These complexities were demonstrated to also affect the transportation of lithic artefacts in experiments conducted by Harding *et al.* (1987), which indicated that artefacts in fluvial environments behave in the same manner as the local mobile sediment, and as such are only episodically mobile. The exact timings and duration of these phases of burial and movement are dependent on the local conditions and fluvial environment. Current experimental research (Hosfield & Chambers 2002a, 2003, 2004; Chapter 5) has confirmed the stochastic nature of artefact transportation, even between two artefacts emplaced in adjacent locations within a river channel.

Critically, it has been demonstrated that no clear relationship exists between particle (or artefact) size and the distances they are transported. To focus on archaeological examples, the experiments of Harding *et al.* (1987) demonstrated an inverse relationship between transportation distance and artefact size. These results contrast with the current experimental research of Hosfield & Chambers (2002a, 2003, 2004), where artefact transportation distances have shown no clear relationship to size, although there is a suggestion that larger artefacts travel *further* than small ones (Chapter 5). These contradictory findings support the general absence of a causal relationship between particle size and transportation distance, as has been accepted within the engineering research community (e.g. Church & Hassan 1992; Hassan & Church 2001; Malmaeus & Hassan 2002; Hunziker & Jaeggi 2002). It is therefore not possible to evaluate the transportation potential of individual artefacts based on characteristics such as size. With respect to the interpretation of spatial palimpsest assemblages, it cannot be presumed that larger artefacts will have remained closer to their original discard locations than smaller artefacts.

A range of other factors have also been identified as influencing artefact movement, although their relative visibility within the archaeological record has restricted their applicability:

- Local fluvial regimes: the micro-characteristics of a fluvial regime will inevitably have influenced the potential for Palaeolithic artefact transportation (e.g. reflecting flow velocities and channel depth variability across a channel cross-section). However, these micro-characteristics are not stable, reflecting the fact that fluvial regimes are both spatially and temporally variable (e.g. between shallow riffles and deep pools over tens of metres, and between winter and summer flow regimes over an annual cycle). Unfortunately, these micro-scale, local variations cannot be fully reconstructed (if at all) from archaeological secondary contexts. This remains the case even when extant sedimentary sections are available (e.g. as at Broom), due to Quaternary erosion of sediments and the limited representation of a 4-dimensional floodplain within 3-dimensional sections. For example, the presence or absence of sediment armoring, local bed forms, and scouring, relative elevation, current velocities, viscosity, and specific gravities have all been demonstrated to influence particle movement, yet most of these variables cannot be known archaeologically. They certainly cannot be reconstructed for each episode of biface movement. It is therefore not possible to reconstruct fluvial palaeoenvironments to the degree where high resolution predictive models of particle movement, as developed by civil and hydraulic engineers, can be applied (Chapter 5). Nonetheless, where sedimentary evidence is available (e.g. in the form of extant field sections), low resolution models of sedimentary regimes and the terminal transportation and deposition of Palaeolithic artefacts can be developed. For example, clast size distributions can provide a relative indicator of flow magnitude, fabric analyses can reveal flow vectors, while local, vertical sedimentary sequences can indicate previous fluvial responses and the relative potential for artefact re-working.

- Regional fluvial regimes: at a larger scale, the geography and geomorphology of individual reaches within a fluvial system will also influence the river's regime and the potential for artefact transportation. Of particular significance are stream competence (e.g. flow energy) and dynamism of deposition/erosion processes on the floodplain. These factors show considerable variations in response to river type (e.g. upland and lowland systems), and geological bedrock characteristics. These issues are discussed in more detail in Section 2 above, but are reviewed here in the context of horizontal artefact transportation. Importantly, these variations in river and bedrock type can be reconstructed from the archaeological literature, Quaternary sediment and terrace mapping, and extant landscape features:

    - Within upland regions, rivers tend to be characterised by relatively steep gradients (> 10m km^{-1} in western and northern Britain), reflecting regional topography, high flow velocity and discharge volumes, and glacio-isostatic uplift (resulting in incision). Valley development is typified by episodic downcutting, while constricted floodplains (steep valley sides frequently merge into the floodplain without an intervening floodplain) limits both the lateral migration of the active channels and the long-term preservation of terraces (Howard & Macklin 1999). The steep channel gradients and high flow velocities inevitably increase the probability of entrained particle movement, due to the higher energy levels inherent in the system. It is therefore proposed that artefacts discarded in upland fluvial catchments and subsequently entrained by the river would be transported through these upland fluvial reaches comparatively quickly, perhaps in a less episodic manner than is characteristic of transportation histories in lowland reaches. Alongside this model of rapid artefact transport there is also a greater probability of spatial artefact reworking within the upland river reaches, due to the processes of sediment erosion and artefact entrainment. Episodic downcutting and high magnitude flood events within constrained valley systems result in the predominant re-working of floodplain and terrace sediments (where the latter have developed), and the potential re-working of archaeological materials previously deposited within those sediments. Such re-working inevitably has a temporal component (artefacts are re-worked from older sediments into younger deposits — discussed further in Section 2 above), but equally inevitably has a significant spatial dimension. In general therefore, the nature of fluvial behaviour in upland rivers promotes relatively high levels of artefact transportation and re-working.

- It is noted that the artefact reworking model referred to above is also likely to occur in chalk bedrock rivers (whether upland or lowland in type), where extensive re-working of floodplain sediments and the absence of long-term terrace preservation is common. This issue is discussed in detail in Section 2.4 above.

- By contrast with upland river systems, lowland reaches are typically characterised by relatively shallow gradients (< 2m km^{-1} in the southern UK), migrating channel systems, wider and unconstrained floodplains, enabling the development and long-term preservation of terrace features (although see comments above with respect to chalk bedrock systems (Howard & Macklin 1999)). In these low-energy systems, artefact transportation is likely to be more episodic than in the upland reaches, with significant burial phases. Moreover, the development and long-term preservation of terrace landforms and sediments (particularly prevalent in Tertiary sand and clay bedrock systems) reduces the potential for intensive spatial re-working of archaeological materials. In other words, material transported and deposited into contemporary floodplain sediments are unlikely to be subsequently re-worked into the deposits of lower and younger floodplains, as their encasing floodplain sediments are preserved as terrace deposits. The taphonomic implications of river system types upon the re-working of Palaeolithic artefact assemblages are discussed in greater detail in Chapter 5 (Section 6.1).

Given the complexities of these relationships and the practical limitations of the sedimentary record, it is therefore proposed here that the physical condition of the artefacts remains the best mechanism for assessing hydraulic transportation.

Chapter 4 reviewed the methodologies previously employed in the analyses of fluvially-transported Palaeolithic artefacts. This research advocates a more holistic approach, recognising the transport information that can be gained from consideration of the entire *état physique* of individual artefacts (Chapter 4 & Chambers in prep). By considering edge damage and overall artefact morphology in combination with a systematic assessment of abrasion damage of biface arêtes, retrospective models of transportation history can be established. For example, laboratory experiments have demonstrated that artefact raw material influences the rate of damage development, that artefact morphology influences the transportation mode, and that damage patterns can develop over relatively short distances (e.g. sub-250m). Field experiments in the Afon Ystwyth gravel-bed river in Mid-Wales (Chapter 5; Hosfield & Chambers 2002a, 2003, 2004) also recorded the stochastic nature of particle entrainment and subsequent movement and/or burial, demonstrating that artefacts emplaced in adjacent channel-bed and gravel bar locations, and subject to the same fluvial processes, displayed a wide range of different transportation behaviours.

The correlation between laboratory and field data is a challenging problem, reflecting the contrasts between the controlled laboratory environment (within which a range of experimental variables were known) and the field environment, in which the documentation of the same range of experimental variables was much more difficult. The potential correlation was therefore assessed by applying the laboratory-derived experimental model of abrasion development to the bifaces abraded and damaged during the Afon Ystwyth field experiments. For these bifaces, transportation distances were known, but transportation modes (e.g. sliding and saltating) were not. The model accurately calculated the transportation distance for 20% of the recovered replica bifaces, while 20% of the transportation distances were under-estimated, and 60% were over-estimated. In the absence of smart tracers, the transportation mode cannot currently be demonstrated for the field experiments, and it is therefore not currently possible to determine where the inaccuracies arise between the laboratory and field data. One possible source of the differential concerns the role of aquatic vegetation in arresting abrasion development on the bifaces (see Chapter 5 for further discussion of this point). It is therefore proposed that a key objective for future research concerning the Palaeolithic archaeological resource from secondary contexts is an expansion of experimental data sets exploring artefact transportation and the spatial derivation of stone tool assemblages.

Nonetheless, it is argued that the currently available experimental data does provide a generic means of assessing the mode and duration of an artefact's fluvial transportation history. A correlation of individual archaeologically abraded artefacts from the Broom Lower Palaeolithic locality with the experimental abrasion development datasets (Chapter 4) was presented as a case study application of the experimental data to an archaeological assemblage. Although the experimental datasets generate precise inferred transportation distances, exact correlation of the *état physique* between archaeological and experimental datasets is not ubiquitous (indeed, it should not be expected given the complex and stochastic nature of field processes). Typically, contrasts between the two data sets occurred with respect to:

- The thickest regions of the biface: these differences probably represent damage sustained to the exposed areas of the biface (e.g. the dorsal spine) during episodes of relative stability and/or partial burial. However, current experimental programs have not produced sufficient quantities of abrasion development data to determine the causal origins of these discrepancies.
- The effects of suspended load transportation: these processes cannot currently be modelled due to the logistical difficulties of creating high-velocity suspended load transportation of bifaces within an experimental flume environment.
- The effects of transportation within fine-grained sediments (e.g. sands and silts): these processes are susceptible for modelling and are the current focus of ongoing experimental research.

Overall, it is clear that the specific distances generated by the laboratory-based flume data models for the fluvial transportation of archaeological clasts (i.e. artefacts) are not, and cannot ever be, accurate representations of all archaeological examples from the real world. However, the robusticity of the transportation distance modelling results for the Broom assemblage (Chapter 4), and the magnitude of the correlation errors between the field and laboratory data (see Section 3.2 below) indicates that these data can be employed as a foundation for future research and analyses.

3.2. A Minimal Spatial Unit (MSU)

The minimum spatial unit (MSU) is proposed as a conceptual framework for addressing the problem of artefact derivation and re-working, and the presence of archaeological spatial palimpsest assemblages within fluvial secondary contexts. The MSU concept is borrowed from Stern (1993, 1994), who presented the minimum archaeological-stratigraphic unit (MASU) in her discussion of the Lower Pleistocene record as revealed in the Koobi Fora Formation. Stern presented the Lower Okote Member (LOM) as an example of the MASU, as it was:

"*the smallest wedge of sediment*, and hence *the smallest unit of time*, that can be used to study the distribution of archaeological debris across the ancient landscape in this portion of the Koobi Fora Formation."

(Stern 1993: 205)

Following Stern (*ibid.*), the concept of the minimum spatial unit (MSU) is therefore defined here as:

The smallest geographical area, and hence the smallest unit of space, that can be used to study the lateral distribution of archaeological debris across the ancient fluvial landscape, prior to the derivation of the debris from their pre-fluvial contexts to their place of deposition with fluvial secondary context sediments.

This definition raises two important issues:

- Pre-fluvial contexts do not necessarily equate to hominid discard activity. Material may have been discarded on valley slopes and re-worked through soil processes (e.g. erosion, solifluction and gelifluction) onto the floodplain.
- The lateral distribution of archaeological debris is only considered in terms of its location upstream from the place of deposition, not in specific 3-dimensional terms. For example, in an eastwards flowing system, the location of the debris is considered in terms of its generic east–west position, but

its exact position (e.g. within the main channel floodplain or associated with a north or south bank tributary valley) cannot, of course, be specified.

It should be immediately clear that the geographical lower limit of the MSU is the location of the secondary context assemblage within the fluvial system (following the assumption that material will not have been fluvially transported upstream). By contrast, the geographical upper limit of the MSU is much more variable, and its identification defines the size of the MSU. Three approaches are proposed here for the identification of the upper limit and the overall scale of the MSU:

1. Drainage basin (coarse-resolution) MSU: the fundamental principle of this MSU definition is that the derivation of artefacts from within different locations of the drainage basin cannot be distinguished. In other words, the relative physical condition of the artefacts provides no indication of their relative degrees of lateral derivation. This MSU type is therefore individually defined as the upstream drainage basin/catchment associated with the fluvial system within which a specific assemblage was located. In the case of the Broom Lower Palaeolithic assemblage for example, the MSU would be defined as the River Axe drainage catchment upstream of Broom (an area of *c.* 20 km channel length — Figure 236). The specific size of the MSU therefore varies between fluvial systems (e.g. consider the potential variations in MSU size between the Pleistocene Thames and the River Axe). However, the MSU size will also vary within the same fluvial system, according to the location of the secondary context assemblage for which it is defined. For example, the MSU for an assemblage recovered at Chard Junction would be smaller than that for the assemblage from Broom (Figure 236). This MSU concept is therefore more useful for derived assemblages located near the source of the river/stream system, while the MSU becomes increasingly coarse with downstream progress through the fluvial system. Overall, this definition of the MSU restricts the spatial analytical resolution to the drainage basin scale, with no potential to explore spatial variability at the sub-drainage basin scale.

2. Sub-drainage basin (medium-resolution) MSU: the previous definition of the MSU takes both an extremely pessimistic view of the potential of the data available from the physical condition of the artefacts, and also severely limits the spatial analytical frameworks available. It is proposed that it is possible to develop a minimum spatial unit that operates at the sub-drainage basin level. However, it was stressed above that the specific distances proposed for artefact transportation on the basis of experimental research (laboratory and fieldwork-based) cannot be directly transposed onto archaeological materials, reflecting the stochastic nature of the processes involved in fluvial entrainment. Nonetheless, results both from experimental research and the analysis of archaeological assemblages (e.g. Broom and Dunbridge — Chapters 4 & 5) suggest that there are potentially robust patterns that develop during the processes of artefact transportation. In both case study assemblages, the data suggested a cluster of artefacts that had been moved a few hundred metres (category b below), and a background scatter of artefacts moved greater and lesser distances (categories a, c and d). Based on these results, an MSU framework is proposed, utilising orders of magnitude categories to represent artefact transport regimes:

    a. $10^{1\text{-}2}$ m (10–100 m): bifaces transported less than 100m.
    b. $10^{2\text{-}2.5}$ m (100–500 m): artefacts derived between 100m and 500m.
    c. $10^{2.5\text{-}3}$ m (500–1,000 m): bifaces transported between 500m and 1km.
    d. 10^{3+} m (1,000 m/1 km+): artefacts transported over 1km.

    The use of increasingly wide categories reflects the importance of differentiating between *in situ* materials and artefacts that have been subjected to relatively minor derivation over short distances. This was also highlighted by the experimental research which indicated that abrasion develops relatively rapidly. The use of an open-ended forth category reflects the problems of modelling long-distance transport, namely the difficulties of laboratory replication and the dangers of extrapolating experimental trends (it is clear from the experimental research that rates of abrasion development change over time). Classification of individual artefacts to one of the categories is based on an assessment of their *état physique* (abrasion development, edge damage, and overall morphology), following the experimental research of Chambers (in prep). Moreover, we propose that the above classification utilises fuzzy categories, based on the quartile values of the category ranges, due to the recognition that the modelled distances are not precise. These fuzzy category boundaries are highlighted below:

a. 10^{1-2} m (10–100 m): modelled distances between 0 and 125m.
b. $10^{2-2.5}$ m (100–500 m): modelled distances between 75m and 600m.
c. $10^{2.5-3}$ m (500–1,000 m): modelled distances between 400m and 1125m.
d. 10^{3+} m (1,000 m/1 km+): modelled distances above 875m.

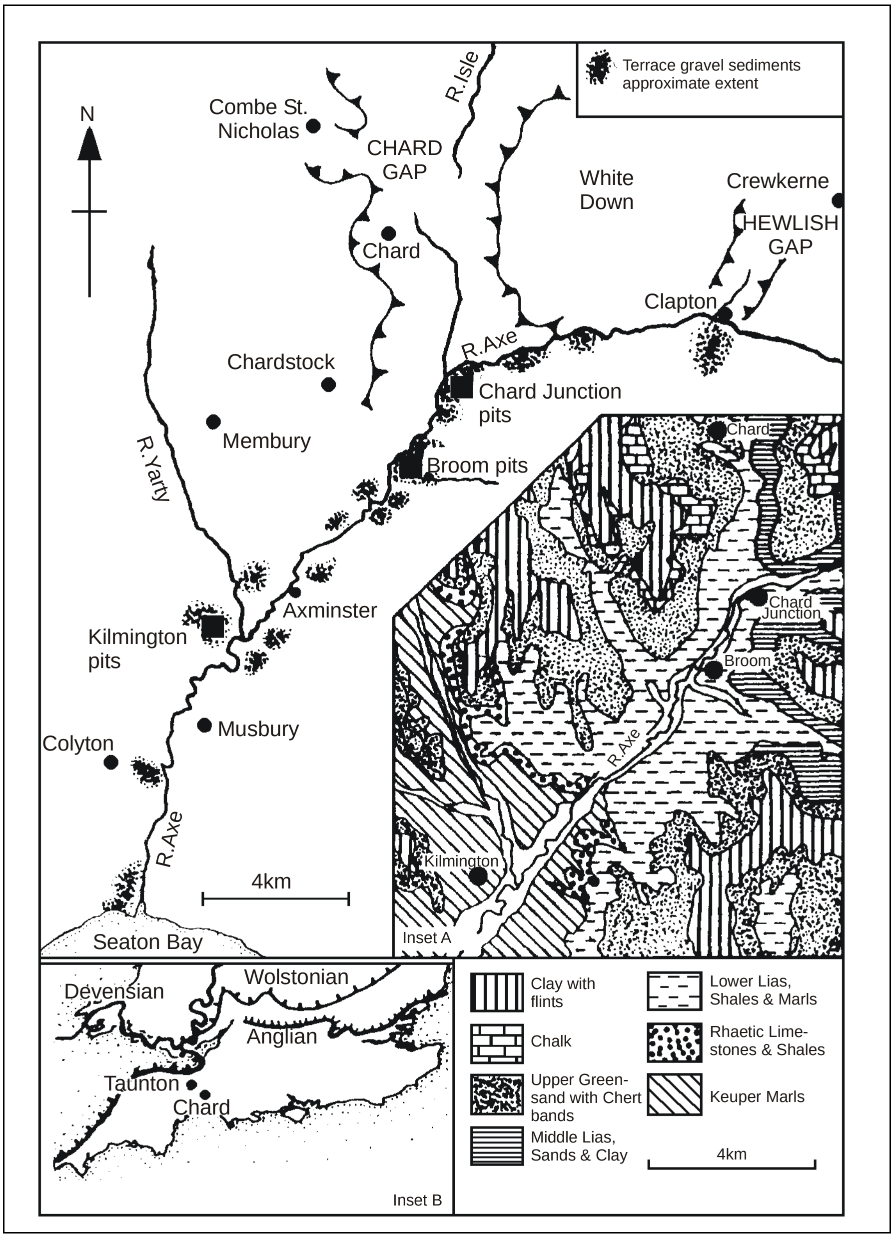

Figure 236: the River Axe valley, Devon/Dorset, UK

Although this classification approach typically results in the assignment of some artefacts to two categories, it also provides a more robust technique for characterising the transport signature of an assemblage. The classification highlights broad contrasts between the transport histories of different artefacts, based upon their physical condition, and therefore supports the classification of assemblages as spatially homogeneous or heterogeneous. It does not attempt to discuss specific distances (an unrealistic goal), but it does provide a means of comparison between different assemblages (after standardisation for sample size differences). The Broom and Dunbridge assemblages are summarised and compared below (Figure 237 & Figure 238), utilising this approach. Both assemblages are characterised as broadly homogeneous, with the majority of the artefacts having been derived from a few hundred metres upstream of the site. In both cases, there is a background scatter of more heavily derived material, but only in the Broom assemblage is there a less heavily derived component. Statistical comparison of the distributions using the Kolmogorov-Smirnov test indicates that there is a significant difference between the distributions of the artefacts across the derivation categories (at the 0.001 level of significance). Visual inspection of the distributions suggest that the Dunbridge artefacts were more heavily derived than the Broom material, although in both cases the material was relatively homogeneous (64% and 83% of the artefacts were in the modal category of the Dunbridge and Broom assemblages) and locally derived (the modal category was the $10^{2-2.5}$ for both data-sets).

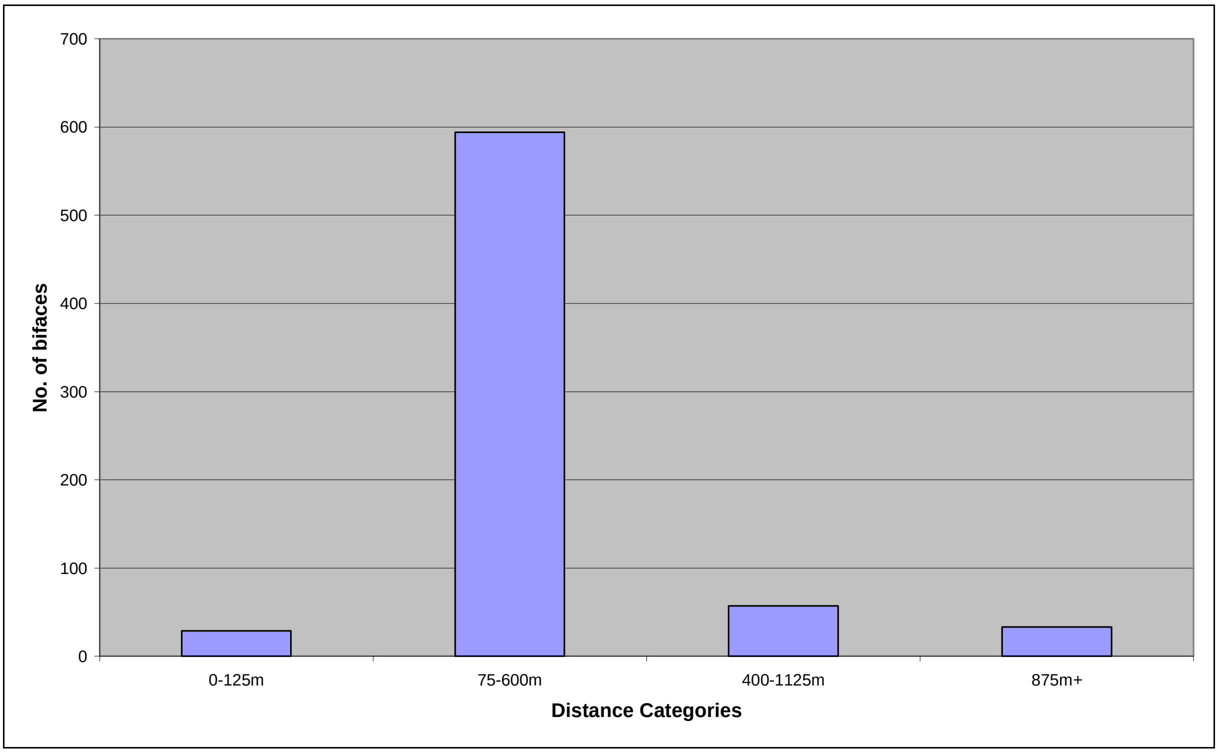

Figure 237: spatial derivation categories for the Broom biface assemblage

3. System-specific (variable-resolution) MSU: the final approach to defining the MSU highlights the geomorphological context and the structure of the fluvial landscapes within which the assemblage was deposited. Specifically, the definition focuses upon areas of terrace preservation within the drainage basin, and proposes that these zones are sedimentary catchments within the fluvial system. Processes influencing the formation of these catchments include the presence of stream confluences (resulting in the loss of stream competence and sediment deposition), and bedrock changes (resulting in the long-term preservation of terrace features and sediments). What is critical however is that these sedimentary catchment points provide a series of geographical upper limits for the definition of the MSU (the lower limit for the MSU is defined by the location of the recovered assemblage). In other words, the approach assumes that archaeological material being transported downstream will be deposited at the first sedimentary catchment that is encountered after the entrainment event. Where those sediments are subsequently eroded (prior to the present), the material will obviously be re-worked, but where the sediments are preserved it is assumed that any archaeological materials will also be present within the deposits. This model therefore enables the MSU to be defined as the distances between each sedimentary catchment with preserved fluvial sediments. In a hypothetical example from the River Axe valley (Figure

236), a derived assemblage of artefacts is recovered from the fluvial terrace sediments at Colyton. Utilising the system-specific approach, the MSU for the assemblage is defined between Colyton and Kilmington (*c.* 4 km), since it is assumed that material derived from above Kilmington would have been deposited within the preserved Kilmington fluvial sediments. This approach clearly makes two assumptions:

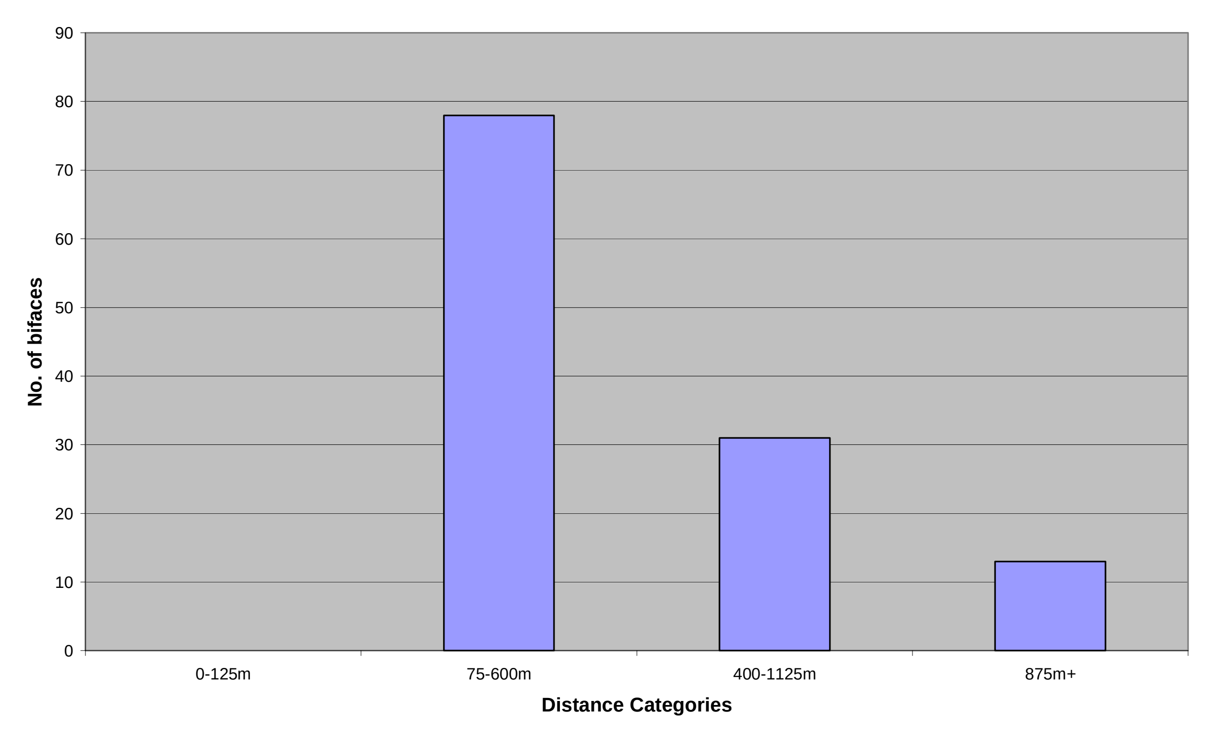

Figure 238: spatial derivation categories for the Dunbridge biface assemblage

- An MSU can only be defined between two sedimentary catchments if the terrace deposits are of the same chronological age (i.e. associated with the same interglacial/glacial cycle).
- Material would be deposited and preserved in each sedimentary catchment, *if* artefacts were discarded in the relevant stretch of river. The absences of artefacts within individual sedimentary catchments are therefore taken as an indicator of the absence of hominid activity (resulting in the discard of artefacts) within the MSU upstream of the catchment, during the time period associated with the terrace feature.

This approach to modelling the MSU can be assessed through an examination of the artefact abrasion data, with focus placed upon clear discrepancies between the two categories of evidence (e.g. the presence of heavily abraded specimens associated with MSU's less than 2 km in length). The approach has clear advantages in that it stresses the regional geomorphological context of artefact re-working in fluvial environments. However, the technique makes some fundamental assumptions which are currently untestable. Principally, it assumes that all transported artefacts will be caught within each floodplain sedimentary trap. If this is not the case, then the model is clearly seriously flawed. It also requires extensive knowledge of the fluvial system geomorphology and the sedimentary sequence, and the availability of robust geochronological models. Finally, it is not possible to apply this approach to single site investigations, as it must instead be employed in system-wide analyses.

With respect to all of the approaches outlined above, there are a series of caveats that require identification:

- It is recognised that materials discarded on valley slopes can be washed into the fluvial system.

However, in terms of the definition of the spatial distribution it is argued that the distances and directions of down-slope movement are unlikely to significantly alter the assemblage transport signature (and associated interpretations of landscape behaviour).

- The experimental modelling of artefact damage through fluvial transport requires further research, specifically with reference to long-distance transport, suspended load transport, transport in fine-grained sedimentary environments, and the development of abrasion on a wider range of raw materials (our current research has explored flint and chert).

3.3. Summary

There are relatively few extant models of artefact re-working and derivation (e.g. Harding *et al.* 1987; Hosfield 1999; Wymer 1999). These models have either focused upon experimental data (e.g. Harding *et al.* 1987) or have emphasised generic models of re-working without explicitly addressing the physical spatial component in the real world. The research presented here has suggested three approaches to identifying the spatial resolution associated with the secondary context archaeological resource, as represented by derived lithic assemblages deposited in fluvial sediments. All three of these approaches utilise the concept of a minimum spatial unit (MSU). The first of these approaches adopts a limited view, defining the MSU as the spatial zone between the assemblage findspot and the head of the river system. This approach argues that physical artefact evidence and the geomorphological structure of the fluvial system cannot be employed to assess the internal structure of spatial palimpsest archaeology. The third approach adopts a geomorphological approach, stressing the role of fluvial features (e.g. river/tributary stream confluences) in creating sediment traps upon river floodplains. The MSU is therefore defined as the spatial zone between the assemblage findspot and the nearest *preserved* sediment trap upstream. This approach is interesting, and emphasises geoarchaeological processes and the sedimentary context of the archaeological resource. However, it requires further field testing prior to its adoption for the interpretation of archaeological assemblages. It also adopts a system-wide approach, and is therefore of limited usage for single-assemblage studies. The second approach emphasises the physical condition of the archaeological assemblage, stressing the *état physique* of individual artefacts. The MSU is variably defined in terms of distance categories, organised through orders of magnitude (10^1–10^3), and based partially upon experimental laboratory work (Chambers in prep.) and partially upon extant assemblage-studies (Broom and Dunbridge). The model suggests that relatively fine spatial resolution is currently detectable, based on the notion of artefacts derived from a series of increasingly distant source ideas. The spatial resolution markedly decreases with distance from the assemblage findspot, which reflects the difficulties of distinguishing transport modes over long-distance movement histories. The model also adopts fuzzy categories, reflecting the complexity of the real world processes of artefact derivation. This second approach is favoured here, primarily because it is based upon the artefact assemblage, which provides the most direct evidence of the transport histories associated with the archaeological resource.

However, it is also vital to integrate this physical data-based model of artefact derivation with the macro-scale processes of fluvial-system behaviour (e.g. intensive erosion and re-working in the upland zone). A provisional framework for the integration of these models and processes is therefore proposed here:

- Artefact-based models: the proposed fuzzy categories ($10^{1–2}$, $10^{2–2.5}$, $10^{2.5–3}$, 10^{3+}) provide a summary for the spatial re-working signature of secondary context assemblages (based on the proportion of artefacts falling into each category). The use of these categories supports the comparison of different assemblages, both from the same and different fluvial systems (although further experimental work is favoured, exploring abrasion patterns in different raw materials, the impact of suspended load transport, fine-grained sediment abrasion, and the development of abrasion during burial and partial-burial phases).

- River system models: this framework stresses the importance of highlighting apparent discrepancies between the re-working signature of assemblages and the generic models of river behaviour in different geomorphological zones or under different bedrock conditions. For example, an assemblage characterised by local derivation, occurring within an upland river zone, or a heavily derived assemblage occurring within a lowland zone. It is argued that under such conditions, further investigation of the artefact assemblage and the fluvial landscape is recommended. At the same time, it is noted that upland/lowland river contrasts in fluvial behaviour should not be over-stressed, given the marked variations in fluvial behaviour that occurred throughout river systems across the glacial/interglacial cycles of the Middle Pleistocene.

Overall therefore, the minimum spatial unit (MSU) defined here is spatially-variable, varying from the sub-hundred metres scale (10^{1-2}) to the km scale (10^{3+}).

4. FRAMEWORKS FOR ANALYSING BEHAVIOUR

The geochronological and spatial resolutions proposed here for the secondary context archaeological resource cover a wide and variable spatio-temporal range. This variability provides a diverse set of spatio-temporal frameworks for the analysis of hominid and early human behaviour through the archaeological secondary context resource. A set of frameworks are therefore proposed, with a generic description of the spatio-temporal scales and an outline of the potential analytical approaches to the problems of early human behavioural reconstruction (Table 54). It is stressed that the frameworks are not exclusive, indeed in many cases informative behavioural analysis relies on the integration of the different, specified frameworks.

The precise analytical applications of these frameworks will inevitably vary from one archaeological investigation to the next. However, a series of examples are worked through below, and where possible, related to extant research.

4.1 Short-term temporal frameworks (10^2–10^3 years)

4.1.1 'On-site' investigations (10^1–10^2m)

The 'on-site' description used here is actually slightly misleading, because it conveys an unhelpful concept, that of the archaeological site, which implies settlements for which there is typically no direct evidence in the secondary context record. However it is intended to stress that the archaeological materials have probably been minimally derived (tens of metres) from the fluvial landscape surfaces upon which they were discarded by hominids (or were dumped onto through valley slope processes such as solifluction). It is therefore theoretically possible to explore patterns in lithic technology (e.g. artefact manufacturing techniques and raw material selectivity), typology, and local hominid behavioural activities (based on the range and combination of artefact types). These patterns are inevitably time-averaged (see also below), but they all reflect a short time period of human behaviour, perhaps occurring during a single climatic episode of distinctive character, and could potentially be mapped against palaeoclimatic data sets where this material is present (but see the comments in the previous chapter). As modelled in Section 2, these short-term geochronological resolutions are associated with the interglacial phase of the climatic cycle, and it is therefore possible that the low-energy regimes and fine-grained sedimentation processes will result in the partial-preservation of spatial patterning associated with the archaeological debris (promoting the indirect analysis of hominid activities).

However, it is vital to recall that all of these patterns are time-averaged, since the minimum geochronological resolution covers a few hundred or a few thousand years. Interpretation of the data must therefore recognise the high probability of temporal over-printing and acknowledge that behavioural interpretations are *not* reconstructing single events, but *are* dealing with short time-span patterns in hominid behaviour. Finally, it is stressed that the sediments associated with these short-term geochronological frameworks float within the sedimentary sequences, and therefore that analysis of landscape activity is restricted to the locale and its immediate environs. Comparison with other assemblages from other, geographically-distinct sedimentary sequences is not currently possible. Only in cases where two or more archaeology-bearing high resolution sedimentary units lie in superposition is it possible to compare these data sets, in this instance to explore short-term changes in hominid behaviour in and around the locale.

	Space		
Temporal	**10^{1-2} (10-100m)**	**10^{2-3} (100m1-km)**	**10^{3+} (kms)**
10^2-10^3 (100-1,000 years)	'On-site', short-term climatic fluctuations: > Hominid activities (temporal over-printing) > Landscape activity patterning (temporal over-printing)	'Off-site', short-term climatic fluctuations: > Hominid activities (spatio-temporal over-printing) > Landscape activity patterning (spatio-temporal over-printing)	Basin-wide, short-term climatic fluctuations: > High resolution demographic modelling > Lithic typology & technology (high resolution)
10^2-10^4 (100-10,000 years)	'On-site', single glacial/interglacial cycle event: > Warm/cold climate patterns in hominid activities (temporal over-printing) > Warm/cold climate patterns in landscape activity (temporal over-printing)	'Off-site', single glacial/interglacial cycle event: > Warm/cold climate patterns in hominid activities (spatio-temporal over-printing) > Warm/cold climate patterns in landscape activity (spatio-temporal over-printing)	Basin-wide, single glacial/interglacial cycle event: > Warm/cold climate demographic patterns > Lithic typology & technology (mid resolution)
10^4-10^5 (10,000-100,000 years)	'On-site', full glacial/interglacial cycle: > Climatic cycle patterns in hominid activities (temporal over-printing) > Climatic cycle patterns in landscape activity (temporal over-printing)	'Off-site', full glacial/interglacial cycle: > Climatic cycle patterns in hominid activities (spatio-temporal over-printing) > Climatic cycle patterns in landscape activity (spatio-temporal over-printing)	Basin-wide, full glacial/interglacial cycle: > Demographic patterns > Lithic industry typology & technology (low resolution)

Table 54: spatio-temporal frameworks for the analysis of early human behaviour through the secondary context archaeological resource

4.1.2 'Off-site' investigations (10^2–10^3m)

The 'off-site' term is employed here to stress that the archaeological materials have probably been derived over several hundred metres. As above, it is still theoretically possible to explore patterns in lithic typology and technology, and human behaviour, with the archaeology still representing relatively short-term phases of human behaviour. However, the major problem at this scale concerns the likelihood that the patterns are both time- and space-averaged. In other words, the problem of temporal over-printing has been joined by the problem of spatial over-printing, reflecting the fact that within a minimum spatial unit of several hundred metres there is a possibility or probability of multiple, and spatially-distinct activity locales. At these scales, it is recommended that analysis of lithic debris focuses on potentially robust patterns that might operate at the local river valley scale. Examples would include raw material types (homogeneity/heterogeneity could be explored against modern field observations), quality (adopting White's (1998b) approach), and nodule/pebble sizes (through artefact size ranges and modern field observations). Homogeneity/heterogeneity in artefact types (e.g. bifaces) might also be indicative of local-scale landscape exploitation strategies, with particular respect to the range and type of activities carried out. As above, in those (rare) instances where high resolution archaeological samples occur in stratigraphic superposition, analysis and comparison of these patterns would enable the exploration of hominid behavioural trends (stasis and/or change) over relatively short-term time periods. In these instances however, field observations would be vital to confirm the presence/absence of sedimentary breaks between the deposition of the two archaeology-bearing stratigraphic units. Finally, comparisons of on- and off-site data sets should be treated cautiously, since there are potentially differential degrees of spatio-temporal over-printing.

4.1.3 Basin-wide investigations (10^{3+}m)

Unlike the two categories above, analysis at this scale is restricted to the spatially-broad concept of the drainage basin. Spatial over-printing is likely to be extremely prevalent in the data, and there will of course also be temporal over-printing of the data. At these scales, it is suggested that analysis of the lithic assemblages explores robust patterns that operate at the basin-wide scale. Examples would include demographic modelling (based on the artefact-based approaches of Ashton & Lewis (2002) and Hosfield (1999)), and robust patterns in lithic typology and technology (if present). The unique value of these approaches concerns the short time-span of the patterns, enabling the investigation of high resolution demographic patterns over just a few hundred or few thousand years. For example, the potential to explore short-term demographic fluctuations (e.g. peaks and troughs) could provide insights into the sizes and structures of hominid populations. Unfortunately, the semi-floating nature of the current geochronology restricts the ability to compare patterns recorded in different river systems.

4.2 Mid-term temporal frameworks (10^2–10^4 years)

4.2.1 'On-site' investigations (10^1–10^2m)

As previously (Section 4.1.1) these archaeological materials have only been derived short distances. However, the potential for temporal over-printing (due to a minimum geochronological resolution ranging between 100s and several 1,000s of years) is considerable, resulting in assemblages that are probably heavily time averaged. In light of this, patterns in lithic technology or typology are unlikely to represent hominid behaviour from short time-spans (and are highly unlikely to be the debris of single occupation episodes). However, the geochronological resolution enables the sedimentary units (and archaeological materials) to be related to distinctive climatic phases within the glacial/interglacial cycle (e.g. warm interglacials, and the warm/cold or cold/warm climatic transitions). It is therefore proposed that analyses focus upon robust patterns in the lithic debris that could operate at the climatic sub-phases of the glacial/interglacial cycle. Examples would include lithic typology (e.g. in biface forms), where the clear dominance of particular artefact types might indicate associations with specific tasks (e.g. wood-working (Dominguez-Rodrigo *et al.* 2001)), or could indicate the imposition of social rules in tool making and mid-term cultural traditions (e.g. as argued by White (1998a) with respect to the twisted ovates of the British Palaeolithic record during MIS-11). Comparison of the archaeological debris from cold- and warm-climate sedimentary units would also support investigation of possible links between tool-making, activities, and the palaeo-environment. For example, would wood-working activities be more common during the heavily forest interglacial phases than during the warm-cold climatic transitions, and would this be detectable through the lithic record?

It is proposed that patterns in landscape activity are difficult to detect at these scales, since although the archaeology has been minimally derived, the coarser geochronological resolution introduces the problem of extensive temporal over-printing, limiting the ability to detect specific activity episodes. Nonetheless, on those occasions where the stratigraphic evidence suggests localised distributions of debris (e.g. as claimed by C.E. Bean at the base of the 1st floor level in Pratt's Old Pit at Broom), analysis of artefact types and proportions may be undertaken to explore the possible evidence for specific activities at localised points within the landscapes. Finally, it should be noted that these geochronological resolutions potentially enable the identification of comparable sedimentary units and archaeological debris from different locations both within and between single fluvial systems, with absolute dating (e.g. OSL), stratigraphic sequences and geomorphological terrace models (e.g. Bridgland 2001) providing the comparative frameworks. This supports sub-regional and regional comparisons of hominid behaviour during a single sub-phase of the glacial/interglacial cycle.

4.2.2 'Off-site' investigations (10^2–10^3m)

As previously (Sections 4.1.2 & 4.2.1), these archaeological debris are likely to have been subjected both to extensive temporal over-printing (reflecting the geochronological resolution) and spatial over-printing (reflecting the larger minimum spatial unit). It is therefore proposed that analysis of the lithic debris should focus upon patterns that would operate at the local river valley scale, over single climatic sub-phases of the glacial/interglacial cycle. Examples would include raw materials (e.g. type, quality, size), since the geochronological resolution would enable the testing of models proposing variable raw material availability under different climatic conditions (e.g. Wenban-Smith's (1998) model of flint-rich landscapes associated with the early temperate stages of post-glacial periods). Robust patterns in lithic typology (and potentially technology) could be indicative of mid-term trends in tool-making (e.g. imposed standardisation or cultural traditions), and could also be potentially related to climatic conditions. It is also important to stress that these mid-term patterns reflect relatively small spatial areas (and are potentially time- and space-averaged indicators of localised landscape activity). As stressed above however (Section 4.2.1) it is possible to undertake intra- and inter-regional comparisons, based on the identification of comparable sedimentary units in different locations, which may enable the homogeneity/heterogeneity of landscape behaviours to be tested.

4.2.3 Basin-wide investigations (10^{3+}m)

With analysis restricted to basin-wide scales, there is a high probability of extensive temporal and spatial over-printing evident in the archaeological patterns. Given the extensive time- and space-averaging of the data, it is recommended that analysis is restricted to the robust patterns in the lithic debris that operate at the river basin level. Examples would include artefact-based demographic modelling and macro-scale trends in artefact typology and technology. Critically, the geochronological resolution of these data provides the potential to explore macro-scale data patterns in relation to the climatic sub-phases of the glacial/interglacial cycle. For example, the exploration of mid-term fluctuations in demographic data (e.g. peaks and troughs in population sizes) can be linked to model testing with respect to hominid palaeo-environmental tolerance and colonisation (e.g. Roebroeks *et al.* 1992). Equally, robust, basin-wide patterns in lithic typology and technology (e.g. Clactonian/Acheulean variations) can be linked to palaeoclimatic and palaeoenvironmental conditions, and utilised to test extant models (e.g. Mithen 1996, Wenban-Smith 1998, White 2000). Finally, the geochronological resolution supports inter-regional comparisons, enabling the homogeneity/heterogeneity of hominid demographic structures and tool-making traditions to be tested over large areas, with respect to generic (e.g. warm/cold) palaeoclimatic factors.

4.3 Long-term temporal frameworks (10^4–10^5)

4.3.1 'On-site' investigations (10^1–10^2m)

Although these materials have been subject to minimal derivation, the potential for temporal over-printing at the identified geochronological resolutions is clearly extremely considerable. Given the high probability for heavy time-averaging of the assemblage, it is noted that any patterns in lithic technology and/or typology will almost certainly not represent single occupation episodes. Moreover, since the geochronological resolution (several 10,000's years) covers full glacial/interglacial cycles, it is noted that the accumulated (and mixed) archaeological debris has the potential to represent hominid activity under a range of different palaeoenvironmental and palaeoclimatic conditions. There is currently little understanding of the types of lithic artefact patterns that might operate at these macro-scales (Stern 1993). It is therefore recommended that there is a need for exploratory analysis, which seeks for patterns in the data against which to test a series of basic hypotheses. For example, the range of lithic industry types and the variability of artefact forms (e.g. bifaces) and morphology (e.g. dimensions and weight) could be used to explore notions such as: i) do lithic tool-making traditions vary over evolutionary time (e.g. between glacial/interglacial cycles) in terms of the types and range of artefacts produced?; ii) when do the major developments in lithic technology occur?; iii) do lithic industries and traditions vary in response to the relative frequency and magnitude of glacial/interglacial cycles? Some of these approaches have been widely utilised (e.g. with respect to the appearance of Levallois technology in the British Palaeolithic (Bridgland 1996)), but it is stressed that new advances in dating (e.g. in luminescence-based approaches) offers new potential since they provide artefact-independent chronological frameworks (avoiding the circularity problem associated with artefact-based frameworks). Finally it is emphasised that at the glacial/interglacial cycle scale, there is considerable potential for extra-regional/national level comparisons of locale-based patterns in lithic technology and raw material exploitation.

4.3.2 'Off-site' investigations (10^2–10^3m)

At these scales, the problems of both temporal and spatial over-printing are considerable, producing severely time- and space-averaged assemblages. As above (Section 4.3.1), it is recommended that focus should be placed on robust patterns in lithic industries, with the geochronological resolution supporting analyses of technological trends between glacial/interglacial cycles, and intra- and inter-regional comparisons of local river valley patterns in time- and space-averaged lithic assemblages. At these scales, robust patterns in palimpsest lithic assemblages will (where they exist) inevitably reflect the majority of tool-making activity, yet the presence of 'outlier' tool-types and tool-making techniques can be explored with respect to robust spatial and temporal variables such as landscape morphology (e.g. fluvial uplands and lowlands), longitude/latitude based-climates (e.g. maritime and continental conditions), and temporal variations in the severity/mildness of glacial/interglacial events. These types of approaches have been explored by Gamble (1997) with respect to the similarities of the widely-separated Olduvai Gorge (Masek Beds) and Swanscombe archaeology, but there is also potential to pursue them at a national and regional level.

4.3.3 Basin-wide investigations (10^{3+}m)

At these scales the spatial and temporal over-printing of the archaeological assemblages is considerable. With such extensive time- and space-averaging of the data, analysis is inevitably restricted to broad-scale patterns in the lithic data, operating at the river basin level (spatial) and across the glacial/interglacial cycles (temporal). The two key examples are artefact-based demographic modelling (e.g. Hosfield 1999; Ashton & Lewis 2002) and patterns in lithic industries and manufacturing traditions. The spatial and temporal scales support the investigation of large-scale processes and provide robust (albeit time-averaged) data sets. For example, the exploration of demographic patterning between glacial/interglacial cycles can be linked to palaeo-landscape evolution (e.g. the breaching of the Dover–Calais landbridge), and palaeoclimatic change (e.g. increasing continentality), as demonstrated by Ashton & Lewis (2002). The use of a glacial/interglacial cycle geochronological resolution also supports the practical, long-term comparison of regional demographic data, supporting the exploration of landscape factors that may have influenced colonisation processes and demographic structure (e.g. the location and evolution of major river systems). These approaches and comparisons can also be applied to lithic technology and patterns in the long-term stasis/change of particular lithic industries and technologies.

4.4 Summary

Overall therefore, these frameworks offer a range of spatio-temporal scales through which to explore a wide range of high and low resolution patterns in lithic technology (e.g. manufacturing techniques), lithic typology, and artefact-based demographic signatures. These patterns can be investigated with reference to a range of factors including socio-cultural (e.g. imposed standardisation, the presence of homogeneity/heterogeneity in assemblages), processual/functional (e.g. raw material exploitation patterns, subsistence strategies and activities), landscape (e.g. river system evolution, raw material availability) and environmental (e.g. long-term fluctuations in the magnitude and frequency of glacial/interglacial cycles, cold/warm climatic contrasts, and habitat types). It is vital to stress that these frameworks are not independent. Indeed it should be apparent that the frameworks and their analytical approaches feed back into one another to provide a fuller understanding of the evidence. For example, population patterns associated with individual cold- and warm-climate events will support interpretation of demographic structure data at the glacial/interglacial level. Similarly, patterns in lithic typology and technology at the individual sedimentary unit level should inform interpretation of long-term patterns of technological change or stasis. Finally, it is stressed that these secondary context frameworks will both inform and be informed by, the evidence that is available from the primary context archaeological record. Although the primary and secondary context data sets ostensibly deal with separate data and issues, there is considerable interaction between the two contexts. For example, on-site evidence of a marginal, scavenging hominid would support a secondary context-based demographic model that revealed unstable, fluctuating populations. To illustrate theses linkages, the analytical frameworks highlighted above are illustrated within Gamble's tacking model (1996; Figure 239), modified to incorporate the approaches outlined here (Figure 240).

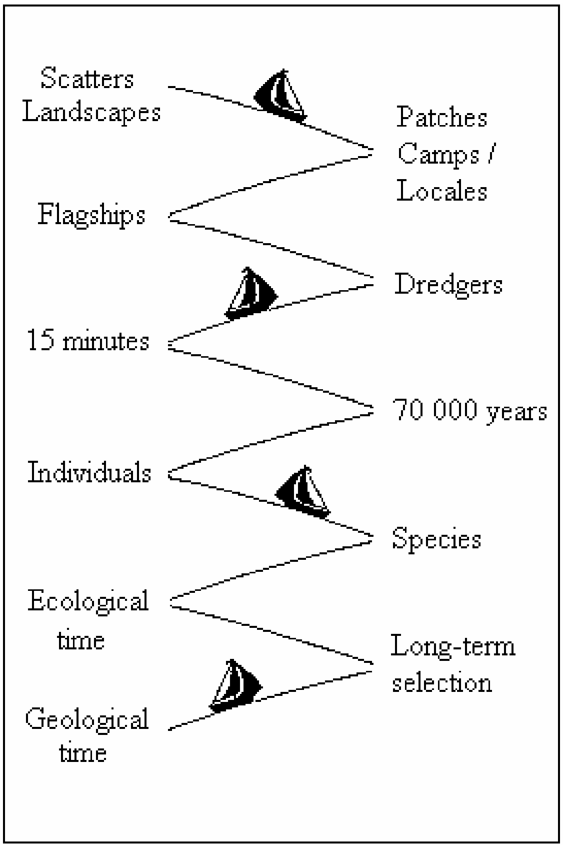

Figure 239: 'Tacking' as a strategy for interpreting the Lower Palaeolithic (Gamble 1996: Figure 7.1)

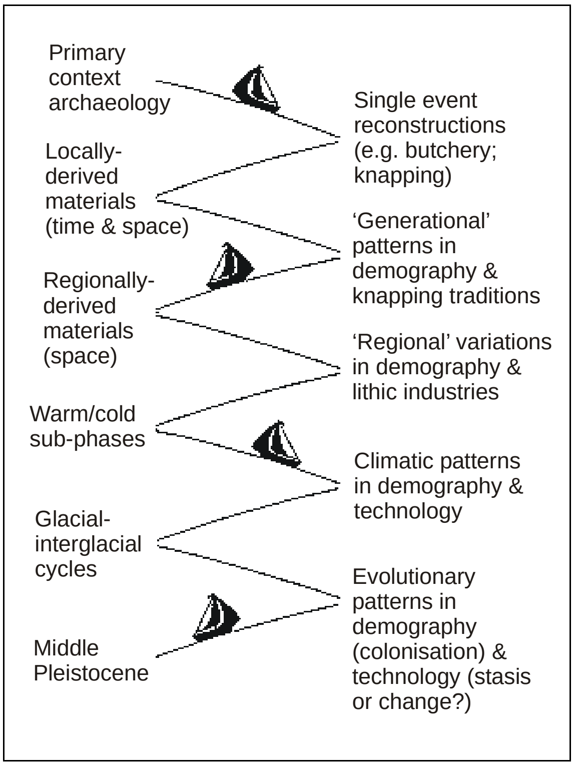

Figure 240: spatio-temporal frameworks for the interpretation of the Lower Palaeolithic (after Gamble 1996: Figure 7.1)

5. REVISITING EXISTING RESEARCH QUESTIONS

The previous section identified a range of spatio-temporal frameworks for the analysis of the secondary context archaeological resource. It also referenced a range of extant Palaeolithic research which has dealt with a number of the same questions (although not always employing secondary context archaeological data to do so). These research themes and questions are returned to here, with a view to the ability of secondary context data to contribute to the resolving of the issues. However, it is obviously vital to reiterate at this point (following Hosfield 1999; Ashton & Lewis 2002), that the interpretation of patterns in secondary context (and sometimes in primary context data) must first consider and assess the potential collection biases associated with the material evidence. Four recent and current themes in of Palaeolithic research are highlighted here:

1. Modelling of hominid demography (e.g. Hosfield 1999; Ashton & Lewis 2002).
2. Identifying colonisation routes and occupation histories (White & Schreve 2000; Ashton & Lewis 2002).
3. Spatio-temporal trends in artefact typology and technology (Mithen 1996; Wenban-Smith 1998; White 1998a, 2000; & Jacobi 2002).
4. Alternative models of technological production, incorporating raw materials (e.g. White 1998b; Ashton *et al.* 1994; McNabb & Ashton 1992), situational contexts (e.g. Ashton *et al.* 1991), and cultural traditions (e.g. Mithen 1996; Wenban-Smith 1998).

5.1 Demographic modelling

In many respects the demographic models of Hosfield (1999) and Ashton & Lewis (2002) have the strongest affinity to the frameworks presented above, since these models employed primarily secondary context lithic assemblage data to model Middle Pleistocene populations in the Solent River basin and the Middle Thames respectively, utilising real world values (Hosfield 1999) and proxy values (Ashton & Lewis 2002). A brief review of the two models is provided here:

- Hosfield's model (1999, 2001) used bifaces as the primary unit of analysis and was driven by assumptions of artefact function, use-life and the frequency of behavioural episodes in which those artefacts were used and discarded. Modelling of the variables generated a range of hypothetical estimates with respect to the accumulation of artefacts over the duration of the Middle Pleistocene occupation of Britain. Hominid group sizes of 25 were assumed, while territory ranges were calculated from raw material transfer distances for the European Lower and Middle Palaeolithic. These hypothetical estimates were compared against the observed archaeological data, which was statistically modelled to account for the partial sampling of the archaeological record, and the comparative differences were interpreted in terms of population densities and the duration of continuous hominid occupation.

  Retrospectively, this model is clearly limited since many of the variables were hugely over-simplified and the approach falls into the trap of over-modelling the data. Moreover the absence (at that time) of suitable geochronological frameworks for the Solent River basin terraces greatly limited the potential geochronological resolution that could be achieved. However, many of the faults of this model were removed by the subsequent work of Ashton & Lewis (2002).

- Ashton & Lewis' model (2002) utilised a simpler and more effective methodology than Hosfield (1999), and was grounded in the MIS-terrace framework developed for the Middle Thames by Bridgland (1994). Artefact densities were calculated for combined totals of bifaces and Levallois material, with the latter artefacts compensating for the reduced prevalence of bifaces in Middle Palaeolithic assemblages. The material was divided into a series of chronological units, following the river terrace units on the River Thames (the Black Park, Boyn Hill, Lynch Hill, Taplow and Kempton Park terraces). The chronological duration of the deposits associated with each terrace unit followed Maddy & Bridgland (2000), and enabled the artefact densities to be standardised by time unit (of

100,000 years duration). The artefact densities were also standardised by terrace (surface) area, urban growth, and quarrying extents (with the last two categories accounting for local variations in archaeological sampling histories). These standardised artefact densities indicated a robust pattern of population decline, using artefacts densities as a population proxy, in the Middle Thames valley during the Late Middle Pleistocene.

Overall, these models highlight the potential value of secondary context data sets for the modelling and interpretation of Palaeolithic demography. The model of Ashton & Lewis (2002) emphasises a basin-wide approach at a glacial/interglacial scale — thus duplicating the lowest resolution example of the spatio-temporal frameworks highlighted above (Section 4.3.3). However, it is suggested that these types of demographic models would also benefit from the exploration of basin-wide patterns at the higher resolution scale of cold/warm sub-phases of the glacial/interglacial cycle (Section 4.2.3). These approaches would reduce the time-averaging of the modelled demographic signal, and also provide a means for testing potential demographic variations in response to climatic variability.

5.2 Colonisation models and occupation histories

Ashton & Lewis (2002) applied their demographic modelling to explore the processes of colonisation and occupation of Britain during the late Middle Pleistocene, and along with the previous work of White & Schreve (2000), these papers provide two of the main discussions of the potential mechanisms influencing the occupation and colonisation of Palaeolithic Britain. A brief review of these works is therefore provided:

- Ashton & Lewis (2002) argued that the formation of the English Channel influenced the cycle and stability of the hominid occupation of Britain, due to the interplay of sea-level and climate change. While they recognise themselves that many of the following factors require further investigation, Ashton & Lewis highlighted issues including the timing of the English Channel breach (a later breach, perhaps in MIS-6, provides a better explanation of the relatively high population levels of MIS-11 and 9 compared to those of MIS-7 and 5e), and changes in the climatic and habitat preferences of hominids during the Middle Palaeolithic. Much of the evidence cited in support of the change in habitat and climatic factors is primary rather than secondary context — including on-site evidence of butchery and hunting strategies, lithic transport and technological mobility, and local habitats and environments. However, the breach timing model does incorporate potential secondary context data, in the form of faunal assemblage comparisons.

- White & Schreve (2000) developed a biogeographical framework of human colonisation, settlement, and abandonment. They proposed mechanisms that linked these patterns with regional palaeogeographical evolution and global climatic change. The framework was tested against the archaeological record and it was concluded that not only were there distinct, chronologically-defined manufacturing traditions, but also that they could be interpreted through the differential ebb and flow of separate, regional populations. Specifically it was argued that the Clactonian represented the early expansion of European populations into Britain during the early post-glacial period (after abandonment during the glacial maxima), while the Acheulean was introduced during a later, secondary phase of colonisation. Finally, during periods of high-sea level isolation, endemic tool-making traditions developed, resulting for example in the twisted ovates of MIS-11. This model utilised a wide range of lithic and biological data, both from primary and secondary contexts, with particular focus upon interglacial assemblages, the presence of Clactonian and Acheulean assemblages, distinctive technological features, and the development of sub-MIS scale chronological frameworks.

As previously, these models highlight the potential of the secondary context data for the interpretation of colonisation patterns and occupation histories. In the case of the Ashton & Lewis (2002) model, secondary context data is primarily employed in the construction of the population model (see above), rather than in the interpretation of the patterns. However, it is argued that higher-resolution demographical modelling approaches (see above) could be employed to test the proposed explanation of changes in habitat and climate preferences during the Late Middle Pleistocene. By contrast, White & Schreve (2000) pre-empt many of the approaches explicitly discussed here, with the usage of secondary context data sets to test their colonisation framework. The model highlights the applications of these data sets and illustrates a range of approaches with respect to lithic technology and typology. However, it is noted that the model focuses primarily on interglacial data sets (MIS-9 and MIS-11), and it is proposed here that secondary context data from the entire glacial/interglacial cycle can yield valuable evidence.

5.3 Lithic industries

Analyses of assemblage composition can be used to identify spatio-temporal trends in the technology and typology of lithic artefact production through the identification of marker artefacts. For example, Levallois technique is widely regarded as having been introduced into Britain during late MIS-9/early MIS-8, as it first occurs in the Lynch Hill/Corbets Tey Formation of the Lower Thames (Bridgland 1996). Both primary and secondary context assemblages can be examined for the presence or absence of such marker technologies, and whilst their presence in secondary contexts can be complicated by factors of both spatial and temporal derivation, resolution to the MIS level is commonly achievable. Due to the historical biases towards the disproportionate collection of bifacial artefacts, it may be argued that secondary context assemblages are of particular use in the search for trends within biface manufacturing techniques (e.g. White 1998a; & Jacobi 2002). Additionally, the examination of secondary context assemblages may assist in the resolution of continuing archaeological debates, for example the temporal relationship between the Clactonian and Acheulean industries (Mithen 1996; White & Schreve 2000). Examples of these approaches are included below, with relevant background to the archaeological industries and technologies:

- Twisted ovates occur in low frequencies in many British biface assemblages, and can be regarded as accidentally created during normal biface manufacture. However in assemblages where they are more common it has been argued that their manufacture was both deliberate and intentional (White 1998a). High proportions of twisted ovates have been recovered from both pointed (e.g. Foxhall Road & Hitchin Lake Beds) and ovate (e.g. Swanscombe, Bowman's Lodge) dominated assemblages, and from both primary and (to a lesser extent) secondary contexts (*ibid*: Table 14.1).

  Assemblages with concentrations of twisted ovates appear to demonstrate a strong chronological correlation. Twisted ovates are virtually absent from sites of a pre-Hoxnian age, such as High Lodge (Ashton *et al.* 1992), Boxgrove (Roberts & Parfitt 1998) or Warren Hill (Wymer *et al.* 1991). They also do not appear to occur in significant numbers in assemblages younger than MIS 11/10, such as those recovered from Purfleet, Stoke Newington, Wolvercote and Furze Platt (White 1998a). The demonstrated chronological trend for greater numbers of twisted ovates within late MIS-11/early MIS-10 appears to be geographically limited to British assemblages, as the record from northern France shows substantial numbers of twisted ovates occurring in MIS-12/11 at Cagny-La Garenne, MIS-10/9 at Cagny-l'Epinette and potentially in MIS-8 at Rue de Cagny (*ibid.*; Callow 1986; Tuffreau & Antoine 1995).

  White (1998a: 103) suggests that twisted ovates may represent a distinctive tradition of manufacture, temporally restricted to sites dated to late MIS-11 to early MIS-10. Whether this tradition occurred as a result of social or technological pressures may be debated, though White suggests that it most likely arose through a combination of factors, and advices against bipartite divisions. As White (*ibid.*) acknowledges, this chronological correlation is based on a small number of sites, and may be subject to revision as dating resolution increases. Therefore the presence of twisted ovates alone cannot be advocated as a chronological marker. However, such a study highlights the ways in which primary and secondary context data sources can be used in conjunction to enhance our understanding of lithic behaviour and variation during the Middle Pleistocene.

- As a typological category *bout coupé* bifaces have been the subject of much debate, with descriptions of their precise characteristics (and the status of individual specimens) varying between researchers. The most rigorous definition was provided by Tyldesley (1987: 155), stating that a *bout coupé* biface is a medium sized cordiform or rectangular biface with a symmetrical planform, straight or slightly convex butt, slightly convex sides and a rounded tip (Figure 241). There should also be marked discontinuity of curvature at the intersection of the sides and butt. Applying these criteria, 75 'true' *bout coupé* bifaces have been recovered from British findspots, of these 37 are unprovenanced, with others recovered from rivers and beaches with some marked only with town or parish data. Despite these problems, *bout coupé* artefacts are considered indicative of the Middle Palaeolithic, particularly Neanderthal settlement during the late Last Interglacial Complex/Early Devensian, in Britain (Gamble & Roebroeks 1999).

The Middle Palaeolithic can be generally categorised by a dominance of flakes and flake-tools manufactured on both Levallois and non-Levallois blanks, with local variations defined by specific forms of biface (e.g. Mousterian of Acheulean Tradition A of south-west France (Mellars 1996). The presence of *bout coupé* uniquely within Britain can be regarded as a further regional variation in Middle Palaeolithic behaviours (White & Jacobi 2002).

In the light of recent dating programs (e.g. Jacobi *et al.* 1998) suggesting a British occupational hiatus from the penultimate glaciation (MIS-6) to the Middle Devensian (MIS-3), the correlation of *bout coupé* artefacts with Last Interglacial/Early Devensian merits re-evaluation (White & Jacobi 2002). This re-evaluation has focused on those *bout coupé* artefacts that are well provenanced, in either primary or secondary context. Of those in primary context, radiocarbon dates are available for Coygan Cave and Kent's Cavern, which while not directly associated with the *bout coupé* artefacts themselves provide dates in the range of 38,684–30,220 BP (*ibid*: 114). These dates are not without contention, but their association with a Pin Hole mammal assemblage type indicates MIS-3 age (Currant & Jacobi 2001). The 'true' *bout coupé* artefacts recovered from fluvial contexts also support a Middle Devensian age in most cases, as exceptions such as the *bout coupé* recovered from Great Pan Farm, Isle of Wight, tend to be poorly provenanced.

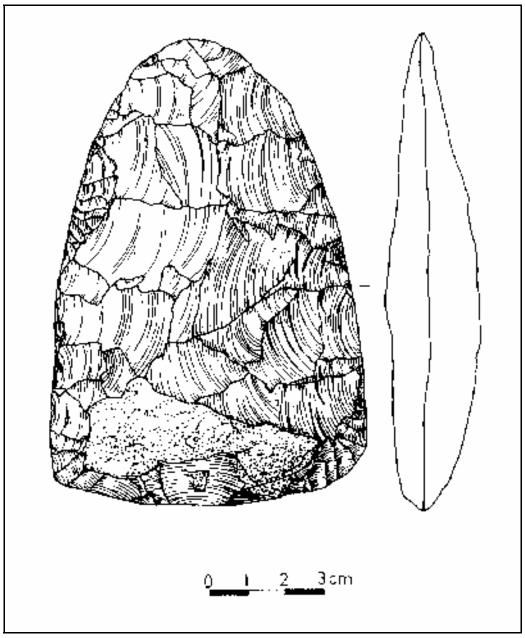

Figure 241: bout coupé *biface (after Coulson 1986: Figure 12.1)*

The research by White & Jacobi (2002) has demonstrated that 15 of the 'true' *bout coupé* findspots are of definite Devensian age, of which 10 can be attributed to the Middle Devensian (MIS-3):

"These data strongly suggest that the 'true' bout coupé is strongly associated with the late Middle Palaeolithic in Britain, but it should not be used uncritically as a Mousterian marker fossil…The same situation holds for the wider bout coupé class"

(White & Jacobi 2002: 123)

The *bout coupé* biface has proved difficult to define both in typological and chronological terms. White & Jacobi (2002) adopted the most rigorous definition of the type available (Tyldesley 1987), looking at the depositional context of all well provenanced 'true' *bout coupé* artefacts, regardless of whether this provenance was to a primary or secondary context. By considering all available data in this manner a revision of the chronological associations of *bout coupé* artefacts has been proposed:

"Although many bout coupes must be removed from consideration due to contextual inadequacies with the data, those with adequate information clearly showed a chronological trend which suggests to us that the bout coupé is associated with a recolonization of the British Isles during OIS 3 by Neanderthals making a MTA type assemblage…The Middle Palaeolithic of Britain can thus be split into two broad groups: an early Middle Palaeolithic dated to the Middle Pleistocene, with a high Levallois index and probably Acheulean type handaxes; and a later Middle Palaeolithic marked by MTA that included bout coupes, but in which Levallois was rare."

(White & Jacobi 2002: 128)

- Mithen (1996) explored the classic typological division between Acheulean and Clactonian industries in the British Lower Palaeolithic through the mechanism of knowledge transfer and social learning. The model stressed that interpretation of early lithic tools through notions of tradition rather than function and adaptation. It also argued that these early technologies were passive reflections of ecological constraints, and were not actively employed as means of restructuring the ecological context (they were therefore markedly different to modern human technologies). A key link was drawn between the sizes of early human groups and the nature of social learning and the strength of cultural traditions. It was proposed that in small groups the opportunities for social learning would be relatively limited. Consequently, knapping practises would be highly diverse due to the weakness or complete absence of cultural traditions (which it is argued would be propagated through social learning). By contrast, in large groups, social learning opportunities are greater, leading to the development of common knapping practises and the reproduction of consistent artefact forms.

  The model was tested against lithic industry patterns in the Lower Palaeolithic, characterised by the distinction between the Clactonian (core and flake) and Acheulean (predominantly biface-orientated) assemblages. These Clactonian and Acheulean assemblages (from both primary and secondary contexts) were argued to have been produced in markedly different palaeoenvironments: Clactonian technologies were associated with interglacial climates and well-forested habitats, while Acheulean industries were linked to glacial conditions and the open tundra. It was suggested that the glacial, tundra environments supported large groups, resulting in strong social learning and the development of social traditions expressed in the technological uniformity of the Acheulean. By contrast, the wooded environments of the interglacials were associated with small groups, low level of social learning and unstandardised, highly variable (Clactonian) technologies.

All of the three models discussed above utilise both primary and secondary context data to explore spatio-temporal issues of technological variability and innovation. It is suggested that the analytical frameworks proposed previously (Section 4) can contribute to all of these case study approaches, both at the interglacial/glacial cycle-scale (e.g. with respect to the macro-chronology identification of marker artefacts), and at the sub-cycle scale. At these finer scales, secondary context data offers the potential to relate patterns in technological production to shorter-term climatic fluctuations (e.g. exploring the patterning proposed by Mithen (1996)), and identify the duration of distinctive phases of tool-making (e.g. as suggested by White (1988a) with respect to the production of twisted ovates).

5.4 Technology and factors of production

Models exploring the factors influencing lithic production (e.g. raw material quality and availability, cultural traditions and situational needs) have typically relied both upon primary and secondary context data sets, focusing upon artefact forms, spatial patterns in primary context data sets, and the structure of archaeological landscapes. A selection of the key concepts with respect to lithic production are summarised below:

- White (1998b) stressed the importance of raw material quality in influencing the outcome of biface form, arguing for a relationship between ovate bifaces and high quality, fresh chalk flint nodules. By contrast, pointed bifaces tended to be produced upon river cobble flint. The model was grounded in the notion that ovate bifaces are primarily produced from flake blanks, which can only be produced from fresh flint. River cobbles are generally unsuitable for the production of large flake blanks due to factors of size and damage during fluvial processes. The model also argued that the ovate was a more desirable form of biface, due to the presence of a circumferential cutting edge, and therefore ovates would typically be produced when high quality raw materials were available. The less desirable points were produced when it was not possible to create ovates from the poorer-quality river cobble flint. The model was tested against both primary and secondary context data sets, set within the context of the contemporary Pleistocene landscape (it was assumed that the nearest available flint resource would be used, irrespective of its quality). The key element of the model was its emphasis upon the constraints imposed by raw material quality, over issues of cultural/industrial traditions which had dominated much of the traditional literature (e.g. Roe 1968b, 1981). However, this model has recently been challenged by Wenban-Smith *et al.* (2000), who noted the presence of pointed bifaces at Red Barns, near a chalk flint outcrop.

- Wenban-Smith (1998) combined issue of raw material availability with notions of *ad hoc* technologies to explain the presence of both Acheulean and Clactonian industries in the British Lower Palaeolithic. The model argued that the flake and core tools of the Clactonian were produced as an *ad hoc* cutting technology, manufactured as needs demanded. Such strategies required flint-rich landscapes (in which a source of raw materials was constantly available), which are proposed to have been characteristic of the early temperate stages of the post-glacial period. As the interglacial progressed, raw material availability became more localised, as fluvial gravels were buried with silts and other sources were covered with vegetation. Under these conditions, the *ad hoc* Clactonian technologies became less viable, and were replaced by portable, curated Acheulean technologies. This model stresses temporal change in tool-making, in response to landscape evolution, rather than focusing upon social factors (e.g. Mithen 1996) or the influx of new populations and cultural traditions (White & Schreve 2000). However, it does assume that the Acheulean and Clactonian are distinctive technological entities within the Lower Palaeolithic record.

- In contrast, Ashton and McNabb (Ashton *et al.* 1991; Ashton *et al.* 1994; McNabb & Ashton 1992) have stressed the importance of the situational context with respect to lithic production. They suggest that the Acheulean and the Clactonian represent different elements of the same technological repertoire, based partly on the recovery of bifaces from assemblages that have traditionally been classified as Clactonian (McNabb & Ashton 1992; McNabb 1996). The potential association of 'Clactonian' and 'Acheulean' elements was demonstrated at Barnham, where artefacts from both traditions were recovered from the same horizon, and it was argued that perceived Clactonian/Acheulean variability reflected the undertaking of different activities in different parts of the contemporary landscape rather than discrete industries. The notion of a baseline technological repertoire (from which both 'Clactonian' and 'Acheulean' artefacts were produced) was also stressed with respect to the production of simple, expedient tools (e.g. flaked flakes) in response to immediate needs and (unknowable) circumstances.

Although some of these models (e.g. White 1998b) stress secondary context data, the spatio-temporal frameworks (Section 4) have a limited potential for contributing to many of the outlined concepts. This reflects the focus upon tool-making variability within local landscapes (Ashton *et al.* 1994), emphasis upon mobile technologies (e.g. Wenban-Smith 1998; Ashton *et al.* 1994), and the discussion of expedient tool-production. These approaches require a degree of data resolution that is unavailable in the secondary context record. However, it is possible to utilise secondary context data to explore broad-scale patterns in biface types (e.g. testing White's (1998b) raw material model) and the potential Acheulean/Clactonian division (e.g. exploring Wenban-Smith's temporal model through patterns in assemblage types over the duration of the glacial/interglacial cycle).

Overall however, it is clear that a number of recent and current research themes in British Palaeolithic studies are amenable to investigation through the analysis of the secondary context archaeological resource. Preliminary case study examples of such approaches are presented in Chapter 9.

6. THE VALUE OF THE ARCHAEOLOGICAL RESOURCE

The secondary context archaeological resource dominates Britain's early prehistoric archaeological record, in terms of the quantity of material, and the spatio-temporal coverage of the assemblages. In many cases, the resource is represented by collections of stone tools (e.g. bifaces), for which relatively little precise provenancing information is available. A key stage in the evaluation of these data is therefore the assessment of the scales of spatio-temporal resolution associated with the assemblages. Given the widespread absence of accurate field data, these assessments are primarily based on the artefacts themselves (with respect to their spatial derivation and re-working) and broad-scale geomorphological mapping of fluvial terrace systems.

The spatio-temporal models presented in sections 2 and 3 proposed a series of analytical scales, based on the relative degree of horizontal and vertical re-working to which the components of the secondary context archaeological assemblages had been subjected. These scales do not identify specific timescales or exact distances in space, reflecting the complexity of the processes being modelled. The analytical scales were based instead upon orders of magnitude, within which the resolution decreased in proportion to the degree of horizontal and/or vertical re-working. The key advantages of these frameworks are that they can be reconstructed on the basis of relatively limited contextual information. The spatial models utilised artefact data (the *état physique*) while the temporal models exploited generic river system behaviours (e.g. upland/lowland contrasts), current models of terrace formation, and low resolution provenance data (e.g. the recovery of artefacts from basal gravels).

The models of spatio-temporal resolution provided a matrix of analytical frameworks, across which different elements of hominid behaviour could be investigated. The frameworks stressed the time- and space-averaged nature of the data, but unlike the majority of existing approaches, exploited these characteristics to explore robust patterning. For example, three frameworks are presented for the exploration of demographic patterns, all at the basin-wide scale, but ranging from short-term traces (lasting a few hundred or a few thousands of years and potentially associated with uniform palaeo-environmental conditions) to long-term signatures, accumulating across single glacial/interglacial cycles. By contrast, the series of locale-orientated frameworks enable short- and long-term patterns of raw material exploitation and its impact upon tool-making to be explored. These approaches therefore provide a long-term perspective upon early prehistoric archaeology and behaviour that cannot be achieved from higher-resolution data.

These secondary context data are dominated by lithic evidence (predominantly core tools and large flakes — although the impact of selective collection histories must always be considered with respect to these data). There are also occurrences of biological data (predominantly large mammal fauna, although other material does occur), although this evidence is more localised, reflecting preservation factors (e.g. soil chemistry). These data have clear, practical applications with respect to the problems of site formation (which is fundamental to the interpretation of secondary context data), through the *état physique* of the lithic data, and the range of lithic and biological artefacts within the assemblages. By contrast, the use of the biological data for palaeoenvironmental reconstructions is more problematic. In those instances where high resolution palaeoclimatic indicators (e.g. beetle assemblages) occur within secondary context sequences (e.g. in localised fine-grained silt lenses within the gravels), it is not possible to relate it to the derived archaeology occurring throughout the sequence. The palaeoclimatic reconstructions based upon these data can provide an indication of possible habitat types that existed at some point during the deposition of the complete sedimentary sequence, but it is not possible to explicitly populate these habitats with either artefacts or hominids. With respect to lower-resolution palaeoenvironmental data (e.g. large mammals) occurring within coarse-grained, gravel units, the same problem exists, namely that direct associations cannot be made between derived lithic materials and derived fauna. However, it should be noted that the two data sets operate at the same order of temporal magnitude, and therefore that provisional comparisons of these time-averaged data sets can be made.

Unlike these palaeoenvironmental questions however, the secondary context resource has clear applications to a range of current behavioural questions in early prehistoric archaeology, as discussed for the Lower and Middle Palaeolithic in Section 5. Inevitably these applications tend towards research themes that operate at the lower-resolution analytical scales, reflecting the minimum chronological and spatial resolutions that are achievable for these data (Sections 2 and 3). Examples include demographic patterning and artefact-based analysis (raw material patterning, industry variability, diagnostic morphologies, and manufacturing processes and traditions). It is stressed that these data can be explored at a series of different spatial and temporal scales, and the interplay between these analytical frameworks provides a more comprehensive understanding of the processes at work:

- For example, demographic models at the glacial/interglacial scale (10^4 and 10^5 years) reveal long-trends in hominid colonisation and population dynamics over the course of the Middle Pleistocene, but reveal little about the ebb and flow of populations over the course of a single warm/cold cycle. These gaps in understanding can be explored through demographic data at the sub-cycle level (e.g. derived artefacts from different sedimentary units in a single terrace sequence, following the Bridgland (1996) sandwich model), which may document fluctuations in occupation histories and therefore reveal hominid habitat and climate preferences. Comparison of river system data may also reveal regional variations in occupation histories, potentially highlighting the importance of a range of factors including habitat preferences, raw material and other resource availabilities, and the role of different networks (e.g. the Thames/Rhine system) in hominid mobility and the ebb and flow of populations.

- With respect to artefact-based analysis, patterns in typology at the glacial/interglacial cycle level may reveal long-term trends in lithic technology (e.g. stability or change), while higher-resolution patterns may indicate shorter-term trends in lithic production, perhaps in response to palaeo-climatic factors. These trends can also be linked to behavioural models of tool-making, for example at Broom the homogeneity of the lithic record over a cold–warm–cold sedimentary cycle (perhaps MIS-9/8/7) is highly suggestive of a typologically diverse, but stable lithic technology. At the higher-resolution scale of the individual units within the sedimentary cycle, the repetitive diversity of the assemblages (Chapter 4) appears to indicate an absence of imposed standardisation upon tool-making activities.

Overall, it is proposed here that the secondary context archaeological resource has a clear, unambiguous value with respect to the investigation of early prehistoric archaeology. It enables the identification of archaeological patterns and behavioural elements that operate at coarse-chronological and spatial levels, and which cannot be identified from high resolution, primary context site investigations. However, it also generates data which can be related back to high resolution studies of hominid behaviour, while the varied spatio-temporal frameworks identified here provide a robust mechanism for the integration of on- and off-site archaeology in time and space.

However, the successful interrogation of this resource is therefore reliant upon:

1. Future field testing of geoarchaeological models of sediment and artefact re-working.
2. Continued refinement of absolute chronological dating methodologies, including optically stimulated luminescence and amino-acid techniques.

3. Ongoing development of geomorphological models of terrace formation and river valley evolution, including improved interaction between the geomorphological and archaeological communities.
4. Further development of geoarchaeological models of artefact transportation in a variety of sedimentary regimes.
5. Targeting of field monitoring of aggregates extraction sites, with specific reference towards sediment dating, geoarchaeological models, and recording of key sedimentary phenomena.

All of these issues relate to the question of how the secondary context archaeological resource is managed, recorded and (potentially) protected — and this theme forms the core of the next chapter.

CHAPTER 8

RECOMMENDATIONS FOR THE MANAGEMENT, PROTECTION AND RECORDING OF THE SECONDARY CONTEXT ARCHAEOLOGICAL RESOURCE

1. INTRODUCTION

Whilst the previous chapters have been primarily concerned with the structure and interpretation of the secondary context archaeological resource, this chapter turns its focus upon the current state of management practice with respect to that resource. This review of resource management is driven by the notion that the secondary context resource has a clear, unambiguous value, and that this resource is continuously threatened by aggregates industry activities, construction and other developments. The review is intended to provide the basis of new recommendations for the management, protection and recording of this archaeological resource. These recommendations are based on the value of the archaeological resource, the available categories of evidence and their differing implications for management and practice, the current position of archaeology within the aggregates extraction industry and the planning process, and the nature of professional archaeological practice. This chapter therefore draws upon the material discussed in previous chapters, summarised here, with references to the related discussions where relevant. The review of current practice and proposed recommendations also draw upon documents from a wide range of sources including: government (Department of Culture, Media and Sport (DCMS)); English Heritage; professional archaeological units (Cotswold Archaeological Trust and Wessex Archaeology); archaeological organisations (e.g. the Institute of Field Archaeologists); amateur archaeologists (e.g. T. Hardaker and the late R.J. MacRae); and academic sources (e.g. the University of Birmingham-led Shotton Project).

Section 2 summarises the background to the management of the archaeological resource, principally with respect to the PPG16 legislation. Section 3 assesses the value of secondary context archaeological resource, as proposed by this project. Specific focus is given to the research questions and spatio-temporal frameworks that may be addressed through these data, while attention is also paid to the different types of evidence that are available, their frequency of occurrence and range of applications. These categories of data are prioritised in Section 4, against a series of different demands including: management strategies; logistics (field strategies); professional archaeological requirements; and academic archaeological requirements. Current watching brief practice is reviewed in Section 5, with respect to the overall planning frameworks for the aggregates industry, archaeology and the planning process (PPG16), and case studies of recent watching briefs at the sites of Dunbridge (Bridgland & Harding 1993; Harding 1998) and Squabb Wood (Cotswold Archaeological Trust 2000). Section 6 proposes a series of recommendations for future watching brief practice, based on the current planning framework, future aggregates demands, and the potential of the archaeological data and the means of maximising this potential through time-efficient and economic strategies.

In summary, the chapter highlights four main issues:

- The relative value of the secondary context archaeological resource, both as a whole and with respect to the different categories of new evidence (artefactual, biological, sedimentary, and dating samples) that can be potentially recovered from pre-excavated secondary context sediments.

- Prioritisation of the different categories of evidence occurring within the secondary context archaeological resource, with respect to management strategies, logistics and archaeological requirements (both academic and commercial).
- A review of current watching brief practise on aggregate sites, based on an analysis of strategy documents produced by professional archaeological units.
- The recommendation of generic and specific strategies for the future management, protection and recording of the aggregate resource. These recommendations will focus upon the potential impact for the aggregates industry (financial and logistical), the relative value of the different components of the geoarchaeological record, strategy efficiency (in terms of time and geoarchaeological data output), and the potential for the training of aggregates industry employees in the recognition of different sedimentary facies.

2 ARCHAEOLOGY AND PLANNING

2.1 PPG16

Issued by the Department of the Environment in 1990, *Planning Policy Guidance Note 16: Archaeology and Planning* (PPG16; DoE 1990) set out the government's policy for the protection of archaeological sites within plans for future development. Central to PPG16 was the argument that:

"Archaeological remains should be seen as a finite and non-renewable resource, in many cases highly fragile and vulnerable to damage and destruction. Appropriate management is therefore essential to ensure that they survive in good condition. In particular, care must be taken to ensure that archaeological remains are not needlessly or thoughtlessly destroyed. They can contain irreplaceable information about our past and the potential for an increase in future knowledge. They are part of our sense of national identity and are valuable both for their own sake and for their role in education, leisure and tourism."

(DoE 1990: paragraph 6)

Despite this recognition of their significance, it was also acknowledged that it is not physically or economically viable to preserve all archaeological remains. Within PPG16, archaeological remains are implicitly attributed different scales of significance. Those sites and their environs that can be described as "nationally important" are subject to "a presumption in favour of their physical preservation" (DoE 1990: paragraph 8), irrespective of scheduling status:

"…where nationally important archaeological remains, whether scheduled or not, and their settings, are affected by proposed development there should be a presumption in favour of their physical preservation in situ i.e., a presumption against proposals which would involve significant alteration or cause damage, or which would have a significant impact on the setting of visible remains."

(DoE 1990: paragraph 27)

The status of archaeological remains where national significance cannot be demonstrated is less clear-cut however. PPG16 advocates that whenever a planning proposal is put forward the archaeology of the affected region should always be considered as part of the overall planning process:

"…planning authorities will need to weigh the relative importance of archaeology against other factors including the need for the proposed development."

DoE 1990: paragraph 8)

PPG16 does not explicitly stipulate the criteria necessary for achieving the status of national significance, instead deferring this decision to professional bodies (e.g. County Archaeologists and English Heritage) and extant legislative guidelines (e.g. the Secretary of State's *Criteria for Scheduling Ancient Monuments* (PPG16 Annex 4)). However, PPG16 does officially and incontrovertibly place archaeological remains among those concerns that must be considered during the planning process.

Overall therefore, PPG16 seeks to provide a framework for safeguarding the entirety of the nation's archaeology within planning proposals and long-term development strategies. When one considers the diversity of the archaeological record of England, spanning all periods from "the camps of the early hunter gatherers…to the remains of early 20th century activities" DoE 1990: paragraph 4), this is a huge remit. The archaeology that PPG16 seeks to protect varies enormously and as such will be of varying vulnerability depending both on the nature of the archaeological remains themselves and the extent of the proposed development.

2.2 Palaeolithic Archaeology and Planning Policy

Sediments that may contain Palaeolithic archaeology are commonly deeply buried under Holocene deposits. In many cases this depth of over-lying Holocene sediments acts as a buffer zone protecting Palaeolithic archaeology from disturbance during domestic planning applications and construction activities. However, when planning applications are concerned with mineral extraction it is these underlying Pleistocene sediments that will be removed, making any Palaeolithic archaeology they contain extremely vulnerable to destruction. The overlying Holocene deposits may contain a relative wealth of later prehistoric and historical archaeology, which in many cases can be evaluated in pre-planning phases of analyses, through mechanisms such as the Sites and Monuments Record (SMR), National Monuments Record (NMR), topographic surveys, non-invasive archaeological investigations (e.g. geophysical prospection techniques), and archival research utilising historical documents and maps. Unfortunately the presence of deep landscape Palaeolithic archaeology cannot be determined in this manner, much less the presence of nationally important Palaeolithic sites as determined by the outlined English Heritage criteria (discussed below).

Although PPG16 recognises that different types of planning application will affect the archaeological record in different ways, the nature and location of mineral extraction places Palaeolithic archaeology at particular risk. As mineral extraction of sands and gravels can only take place in regions where these sediments exist, there can be considerable overlap between identified areas of potential mineral extraction and areas of known archaeological occurrences, not least due to the demonstrated sustained attraction of river valleys throughout the Palaeolithic occupation of the British Isles (English Heritage 1998; Wymer 1999). Moreover, Palaeolithic archaeology presents a unique suite of characteristics that make it particularly vulnerable to destruction during construction and mineral extractions:

"Most Palaeolithic sites occur in valleys which have been infilled with sediments, often laid down by former rivers, which have buried the archaeological evidence. These sediments, whether brickearth, sand or gravel, are often sought for modern construction, and commercial quarrying for the minerals can inadvertently remove archaeological evidence…it is vital therefore that developers and planners are aware of the circumstances under which this might occur and take effective steps to minimise the risk of destroying important remains. Development plan policies and the assessment of individual proposals should take account of the Palaeolithic remains…so that they may be located, protected or investigated as is appropriate to their significance."

(English Heritage 1998: 2)

In addition to commonly being situated in sediments viewed as highly desirable for mineral extraction, it can be argued that Palaeolithic archaeology is particularly prone to inadvertent destruction during construction/extraction activities, due to the absence/rarity of large structures or features such as hearth complexes or graves (features readily identifiable to the non-specialist and therefore of increased visibility) which are much more common in the archaeology of subsequent periods. The primary archaeological remains for the Lower Palaeolithic are lithic artefacts, most typically the biface (handaxe), which could easily be overlooked during gravel extraction. Secondary context Palaeolithic archaeology is particularly vulnerable during mineral extraction, as these sites occur exclusively in gravel and sand deposits, and typically consist solely of lithic artefacts that have become incorporated into these high-energy fluvial deposits. This can be described as an archaeological signature of very low visibility, though this should not be taken to be synonymous with low value.

Irrespective of period, the definition of archaeological 'value' in response to PPG16 has been controversial, though the realities of selective preservation in the face of continued urban/economic growth cannot be escaped. In order to emphasise the value of Palaeolithic archaeology, guidelines for the selection of important remains have been devised by English Heritage (1998). As has been demonstrated for the archaeology of other periods, Palaeolithic sites are of varying importance and evaluation is necessary in order for the degree of protection, management or recording merited by each site to be determined. According to these guidelines, Palaeolithic remains have particular importance if (*ibid*: 7):

1. Any human bone is present in relevant deposits.
2. The remains are in an undisturbed primary context.
3. The remains belong to a period or geographic area where evidence of a human presence is particularly rare or was previously unknown.
4. Organic artefacts (such as the wooden spear from Clacton-on-Sea) are present.
5. Well-preserved indicators of contemporary environment (floral, faunal, sedimentological etc) can be directly related to the remains.
6. There is evidence of lifestyle (such as interference with animal remains).
7. One deposit containing Palaeolithic remains has a clear stratigraphic relationship with another.
8. Any artistic representation, no matter how simple, is present.
9. Any structure, such as a hearth, shelter, floor, securing device etc survives.
10. The site can be related to the exploitation of a resource, such as a raw material.
11. Artefacts are abundant.

"Sites containing any of these types of evidence are so rare in Britain that they should be regarded as of national importance and whenever possible should remain undisturbed."

(English Heritage 1998: 7)

The establishment of these eleven criteria of Palaeolithic importance leads to the rather interesting question of how this importance can actually be demonstrated. With the partial exception of criteria #2, (the identification of fine-grained sediments which may *potentially* contain *in situ* Palaeolithic archaeology could, in certain circumstances, be identified from extant geological knowledge — e.g. Pope 2001), none of the criteria identified as significant by English Heritage can reasonably be assessed through desk-top approaches (Table 55). Reviews of the relevant Sites and Monuments Record (SMR) may indicate the presence (or absence) of similar Palaeolithic remains in the vicinity, although the absence of evidence/evidence of absence problem (Roebroeks 1996) is paramount in under-studied regions. Understanding of the Palaeolithic archaeology of a specific region will of course be greatly enhanced by consultation of the relevant volume of the recently completed Southern Rivers Palaeolithic Project (SRPP), the Welsh Lower Palaeolithic Survey, and The English Rivers Palaeolithic Project (TERPS), an extensive survey commissioned by English Heritage to generate (among other purposes) a common database which can be used to assist management strategies in the protection of Palaeolithic remains (Wessex Archaeology 1993a, 1993b, 1994, 1996a, 1996b, 1996c, 1997). This might lead to the preservation of sediments adjacent to the handful of scheduled, significant Palaeolithic sites in this country (primarily located in south-eastern England) that have met enough criteria to have been deemed of national importance. Such a strategy would advocate the preservation of sediments *adjacent* to known, substantial, Palaeolithic sites and in accordance with PPG16 such areas would be preserved *in situ*. This preservation *in situ* would protect sediments primarily on the basis of their proximity to known, significant Palaeolithic sites. Yet paradoxically their very preservation would prohibit their Palaeolithic potential from ever being demonstrated.

	'Significant' Criteria as Identified by English Heritage (1998)	Detectable via Desktop Assessment?	Caveat	Ground truthing confirmation through excavation/watching brief necessary?
1	Any human bone is present in relevant deposits	NO	Identification of sediments known to contain hominid remains would allow desktop assessment of the *potential* of directly adjacent sites (limited applicability).	YES
2	The remains are in an undisturbed primary context	NO	Identification of sediments which may *potentially* contain *in situ* materials may be possible in locations directly adjacent to known sites (limited applicability).	YES
3	The remains belong to a period or geographic area where evidence of a human presence is particularly rare or was previously unknown	NO	Absence in adjacent areas can be demonstrated via desktop assessment, but cannot be assumed in unexcavated locations.	YES
4	Organic artefacts (such as the wooden spear from Clacton-on-Sea) are present	NO	Identification of sediments which may *potentially* contain organic artefacts may be possible in locations directly adjacent to known sites (limited applicability).	YES
5	Well-preserved indicators of contemporary environment (floral, faunal, sedimentological etc) can be directly related to the remains	NO	Identification of sediments which may *potentially* contain biological data may be possible in locations directly adjacent to known sites (limited applicability).	YES
6	There is evidence of lifestyle (such as interference with animal remains)	NO	-	YES
7	One deposit containing Palaeolithic remains has a clear stratigraphic relationship with another	NO	The *potential* for stratigraphic superpositioning may be identified from known adjacent sites (limited applicability)	YES
8	Any artistic representation, no matter how simple, is present	NO	-	YES
9	Any structure, such as a hearth, shelter, floor, securing device etc survives	NO	-	YES
10	The site can be related to the exploitation of a resource, such as a raw material	NO	-	YES
11	Artefacts are abundant	NO	The *potential* for artefact proliferation may be determined from known adjacent sites	YES

Table 55: The potential for desktop assessment of significant Palaeolithic remains during planning applications

Table 55 illustrates the limitations of desktop assessment of potential Palaeolithic sites. Geographical and geological proximity to known sites will allow a degree of extrapolation to adjacent sites of comparable sedimentology, although such work is inevitably hypothetical. Moreover, in regions where little is known about the nature and extent of Palaeolithic occupations, or no significant sites have been documented, desktop assessment prior to planning and/or mineral extraction approval cannot facilitate the pro-active assessment of the Palaeolithic potential of the threatened sediments.

The limitations of desktop assessment for Palaeolithic sites springs partly from the criteria, identified by English Heritage (1998), used to determine significance and partly from the nature of Palaeolithic archaeology in general. Sediments that may contain Palaeolithic archaeology are commonly overlain by substantial depths of more recent, typically Holocene, sedimentation. This depth of overburden prohibits the identification of Palaeolithic archaeology by non-destructive mechanisms such as desktop evaluations and/or geophysical prospection. Therefore the character of Palaeolithic archaeology at individual sites or regions can only be realistically evaluated once the overlying sediments have been removed and the archaeology itself becomes accessible. In addition to these logistical issues, Palaeolithic archaeology is dominated by low resolution signatures, most commonly (although not exclusively) lithic artefacts incorporated within sand and gravel deposits — the secondary context archaeological record.

2.3 The Characteristics of Palaeolithic Secondary Context Sites

The Palaeolithic record of England is dominated by assemblages of lithic artefacts (primarily bifaces) recovered from fluvial gravels. The majority of these assemblages were acquired during commercial mineral extraction activities. Despite their dominance in the archaeological record, secondary context Palaeolithic assemblages are perceived as being of a lower academic value than those sites in primary context with *in situ* archaeology and behaviours (e.g. Boxgrove (Roberts & Parfitt 1998). This project has sought to redress the balance with respect to the perceived value of the various components of the archaeological record (see Chapters 1–7 & Section 3 below), and has outlined new approaches by which the secondary context data may be meaningfully interpreted within the framework of current Palaeolithic research questions.

With regard to the potential significance of secondary context sites, a strong case can be made for the value and potential of secondary context sites through reference to the criteria devised by English Heritage (1998) for determining the significance of Palaeolithic sites (Section 2.2; Table 55 & Table 56). Of the eleven criteria identified, secondary context sites could readily fulfil six:

- *Any human bone is present in relevant deposits*: the hominid skeletal record of the British Isles is very limited, however preservation is not limited to *in situ* localities, as skeletal material can (and has) been recovered from gravel contexts (Swanscombe (Ovey 1964)).
- *The remains belong to a period or geographic area where evidence of a human presence is particularly rare or was previously unknown*: the expansion of the range of known Palaeolithic activity is not dependant on the depositional context of this activity. Indeed as mineral extraction provides one of the few ways of accessing deposits which may potentially contain Palaeolithic archaeology, it is highly probable that with appropriate archaeological assessment during extraction, more artefacts and therefore 'sites' will be identified from previously 'blank' areas.
- *Organic artefacts (such as the wooden spear from Clacton-on-Sea) are present*: preservation of organic artefacts is generally very limited, although it could occur within fluvial sediments where local conditions (e.g. sediment chemistry and/or waterlogging) are favourable.
- *One deposit containing Palaeolithic remains has a clear stratigraphic relationship with another*: secondary context sites can potentially provide stratigraphic superposition at two scales. Superposition of artefacts can occur within a single terrace (e.g. as claimed at Dunbridge), potentially providing evidence of changing (or continuing) lithic industrial traditions. Stratigraphic superpositioning can also occur between individual terraces in a single river system (e.g. as demonstrated in the River Thames), enabling changing industrial or manufacturing traditions, and technological stability and innovation to be examined within this framework. Given the scarcity of primary context sites, secondary context data can be invaluable in addressing such long-term issues.

	'Significant' Criteria as Identified by English Heritage (1998)	Potential Preservation in Primary Contexts?	Potential Preservation in Secondary Contexts?
1	Any human bone is present in relevant deposits	YES	YES
2	The remains are in an undisturbed primary context	YES	N/A
3	The remains belong to a period or geographic area where evidence of a human presence is particularly rare or was previously unknown	YES	YES
4	Organic artefacts (such as the wooden spear from Clacton-on-Sea) are present	YES	YES, but dependant on local conditions (see below)
5	Well-preserved indicators of contemporary environments (floral, faunal, sedimentological etc) can be *directly related* to the remains	YES	NO, however, detailed sedimentological data can be generated
6	There is evidence of lifestyle (such as interference with animal remains)	YES	UNLIKELY, though cut-marked bone may be preserved
7	One deposit containing Palaeolithic remains has a clear stratigraphic relationship with another	YES	YES
8	Any artistic representation, no matter how simple, is present	YES	YES, it is possible that portable pieces (*art mobilier*) may become incorporated within fluvial context
9	Any structure, such as a hearth, shelter, floor, securing device etc survives	YES	NO, such structures would not occur within fluvial gravels
10	The site can be related to the exploitation of a resource, such as a raw material	YES	PERHAPS, it may be possible to link specific raw materials to a known source
11	Artefacts are abundant	YES	YES

Table 56: The preservation potential of secondary context sites

- *Any artistic representation, no matter how simple, is present*: Palaeolithic art is largely unknown within Britain, however the possibility of the preservation of portable pieces (*art mobilier*) within secondary contexts cannot be totally discounted.
- *Artefacts are abundant*: abundant assemblages of palaeoliths (especially bifaces) have been recovered from numerous secondary context sites (e.g. Swanscombe (Conway *et al.* 1996; Wymer 1999), Dunbridge (Dale 1912a, 1918; Harding 1998) and Broom (Green 1988)). Large assemblages, such as these, become additionally significant as continued refinements are made to our geochronological techniques and methods of modelling the spatial and temporal origins of derived secondary context artefacts (Chapters 2–5).

It is therefore argued that secondary context Palaeolithic sites can provide a range of significant data. It should consequently be apparent that the consideration of Palaeolithic archaeology within the planning/mineral extraction licensing applications should not be limited to a search for *in situ* archaeology and that secondary contexts themselves should be being examined in as meaningful a manner as possible. The following section highlights the specific value of the secondary context resource, explicitly linking these data with current and original models of Palaeolithic research.

3. THE VALUE OF THE SECONDARY CONTEXT ARCHAEOLOGICAL RESOURCE

One of the principal driving forces behind this research project has been the recognition that for the British Lower and Middle Palaeolithic, the secondary context archaeological resource represents the majority of the extant data. This project has therefore been concerned with developing new models and frameworks for the re-interpretation of these extant data, which will maximise their potential and apply the data to the resolving of current and new archaeological questions. It is proposed that the secondary context archaeological resource has a clear and unambiguous value with respect to the investigation of early prehistoric archaeology. This statement is based on the following arguments, discussed and developed within the course of this project:

1. Geochronological frameworks have been established for fluvial sedimentary sequences and the secondary context archaeological resource at the scale of marine isotope stages (MIS) over the last ten years. This has based upon climatically-driven models of river terrace formation (e.g. Bridgland 2000, 2001; Maddy *et al.* 2001), allied with models of uplift rates (e.g. Maddy 1997; & Bridgland 2000), characteristic faunal assemblages (e.g. Schreve 2001b), and diagnostic artefact types as geochronological markers (e.g. Bridgland 1996). These frameworks support the modelling of long-term archaeological patterns (e.g. population sizes, using artefact densities as a proxy), as demonstrated recently by Ashton & Lewis (2002), Hosfield (in prep), and illustrated here (Chapter 7).

2. There is considerable scope for the further development of these MIS-scale geochronological frameworks through the recent advances in optically stimulated luminescence (OSL) and amino-acid dating techniques (Toms 2003; Collins 2003). The application of the OSL dating to the Broom sediments (Chapter 3) suggested a MIS-scale geochronology of stages-8/7 for the middle beds/upper gravels sedimentary sequence (the lower gravels have not been dated due to lack of access).

3. It is proposed that higher resolution geochronological frameworks may also be developed. These are based upon Lateglacial analogues (Chapter 2), which suggest a strong link between fluvial activity (e.g. erosion, sedimentation) and phases of climatic change and/or transition. Although it is clear that the specific duration of these fluvial activity episodes cannot be estimated (Lateglacial analogues involve too many variables and OSL dating is not sufficiently precise), current geomorphological research suggests periods of a few hundred (or at the very most a few thousand) years. The sedimentary units deposited during these individual fluvial activity episodes therefore provide a higher resolution geochronological context from which to explore patterns in their archaeological content (although see comments in point 4 below with regard to the vertical derivation of artefacts). These higher resolution contexts effectively float within the broader framework of the MI (marine isotope) stages, since current OSL precision does not permit their exact ageing, while the tendency for partial erosion of the sequences does not allow individual sediments to be mapped against sub-MIS climatic fluctuations (this approach is also hindered by the complexity of fluvial system response to climatic change and the role of system thresholds).

4. Refining the geochronological precision associated with the sedimentary units does not resolve the issue of artefact re-working and the potential for artefacts in secondary contexts to be considerably older than their associated sediments. New models have therefore been proposed for assessing the degree of temporal derivation undergone by re-worked artefacts (Chapter 7). These models are based on:

    a. The chronological position of the encasing sediments within the glacial/interglacial cycle (e.g. preserved, fine-grained sediments laid down at the beginning of an interglacial are likely to contain artefacts derived from the contemporary floodplain, while coarse-grained sediments deposited at the end of a glacial are more likely to include artefacts re-worked from the old floodplain (the next highest terrace level).
    b. The stratigraphic position of the artefacts within the sediments (e.g. artefacts from the base of the sedimentary unit are more likely to have been derived from older, eroded sediments, while artefacts from higher up in the unit are more likely to be broadly contemporary with those sediments).
    c. The condition of the artefacts, with heavily abraded artefacts more likely to have undergone multiple re-working episodes, potentially from higher terrace deposits into

lower sedimentary units.

d. The geomorphology of the river system and its impact upon the potential for vertical re-working through erosion (e.g. the variations in river terrace preservation on Cretaceous chalk and Tertiary clay bedrocks, or the differences in erosion potential between the upland and lowland stretches of the same river).

Temporal estimates of the degree of vertical derivation are based on orders on magnitude (10^n), reflecting the complexity of the processes and the limitations of current understanding. These models are currently theoretical and require further testing through field observations (see also Section 5 below). Nonetheless, they highlight the potential for assessing the temporal derivation of secondary context assemblages, refining the levels of geochronological precision associated with the data, and mapping data sets against research questions at different temporal scales.

5. The issue of temporal re-working also highlights the processes of spatial re-working (the fluvial transportation of artefacts downstream), which may result in the creation of spatial palimpsests in the archaeological record. New models have therefore been proposed for assessing the degree of spatial derivation undergone by re-worked artefacts (Chapters 5 and 7):

   a. The condition of the artefacts. These data form the principle basis of the models, since they are available from all archived artefact collections (although the data has rarely been recorded) while a comprehensive 3-dimensional archive of the fluvial landscape is rarely (if ever) available for the Middle Pleistocene. As with the temporal re-working models, heavily abraded artefacts are more likely to have undergone greater downstream distances of fluvial re-working.
   b. Experimental archaeology. Laboratory (Chambers in prep) and field-based (Hosfield & Chambers 2002a, 2003, 2004) experimental archaeology has provided a range of data relevant to the nature of artefact transport including the *état physique* of transported artefacts, spatial patterning in transported materials, and the generally stochastic nature of the transport process. These data have highlighted the importance of the artefacts' physical condition data as the best indicator of transport distances.
   c. The geomorphology of the river system and its impact upon the potential for spatial re-working. As with the temporal re-working models, variations in river type (e.g. upland/lowland) and fluvial behaviour (e.g. terrace preservation and migration tendency in response to bedrock type) impact upon the potential for relatively minor or more extensive phases of spatial derivation.

The spatial estimates of the degree of lateral derivation are based on orders of magnitude (10^n), reflecting the complexity of the processes, the difficulty of modelling long-distance transport and the limitations of current knowledge. These models are grounded in experimental data and observations on archaeological assemblages, but still require further development and testing. However, they represent a significant step forward in the assessment of the spatial derivation of secondary context assemblages, providing a refinement of the levels of spatial precision associated with the data, and supporting the mapping of data sets against research questions at different spatial scales.

6. The spatio-temporal models have provided a new framework for the analysis of secondary context archaeological data sets (Chapter 7). The proposed framework outlines the different analytical scales in time and space (9 are defined within the current models described here) which can be applied to the investigation of these data. The analytical scales range from on- to off-site (in the spatial sphere) and from individual millennia to tens of millennia (in the temporal sphere). These different analytical scales manipulate the data (essentially derived, stone-tool assemblages) to explore a range of processes and behavioural adaptations, including colonisation trends, population patterning (at different temporal scales), and tool-making (including typological variability, technological strategies, and raw material exploitation). Some of these approaches have been demonstrated elsewhere over the last few years (e.g. White & Schreve 2000; Ashton &

Lewis 2002), but the strength of the frameworks proposed here is in their formalisation of the spatio-temporal structures and the potential for operating at different scales and linking the different strands of investigation.

7. Investigation of the biological data that occurs within archaeological secondary contexts has highlighted the potential spatio-temporal discrepancies between the different types of biological data and the derived stone tool assemblages. Although biological data can provide extremely high resolution palaeoenvironmental reconstructions on the basis of highly-responsive micro-species (e.g. non-marine molluscs, and coleoptera), it cannot be assumed that the secondary context artefacts relate to these environments. In other words, these environments cannot be *inhabited* with either hominids or their artefacts. In the case of more tolerant, less responsive organisms (large mammals are a classical example), the palaeoenvironmental reconstructions are of a lower resolution. As with the higher-resolution reconstructions, it cannot be *demonstrated* that hominids and their artefacts were present within these environments (unless butchery evidence was identified on the faunal biofacts). However, these low resolution reconstructions are proposed to operate at a comparable magnitude to the derived, secondary context archaeology, and this scalar similarity supports the drawing of broad comparisons between these time-averaged data-sets. Finally it is stressed that biological data sets have clear archaeological applications even where they cannot be directly related to archaeological material, since these materials have a well-demonstrated value as biostratigraphical markers.

8. The value of the secondary context archaeological resource is not dependent upon comprehensive documentation of the data-sets (e.g. logging of the sedimentary sequence and the stratigraphic provenance of stone tools and/or biological data). Although secondary context archaeological assemblages with excellent documentation do exist (e.g. Broom, due to the work of C.E. Bean (Reid Moir 1936; Shakesby & Stephens 1984; Green 1988; Chapter 4), and Swanscombe (Smith & Dewey 1913, 1914; Conway *et al.* 1996)), in many cases available documentation is either limited (e.g. Dunbridge (Dale 1912a, 1918; Bridgland & Harding 1993; Harding 1998) or virtually non-existent (e.g. the majority of the secondary context sites of Southampton (Evans 1872; Dale 1896; Roe 1968a)). A key advantage of the analytical framework proposed here (point 6 above) is that all types of data (documented and undocumented) from archaeological secondary contexts can be analysed, at the relevant spatio-temporal scale or scales. For example, artefacts provenanced to an overall terrace level can be explored in terms of technology or population size at the MIS-cycle scale, while material that is documented to individual sedimentary units can be explored at both the course MIS-cycle scale and at the level of shorter-term, higher resolution fluvial/climatic/temporal events.

The above discussion has highlighted the range of data that are available from archaeological secondary contexts: artefactual (stone tools), biological, and sedimentary. These data types are prioritised in the following section, but it is important to stress that the presence of stone tools is not required for secondary contexts to have clear *archaeological potential*. This is an important distinction, since it is concerned with the perceived boundaries between Palaeolithic archaeology and Quaternary science. It is proposed here that these boundaries are essentially artificial, and are unhelpful to the continuing development of Palaeolithic archaeological research. They key point is that in many cases, stone tools are not recovered from secondary contexts (e.g. fluvial deposits) that date to the overall hominid occupation of Britain during the Palaeolithic, but those sediments are still capable of yielding a range of valuable information:

- Fine-grained sediments for optically stimulated luminescence dating, resulting in the development of absolutely-dated local and regional geochronological sequences.
- Molluscs for amino-acid dating, contributing absolute dates to the development of local and regional geochronological sequences.
- Macro- and micro-fauna for the reconstruction of Pleistocene palaeoenvironments.
- Macro- and micro-fauna for the development of faunal biostratigraphies.

- Sedimentary evidence of fluvial activity rates, erosive contacts in the depositional sequence, and landsurface development.

These data are critical in the development of wider geochronological frameworks (e.g. within which to interpret archaeology recovered from different locations in the same drainage system), improving current palaeoenvironmental understanding (e.g. against which to explore variability in hominids' behavioural repertoire), and advancing knowledge with respect to fluvial activity and its documentation within the sedimentary archive (e.g. critical to the interpretation of stone tool assemblages recovered from fluvial secondary contexts). Against this definition, an ordinal classification for the frequency of different data types associated with the secondary context archaeological resource is proposed:

1. The sedimentary archive: these deposits are the working definition of an archaeological secondary context within this project. Even in cases where aggregates extraction occurred during the 19th and/or 20th centuries (sometimes resulting in the recovery of stone tool collections), remnants of the sedimentary sequence are often available for re-investigation (e.g. Shakesby & Stephens 1984; Bridgland & Harding 1987; Bridgland 1994).
2. Biological data: the frequency of these data vary with respect to the different types (e.g. large mammal remains are more common than rodent bones for example, reflecting extraction techniques, sampling strategies and the robusticity of the material itself) and the local soil and sediments conditions.
3. Lithic artefacts: although biological data are susceptible to destruction through soil and sediment chemistry (Chapter 6), data from Bridgland (1994; Table 57) indicates that in the case of the Thames valley, palaeoenvironmental data was recovered more frequently than lithic artefacts from a total of 37 Quaternary sites (measured on a simple presence/absence basis). It is also noted that in many instances, artefacts are recovered from numerous exposures of a continuous sedimentary unit, resulting in several 'findspots' or 'sites' being recorded from a single secondary context (Hosfield 1999).

This ordering was based upon data from the Pleistocene Thames (Bridgland 1994). The presence/absence of the two data types (stone tools and biological data — fluvial sediments are inevitably present at all of the sites) at each of 31 sites was documented (Table 57, Table 58 & Table 52). The 31 sites cover a wide range of geographical localities (Figure 227) and this minimises (without wholly removing) the effects of localised preservational biases with respect to the biological data (see also Chapter 6 for further discussion of this issue). Sites dated prior to 500,000 kya BP were excluded, as this period is generally considered to pre-date the first hominid occupation of Britain during the Middle Pleistocene (Gamble 1999; Wymer 1999).

Data Type	Present	Absent
Biological	23	8
Stone tools	13	18

Table 57: occurrence of biological data types in 39 Thames Quaternary sites (after Bridgland 1994)

Overall, the key point is that the secondary context archaeological resource is of considerable value, due to the breadth of its spatio-temporal coverage and the unique long-term perspective that it provides. With data ranging from sedimentary (geochronological dating, deposition and assemblage formation processes), to artefactual (hominid behaviour [stone tools] and the palaeoenvironmental context [biological]), this is a unique archaeological resource. The key question therefore concerns how this resource is managed within the potentially conflicting demands of industry and archaeology.

Site	Sediment types	Biological data	Stone tools
Sugworth Road Cutting	Gravels, sands, silts & clays	YES	NO
Long Hanborough Gravel Pit	Gravels (incl. silt & sand lenses)	YES	NO
Wolvercote Channel	Gravels, sandy-gravels, silty-clays & peats	YES	YES
Stanton Harcourt Gravel Pit	Gravels, sands, silts & organic sediments	YES	YES
Magdalen Grove	Gravels & silty-sands	YES	NO
Westmill Quarry	Tills, gravels & sands	YES	NO
Moor Hill Quarry	Till, gravels & glacio-lacustrine sediments	NO	NO
Ugley Park Quarry	Till, gravels & sands	NO	NO
Highlands Farm Pit	Gravels	YES	YES
Hampstead Marshall Gravel Pit	Gravels	NO	YES
Cannoncourt Farm Pit	Gravels & sands	YES	YES
Fern House Gravel Pit	Gravels	YES	NO
Brimpton Gravel Pit	Gravels, sands, silts & organic muds	YES	NO
Hornchurch Railway Cutting	Till & gravels	NO	NO
Wansunt Pit, Dartford Heath	Gravels, silts & clays	YES	YES
Swanscombe (Barnfield Pit)	Gravels, sands & loams	YES	YES
Purfleet (Bluelands, Greenlands, ESSO & Botany Pits)	Gravels, brickearths & coombe deposits	YES	YES
Globe Pit, Little Thurrock	Gravels & brickearths	YES	YES
Lion Pit, Tramway Cutting (West Thurrock)	Gravels, sands, silts & silty-clays	YES	YES
Aveley, Sandy Lane Quarry	Sands, silty-clays & peaty-clays	YES	NO
Northfleet (Ebbsfleet Valley): Baker's Hole Complex	Gravels & fine-grained sediments	YES	YES
Wivenhoe Gravel Pit	Gravels & organic silty-clays	YES	NO
St. Osyth Gravel Pit	Ice-sheet outwash sediments & gravels	NO	NO
Holland-on-Sea Cliff	Ice-sheet outwash sediments & gravels	NO	NO
Clacton	Gravels, sands & clays (channel-fill sediments)	YES	YES
Cudmore Grove, East Mersea	Gravels & channel-fill estuarine sediments	YES	NO
Southminster, Goldsands Road	Sandy-gravels, sands & clayey-sands	NO	NO
Maldon Railway Cutting	Tills, gravels & sandy-silts	NO	YES
East Mersea Restaurant Site	Gravels, sandy-silts & clay-silts	YES	NO
East Mersea Hippopotamus Site	Gravel & silts (incl. sand & gravel stringers)	YES	NO
Great Totham (Lofts Farm Pit)	Gravels, silts & organic clays	YES	NO

Table 58: presence/absence of biological and artefact data types for 31 Quaternary sites from the Thames (after Bridgland 1994)

4. PRIORITISING EVIDENCE?

Prioritising the various categories of data associated with archaeological secondary contexts is a far from straightforward task. The main difficulties stem from the range of different organisations and interest groups linked to the secondary context archaeology/aggregates resource. These are defined here as follows (in no order of importance):

- Academic archaeologists.
- Amateur archaeologists.
- Professional archaeologists (involved in the implementation of PPG16 legislation), employed (directly or indirectly) by local government and/or professional archaeological units (e.g. Wessex Archaeology, Cotswold Archaeological Trust).
- The aggregates industry.

From an academic perspective, the recovery of lithic artefacts from archaeological secondary contexts is not inevitably assigned the highest priority. For example, our re-investigation of the Broom Lower Palaeolithic site (Chapters 3 and 4) was principally concerned with exploring the influence of chert raw material on Lower Palaeolithic technology and evidence for Levallois technique (through a study of the extant artefact collection) and assessing the age of the archaeological sequences (through OSL sampling of the sequence). These types of re-investigations of Palaeolithic secondary contexts have been widespread over the last few decades (e.g. Ashton *et al.* 1992, 1998; Bridgland & Harding 1987; Schreve *et al.* 2002; Shakesby & Stephens 1984; Wenban-Smith 1990, 1992) and in many cases the prime emphasis was not necessarily placed upon the recovery of new artefacts. These priorities will inevitably vary in response to levels of existing knowledge concerning the Palaeolithic archaeological presence within the local region. For example, in 'blank' areas priority may well be placed on the identification (if possible) of a Palaeolithic heritage through the recovery of the first stone tools from that region or type of landscape (e.g. Scott-Jackson 1992, 2000). In areas with large, but poorly contextualised, extant collections (as at Broom), the focus may move away from the recovery of more artefacts and towards other priorities such as dating and sediment mapping (see above). However, these goals tend to be dictated by research interests and agendas (see also Section 5 below), and integration with management policies and field practice is typically not straightforward.

Amateur archaeologists have traditionally highlighted the recovery of stone tools as a key goal in the investigation of archaeological secondary contexts (e.g. MacRae 1988, 1990, 1991, 1999; Hardaker & MacRae 2000; Hardaker 2001). This reflects a well-established tradition amongst amateur (and professional) archaeologists, with the scouring of gravel pit sites for bifaces and other stone tools dating back to the second half of the 19th century (e.g. Read 1885; see Roe 1981 for a fuller review). The focus upon the recovery of artefacts reflects a combination of factors, including the low-technology requirements of this type of fieldwork, the archaeological discipline's traditional concern with artefacts, and the lack of requirement for any formal qualifications or training (although it should be stressed that many so-called 'amateur' archaeologists are better artefact-finders than many of their professional colleagues). It is also emphasised that many of these fieldworkers (e.g. R.J. MacRae and T. Hardaker) had and have established excellent working relationships with quarry managers and staff (perhaps partly because the aggregates industry perceives a reduced threat of major disruption due to long-term archaeological excavations as a result of their activities), facilitating their regular access to these sites. However, it is proposed that modern health and safety at work legislation will increasingly result in the restriction of access for amateurs to working aggregates sites. Specifically this may result from the recent introduction of a number of safety passport training schemes (recently reviewed by the Health and Safety Executive (2003a, 2003b)). Although the long-term implications of these schemes for archaeologists working on aggregates sites are not yet fully understood, it is conceivable that programmes such as the Client/ Contractor National Safety Group's (CCNSG) Safety Passport Scheme (http://www.safetydomain.co.uk/ccnsg/) may deter amateur archaeologists both by their financial cost (£100) and limited duration (the safety passport is valid for three years). Finally, it is noted that amateur fieldwork and its resulting collections are often not integrated into current research frameworks, and it can perhaps be suggested that this activity is 'collection for collections sake', although there are still instances where amateur observation has resulted in discoveries of significance (e.g. the work of R.J. MacRae and

Terry Hardaker in highlighting the Palaeolithic quartzite artefact record of the Upper Thames valley region).

The professional archaeological perspective is rather more difficult to classify, not least because it is clear that there is considerable regional variation (Wilkinson pers. comm.; see Section 5) within the watching brief frameworks developed and implemented as part of the PPG16 process. Since a guiding principle of PPG16 is the avoidance of the needless destruction of *archaeological remains* (see Section 5 below for further details), the key issue concerns *what* is perceived as archaeological remains for the Palaeolithic period, when dealing with archaeological secondary contexts. This issue was introduced above and is discussed in further detail below (Section 5), but examples of recent watching brief activity in Hampshire (Harding 1998; Cotswold Archaeological Trust 2000) indicate that the recovery of stone tool artefacts from working aggregate extraction sites (whether from exposed sections or reject heaps) is seen in the professional archaeological sector as the primary indicator of Palaeolithic archaeology. The Squabb Wood project design also places emphasis upon the instigation of emergency excavations should *in situ* archaeology be identified (Cotswold Archaeological Trust 2000: 1–2), suggesting again that artefacts are seen as the primary indicator of an archaeological secondary context and are therefore the main focus on any monitoring activity. It is noted that artefact recovery is often combined with mapping and litho-stratigraphical logging of exposed sections (e.g. Harding 1998; Cotswold Archaeological Trust 2000). This combination of activities occurred at sites with large, extant collections (e.g. Dunbridge (Harding 1998)) and at sites with no recorded archaeology (e.g. Squabb Wood (Cotswold Archaeological Trust 2000). However, in the latter case it is not always clear whether the mapping and logging of geological sequences is undertaken as an end in itself, or *in case* artefacts are subsequently found (in the case of Dunbridge the geological mapping and logging was undertaken to provide contexts for the extant collections and the contemporary artefact discoveries). Overall, it is clear that the primary focus is on the identification of Palaeolithic archaeology, as defined by stone tool artefacts. A key issue for further discussion is therefore whether this definition requires modification.

From the perspective of the aggregates industry, the key concern is with the amount of time spent on site by archaeologists, and how this can be minimised to reduce disruption to the extraction process. This is a wholly understandable position and must be fundamental to any proposed alterations to current management practice (as should the recognition that a very large proportion of archaeological knowledge with respect to the Palaeolithic period has come courtesy of the aggregates industry over the last 150 years). Finally, it should also be recognised that any changes in the definition of Palaeolithic archaeology (e.g. reducing the emphasis upon stone tools and mammoth bones and focusing upon sediments, chronological frameworks and micro-fauna) may also severely reduce the saleability of archaeology to the aggregates industry as a publications relations resource.

It is therefore clear that there are conflicting views as to which elements of the record are of the highest priority when it comes to archaeological secondary contexts. A provisional ordering of the data is outlined below, based on the research issues raised as part of this project and the perspectives of the secondary context archaeological resource outlined above:

- Artefacts (stone tools): these data are the critical component of archaeological secondary contexts. Irrespective of whether the sphere is academic research (e.g. population modelling and investigating technological practice (Chapter 7)), or archaeology and planning (e.g. recording the presence of artefacts during aggregates extraction), stone tools remain the key component. However, it is stressed that artefacts are not required in order to define an archaeological secondary context (see below). It is also clear that in the historical collection of stone tools from archaeological secondary contexts bifaces have been prioritised, as a result of sampling bias (issues include collection practice, ease of recognition and perceived value) and taphonomic factors associated with fluvial transport. The relative value of bifaces (core tools) and flake material (both flake tools and débitage) is a complex issue. In 'blank' areas all artefacts are important, as they indicate a Palaeolithic presence. In areas with a well-documented Palaeolithic heritage however, bifaces can be argued to be of greater value since they provide a range of robust mechanisms for comparison (e.g. technological features such as butt and tip working and edge profiles). Flakes have often been perceived as evidence for minimally derived knapping debris, but recent experiments (Hosfield & Chambers 2004; Chapter 5) have indicated that flake material is capable of surviving fluvial transport. It is also suggested that it is not only the large, thick flakes (e.g. handaxe roughing out flakes) that are capable of surviving transport (*c.f.* Harding 1998: 75), but that more fragile material (e.g. handaxe thinning flakes) are also capable of surviving a transportation episode. Nonetheless, in cases where large quantities of flake material were recovered, then its implications for a probable local source should be seriously assessed.

- Sedimentary (geological context): it is stressed that Palaeolithic artefacts are of limited value without geoarchaeological context. Investigation of the sedimentary context provides a wide range of valuable data:

    - The sedimentary archive of fluvial activity enables the testing of extant models of terrace formation, both in response to long-term climatic cycles (e.g. Bridgland 2000) and short-term climatic fluctuations (e.g. Vandenberghe 2002). These models are fundamental to our wider understanding of the secondary context archaeological resource (Chapter 7), and it is emphasised that the fluvial sedimentary archive is a secondary context of clear archaeological value, *irrespective* of whether individual exposures contain artefacts or not.
    - Geochronologies, based both upon terrace sequences (e.g. Bridgland 1994) and the increasing application of absolute dating techniques to suitable sediments (e.g. the use of optically stimulated luminescence to fine-grained sands) and their biological content (e.g. the testing of amino-acid ratios from shell remains). These geochronologies provide a critical temporal context for our interpretation and understanding of the secondary context archaeological resource, at local, regional, national and international scales. As above therefore, it is stressed that datable sediments form a secondary context of clear archaeological value, *irrespective* of the presence or absence of artefacts.
    - Assemblage taphonomy can be partially explored through the structure of individual sedimentary units (alongside the physical evidence for artefacts), which can indicate depositional conditions and the degree of material re-working (e.g. through the presence/absence of erratics). Although assemblage taphonomy is reliant on the presence of an assemblage, it highlights the importance of not simply the artefacts themselves but also their spatio-temporal origins and its implications for understanding prehistoric behaviour.

- Biological (palaeoenvironmental data): although biological data has clear archaeological importance (e.g. for palaeoenvironmental reconstructions, modelling subsistence strategies, or developing biostratigraphical frameworks), it is problematic when dealing with archaeological secondary contexts and stone tool assemblages. These problems stem from the contrasts between the spatio-temporal frameworks of the biological and archaeological data (e.g. between derived bifaces in coarse-grained gravels and molluscs with fine-grained sediment lenses occurring within with gravels — see Chapter 6), which make it currently impossible to map the data against each other. This problem is most notable when dealing with species that are highly sensitive and responsive to climatic and/or environmental change (e.g. beetles and molluscs), but it is also relevant to less responsive species (e.g. large herding fauna). Overall, the biological data can be cautiously employed in a number of different spheres:

    - Developing biostratigraphical/chronological frameworks. This has been successfully undertaken by Schreve (2001a, 2001b) with large mammal fauna, but is potentially problematic with secondary context data due to the problems of re-working and vertical derivation of specific species from older to younger terraces. Recovered shell materials can also be applied to the development of amino acid-based chronological frameworks.
    - Modelling subsistence strategies. This is dependent upon the identification of processing evidence (e.g. cut-marks, bone smashing or cracking) and is again limited by the difficulty of associating faunal and lithic material from derived contexts. Nonetheless, such evidence is still important evidence of hominid activity, albeit at rather generic levels.

- Building palaeoenvironmental reconstructions. These data are valuable for developing general understanding of Pleistocene environments, and can be considered in terms of their *potential* impact upon hominid behaviour. However, and as highlighted above, it is impossible to explicitly populate these reconstructed environments with hominids or their artefacts, when we are dealing with derived data from archaeological secondary contexts. This is true with respect both to fine resolution reconstructions (e.g. based on short-lived beetle assemblages) and to coarse, time-averaged (e.g. based on derived animal bones from large, herd species), although in the case of the latter it is at least possible to acknowledge the similar magnitude of the derived and time-averaged biological and lithic data.

Based upon these priorities it is therefore fundamental to consider current policy with respect to the management, protection and recording of the secondary context archaeological record.

5 MANAGEMENT, PROTECTION & RECORDING — CURRENT PRACTICE

5.1 The Field Evaluation of Palaeolithic Archaeology

As outlined above, Palaeolithic archaeology cannot readily be accurately evaluated by desktop means, or by the utilisation of non-invasive techniques such as geophysical survey. Evaluation of Palaeolithic archaeology requires ground truthing data, which is generally only possible once excavation has commenced and the over-lying Holocene deposits removed. This situation occurs most frequently during mineral extraction, when overlying deposits are stripped prior to the removal of the Pleistocene sands and gravels which may themselves contain Palaeolithic archaeology.

Mineral extraction planning applications explicitly have to consider the threat they pose to archaeological remains, acknowledging that:

"Mineral exploration and working may damage or destroy irreplaceable sites, structures and remains of archaeological interest that are of importance to the national heritage. The industry should, wherever practical, ensure the physical preservation of important archaeological or historical remains or features, and MPAs (Mineral Planning Authority), when determining applications for extraction, should have regard to the desirability of preserving historic buildings and landscapes, conservation areas, ancient monuments and their settings…identifying as early as possible the likely presence and importance of any archaeological sites liable to be affected by the proposed development"

(DoE 1989: paragraph 76)

Later prehistoric and historic archaeology are most likely to be uncovered during the stripping of overburden from the underlying sands and gravels. As such, archaeological surveys and test pitting can be undertaken prior to the commencement of mineral extraction. Should significant remains be uncovered, then it is relatively easy (though not necessarily popular) to manage the logistical practicalities of their preservation and/or detailed excavation. In contrast, while the potential of sediments to contain Palaeolithic archaeology may be evaluated in relation to known occurrences in adjacent locations, the extent of any Palaeolithic archaeology can only be demonstrated during the mineral extraction phase. This places Palaeolithic archaeology in a rather unique position; mitigation for its preservation cannot be made prior to the commencement of activities that could lead to its potential destruction. English Heritage recommends that where desk-based assessments prove inadequate, Palaeolithic archaeology is best safeguarded during the extraction process by "limited field evaluations conducted by suitably qualified archaeologists" (English Heritage 1998: 4).

Though strategies vary from county to county (Wilkinson pers. comm.), as a result of differing Pleistocene sedimentary records and research histories (e.g. indicated by the current focus upon raised beach sediments in West Sussex, presumably in response to the Boxgrove discoveries), such field evaluations typically take the form of 'watching briefs'. These watching briefs are emplaced in response to threats to archaeology posed by development and are recommended either as part of the planning process and/or development plan policies, or as part of an Environmental Impact Assessment conducted prior to mineral extraction. In accordance with the Institute of Field Archaeologists (IFA) *Standard and Guidance* document (IFA 2001), a watching brief is defined as:

"A formal program of observation and investigation conducted during any operation carried out for non-archaeological reasons…where there is a possibility that archaeological deposits may be disturbed or destroyed"

(IFA 2001: 2)

The IFA *Standard and Guidance* document describes watching briefs as being of dual purpose, providing both the opportunity to identify the need for more intensive archaeological investigations to be undertaken, but also enabling the detailed recording of archaeological deposits. It is stipulated that watching briefs should:

"allow, within the resources available, the preservation by record of archaeological deposits, the presence and nature of which could not be established (or established with sufficient accuracy) in advance of development or other potentially disruptive works…to provide an opportunity, if needed, for the archaeologist to signal to all interested parties, before the destruction of the material in question, that an archaeological find has been made for which the resources allocated to the watching brief are not sufficient to support treatment to a satisfactory and proper standard"

(IFA 2001: 2)

The IFA watching brief guidelines are not period specific, and as such cannot provide a step-by-step policy appropriate for all archaeological remains in all depositional scenarios. Instead the guidelines focus on stressing the importance of agreeing and formalising activities and contingencies between the archaeologist and the commissioning body in the form of a detailed project design.

The practicalities of watching brief investigations will vary enormously depending both on the archaeology being assessed and the nature of the development threat. In the case of secondary context Palaeolithic archaeology the threat of destruction is total, as the sediments in which it occurs are in the process of being extracted. Therefore the 'preservation by record' component of the watching brief strategy is of extreme significance.

5.2 Watching Brief Strategies

In one form or another, secondary context Palaeolithic sites have a long history of subjection to formal and informal watching briefs. During the late 19th and early 20th centuries many gravel pits were active, the result of urban expansion and industrialisation (Roe 1981; Hosfield 1999; Ashton & Lewis 2002). These gravels were primarily extracted manually, and many workers came to recognise the stone tools (especially the bifaces) that could be contained within these gravels. Local antiquarians and amateur archaeologists (such as C.E. Bean at Broom — Chapters 3 & 4) became increasingly interested in these artefacts, often paying the quarry labourers for their finds. Such collectors were primarily interested only in acquiring artefacts, and the degree of interest shown in the stone tools' provenance (their depositional contexts) varied enormously between collectors, although it could be quite extensive as the records of C.E. Bean demonstrate (Chapter 4; Green 1988). Activities such as these led to the amassing of large collections of artefacts, but typically with only limited contextual data.

In more recent times these collecting activities have both continued (e.g. MacRae 1988, 1990, 1991, 1999; Hardaker & MacRae 2000; Hardaker 2001) and have become incorporated within formal watching brief strategies. These have developed since PPG16 as professional archaeological contractors have tendered for projects initiated by County Archaeologists in response to planning/mineral extraction applications. In comparison to the amateur collecting of the earlier periods, far more attention is now paid to the geological contexts exposed during active mineral extraction and to the identification of palaeoenvironmental evidence. However, the prime emphasis is still placed upon the recovery of lithic artefacts. Two recent watching briefs (Dunbridge and Squabb Wood) are presented as case studies below to illustrate these issues. These practices and the very different results they produced are presented and evaluated against the archaeological value review detailed in Section 3.

5.3 Dunbridge

The Dunbridge gravel pits lie to the west of the river Test, immediately below its confluence with the tributary river Dun. These gravels were extensively worked during the first quarter of the 20th century. Artefact collections were made by William Dale (1912a, 1912b, 1918), a local Southampton-based antiquarian. Roe (1968a: 96) listed 1021 artefacts, including 953 bifaces (93.3%), 14 roughouts, 3 cores, 16 retouched flakes, 24 unretouched flakes, 8 miscellaneous pieces, and 3 Levallois flakes, making Dunbridge the most prolific Palaeolithic site in Hampshire. A more comprehensive review of the archaeology recovered from the Dunbridge site can be found in Chapter 4.

In addition to collecting artefacts, Dale (1912a) described the geology of the Dunbridge gravels as comprising of up to 7m of gravel, overlying the clays and sands of the Woolwich and Reading Beds. Dale (1918) suggested that artefacts of different physical conditions originated from different stratigraphic levels in the gravel, proposing that the sharp, white implements from the upper deposit were of a later character than those from the lower beds. The sub-division of the gravel deposit was based on colour: a lower, dark red gravel, a middle yellow-brown gravel and an upper white gravel, and Dale (1912a) suggested that the gravel of two periods were present. He subsequently modified this interpretation (Dale 1918), arguing for an upper, paler deposit that was separated from a lower, darker aggradation by an iron pan horizon. These observations suggest the possibility that different Lower Palaeolithic industries exist in stratigraphic superposition at Dunbridge.

These geological observations and the extensive collection of Palaeolithic artefacts recovered from the site, indicate the potential fulfilment of two of the eleven national significance criteria that have been outlined by English Heritage.

In 1987 Halls Aggregates (South Coast Limited) applied for planning permission to extract hoggin (an aggregates industry term given to a mixture of clays, sands and gravels) from the lands adjacent to the former gravel pits at Kimbridge Farm, Dunbridge (SU 321255). Due to the known Palaeolithic evidence from the adjacent deposits, the Hampshire County Archaeological Officer was not in favour of the application being granted. However, the timing of the extraction application coincided with Governmental pressure to meet growing national demands for aggregates. After a lengthy planning enquiry, including test pit evaluations of the potential for *in situ* preservation within the Dunbridge gravels, permission to extract was granted. In response to archaeological concerns a Section 52 agreement was reached which allows the gravel extraction to be archaeologically monitored by watching brief. The watching brief monitoring was initially undertaken as two half day visits to the extraction site every month. This structure was modified in 1997 to a single half day visit per month, as extraction at the site became focused upon the exploitation of Tertiary pebble beds, which are not of Palaeolithic significance (Harding 1998). Since 1998, extraction of Pleistocene gravel has been limited, due to a focus of extraction activity upon Tertiary pebbles and sands, and the frequency of watching brief visits has declined (Harding pers. comm.). Overall, the purpose of the watching brief was twofold, both to record the geological sequences as the aggregates were extracted and to search for additional implements:

"Routine visits included the processing plant and the pit. The hoggin at Dunbridge has a clay matrix and artefacts are much easier to identify on the reject heap after material has been washed. This has the disadvantage that implements cannot be provenanced to specific areas of the pit, especially as material is routinely stockpiled, often for long periods of time, before it's washed…Periodically the pit face is planned and the face profile drawn at scale to construct a composite record of the gravel. Areas of extraction are plotted routinely to note progress in the rates of quarrying."

(Harding 1998: 73)

The interim geological results of the Dunbridge watching brief were published by Bridgland & Harding (1993). The presence of between 1m and 5m of well-bedded sand and gravel, overlying the surface of the Reading Beds at approximately 42–44m OD, was demonstrated. The top 2m of the gravel shows marked cryoturbation and bleaching, accounting for the 'white' gravel described in earlier reports (e.g. Dale 1912a; 1918). The cyroturbated gravel is demarcated by a cemented iron/manganese horizon, which can be traced across the pit. The entirety of the exposed gravel (the cyroturbated gravel and the underlying well bedded gravel) is interpreted as representing a single terrace deposit of the Test (Bridgland & Harding 1993; Harding 1998). The origins of the underlying lower terrace identified in mechanically excavated test pits during the planning enquiry could not be determined (*ibid.)*, due to the lack of exposures.

Subsequent visits, undertaken as part of the continuing watching brief, have shown the composition of the gravel to be consistent across the pit, though a noticeable thinning towards the southwest occurs along the lines of 'deeps' in the Reading Beds. In some areas the Reading Beds are overlain by less than one metre of cyroturbated gravel, or outcrop directly at the surface. Well-bedded gravel and remnants of the manganese horizon are only visible in the west of the pit. These features have been interpreted as suggestive that the current extraction is approaching the edge of the terrace, though the underlying terrace identified during the planning enquiry evaluation has still not yet been reached (Harding 1998).

In terms of artefact recovery, the current watching brief at Dunbridge has certainly proved productive; 123 visits have led to the recovery of 163 artefacts (Harding 1998). Of these *c.* 72% (n=116) were recovered during examination of the reject pile, an area where oversized cobbles are temporarily stored prior to their crushing down into smaller, commercially viable, aggregate. Harding (1998) attributes the proportionally high recovery of artefacts from the reject heap to the washing processes employed by the pit to clean the gravel. Of the 47 artefacts recovered from within the pit, the majority were found as rain-washed (and therefore visible) pieces within talus slopes at the base of the advancing extraction face, or within the retained bunds of unexcavated hoggin. Therefore only a very small proportion of the recovered artefacts can be linked in any meaningful manner to their specific depositional or spatial context origin within the pit.

Table 59 describes the typology of the artefacts recovered from Dunbridge during the current watching brief. Comparison with Roe's (1981) assessment of the Dunbridge assemblage as dominated by bifaces, the watching brief assemblage is markedly different in character. Unretouched flake material (débitage) is the most common artefact form recovered. This flake dominance can be argued to be more representative of the true character of archaeology preserved within secondary contexts; the biface dominance in the extant record more accurately reflecting historical collection biases rather than a genuine dominance (see Hosfield 1999). The biface component of the assemblages consists of roughly equal quantities of pointed and ovate forms (Harding 1998). The current assemblage includes pieces of potential chronological significance; a Levallois blade core and the butt of a *bout coupé* biface have been recovered, but are unprovenanced within the pit leading to uncertainties about their origins. Harding notes their physical condition and suggests that:

"Both the handaxe fragment and the core are lightly stained and slightly rolled and probably come from within the bleached fluvial gravel"

(Harding 1998: 75)

However, this interpretation should be viewed cautiously as the distinctive ferruginous staining typical of gravel deposits can be quickly bleached away by exposure to sunlight.

Artefact Type	Numbers Recovered
Biface	43
Core	12
Scraper	3
Flake	102
Miscellaneous	3
TOTAL	**163**

Table 59: Typology of artefacts recovered during watching brief activities at Dunbridge (after Harding 1998: Table 11.1)

In summary, the watching brief at Dunbridge has provided a clearer picture of the site's geology (Bridgland & Harding 1993), increased the proportions of non-bifacial artefacts within the extant assemblage, and documented a continued Palaeolithic archaeological presence that *appears* to occur throughout the lateral and vertical extents of the terrace gravels under extraction. Sadly, this archaeology cannot be provenanced within the pit, and therefore provides only limited data relating to the distribution of artefacts through the deposit and the potential occurrences of any concentrations of artefacts remain unknown. Geological questions also remain as Harding (1998) acknowledges:

"It is also not yet possible to relate the deposits and the material on a regional basis."

(Harding 1998: 76)

The establishment of such relationships on both a regional and national basis should be of prime importance, and would be greatly enhanced by the development of an independent chronological framework, such as may be provided by chronometric dating techniques such as optically stimulated luminescence (OSL).

5.4 Squabb Wood

The site of Squabb Wood lies on a Middle Pleistocene terrace of the River Test, north of Romsey, Hampshire. The River Test was a major northbank tributary of the Pleistocene Solent River, and many Palaeolithic artefacts have been recovered in the terrace deposits elsewhere around Romsey (e.g. Chivers Gravel Pit (also known as Cupernham Pit and Abbotswood), Belbin's Pit, and Test Road Gravel Pit (Wessex Archaeology 1993a)). Of particular significance is the site of Dunbridge (see above), where a long history of antiquarian activity has recently been supplemented by the systematic artefact collection and section logging undertaken during an archaeological watching brief (Bridgland & Harding 1993; Harding 1998). Hampshire County Council granted permission for aggregates to be extracted from Squabb Wood and though the gravels at the site are in a higher (older) terrace than those of the implementiferous deposits at Dunbridge, archaeological mitigations were emplaced:

"In light of the potential for similar remains being encountered during the present extraction of somewhat older strata an archaeological watching brief, backed up by limited archaeological excavation (should artefacts/strata be found which are deemed by the project team and county archaeologists to be of high importance), is considered the best form of archaeological mitigation."

(Cotswold Archaeological Trust 2000: 1)

As at Dunbridge, the aims of the watching brief were twofold: the identification of any Palaeolithic archaeology present but also the preservation by record of the geological strata, which at Squabb Wood were to be extracted through an advancing face technique removing the entire gravel stratigraphy in a single phase:

"The objectives of the watching brief component of the project are to identify zones of stratigraphy which contain Palaeolithic artefacts, to recover those artefacts under controlled archaeological conditions and to characterise the geological stratigraphy in terms of environment of deposition".

(Cotswold Archaeological Trust 2000: 1)

The identification of artefacts that were deemed to be *in situ* would trigger sample excavations to document the spatial relationships of the artefacts and to obtain environmental and chronometric dating samples. Visits to the site documented stratigraphy through section logging, and searches were made of exposed faces and reject heaps for Palaeolithic artefacts:

"During these visits the visible deposits will be logged, sketched and photographed, and a search made of exposed faces and discard piles for Palaeolithic artefacts…exposed sections will be logged to standard geological criteria…related to Ordnance Datum…Photo mosaics will be used…to construct 'type' sections, which will then be used in conjunction with the geological descriptions to develop a facies model for the development of the stratigraphy. Where artefacts are noted they will be related to 'Bed numbers'…while artefacts recovered from the discard pile will be provenanced as closely as possible through consultation with the quarry manager and digger drivers."

(Cotswold Archaeological Trust 2000: 1–2)

The frequency of visits to the site is determined by the speed of extraction and variability of the stratigraphy, though a minimum of one visit per month has been maintained. The Squabb Wood watching brief is undertaken under the direction of Neil Holbrook, Archaeological Director of Cotswold Archaeological Trust, with day-to-day activities undertaken by a team of appropriate personnel managed by Dr Keith Wilkinson (King Alfred's College, Winchester). Between 22nd April 2002 and 28th August 2002 regular visits to Squabb Wood (8 in total) were undertaken by the authors (Dr Hosfield and Ms Chambers). The irregularity of the visits reflected pauses in aggregates extraction and the localised extraction of underlying bedrock sands. During each visit the progress of gravel excavations was logged, and extant faces were sketched, logged, and photographed. Whilst section recording, attention was paid to the potential presence of artefacts, however despite this vigilance, none were recovered during the logging of 12 sections. A characteristic depositional sequence at Squabb Wood is included (Table 60). In general, the sediments were dominated by medium, matrix-supported gravels, with smaller amounts of fine gravels, and localised lenses of sands, silts and clays. The medium gravels were predominantly massively bedded, although there was a suggestion of increased horizontal bedding at depth. Within individual sections, small lenses of fine-grained sands were identified which, while containing no discernable archaeological remains, would have provided the opportunity for chronometric dating to be undertaken.

In addition to scouring the exposed faces for Palaeolithic artefacts, during each visit a trip was made to the discard pile to search for artefacts. Approximately 33–50 % of each visit was spent in this manner, though no artefacts were recovered. However, even had artefacts been recovered from the discard pile they would have been extremely difficult to provenance, as in addition to the standard difficulties of provenancing such recovered artefacts to within a single pit, gravel extracted at Squab Wood is not sorted on site but at a shared washing and sorting facility at the nearby Ridge site. Thus any artefacts recovered from this communal discard pile could only tenuously be attributed to Squabb Wood deposits. This type of problem has also recently become an issue for the Dunbridge site, where the washing plant now processes Tertiary gravels from Dunbridge, which masks the river gravels when they are mixed, and also washes stocks imported from another pit — making it impossible to be certain where any implements have come from (Harding pers. comm.).

The watching brief at Squabb Wood has not produced any Palaeolithic artefacts, however a much clearer understanding of the depositional environments that prevailed during the deposition of this terrace of the River Test has emerged. The current absence of artefacts should also not be interpreted as incontrovertible evidence for an absence of stone tools throughout the deposits, considering the small percentage of material it is feasible to examine in the course of a watching brief. Even if this is the case, the importance of negative evidence in the understanding of regional sequences should be emphasised.

5.5 Watching briefs — measuring success?

Comparisons of the results of the watching brief activities conducted at Dunbridge and Squabb Wood may initially suggest that the Dunbridge deposits were far more 'worthy' of archaeological mitigation than those at Squabb Wood. The Dunbridge watching brief has produced a comparative abundance of artefacts, facilitating the recognition that flake material can occur in substantial quantities within secondary contexts and confirming the density of the Palaeolithic remains within the Dunbridge gravels; the Squabb Wood watching brief, though conducted in a very similar manner, has failed to produce any Palaeolithic artefacts. Does this mean that the investigations at Squabb Wood have therefore failed? An archaeological watching brief is not about the simple collection of 'archaeology' (e.g. bifaces and flakes) as they become exposed. The IFA *Standard and Guidance* document describes watching briefs as both providing the opportunity to identify the need for more intensive archaeological investigations to be undertaken (e.g. the identification of *in situ* artefacts) but also for the *detailed recording of archaeological deposits*.

Site: Squabb Wood				**Log No.**: 11							**Section No.**: 11			**Date**: 05/08/02	**Recorder**: JCC & RTH
Metres above Base	**Thickness**	**Bed Number**	**Lithology**	**Texture**							**Sedimentary Structures**	**Palaeocurrents**	**Fossils**	**Colour**	**Notes**
				Clay/Silt	**Sand**			**Gravel**							
					F	**M**	**C**	**F**	**M**	**C**					
2.98 -2.71	0.27	10	-						✓		-	-	-	Mixed	Massively disturbed medium gravel. Mixed colour. Sharp irregular contact.
2.71 -2.63	0.08	9	-					✓			-	-	-	7.5YR 4/6	Fine matrix-supported gravel. Well sorted with no grading or imbrication. Sharp regular contact.
2.63 -2.56	0.07	8	-			✓					-	-	-	No sample	Laterally discrete medium sand. Sharp irregular contact.
2.56 -1.62	0.94	7	-						✓		-	-	-	7.5YR 4/3	Medium matrix-supported gravel. Massively bedded. Moderately sorted with no grading or imbrication. Sharp irregular contact.
1.62 -1.18	0.44	6	-			✓					-	-	-	7.5YR 4/6	Medium sand with fine clast component (*c.* 1–2% by volume of exposure). Includes inclined lenses (laminations?) of very fine gravel. Lenses 0.5 cm thick and dip of 38°E. Sharp irregular contact.
1.18 -1.16	0.02	5	-					✓			-	-	-	No sample	Thin bed of very fine clast-supported gravel. Very well sorted with no grading or imbrication. Bed inclined at 22°E. Sharp irregular contact.
1.16 -0.97	0.19	4	-			✓					-	-	-	5YR 4/6	Medium sand with increased fine clast component (*c.* 5–10% by volume). Sharp irregular contact.
0.97 -0.65	0.32	3	-						✓		-	-	-	5YR 4/4	Medium matrix-supported gravel. Moderately sorted with no grading or imbrication. Sharp irregular contact.
0.65 -0.59	0.06	2	-				✓				-	-	-	7.5YR 3/4	Laterally discrete coarse sand. Sharp irregular contact.
0.59 -0.00	0.59	1	-						✓		-	-	-	7.5YR 4/4	Medium matrix-supported gravel. Moderately sorted with no grading or imbrication. Suggestions of horizontal bedding towards base of bed (at base of section).

Table 60: Lithostratigraphic log data (section 11, Squabb Wood)

Palaeolithic archaeology is unique, concerned not only with the reconstruction of hominid behaviour through the artefactual remains they left behind, but also reconstructing the *vastly different* world and period in which the artefacts were produced; this allows us to assess the hominids' abilities to deal with repeatedly changing climatic conditions and available resources during the Pleistocene. These factors can only be assessed by consideration not only of the *sensu stricto* archaeological remains (stone tools, cut marked animal bones) but also a wider *sensu lato* interpretation of Palaeolithic archaeology which can incorporate not only artefactual remains but also lines of evidence that lead to improved chronological frameworks, palaeoenvironmental reconstructions and an understanding of depositional context. This *sensu lato* approach is as important (if not more so) for secondary context sites as it is for those of primary context, given the dynamic physical processes associated with the formation of archaeological secondary contexts. Since the artefacts that comprise Palaeolithic archaeology cannot be divorced from the Pleistocene sediments in which they occur, it is suggested here that the sedimentary analyses of secondary context sites currently under extraction are of at least equal importance to the recovery of artefacts. Such geological analyses provide understanding of the depositional regimes responsible for river terrace formation. This understanding is fundamental for an appreciation of the conditions that fluvially incorporated artefacts would have been subjected to, and provides the basis for off-site models. Advances in the application of optically stimulated luminescence (OSL) dating to fine-grained sands of Pleistocene age provide a means with which to absolutely date the terrace deposits in which suitable sediments can be identified. Therefore detailed sedimentary facies analyses not only aide the development of robust depositional models, they can also provide the opportunity to develop the geochronological frameworks so long absent in the British Palaeolithic record.

The watching briefs at both Dunbridge and Squabb Wood have furthered the understanding of geological and depositional contexts within the Pleistocene River Test. At Dunbridge these depositional environments can be populated with artefacts which are direct (albeit fluvially modified) evidence of hominid activity. At Squabb Wood, no direct evidence of hominid activity has been recovered, suggesting a less intensive presence or an absence of hominids in the region immediately prior to and during the deposition of this terrace. For the modelling of hominid colonisation and demography in Britain periods of absence are as significant as periods of presence, and in this respect the Squabb Wood negative evidence provides positive data. Within both sequences material suitable for OSL dating has been identified, although not utilised: this is a critical area of investigation that needs to be expanded within watching brief strategies in future. In conclusion, we propose that the watching brief investigations at Dunbridge and at Squabb Wood have been of equal import and significance.

This review of current watching brief strategies has suggested that their construction and implementation for aggregate extraction sites are unjustifiably biased towards artefact recovery, and over-emphasise the importance and value of stone tools alone. This practice can seriously inhibit the range of significant data which should be salvaged from these fluvial sequences prior to their destruction. The following section therefore proposes new recommendations for future watching brief strategies with respect to aggregates extraction sites, and seeks to accommodate and integrate the needs of research archaeology, archaeological resource management and the aggregates industry. It also examines the past and future role of the amateur collector.

6. FUTURE STRATEGIES

Based on the above review of current watching brief practices and this project's re-assessment of the value of the secondary context archaeological resource, a series of recommendations for the future implementation of watching brief strategies are proposed below. The importance of these recommendations is evident in the current danger posed to the secondary context archaeological resource by national aggregates extraction (after peaking at 300 million tonnes per year in 1989 it is currently estimated at 210 million tonnes per year by the Quarry Products Association (QPA) (http://www.qpa.org/profile.htm)), despite the recent proposal by government to reduce this demand by developing sustainable aggregates supply. Despite the recent claims by the British Aggregates Association (BAA) that the aggregates levy is severely damaging the UK industry (http://www.british-aggregates.com/pr14.htm) it seems likely that extraction activity will continue for the foreseeable future and will continue to pose a threat to the archaeological resource (however see comments below with regard to the archaeological opportunities for access to Palaeolithic/Quaternary materials that the aggregates industry has, and continues to, provide).

It is emphasised of course that the following recommendations are intended for watching brief monitoring of terrestrial aggregates extraction sites, once aggregates extraction has begun. They are not intended for application during the topsoil stripping phase of extraction, for which there are well-established approaches that address the distinctive requirements of Holocene archaeology. With respect to the geographical distribution of aggregate sites and the potential age of the sediments, the following caveats are stressed:

- Watching brief activity should not be restricted or even biased towards aggregates sites in the south of England, beyond the impact of Pleistocene glaciations (Figure 1). Although these areas have produced a far richer Palaeolithic record (Wymer 1999), there is no reason why glacially-modified sediments in the northern regions should not contain either some or all of the following: re-worked artefacts, re-worked biological evidence, geochronological data, and stratigraphic sequences (e.g. as at High Lodge (Ashton *et al.* 1992)). The implementation of watching brief strategies in the northern regions therefore reduces the potential for reiterating the current southern bias in the archaeological record, and will also improve current knowledge of the presence (or absence) of Palaeolithic archaeology and Pleistocene environments in northern England.
- Watching brief activity should not be restricted or biased towards aggregate sites whose sediments are *believed* to post-date the first hominin occupation of Britain. This is both because the age of this first occupation remains controversial, with the widely accepted date of *c.* 500,000 (based primarily on Boxgrove (Roberts & Parfitt 1998)) being increasingly challenged by new, earlier finds from the Norfolk coast (Rose *et al.* 2001). However, bias towards later sites also ignores the valuable geochronological and sedimentological evidence that such sites yield, and which are significant for our understanding of landscape evolution and palaeoclimatic trends (e.g. Bridgland 1994). The implementation of watching brief strategies on early Middle Pleistocene and (where available) Early Pleistocene sites therefore reduces the potential for simply reinforcing current models of the Palaeolithic occupation of Britain.

Our recommendations for modified watching brief strategies are as follows:

- Focus upon the potential for geochronological dating of the sediments, principally through the application of the optically stimulated luminescence (OSL) dating to fine sand sediments (Chapter 3 and this project's accompanying Centre for Archaeology dating report (Toms *et al.* in prep.)). These data are fundamental for the development of geochronological models of Pleistocene fluvial sequences and the secondary context archaeological record. Although this is currently being implemented in research projects (e.g. Hosfield & Chambers 2002b; Toms 2003; Hosfield *et al.* in prep; Wenban-Smith pers. comm.), it has not yet been widely incorporated into watching brief strategies. Recent research into optical dating techniques (e.g. Hütt *et al.* 1988; Prescott & Hutton 1994; Markey *et al.* 1997; Murray & Roberts 1997; Roberts *et al.* 1999; Murray & Wintle 2000; Adamiec & Aitken 1998; Toms 2002, 2003; Bailey in press) has indicated that the OSL technique can date older sediments than previously demonstrated, and that it has considerable potential as a geochronological tool with respect to Middle Pleistocene fluvial sediments. Although OSL dating has primarily been employed as a research tool, we recommend its incorporation within watching brief strategies as standard due to the totally destructive nature of aggregates extraction. Exposure during extraction provides the single opportunity for the dating of these sediments, and if OSL sampling is not implemented during extraction then both the opportunity and the sediments will be irretrievably lost. It is recognised that the incorporation of OSL sampling with watching brief strategies has a number of implications for working practice:
    - Flexible working relationships between watching brief staff (archaeologists) and the OSL specialists: specifically the availability of OSL personnel to undertake sampling in response to

the short-term availability of suitable sediments. Although archaeological staff could be trained to take OSL samples on-site, the requirement for specialist sampling equipment may limit such an approach.

- Flexible working relationships between aggregates industry personnel and watching brief staff. Identification of OSL-suitable sediments can be conducted by watching brief staff during infrequent site visits, but we recommend that during the interim periods, industry staff could identify suitable and accessible sediments and notify watching brief staff. This formal structure of notification is obviously a significant variation on extant industry/archaeology relationships, where the informing of archaeologists has often been dependent on individual aggregates industry employees. It is stressed that the implementation of this structure would not result in greater disruption (see below), and that should result in fewer, less frequent, and shorter watching brief visits being made by archaeological staff.
- Changing perceptions of watching brief activity. This emphasis upon scientific dating of sediments should help to alter the perceptions (both amongst the industry and amongst archaeologists) of watching briefs as being an extension of the amateur collecting activities of the 19th and 20th centuries. These changing perceptions are important for the acceptance by the aggregates industry of new watching brief strategies, and are related to the need to see Palaeolithic archaeology as Quaternary science rather than as an ever-expanding collection of stone tools. These changing strategies are also vital for integration of resource management data into current research strategies, which are increasingly fundamentally different from those of the 19th and (most of the) 20th centuries.
- Frequency of site visits and disruption of the aggregates industry. It is recognised that the industry's key concern would remain the degree of disruption caused by archaeological watching briefs and their associated costs. It is proposed that this element of the watching brief strategy would require a small number of visits, either as part of a pre-arranged schedule or in response to notification from industry staff. This reflects the cost of sample processing, the speed of sample collection, and the need to balance the 'ideal' of number of dating samples against the disruption factor. It is impossible to recommend a specific figure, and numbers of visits and samples would vary by site in response to the specifics of the sedimentary sequence, and the presence of other important data (e.g. biological or artefactual). It is stressed however that single samples would not be acceptable, and Toms (pers. comm.) recommends the following generic guidelines:
    - When dealing with a sand unit (not a lens) that is traceable across multiple exposures or sections within an aggregates site, two dating samples from the top and bottom of the unit are sufficient.
    - When dealing with discrete sand lenses and addressing the question of whether they are contemporary or chronologically distinct, single dating samples should be taken from multiple sand lenses, to a minimum of three in total.

- Focus upon the importance of fluvial sedimentary sequences. While the recording of geological sequences is a well-established element of current watching brief strategy (e.g. Cotswold Archaeological Trust 2000), we recommend that increased emphasis is placed on issues of formation processes within fluvial sedimentary sequences. Examples would include evidence of landsurface development (indicative of significant breaks in fluvial activity), different sedimentary contacts (e.g. sharp contacts can indicate evidence of major phases of erosive activity), 3 and 4-dimensional variability in sedimentary units, and the general character of the sediments (e.g. sorting, grading, imbrication and bedding structures). This type of field data is vital for the testing of new taphonomic models of secondary context assemblages (e.g. Chapters 5 & 7), which is critical for wider understanding and interpretation of stone tool data sets. Such sedimentary data operates both at a specific level (e.g. on sites from which derived artefacts have been recovered) and as generic data to contribute towards broader understanding of fluvial sedimentation processes.

- Focus upon the importance of biological data, ranging from large mammalian fauna (potentially re-worked) to small, *in situ* vertebrates, invertebrates and molluscs. While their recording and sampling is a well-established element of current watching brief practice, it is stressed that the importance of these data is not in their capacity for providing reconstructed palaeo-environments into which artefacts and hominids can be placed. As discussed in chapter 6, these data cannot be directly linked to derived artefacts because of scalar contrasts. Instead, the importance of these data is in their ability to:

- Illustrate examples of the types of fluvial palaeoenvironments that existed at different points during the Pleistocene.
- Form the basis of biostratigraphic frameworks, such as developed by Schreve (2001a, 2001b) for mammals, Keen (1990, 2001) and Preece (2001) for molluscs; and Coope (2001) for coleoptera.

These data are therefore important irrespective of whether lithic archaeology has been (or is being) recovered from the sediments exposed at a particular site.

- Frequency of visits. While this is still partially dependent upon the speed of extraction, these recommendations follow current practice (e.g. Harding 1998; Cotswold Archaeological Trust 2000) and suggest between 1–2 visits per month during periods of extraction. It is stressed that unless there was an industry-employed archaeologist permanently on site, the probabilities of missing evidence are high. Since either a permanent presence or very regular visits are impractical (due to logistics and finance), these limitations in the watching brief approach must be accepted by the archaeological community. As with current practice, the regularity of visits should be flexible and can be altered in response to information supplied by the industry. However, the danger with this approach is that it increases cost to the industry and therefore has the potential to alienate them. We therefore recommend that while a relatively high frequency of visits should be maintained, the focus of watching brief activities while on site requires modification. It is proposed that emphasis should be placed upon extensive searches for:

    - OSL-suitable sediments (see above).
    - Generic sedimentary sequences.
    - Distinctive or unique (within individual sites) sedimentary units (e.g. palaeo-channel fills).
    - *In situ* (not primary context but recovered from sections and not on reject heaps) artefacts (lithic and biological).

  By reducing the focus upon time-intensive searches for artefacts (e.g. both in exposed sections and upon reject heaps), it is proposed that time spent on-site during individual visits can be reduced. This would also be achieved through the use of digital data-capture devices during the watching briefs (e.g. digital cameras, palm-tops and GPS survey equipment). Overall, this watching brief recommendation stresses frequent, rapid surveys of aggregate sites, limited sampling and recording programmes with respect to OSL dating and lithostratigraphic logging of generic sequences, and specific sampling only *if* unique sequences or artefacts are identified.

The watching brief recommendations outlined above are intended as starting points for discussion, and not as rigid policy guidelines. However, they are all informed by a central principle: namely, that the Palaeolithic archaeology of secondary contexts must move beyond the dots on maps approach that is typified by Roe (1968a), and which has also characterised more recent research (e.g. Wessex Archaeology 1993a, 1993b, 1994, 1996a, 1996b, 1996c, 1997; Wymer 1999). It is acknowledged that The Southern Rivers Palaeolithic Project, the Welsh Lower Palaeolithic Survey and The English Rivers Palaeolithic Survey (both summarised In Wymer 1999) had to adopt that type of approach, since there was a considerable body of diverse information that required synthesis. However, now that this base-line has been established, it is vital for the subject to move forward in its interpretation of the data. It is also clear that for interpretation to move beyond typological approaches (e.g. Roe 1981), it is necessary to consider the full range of available contextual information from archaeological secondary contexts (sedimentary, geochronological, and biological).

PPG16 would seem to have provided a mechanism for Palaeolithic archaeology to make this change, since it offered an opportunity for inclusive sampling of secondary contexts. Yet despite the fact that PPG16 and other mechanisms for archaeological intervention stress the preservation either *in situ* or by record of archaeological information that would otherwise be lost, current watching brief practice in aggregates extraction sites is resulting in the unnecessary loss of archaeologically valuable information. While it is recognised that some data will always be lost (due if nothing else to the frequency of visits), we propose that data categories such as sediment samples for OSL dating are being lost due to a combination of:

- Lack of awareness of the importance and potential of these data.
- An over-emphasis in current watching brief strategy upon the recovery of stone tool artefacts. Although the importance of finding new stone tools varies between sites and deposits with large extant collections and those that are currently 'blank', it is stressed that in all cases, stone tools that are collected with no contextual information are of limited value. There is no more eloquent expression of this than the thousands of stone tools that have languished, under-studied, in the basements and storerooms of British museums for decades.

Therefore, the underlying principle of these recommendations is that we need to recognise that Palaeolithic archaeology is about more than artefacts, even when we are dealing with secondary contexts. This realisation has been broadly accepted by academic archaeologists (e.g. White & Schreve 2000; Wenban-Smith *et al.* 2000; Ashton & Lewis 2002), but it is now essential that this message reaches government organisations, professional archaeological units, local government archaeologists and planning departments, and the aggregates industry. This need reflects a situation in which academic archaeologists rarely have the opportunity to share their more widely defined concept of Palaeolithic studies with those involved in the processes of managing and recording the secondary context heritage as it is exposed and then destroyed. Dissemination of this message can be achieved through informal outreach (e.g. seminars and workshops) but may also require new documentation that both stresses the value of the secondary context archaeological resource and highlights new approaches for its effective management.

6.1 Balancing Research Interests, Management Concerns & Industrial Priorities

The majority of the above discussion has reflected research priorities as perceived by academic archaeologists. With specific reference to the new research frameworks highlighted in this project (Chapter 7), the above recommendations seek to highlight the importance of absolute dating (providing the geochronological context for the derived archaeology), sedimentary sequences (providing the spatio-temporal context for modelling derived assemblage origins), and biological data (providing the wider palaeo-environmental context).

However, following the PPG16 legislation, professional archaeology (used here as a generic term to cover local government archaeologists engaged in the implementation of planning process legislation and commercial archaeological organisations) is inevitably primarily concerned with whether archaeology is at threat, in the face of any types of proposed development. Their solution has typically been preservation by record, and this has been the overwhelming response with respect to aggregates extraction sites. Yet, with respect to Palaeolithic archaeology, it cannot be known whether there is archaeology present prior to the beginning of the extraction. Once extraction has begun, the principle concern has been to avoid the loss of stone tools to the aggregate processing sites through site visits, section checking and reject heap searching. The finding or non-finding of stone tools demonstrates archaeological presence or absence, and this appears to be the primary goal of watching brief activity. However, because of the dichotomy between concern for whether archaeology is at risk, and the inability to know prior to extraction, there also tends to be measures set in place for emergency excavation if *in situ* archaeology is located (e.g. as at Lynford (Boismier *et al.* 2003)).

The problem is that archaeological residues such as Lynford are identified only once very few decades. There is therefore actually relatively little preservation by record, and rather more searching (often unsuccessfully) for artefacts and waiting for the jackpot *in situ* archaeology. This strikes us as a flawed and unhelpful approach, as not only is valuable secondary context data lost (see below), but also the approach places a strain on relations with the aggregates industry who are left to feel that each watching brief is a minefield of potentially long-term interventions. There is therefore an urgent need for a paradigm shift in what is perceived as Palaeolithic archaeology. As we have argued throughout this chapter, Palaeolithic archaeology (we prefer Quaternary Studies as a less loaded term) includes sediments, biology, and stone tools. Under this definition, during aggregates extraction there can be extensive preservation by record (e.g. dating sampling and lithostratigraphic logging), while still searching for *in situ* archaeological material. There needs to be a redress of the balance between *in situ* and secondary context archaeology, especially when the search for *in situ* archaeology results in the loss of secondary context data due to the destructive nature of the extraction process.

It is recognised that the need to demonstrate a Palaeolithic presence through lithic artefacts will inevitably be more important in 'blank' areas of the country, since the finding of a single stone tools will be significant. However, even in these areas, focus should equally be given to sediment dating and geological recording since these data may well indicate the reasons for the absence of stone tools (or indeed suggest that further stone tool searching is justified). Overall, in these 'blank' areas a balanced watching brief approach is important, since it avoids false reinforcement of existing patterns and improves Quaternary knowledge. However, in areas with rich, well documented artefact assemblages, it is now necessary to downplay the significance of recovering additional stone tools, and emphasise the importance of preserving geological data by record, prior to its destruction.

We propose that the gap between professional archaeology and academic research is narrower than commonly perceived. There is little value in the selective preservation of specific data categories from the past (e.g. artefacts over sediments), since such an approach results in the construction of limited archaeologies. The purpose of preservation, whether by record or as *in situ* remains, must be to improve knowledge about the past. It is therefore possible to link research and management through the common objectives of achieving greater understanding of the Palaeolithic period (Figure 242). However, the gap between professional archaeology and academic research still exists to a degree, because of the financial considerations — these are addressed below.

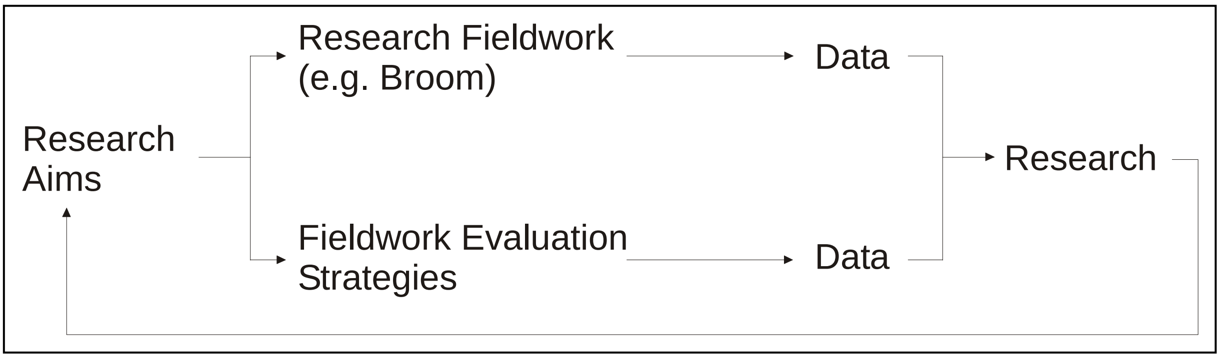

Figure 242: Academic research, fieldwork and field evaluations

The impact of the aggregates industry upon archaeological remains is twofold: firstly, the threat to Holocene archaeology that can be destroyed during the stripping of overburden from quarry sites prior to aggregates extraction; and secondly, the threat to Palaeolithic archaeology contained with the aggregates. The industry must therefore fund an archaeological evaluation prior to the removal of the overburden, and then fund a watching brief conduced throughout the period of aggregates extraction. It is therefore advantageous for professional archaeology to develop watching brief strategies that limit the time spent on site by archaeologists and the resulting disruption of the industrial processes. In light of this, the proposals highlighted above for non-selective preservation by record must also incorporate a time-saving element. We propose that this is achieved by markedly reducing the time spent searching for artefacts on reject heaps, and by recognising that sediment sampling and recording procedures must be streamlined and avoid unnecessary duplication of data. This was illustrated by work undertaken by the authors at the

Squabb Wood site, where only three of the 12 lithostratigraphic logs recorded documented markedly different sedimentary sequences. The downsizing of artefact searching on reject heaps is also supported by the fact that there is an increasing trend for gravel processing at central sites, to which material from multiple pits is brought. Under these circumstances, provenancing of artefacts to individual sites is impossible, and the time and money spent on the activity is therefore considered unjustifiable.

The above comments are in no way intended to marginalise the huge contributions made by amateur collectors over the past 150 years to the British Palaeolithic record. However, it is clear that with recent changes in industrial practice, in particular the advent of stricter health and safety at work policies and the spectre of litigation, opportunities for the access of amateur collectors to active quarry sites have been markedly reduced, and will continue to be so. The discovery of artefacts in 'blank' areas or the recovery of atypical specimens (e.g. the quartzite discoveries of R.J. MacRae in the upper Thames (MacRae 1988) are of clear value to Palaeolithic research. However, in well-documented areas (e.g. sites or deposits from which large numbers of artefacts have already been recovered) we suggest that the collection of additional, unprovenanced artefacts does not substantially contribute to the wider understanding of the archaeology. Moreover, this type of collection activity also contributes to the perception that Palaeolithic archaeology is primarily concerned with finding stone tools. As we have argued above, this is not an accurate reflection and complicates relationships with the aggregates industry and with local government archaeologists who may be specialists in the archaeology of later periods.

It is obvious that neither this document nor a hundred others like it will ever stop the activities of amateur collectors — moreover such an outcome would certainly not be our intention. However, we feel that it is important to stress the following:

1. There is a considerable (and arguably increasing) gap between the activities of the amateur collectors and the work of professional and academic Palaeolithic archaeologists. This gap is evident in research focus, fieldwork methodology, resources, and logistical support.
2. The size of this gap needs to be emphasised to the aggregates industry, in order to reduce resistance to the types of proposals suggested here for future changes in watching brief practice. In other words, Palaeolithic archaeology needs to lose its 'amateur collectors and gentleman antiquarians' image and stress its status as an integrated branch of Quaternary Science.
3. However, amateur collectors can be educated with respect to current research frameworks and the place of non-artefact data within these. This could be undertaken through local and regional seminars, distribution of educational materials (e.g. web-based resources, pamphlets), and the television/radio media. We argue that those collectors currently in contact with the professional and/or academic archaeological worlds would be amenable to this type of education. Through these types of outreach schemes collectors could become aware (where they are not already) of non-artefact data (e.g. sediments for dating etc) and bring it to the attention of local and regional archaeological contacts — who are properly equipped to deal with these data.

Overall, it is stressed that this document is not attempting to eradicate amateur collecting, but it is trying to integrate it within modern research frameworks and the current and future practices of Palaeolithic archaeology.

In conclusion, it is proposed that there is a clear need for changes in the practice of archaeological watching briefs with respect to Palaeolithic secondary contexts. These changes reflect new research frameworks and the need to avoid the irretrievable loss of valuable data. Implementation of these changes is a challenge and will require informed discussion between academic and professional archaeologists, and the aggregates industry. We hope that some of the issues raised here may provide a valuable starting place.

7. CONCLUSIONS

This chapter has sought to assess current practice in the management of the secondary context archaeological resource, and propose generic recommendations for the future management of that resource. This is obviously with respect to continued PPG16-driven monitoring (watching briefs) of industrial extraction at aggregates sites which may contain sedimentary and/or artefactual evidence of archaeological interest. This assessment was therefore primarily concerned with:

- The relative value of the secondary context archaeological resource, both as a whole and with respect to the different categories of new evidence (artefactual, biological, sedimentary, and dating samples) that can be potentially recovered from secondary context sediments.
- Prioritisation of the different categories of evidence occurring within the secondary context archaeological resource, with respect to management strategies, logistics and archaeological requirements (both academic and commercial).
- A review of current watching brief practise on aggregate sites, based on an examination of strategy documents produced by professional archaeological units.
- The recommendation of generic and specific strategies for the future management, protection and recording of the aggregate resource. These recommendations will focus upon the potential impact for the aggregates industry (financial and logistical), the relative value of the different components of the geoarchaeological record, strategy efficiency (in terms of time and geoarchaeological data output), and the potential for the training of aggregates industry employees in the recognition of different sedimentary facies.

7.1 Value of the secondary context archaeological resource

It is argued that the secondary context archaeological record has clear value with respect to the investigation of hominid behaviour during the Palaeolithic. This value stems from the unique spatio-temporal scales of the data, which are exploited by the new interpretive frameworks and models developed as part of this project (Chapter 7). These frameworks are dependent upon geochronological and process-driven geoarchaeological models, and emphasis was therefore not confined to the stone tool component of secondary context data. The value assessment therefore also highlighted the contextual geoarchaeological data from archaeological secondary contexts, with particular focus upon sedimentary facies modelling, geochronological frameworks and biological evidence.

7.2 Prioritisation of the secondary context archaeological resource

It is clear that prioritising the different categories of secondary context data (e.g. stone tools, biological data, and sedimentary sequences) is a highly contextual activity. It is dependent both upon the location of the secondary contexts (e.g. in 'blank' archaeological regions, the highest priority will inevitably be attached to the recovery of stone tools — or the continued demonstration of their absence) and upon the interest group making the definition. For example, academic archaeologists may stress sediments and dating samples (reflecting regional research frameworks and issues of Quaternary Science), while local government archaeologists may be primarily concerned with the incontrovertible demonstration of Palaeolithic archaeology through the recovery of stone tools.

This discussion highlighted the importance of a widely-acceptance definition of Palaeolithic archaeology — as artefact-driven archaeology or as Quaternary Science for whom the local demonstration of hominid presence through stone tools is not a necessity. In other words, when dealing with remote time periods, low density populations, and large regions, it must be acknowledged that i) artefacts will not be found everywhere; and ii) chronological, biological and sedimentological evidence is vital to our understanding of the Pleistocene world within which hominids lived and stone tools were manufactured. These are archaeological data.

Ultimately, stone tools are the building blocks of Palaeolithic archaeology — they are the commonest physical residue to hominid behaviour. However, it is vital to recognise that these data are currently vastly over-represented in the extant archives from the Pleistocene period, and exist in an interpretive vacuum due to the paucity of contextual evidence. Therefore, when prioritising categories of evidence with respect to future management and practice, we have to consider that in many cases the current need for contextual evidence is far greater than the need for further assemblages of unprovenanced stone tools.

7.3 Current watching brief practice

Reviews of watching brief practice indicated that it was highly variable. In some cases (e.g. at Squabb Wood (Cotswold Archaeological Trust 2000)), project designs indicated a general awareness of the scope of the secondary context resource and the methodologies required for the preservation by record of those data. In other cases however (e.g. at Dunbridge (Harding 1998)) the projects were characterised by an over-emphasis on the search for artefacts, both provenanced and unprovenanced, potentially at the expense of other data. In many cases, the impression was given that the secondary context was being recorded almost as a side-effect of watching for *in situ* archaeology. We argue that the secondary context should be recorded as an archaeology in its own right. This shift of emphasis could also have the added benefit of indicating to the aggregates industry that watching briefs are not instigated with the primary goal of uncovering the next Boxgrove or Lynford — and therefore causing lengthy disruption to industrial production.

It is therefore apparent that fundamental education is required across the board with respect to the types of evidence that may be encountered within archaeological secondary contexts, their potential value to Quaternary research, and the methodologies and techniques which maximise the value of these data. The nature of this education is discussed below.

7.4 Recommendations for future practice

In light of the opportunities that the aggregates industry presents for Palaeolithic archaeology it is emphasised that any new strategy recommendations need to be mutually beneficial wherever possible, minimising disruption to the industry and maximising Quaternary data return. This is primarily achieved by downsizing the time spent in searching for artefacts, especially from reject heaps where provenancing data is extremely limited. These recommendations stress the importance of OSL-suitable sediments, generic sedimentary sequences, distinctive or unique sedimentary units, and lithic and biological artefacts recovered from recorded sections.

Time spent on site can also be reduced through the use of new recording techniques (e.g. GPS, digital photography) and small-scale sampling strategies (e.g. with respect to the documentation of generic sedimentary sequences). It is also proposed that the establishment of notification procedures between industry and archaeology could reduce the frequency of visits, on a demand-response principle. Obviously this relies upon education and trust, but we see it as one of the few ways out of the current impasse between archaeology and the aggregates industry.

In conclusion, this module has sought to stress the importance of all categories of data from archaeological secondary contexts. This has been guided by the underlying principle that Palaeolithic archaeology is about more than stone artefacts, and can be more profitably perceived of as Quaternary Science. Under this principle we can begin to reduce the continual loss of significant evidence, and set in place mechanisms that will support the meaningful interpretation of the extant artefact record, rather than simply adding to it.

CHAPTER 9

INTERPRETIVE FRAMEWORKS FOR EARLY PREHISTORY AND ARCHAEOLOGICAL SECONDARY CONTEXTS

1. INTRODUCTION

Where chapter 7 highlighted the scope and potential of archaeological secondary contexts in terms of their unique spatio-temporal framework, this chapter explores specific applications through two case studies, and proposes new interpretative frameworks. These case studies demonstrate both the practical applications of the data resource and, it is hoped, highlight the extensive scope for further, future work in these areas.

We review three recent interpretive models that have stressed hominid behaviour at the landscape level. Although the models adopt different approaches, they are all linked by the use of regional data sets, occurring at coarse spatio-temporal scales:

- Gamble's (1999) heuristic framework, linking locales and regions through the rhythms of social and technological behaviour.
- White & Schreve's (2000) framework of hominid colonisation, settlement and abandonment of Britain during the Pleistocene.
- Ashton & Lewis' (2002) model of late Middle Pleistocene population decline and possible strategies for re-colonisation.

This chapter therefore explores whether the approaches and methodologies of Gamble (1999), White & Schreve (2000) and Ashton & Lewis (2002) can be expanded, based on our re-assessment of the value and potential of archaeological secondary contexts (as discussed in chapter 7). The models are tested against two regional sets of secondary context data — the Lower and Middle Palaeolithic assemblages of the Test and Axe rivers (Wessex Archaeology 1993a, 1993b). Modified interpretive frameworks are presented where relevant, while the limitations of the archaeological secondary context resource are also explicitly addressed.

Section 2 summarises the three models, stressing their broad approaches, specific methodologies, results and conclusions. Section 3 presents new case studies, interpreting the regional data sets from the Test and Axe rivers through the three reviewed frameworks. Section 4 assesses the value of both the models and the data, exploring their potential and their limitations. Based upon this assessment, modified interpretive frameworks are presented as and where necessary. Finally, section 5 reviews the value and potential of the secondary context archaeological resource, drawing upon the results of the model testing and the new analytical frameworks proposed in Chapter 7. In particular, this final section stresses the mapping of archaeological questions onto appropriate data sets, and vice-versa, through the identification of relevant analytical scales.

2. LANDSCAPE ARCHAEOLOGY IN THE PALAEOLITHIC: THREE MODELS

2.1 Gamble (1999) — locales, rhythms and regions

This review of Gamble (1999) is divided into two sections. The first is concerned with his Palaeolithic framework of locales, rhythms and regions, while the second section summarises how data from the European Lower Palaeolithic was explored within the concepts of the framework.

2.1.1 Locales, rhythms and regions

Gamble (*ibid*: 65) argues that the investigation of Palaeolithic society should operate at two levels of analysis, the locale and the region, linked by the rhythms of social technology. The concepts are intended to provide a missing vocabulary for the investigation of Palaeolithic social life, including change and stasis. These concepts as defined as follows:

- Locales: these are discussed in terms of the archaeology of encounters, gatherings, social occasions and places. In other words, they are points on a landscape and these may be highly ephemeral (defined by the temporary presence of a hominid and leaving no archaeological residue) or durable (e.g. places with associations, based on the rhythms of actions, repeated over many millennia and leaving a clear archaeological signature).
- Regions: this is essentially an arbitrary spatial unit, but it is further defined through the concepts of a landscape of habit (the setting for habitual action and daily encounters) and the wider social landscape(s) (composed of multiple landscapes of habit and their overarching extended and global networks).
- Rhythms: these are the actions of individuals (e.g. operational sequences, movements along well trodden paths, attentions paid to others) which are archaeologically invisible, but which provide the conceptual link between the dynamics of past action and the inert residues of those actions.

These concepts fit together within an analytical framework (Table 61) and underpin the notion of analytical tacking (between data of contrasting spatial scales and temporal resolution), visually summarised in chapter 7 (Figure 239).

LOCALES	***RHYTHMS***	**REGIONS**
Encounters	*Chaîne opératoire*	Landscape of habit
Gatherings		
	Taskscape	
Social occasions		
Place	*Paths & tracks*	Social landscape
INDIVIDUALS	↔	NETWORKS

Table 61: a framework for studying Palaeolithic society (Gamble 1999: Table 3.1)

So how does the concept of linking rhythms work? Gamble (*ibid*: 80) defines rhythms as being bodily actions, such as walking, sleeping and making. It is clear that many of these rhythms can be described as habitual actions, those that we complete with little or no thought, enabling us to undertake other, more complex actions. Gamble (*ibid*: 81) relates these habitual actions to Gidden's (1984) notion of practical consciousness, in contrast with the state of discursive or problem-solving consciousness. Gamble stresses the concepts of rhythms and practical consciousness as they address the notion of the unification of action, and the involvement of individuals *in*, rather than detached and separate *from*, the world. This notion of the unification of action is applied to the concepts of the chaîne opératoire and operational sequences, and stresses that social and technical acts cannot be separated:

"Material action, or gesture, is in part determined by physical laws. Therefore it is to some extent fixed. Stone and wood have different properties which determine not only what can be made but how it can be made. But material action is also flexible.

There are choices to be made concerning the what and how of any technical process. The flexibility of these choices stems from social and cultural contexts, the gatherings and social occasions with actors engaged in the performance of society. Consequently, the fixed properties in any operational sequence do not in themselves make the technical act less social, cultural or indeed human."

(Gamble 1999: 83)

This line of argument is pursued to emphasise technology as a social phenomenon that plays an active role in the construction of social life. It is these constructions and re-constructions of social life which occur continuously between individuals at the encounter (e.g. between a hominid and a deer), the gathering (encounters of an intensity that archaeological residue is generated), the social occasion (a stage for performance) and the place (a named locale invested with associations and meanings).

The landscape of habit has been adopted by Gamble (*ibid.*) as a concept describing the wider region, within which individuals travel and interact with others on a daily basis: in this respect it is a wider spatial network for the interactions and negotiations that occur between individuals at locales. Archaeological and ethnographic studies of raw material transfers suggest that the landscape of habit is small in scale (e.g. a radius of 40 km with an upper limit of 100 km) and that all activities occurring within it are essentially local with respect to their social and organisational implications.

Unlike the landscape of habit, the social landscape achieves the stretching or distancing of social systems across time and space. It is the spatial outcome of individuals developing extended networks (of *c.* 100–400 people) and the appearance of the global network (*c.* 2500 individuals). This stretching is fundamentally important as:

"The hominid environment is therefore truly extended beyond either a foraging or a subsistence scale [the landscape of habit]. *It transcends habitual actions and the pattern of life routines contained in the landscape of habit."*

(Gamble 1999: 92)

This development of extended and global networks therefore enables social landscapes to not only consist of a series of exclusive, local networks, but also to expand almost limitlessly in size. This is expressed both today through global branding and in the Upper Palaeolithic through shared artistic styles (e.g. Venus figurines) and burial practices, and the long-distance transportation of raw materials.

In summary, Gamble's (*ibid.*) conceptual framework supports a view of Palaeolithic social life in which hominids were continually involved in the construction of their environment. This occurs at the spatial scales of the locale and the region, both linked by rhythms of action, ranging from the treading of paths and tracks to the operational sequences of tool-making. These social actions of living are recorded within the spatial dimensions of both the landscape of habitat (defined by the exclusive networks of individuals) and the social landscape (defined by inclusive networks that stretch social relationships across time and space). All of these concepts are underpinned by an emphasis upon the social nature of technical acts. Through this, social archaeology is no longer confined to the analysis of stylised artefacts but can expand into the realms of mobility, production, consumption and discard.

2.1.2 Frameworks & data

These realms of mobility, production, consumption and discard can all be detected within the Lower Palaeolithic archaeological record[11], and Gamble (*ibid.*) presented a number of explorations and interpretations of those data:

- That the delay of the colonisation of Europe (especially northwest Europe) until after 500,000 BP was due to the limitations and local-scales of Middle Pleistocene hominid social systems. This conclusion

[11] The Lower Palaeolithic period is stressed here, as the secondary context archaeological resource is dominated by material from this period, partly reflecting the absence of hominids from Britain between MIS-6 and MIS-3.

is based on a range of evidence including site chronology, the widespread distribution of the initial occupation after 500,000 BP, the extreme seasonality of the plains environments, and the widely spaced faunal and floral habitat mosaics of the plains. Gamble (*ibid.*) stressed two key issues:

"that to sustain population at a continental scale, and so cross the threshold of archaeological visibility, it was a necessary condition that large areas had to occupied. Only then would a demographic balance be assured within the continent rather than continually relying on further immigration to counter local extinctions."

(Gamble 1999: 124)

"In terms of hominid behaviour this seasonality could only be overcome through greater annual mobility and the fissioning of populations…Only with alterations to the seasonality regimes in central and western Europe, which coincided with changes that were detrimental to the large carnivores, did a match emerge between the scale of the hominids' social systems and the spatial structure of resources in the environment which permitted colonisation."

(Gamble 1999: 124–125)

- Gamble (*ibid.*) stressed that the scales of the paths and tracks of hominid social life can be explored through lithic evidence, and that current evidence indicates a landscape of habitat that is predominantly local in character. Specifically, raw material transfer data is used to model the spatial extents of hominid movements associated with the acquisition of lithic resources. Reconstructing these habitual encounters provides a key to demonstrating the size and scale of the landscapes of habit. A European review by Féblot-Augustins (1997) indicated that the majority of raw material procurement occurred from local sources, with an average transfer distance of 28 km. This has been independently demonstrated in the Upper Thames area of southern England, where quartzite artefacts are only found in the Bunter areas where quartzite occurs locally — they do not occur in the more distant flint-bearing regions of the south.

- Gamble (1999) adopts the concept of social technology to explore traditional lithic frameworks and argues, with respect to Lower Palaeolithic technology, that flake and biface traditions emerge as different outcomes to immediate conditions. It is argued that these outcomes were not planned beyond the perception of an immediate need and/or opportunity. This interpretation was based on a range of extant data including: the use of immediately available raw materials, as demonstrated at Swanscombe (White 1998b), and their implications for biface shape; the situational character of early Palaeolithic technology, with material output varying in response to raw material quality and availability, site function and other immediate circumstances (White & Pettitt 1995); and the rejection of a mental template or blueprint for lithic production, as emphasised through Davidson & Noble's (1993) fallacy of the finished artefact and Boëda's (*et al.* 1990) exploration of the chaîne opératoire through the manufacturing principles of façonnage and débitage. This concept of a social technology constrained by local and immediate circumstances is also reflected in the evidence for organic artefacts and tool manufacture from the Lower Palaeolithic.

- Gamble's (1999) concept of the taskscape is as an array of related and continuous activities, which carry forward the processes of social life. Archaeologically this social life is most commonly preserved in the form of lithic artefacts and their associated debris (e.g. faunal remains). These remains provide a means of assessing the skills of Middle Pleistocene hominids. Gamble highlights two sets of socially-transmitted skills, generic (or transferable) and specific, and argues that their respective detection in the archaeological record can indicate whether we are dealing with tool assisted hominids or more 'sophisticated', modern humans. An example is given from the sites of Swanscombe (51°N latitude) and Olduvai Gorge (on the equator). In two similar contexts (stream channels), the overriding image is the similarity of the archaeology, and there is no evidence for specific skills or adaptations to the cold winters of the northern latitudes:

"How different, in terms of technology, settlement systems and camp-site organization, would a similar latitudinal transect be among modern foraging peoples?"

(Gamble 1999: 140)

Gamble argues that under a model of generic skills we should expect populations to ebb and flow in and out of the northern environments (e.g. Swanscombe), and that population and colonisation data can therefore provide robust evidence of behavioural variability at regional scales.

- Although paths and tracks and the landscape of habit have already been discussed through raw material transfers, they can also be explored at a regional scale. This approach has often been pursued through the investigation of well-preserved gatherings (e.g. the Boxgrove beach landscape (Roberts & Parfitt 1998) and the riverbanks of the Somme (Tuffreau & Antoine 1995)), but can also be undertaken at a truly regional scale, although here preservation quality is blurred due to periglacial and fluvial processes. However, Gamble (*ibid*: 142) argues that it is possible to take account of these factors and document regional variations in the density and distribution of artefacts that relate to habitual hominid behaviour in the form of cumulative actions, repeated over the long-term.

- Gamble (*ibid*: 144) argues that there is no evidence for social landscapes in the Lower Palaeolithic, given the absence of symbolic resources. He stresses that the absence of these networks would have had repercussions for the ability of hominids to colonize the more seasonal and northerly environments of Europe, as this would have required group fragmentation to cope with shortages and resource availability.

Overall, Gamble (*ibid*: 173) concludes that social life in the Lower Palaeolithic was routinized and locally-based. The predominance of generic rather than specific skills is indicated by the similarity of the archaeological record throughout Europe, while lithic transfer data confirms the local dimension of hominids' habitual, daily actions.

2.2 White & Schreve (2000) — palaeogeography and the colonisation of Britain

White & Schreve (2000: 1) developed a biogeographical framework of human colonisation, settlement and abandonment, built upon models of regional palaeogeographical evolution and global climatic change. Large-scale patterns in the lithic record were then explored within this framework, with patterns interpreted as evidence of population ebb and flow and colonisation pulses.

Central to the model was the issue of Britain's fluctuating island status during the Middle and Late Pleistocene. These fluctuations occur in response to eustatic sea-level change (in association with glacial/interglacial climatic conditions), evolving palaeogeography, and local and regional isostatic processes (e.g. downwarping and uplift). This issue has rarely been explicitly addressed with respect to the archaeology of the Lower and Middle Palaeolithic. While a detailed review of the model is not included here (for specifics refer to White & Schreve (2000)), the documentation of Britain's insularity and peninsularity was grounded in data that occur within archaeological secondary contexts:

- Sedimentary evidence of different regimes (e.g. river-bed, estuarine and shallow sub-littoral). Such sediments occur both offshore (e.g. the submerged and infilled valleys of the English Channel, which are vulnerable to current and future marine aggregates extraction) and onshore (e.g. the sequences at Aveley and West Thurrock).
- Mammalian evidence, whether indicating direct contact with the continent during cold-climate phases or isolation during periods of high sea-levels. For example, the contrast in species from the early and later parts of the MIS-7 interglacial as documented at Aveley and Crayford indicate a shift from woodland (e.g. Merck's rhinoceros and straight-tusked elephant) to open conditions (e.g. narrow-nosed rhinoceros, woolly mammoth and horse), and also indicate an intervening cool period, with lowered sea-levels permitting faunal turnover and the immigration of new species (White & Schreve 2000: 10; Schreve 2001a).
- Molluscan and ostracod evidence, which are indicative both of peninsularity (e.g. the indication of a Thames/Rhine river system in the Rhenish fauna recovered at Swanscombe and Clacton-on-Sea) and of insularity (e.g. the marine and brackish water mollusca from Clacton (the Estuarine Beds) and Dierden's Pit, Ingress Vale).

Based upon these types of data, a framework was established which mapped cycles of insularity and peninsularity during the Middle Pleistocene, and hominid responses to those cycles (White & Schreve 2000: 11–14):

- Phase One: Cold-Stage Peninsula — residency and abandonment. It is assumed that Britain would have been attached to the continent during glacial episodes, due to the high global ice volumes and low sea-levels. However, patterns of hominid settlement and movement would have varied during the glacial phase:
    - Early glacial period: cool, intermediate conditions offered suitable mosaic habitats for settlement and movement in Britain, the North Sea and the English Channel. However, deteriorating conditions eventually resulted in glaciation of the North Sea basin and probable retreat southwards in response to worsening conditions.
    - Glacial maximum: extremely harsh climatic and environmental conditions dominated the region, resulting in depopulation of southern Britain through local extinction and/or southerly migration.
- Phase Two: Lateglacial/Early Interglacial Peninsula — human colonisation and residency. Gradual ice retreat saw the re-appearance of Britain as a viable habitat, while initial low sea-levels maintained a physical link with the continent. There was re-colonisation of Britain by temperate fauna and hominids, although the exact routes would have been dependent on the location of founder populations on mainland Europe, the presence of local barriers to movement, and the precise mechanism of hominid colonisation. As the phase progressed, sea-level rise would have increasingly restricted opportunities for movement and settlement.
- Phase Three: Interglacial Island — residency and isolation. Due to sea-level rise, Britain was now an island and isolated from the rest of Europe, severing genetic and cultural contacts between British and continental hominid groups. At the end of this phase, colder conditions returned and sea-levels began to fall, ultimately returning Britain to peninsular status (see Phase One).

The key implications of the model are well summarised:

"while continuous occupation could potentially have occurred throughout an entire late glacial–interglacial–early glacial cycle, with Britain in a variety of palaeogeographical and environmental states, it is proposed that the glacial maxima witnessed an environmental threshold that caused the complete human abandonment of the British landmass. Therefore each glacial maximum and subsequent recolonisation event would have witnessed a complete population turnover."

(White & Schreve 2000: 14)

White & Schreve (*ibid*: 14) presented a series of generic archaeological implications that arise from their biogeographical framework:

1. Britain was not continuously occupied, and hence the archaeological record is a fluctuating register of colonisation, settlement and depopulation, and has no persistent cultural signature.
2. There was an almost continuous link between Britain and the continent prior to the Anglian glaciation, suggesting that the absence of hominids before the late Cromerian Complex is a genuine northwestern European pattern, and not due to local palaeogeographical factors.
3. Colonisation and recolonisation events may explain some of the industrial variation evident in the British Palaeolithic record.
4. The severing of cultural and genetic contacts between Britain and the continent during island phases could lead to insular and endemic developments in technological practice, identifiable in the archaeological record as distinctive regional and sub-regional traditions.

With respect to regional data and archaeological secondary contexts, the model highlighted two distinctive patterns:

- The Clactonian and the Island Britain model: although the claims for this core and flake industry as the earliest British lithic technology have been comprehensively rejected (White 2000), there are currently a wide variety of different interpretations of the industry, stressing a range of factors including raw materials (Wenban-Smith 1998), social learning (Mithen 1996), expedient behaviour (McNabb & Ashton 1992; McNabb 1996), and landscape use (Ashton *et al.* 1994, 1998). White & Schreve (2000) highlighted the repetitive chronology of Clactonian assemblages, noting that they tended to occur in basal sediments dating to the early phases of the MIS-11 and MIS-9 interglacials. Examples include the basal sediments of the Lynch Hill/Corbets Tay Formation at Globe Pit, Little Thurrock, Cuxton and Purfleet. By contrast, Acheulean biface assemblages were associated with the later phases of these interglacials, and at the current time temporal overlap of these two industries during MIS-11 and MIS-9 has not been demonstrated. It was concluded that the Clactonian was associated with the initial recolonisation event of early phase 2 (see above) in both MIS-11 and MIS-9, with the Acheulean appearing in a later part of phase 2 (the interglacial peninsula period). The Clactonian and Acheulean are therefore proposed to represent separate and distinct pulses of colonisation, although other researchers have argued in favour of the *in situ* development of the Acheulean from the Clactonian (e.g. Wenban-Smith 1998). White & Schreve (2000) have also proposed geographically distinct origins for the Clactonian and Acheulean colonisation pulses, following the long-standing division in the Lower Palaeolithic record between the biface zones of Italy, Spain and France, and the non-biface zones of Germany, the Lowlands and Eastern Europe. Although this model requires further study, it utilises regional patterns in lithic distribution and stratigraphy to explore major archaeological issues of colonisation, settlement, and lithic industries.

- Biface typology and the Island Britain model: as with the Clactonian industry, biface typology has been the subject of intense debate, with explanations emphasising factors such as raw materials (e.g. White 1998b), reduction sequences, and function. White & Schreve (2000) highlighted the need to identify suitable attributes for assessing patterning, and White (1998a) presented twisted profiles as an example of a distinctive biface feature that varies independently of raw materials. While twisted ovate bifaces are a small component of many assemblages, in some cases they dominate the typology. It was stressed that these latter assemblages were all independently correlated to MIS-11 and early MIS-10, with very few examples from pre-MIS-11 or post-MIS-10. This contrasts markedly with northern France, where assemblages with high proportions of twisted ovate bifaces occur from MIS-12 through to MIS-8. White & Schreve (2000) argue that this association of a chronologically well-defined and distinctive knapping technique with a period of island isolation represents the type of endemic cultural development that the island Britain framework predicts.

Although this model has been used to address specific research questions, the framework also:

"approaches the British Palaeolithic record on a large scale and highlights patterns of potential social and cultural significance, in contrast to other recent works which have focused almost exclusively on functional or economic factors. These approaches are not mutually exclusive, but operate on different scales of analyses, some of which are more applicable to certain problems and types of data than others."

(White & Schreve 2000: 22)

2.3 Ashton & Lewis (2002) — Middle Pleistocene population patterns

Ashton & Lewis (2002) explored Middle Pleistocene population patterning over time through artefact data from the Middle Thames valley. Artefact densities were interpreted as a proxy of population size, and were calculated across the Middle Thames region for a series of progressively younger chronological periods. Evaluation of these data suggested population decline during the late Middle Pleistocene. The adopted methodology recognised the difficulties of assessing Palaeolithic population levels, in particular (*ibid*: 388):

- The variable preservation of artefact-bearing sediments.
- The variable intensity of fieldwork.
- The uncertain relationship between artefact assemblages and the temporal duration of hominid activity — e.g. 1,000 artefacts could represent occasional discard over several thousand years or the

product of one year's knapping.

Their methodology reduced the impact of these issues by (*ibid*: 388–389):

- Examining fluvial terrace aggradations, from which artefacts occurring within the deposits represent activities from a broad area over a defined length of time. They assumed that artefacts were broadly contemporary with their sedimentary units, although the problem of vertical re-working was also acknowledged (see below).
- The research question being addressed was whether population decreased through time. Since the results did indicate a marked decrease in population over time (from the top to the base of the terrace sequence), the problem of vertical artefact re-working from higher and older terraces was marginalised. If however the results had not followed such a clear pattern (e.g. if there was a population spike in the middle of the sequence), then the issue of re-working would have been highly significant.
- Mapping of the terraces, thus reducing the problem of variable preservation of the sediments.
- Focusing upon part of a single river system, lessening the problem of collector bias.
- Documenting aggregates quarrying until the mid-1930s, thus recognising all manual extraction activity that was contemporaneous with antiquarian collecting, and ignoring the mechanized industrial era.
- Bifaces and Levallois artefacts were utilised as a proxy for artefact discard rates. This reflects the selective collection of artefacts during the 19th and early 20th centuries, and the particular focus of antiquarians upon bifaces. The inclusion of Levallois artefacts was used to compensate for the lower prevalence of bifaces during the Middle Palaeolithic, although it was acknowledged that these artefact types are not direct equivalents.
- Artefact discard rates were adopted as a constant proxy for population sizes, although it was recognised that a number of uncontrolled factors were at play, including changes in raw material availability, artefact function, and increasing reliance on other raw materials.

The artefacts from the Middle Thames valley were divided into a series of chronological units, following the river terraces of the River Thames (the Black Park, Boyn Hill, Lynch Hill, Taplow and Kempton Park terraces — Figure 243). These terraces have been demonstrated to represent a simple succession through time from top to bottom (Bridgland 1994). The chronological duration of the deposits associated with each terrace unit was established (Table 62), following Maddy & Bridgland (2000). Artefact densities were standardised by terrace (surface) area, time (100,000 year units), areas of urban growth between 1861 and 1927, and quarrying extents prior to the mid-1930s. These last categories acknowledge that not all of the mapped terrace sediments will have been exposed for the collection of artefacts. The standardised artefact densities were then utilised to demonstrate general trends in the hominid populations of the Middle Thames valley through time. The key pattern was the reduction in artefact densities from the higher (Boyn Hill) to the lower (Kempton Park) terraces, with a marked drop from the Taplow terrace downwards (Figure 244–Figure 246). This was interpreted as evidence for peak populations from the end of MIS-13 to MIS-10, declining into MIS-8 and then dropping sharply from MIS-7 onwards.

These results were compared with site-based data and chronologies which had also suggested a pattern of declining population during the late Middle Pleistocene. The paper then presented a number of reasons for this decline, including climatic factors (increasingly cold conditions), the timing of Britain's connections with and separations from mainland Europe, and changes in the climatic and habitat preferences of hominids during the Middle Palaeolithic. These issues are discussed at greater length in Ashton & Lewis (2002). However, of primary concern here is the artefact model, since it highlights an application for secondary context data sets. Nonetheless, it is worth noting that Ashton & Lewis (*ibid.*) highlight the potential for combining primary and secondary context data for the investigation of key research questions (this aspect of the model is discussed in Section 5 below):

"The strength of the model lies in the robust evidence for population decline from the data in the Middle Thames valley, although this needs to be substantiated by evidence from other valley systems."

(Ashton & Lewis 2002: 395)

Terrace	OIS	Duration estimate (years)	No. of artefacts (Bifaces and Levallois pieces)	Terrace area (km²)	Artefact density/km²	Artefact density/ 100,000 years	Urban growth 1861-1927 (km²)	Artefact density over area of urban growth/ 100,000 years	Quarrying until 1932/ 1935 (km²)	Artefact density over area of quarrying/ 100,000 years
Black Park	Late 12	15,000	373	17.9	20.8	139.0	0	-	0.15	16,580
Boyn Hill	11-10	75,000	808	11.9	67.9	90.0	2.42	445.0	0.04	26,933
Lynch Hill	9-8	100,000	3038	59.2	51.3	51.0	15.78	192.0	0.23	13,208
Taplow	7-6	110,000	143	36.4	3.9	3.0	4.04	32.0	0.57	227
Kempton Park	5-2?	112,000	9	60.4	0.1	0.1	24.67	0.4	0.36	22

Table 62: standardised artefact densities for the Thames Valley (Ashton & Lewis 2002: Table 1).

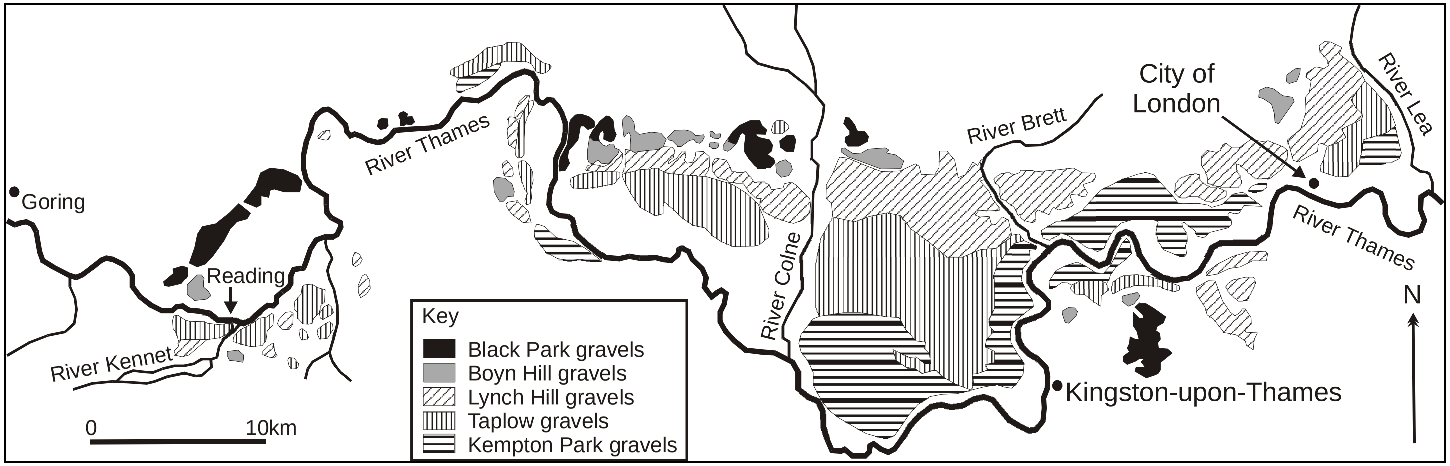

Figure 243: distribution of the Black Park, Boyn Hill, Lynch Hill, Taplow and Kempton Park terrace aggradations in the Middle Thames valley (Ashton & Lewis 2002: Figure 1)

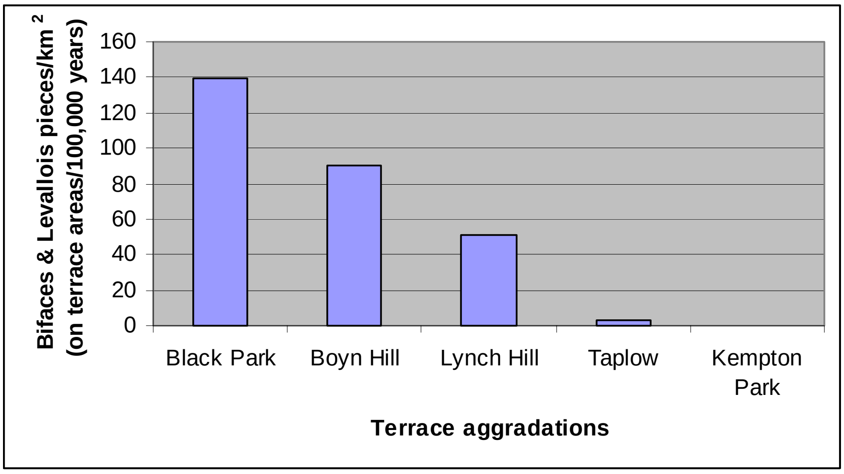

Figure 244: artefact density model for the Middle Thames valley. Artefact density calculated per km^2 of terrace area/100,000 years (after Ashton & Lewis 2002: Figure 2).

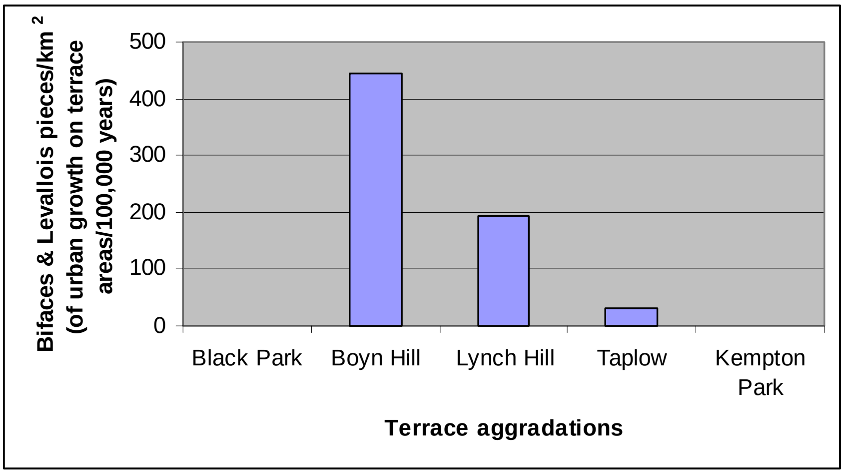

Figure 245: artefact density model for the Middle Thames valley. Artefact density calculated per km^2 of urban growth on terrace area/100,000 years (after Ashton & Lewis 2002: Figure 2). The Black Park terrace aggradation has no data.

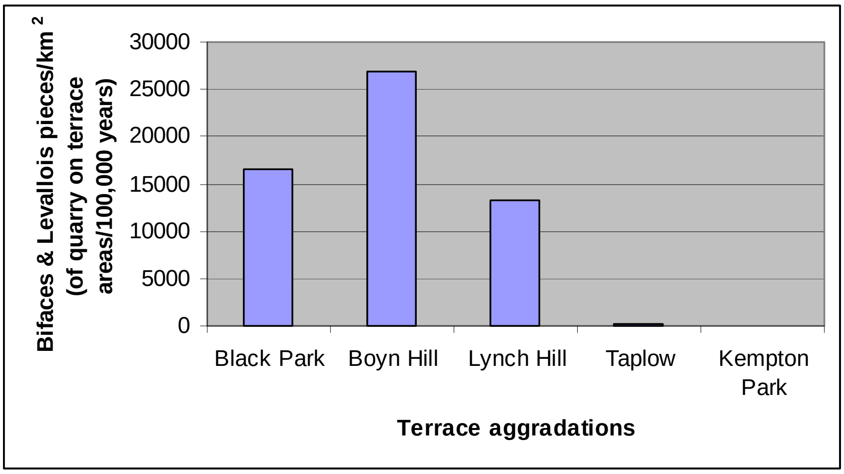

Figure 246: artefact density model for the Middle Thames valley. Artefact density calculated per km^2 of quarry on terrace area/100,000 years (after Ashton & Lewis 2002: Figure 2)

3. CASE STUDIES: THE RIVER AXE AND RIVER TEST VALLEYS

In keeping with Ashton & Lewis' (2002) call for evidence from other valley systems, this section presents six case studies, testing the three models reviewed above against regional, secondary context data sets from the River Axe and River Test Valleys. The case studies explore whether the models' methodologies can be effectively applied in the analysis and interpretation of regional secondary context data. A summary of the two regions follows (the Axe valley summary builds upon the brief introduction in Chapter 3, Section 1.2)), providing the background for the case studies.

3.1 The River Axe Valley

The River Axe is the only major river in the southwest of England. It flows through South Somerset, West Dorset and East Devon, entering the English Channel at Seaton. The Axe has one major tributary (the River Yarty) and a number of small tributary brooks in its lower reaches. The river rises in West Dorset to the west of the chalk outcrops and flows in an insignificant valley until it reaches Chard. From Chard the valley broadens markedly and is flanked by wide spreads of low, gravel capped hills. Some west and north-west facing escarpments are prominent, although the basin tends to lack steep slopes. Overall, the Axe has a steep profile, falling 25m in the 10km between Axminster and Seaton (Stephens 1977; Shakesby & Stephens 1984: 77–78; Wessex Archaeology 1993b: 159).

For the most part the river flows over soft Cretaceous or Jurassic rocks. However, below Axminster the river cuts through Triassic mudstones (Figure 247). The interfluves and the upper higher valley slopes are underlain by Upper Greensand, consisting of the Foxmould-Chert Beds. The Foxmould Beds are up to 35m in thickness and consist mainly of soft sands, which occasionally contain lenticular chert lumps. The Chert Beds are up to 15m thick and comprise hard, glauconitic sandstones, sandstones with calcite cement, lenticular layers and nodules of chert, and hard nodular calcareous sandstones with strongly developed chert bands. In some cases these chert bands have broken up, producing masses of angular material, sometimes moved downslope as head deposits. The low hills and plateaux that surround the Axe valley are widely but discontinuously capped by a cover of drift deposits several metres thick, typically described as Clay with Flint Chert or Plateaux Gravels. In addition to the dominant flint and chert these deposits also contain small percentages of grits, quartzites and Palaeozoic clasts (Shakesby & Stephens 1984: 79–80; Wessex Archaeology 1993b: 159).

The lower valley slopes, the Axe floodplain and the floor of the Chard 'Gap' are underlain by Lower Lias Clays and limestones, with Middle and Upper marls, silts and sands all present. Further downstream in the Kilmington and Axminster area, Keuper Marls underlie the floodplain. There are few traces of terraces associated with the floodplain, and those gravels which do remain are the residue of many different lithologies, including Eocene pebbles and other materials from more recently eroded deposits. Nonetheless, considerable thicknesses of Pleistocene sand and gravel occur along the Axe Valley (Figure 247). Exposures at Broom, Kilmington and Chard Junction have revealed these sediments to predominantly comprise of angular to rounded chert and greensand clasts. Flint is constantly present but varying in quantity, with additional small percentages of exotic, far-travelled materials such as quartz, quartzite, arenaceous grits and Palaeozoic grits (Shakesby & Stephens 1984: 79–80; Wessex Archaeology 1993b: 159–160).

It has been suggested that the sand and gravel deposits are at least partly fluvio-glacial, deriving from an ice margin somewhere to the north of the Chard Gap. Stephens (1974) in particular has emphasised the role of the Chard Gap (at 90m OD, compared to the local interfluves at 230–290m OD) in the origin of the Axe gravels. He argued that a pro-glacial lake may have existed in the Bristol Channel–Severn Valley as a result of ice blocking the western end of the Bristol Channel, and that the lake may have discharged southwards through the Chard Gap. This discharge event would have washed masses of rock debris into the Axe Valley, accounting for the thick gravel deposits and their absence along the upper Axe Valley east of Chard. This model follows work as far back as Maw in 1864 in its view of a Bristol Channel which was once blocked with ice. Green (1974) however has challenged this interpretation, pointing out the total absence of erratics which should have been discharged by the meltwaters of a glacier lying to the north.

Current models are generally agreed upon a fluvial origin for the sands and gravels of the Axe valley (Shakesby & Stephens 1984; Green 1988; Chapter 3).

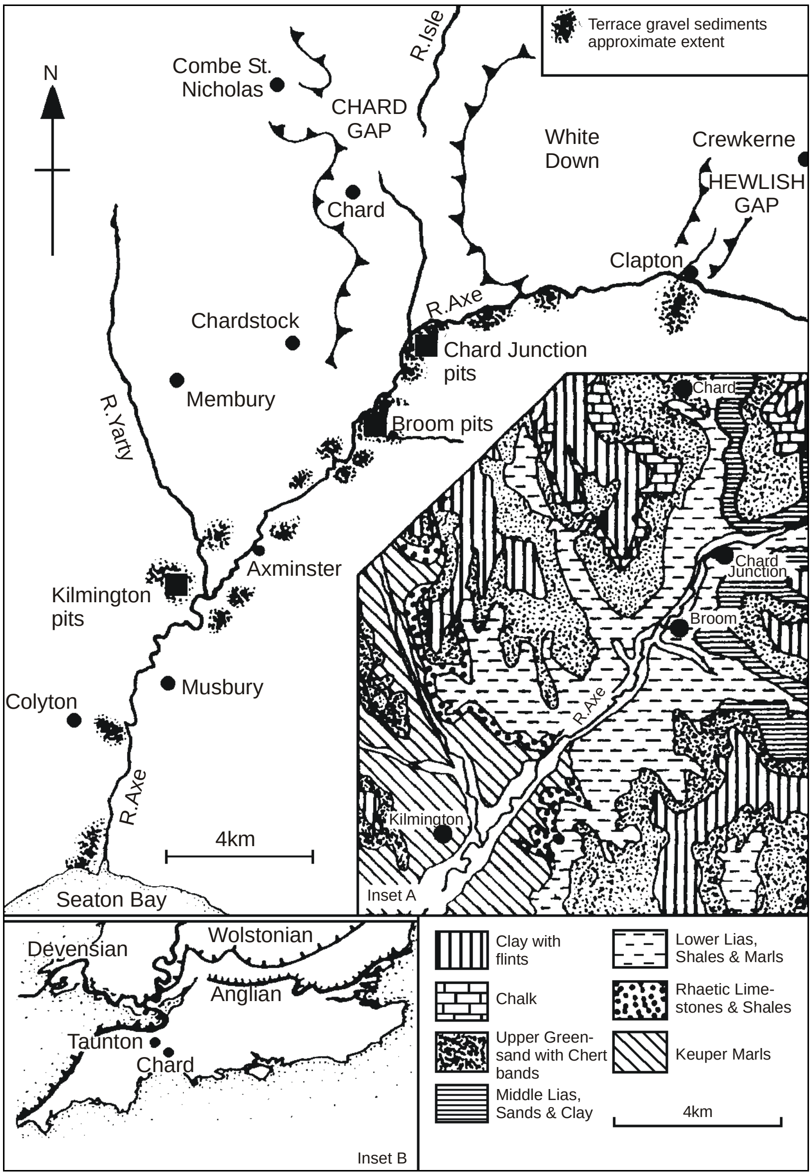

Figure 247: the geology of the River Axe Valley (Shakesby & Stephens 1984: Figure 1)

The Southern Rivers Palaeolithic Project (Wessex Archaeology 1993b) highlighted 25 findspots from the River Axe region (ranging from Lyme Regis in the east to Sidmouth in the west, and north from the coast to Chard). These findspots have yielded a total of 1922 Lower and Middle Palaeolithic lithic artefacts (1887 bifaces, 15 flakes, 15 retouched flakes, 4 Levallois flakes and 1 Levallois core). Of these findspots, six are documented as originating from river gravel sediments in specific locations along the River Axe valley (Table 63), while a further three are associated with river gravels, although their location is uncertain (Table 64). The six secure findspots have yielded 1834 artefacts (1815 bifaces, 9 flakes, 7 retouched flakes, 2 Levallois flakes and 1 Levallois core), the majority (95%) of the material documented from this region. The three non-secure findspots have yielded 62 artefacts (49 bifaces, 4 flakes, 7 retouched flakes, and 2 Levallois flakes).

Findspot	Description	Geology	Archaeology
Thorncombe, Dorset	Bateman's Dairy Gravel Pit, on north side of road, "500 yards south of Chard Junction Station". Generally referred to as Chard	River Gravel	6 bifaces
Thorncombe, Dorset	Chard Junction Pits	River Gravel	4 bifaces, 1 flake
Thorncombe, Dorset	Broom Pits, Holditch Lane (Pratt's Old Pit, Pratt's New Pit, King's Pit)	River Gravel	1804 bifaces, 1 Levallois core, 2 Levallois flakes
Hawkchurch, Devon	Railway or Ballast Pits	River Gravel	Nothing specifically listed, but likely to have produced some of the material listed as Broom Pits, Holditch Lane
Kilmington, Devon	Gammons Hill Quarry or New Pit	River Gravel	1 biface, 8 flakes
Kilmington, Devon	Kilmington Pit	River Gravel	1 flake, 7 retouched flakes

Table 63: River Axe valley findspots with secure river gravel contexts (after Wessex Archaeology 1993b: 162–165)

Findspot	Description	Geology	Archaeology
Chard Town, Somerset	Probably material collected from Broom or the Chard Junction Pits	-	21 bifaces, 5 retouched flakes, 3 flakes, 2 Levallois flakes
Hawkchurch, Devon	Hawkchurch — probably the same site as the Broom Pits	-	10 bifaces and 4 other bifaces listed as Hawkchurch
Axminster, Devon	Probably material collected from Broom or the Kilmington Pits	-	6 bifaces, 1 retouched flake, 1 flake, 8 other bifaces, 1 other retouched flake

Table 64: River Axe valley findspots with non-secure river gravel contexts (after Wessex Archaeology 1993b: 162–165)

Until recently very little of this archaeology had been dated. This partially reflects the paucity of terrace landforms, which prohibited the application of geochronological schemes such as those applied by Bridgland (1994) to the River Thames terraces and deposits. There is also very little material that can be employed as a diagnostic chronological marker (due to recent revisions in the interpretation of Lower and Middle Palaeolithic typologies), although the Levallois material probably dates to between MIS-8 and MIS-6, following Bridgland (1994, 1996). Recent work (Hosfield & Chambers 2002b; Hosfield *et al.* in prep.; Chapter 3) has yielded dates between 218±17 kya BP and 297±29 kya BP (spanning MIS-8 and MIS-7) for the sedimentary sequence of terrace gravels and sands at Broom.

3.2 The River Test Valley

The River Test flows southward out of the Hampshire Downs, to its estuary in Southampton Water (Figure 248). In its upper reaches, the solid geology is dominated by Chalk, with the result that the river is predominantly confined to a straight, narrow valley with only small terrace gravel remnants above Mottistone (with the exception of the 20m and 30m terraces that lie on its right bank for approximately 5 km south of its confluence at Hurstbourne Priors). Once the river reaches the softer Tertiary sands and clays at Mottistone, wide gravel terraces and deposits occur (the Tertiary sands and clays underlie the remainder of the river after Mottistone). Tracing the terraces and deposits into the region underlying the modern city of Southampton and flanking Southampton Water remains difficult, due to the paucity of integrated synthesis undertaken on these deposits, the confluence of the Test and the Itchen in the area of Southampton, and the major impact of the extinct Solent River and estuarine/marine processes within the region of Southampton Water. Southampton stands mainly on terraces 3 and 4 of the Test and the Itchen (as defined by the 1987 BGS survey), with only small spreads of higher terrace gravels (Wessex Archaeology 1993a: 78–80).

Unlike the limited terraces of the Axe Valley, the terrace features of the Test Valley have been mapped by the BGS, both as valley gravels in the areas north of Mottistone, and as a series of numbered terraces to the south of this point. It is regrettable that the BGS mapping did not extend to the Dunbridge deposits (given the archaeological importance of these sediments), although it has been suggested that this may correlate with terrace 5 or 6 (Wessex Archaeology 1993a: 88) or terrace 4 (*ibid*: 92). There is clearly a need for future clarification with respect to the age of these deposits.

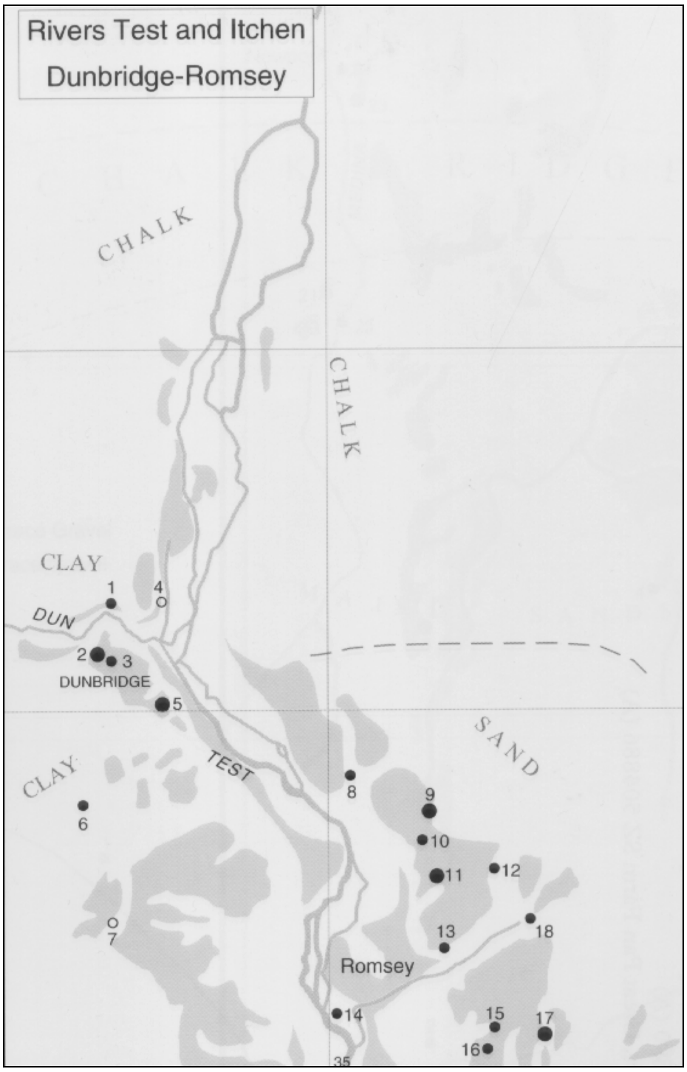

Figure 248: the River Test north of Romsey (Wymer 1999: Map 28). 1: Dunbridge, Hatt Hill; 2: Dunbridge Hill; 3: RMC Gravel Pit, Dunbridge Hill; 5: Kimbridge; 7: Stanbridge; 8: Near Brook Farm; 9: Belbin's Pit; 10: Cupernham Lane Gravel Pit; 11: Chivers Gravel Pit; 12: Great Woodley Farm; 13: Mile Hill; 15: Mountbatten School; 16: Luzborough Gravel Pits; 17: Test Road Gravel Pit; 18: South of Ganger Wood.

The Southern Rivers Palaeolithic Project (1993a) recorded 103 findspots from the River Test region (ranging from Romsey and Chandlers Ford in the south to Andover, Whitchurch and Basingstoke in the north). However, this River Test region also incorporates material associated with the River Itchen and surface finds from the Basingstoke area, lying to the east of the headwaters of the Test. Overall, these findspots have yielded a total of 2368 Lower and Middle Palaeolithic lithic artefacts (1840 bifaces, 363 flakes, 64 retouched flakes, 8 scrapers, 16 Levallois flakes, 2 Levallois cores, 23 cores, 11 roughouts, and 36 miscellaneous pieces). Of these findspots, 20 are documented as originating from river gravel sediments in specific locations along the River Test valley (Table 65) — findspots associated with fluvial sediments of the River Itchen are excluded from this analysis. The 20 secure findspots have yielded 1797 artefacts (1586 bifaces, 138 flakes, 19 retouched flakes, 8 scrapers, 11 Levallois flakes, 13 cores, 6 roughouts, and 16 miscellaneous artefact), the majority (76%) of the material documented from this region. These totals have been modified where necessary on the basis of a recent archaeological watching brief undertaken by P. Harding (1998) of Wessex Archaeology at the Halls Aggregates (South Coast Limited) extraction site at Dunbridge.

Findspot	Description	Geology	Archaeology
St. Mary Bourne, Hampshire	Vicarage garden	Valley Gravel	1 biface
Longparish, Hampshire	Cottage End, large gravel pit	Higher Terrace Gravel	1 biface (tip), 2 flakes
Andover	Andover Town	Valley Gravel (River Anton)	1 biface
Wherwell, Hampshire	Fullerton, near the station	Gravel on Chalk	1 biface
King's Somborne, Hampshire	Yew Hill	Terrace Gravel (River Test)	9 bifaces
Mottisfont, Hampshire	Kimbridge. Gravel pits east of Dunbridge Lane	Higher Terrace Gravels (T3 or T4)	77 bifaces, 3 roughouts, 1 core, 2 flakes, 3 retouched flakes
Michelmersh, Hampshire	Near Brook Farm	Higher Terrace Gravel	Flakes and scrapers (unspecified)
Romsey Extra, Hampshire	Chivers Gravel Pit, also known as Cupernham Pit or Abbotswood	Terrace Gravels (T4 and T5)	100 bifaces (minimum), 11 flakes, 5 retouched flakes, 3 Levallois flakes, 2 miscellaneous
Romsey Extra, Hampshire	Belbin's Pit	Terrace Gravels (T4)	200 bifaces (minimum), 3 flakes, 5 retouched flakes, 3 Levallois flakes, 1 miscellaneous
Romsey Extra, Hampshire	Test Road Gravel Pit	Terrace Gravels (T4)	100 bifaces (minimum), 6 flakes, 5 retouched flakes, 3 roughouts, 5 miscellaneous
Romsey, Hampshire	Mile Hill	Terrace Gravels (T4)	11 bifaces
Romsey Extra, Hampshire	Great Woodley Farm. Field next to Dibden Building Site = Ganger Farm	Terrace Gravels (T5)	5 miscellaneous
Romsey Extra, Hampshire	South of Ganger Wood	Terrace Gravels (T5)	1 biface
Romsey Extra, Hampshire	Luzborough Gravel Pits. One also known as Webb's Pit	Terrace Gravels (T4)	28 bifaces, 1 flake, 2 retouched flakes
Romsey Extra, Hampshire	Mountbatten School	Terrace Gravels (T4)	2 bifaces, 5 flakes
Mottisfont, Hampshire	Dunbridge Hill	Higher Terrace Gravels (T5 or T6)	1000 bifaces (estimate), 5 Levallois flakes
Mottisfont, Hampshire	The Ready Mixed Concrete Gravel Pit, Dunbridge Hill (immediately south and east of earlier workings)	Higher Terrace Gravels (T5 or T6)	43 bifaces, 102 flakes, 3 scrapers, 12 cores, 3 miscellaneous
Mottisfont, Hampshire	Dunbridge, Hatt Hill	Higher Terrace Gravels	1 biface
Romsey Extra, Hampshire	Gravel Pit at top of Cupernham Lane	Terrace Gravels (T4)	5 bifaces
Romsey Extra, Hampshire	Stanbridge	Terrace Gravels (T7, T8)	5 bifaces

Table 65: River Test valley findspots with secure river gravel contexts (after Wessex Archaeology 1993a: 81–91; Harding 1998)

Currently very little of this archaeology has been dated, although Bates and Wenban-Smith (English Heritage (ALSF) Project 3279) are presently sampling selected terrace sediments of the River Test for dating using the optically stimulated luminescence and amino acid geochronology methods. It is anticipated that these results will be of considerable importance and their publication is awaited with interest. Although Bridgland (1996, 2001) has applied his geochronological models to the river terraces of the Solent region, this work focused upon the deposits associated with the Solent River itself, in the areas of Bournemouth and the southern New Forest. Hosfield (1999) tentatively suggested a marine isotope stage 8 age for the terrace 6 gravels of the River Test, based on the highest (oldest) presence of Levallois material in the Dunbridge deposits.

3.3 Population Models

3.3.1 The River Axe Valley

Fundamental to the population modelling methodology of Ashton & Lewis (2002) is the presence of a long, well differentiated and chronologically discrete terrace sequence, and the presence of archaeological materials within at least some (if not all) of the associated deposits. As outlined above (Section 3.1), the first of these conditions (and by inference the second as well) is not met by the current understanding of the River Axe valley. As presently mapped there are relatively few distinct terrace features in the valley, and there is no clear sequence of terrace landforms and deposits, in the manner of the Thames (Bridgland 1994) and the Solent River (Bridgland 2001). For example the base of the fluvial sands and gravels sequence at Broom lies several metres below the current floodplain of the Axe. Recent OSL dates from the upper parts of the sequence suggest that these deposits date to MIS-7 and MIS-8, yet there is no current evidence in the remainder of the valley for terrace landforms and deposits that are either older or younger than these sediments. This problem could potentially be resolved in future by an expanded OSL sampling programme, dating the implementiferous deposits at Chard Junction and Kilmington for example. At the current time however, it is not possible to develop a long-term geochronological framework for the sediments of the Axe valley, and therefore the methodology of Ashton & Lewis (2002) cannot be applied.

Moreover, the archaeology of the river valley is predominantly restricted to a single location (the Broom pits), and is therefore not a regional data set in the manner of the material from the Middle Thames valley (*ibid.*). This distribution is an extremely interesting phenomenon and requires further investigation, but does limit the use of the data as the basis for a regional investigation of population trends. As it stands, any model would essentially be a site or findspot-based approach, since the only location within the Axe valley where the stratigraphical superposition of lithic artefacts can be demonstrated (within fluvial sediments) is at Broom. However, these data should not be extrapolated as a population proxy for the entire valley for two key reasons:

- Current geochronological resolution is insufficient for confidently assessing the relative ages of the different sedimentary units (lower gravels, middle beds, and upper gravels) within the sequence.
- Despite the excellent records of C.E. Bean (see Chapter 4), the proportion of the artefact assemblage that can be accurately provenanced to different sedimentary units is too small to act as the basis of a representative population model.

3.3.2 The River Test Valley

By contrast, the archaeology of the River Test valley does lend itself to a regional population modelling approach. Nine distinct terrace landforms and their associated deposits have been mapped by the British Geological Survey (terraces 1 through 9), of which the sediments associated with terraces 4, 5, 6 and 8 have yielded Lower and Middle Palaeolithic artefacts, albeit in varying numbers (Section 3.2). Unfortunately these terraces have not yet been either absolutely dated or placed within a climate-driven model of terrace development, as pioneered by Bridgland (1994) for the River Thames. Therefore the individual terrace units are adopted as distinct geochronological features, and it is argued that their formation would have occurred in response to the major interglacial/glacial climatic cycles of the Pleistocene. Their archaeological content suggests that they all date to the Middle Pleistocene (based on the presence of bifaces in all of the deposits), and it is assumed that none of the terrace units are older than MIS-13, which is supported here as a conservative earliest date for the hominid occupation of Britain. Terraces 8 through 4 are therefore adopted as a series of distinct units which provide a relative chronological framework through which to examine change through time in the quantity of archaeological material. The framework is ordered on the basis of terrace height, from highest (oldest) to lowest (youngest).

Following Ashton & Lewis (2002), this model makes a number of assumptions:

- That the artefacts occurring within the fluvial deposits represent activities from a broad area over a defined length of time. It is assumed that the artefacts were broadly contemporary with their sedimentary units, although the problem of vertical re-working was also acknowledged with respect to the interpretation of the results.
- That collector bias was limited, given the localised focus of the study upon a relatively small river system (the River Test is *c.* 35 km in length between its source and the most southerly point of the study area at Romsey).
- The documentation of aggregates quarrying until the early-1990s, thus recognising all manual and industrial extraction activity that was both contemporaneous with antiquarian collecting and with more recent watching brief activity.
- Bifaces and Levallois artefacts were utilised as a proxy for artefact discard rates, reflecting the selective collection of artefacts during the 19th and early 20th centuries, and the particular focus of antiquarians upon bifaces. The inclusion of Levallois artefacts was used to compensate for the lower prevalence of bifaces during the Middle Palaeolithic, although it was acknowledged that these artefacts are not direct equivalents.
- Artefact discard rates were adopted as a constant proxy for population sizes, while recognising that a number of uncontrolled factors were at play, including changes in raw material availability, artefact function, and increasing reliance on other raw materials.

The bifaces and Levallois artefacts from the River Test valley were therefore divided into a series of relative chronological units, following the river terraces of the Test (Figure 248). These terraces are assumed to represent a simple succession through time from top to bottom (following Bridgland 1994). The chronological duration of the deposits associated with each terrace unit was assumed to be a constant, given the current absence of chronological frameworks (see above). The artefact assignments to the individual terrace units (Table 66) were based on the Southern Rivers Palaeolithic Project mapping and report (Wessex Archaeology 1993a) and more recent documents (Harding 1998; Hosfield 1999). Artefact densities were standardised by terrace (surface) area, areas of urban growth between 1861 and the early 1990's, and quarrying extents prior to the early-1990's (Table 67). These two last categories are intended to account for the fact that not all of the mapped terrace sediments will have been exposed for the collection of artefacts.

The resulting standardised artefact densities were then utilised to demonstrate general trends in the hominid populations of the River Test valley through time (Figure 249–Figure 251). Unlike the data from the Middle Thames valley (Ashton & Lewis 2002) there is no clear pattern of increasing or decreasing artefact densities through time. The main features are the primary peak in artefact density associated with terrace unit 6, and the secondary peak associated with terrace unit 4. This could be interpreted both as evidence for a relatively large population in the time period associated with terrace unit 6, and a smaller population associated with terrace unit 4, and for very small populations associated with the other terrace units. Overall, this could be interpreted as evidence for highly sporadic colonisation of the River Test valley over the long-term.

However, such an interpretation ignores the problems of vertical re-working and this is a serious issue given that the major artefact densities occur in the middle and the bottom of the modelled terrace sequence, and could therefore have been derived from higher and older deposits (e.g. terraces 7 and 8). The potential problem is indicated by the relatively poor preservation of terrace 8 deposits (0.40 km^2), although it is perhaps significant that the terrace 7 deposits (which have yielded no artefacts) are relatively well preserved (2.04 km^2). Moreover, the main implementiferous deposits (in the areas of Romsey and Dunbridge) lie immediately downstream of the chalk stream stretch of the River Test. Bridgland (1985) and Allen & Gibbard (1993) have stressed the poor preservation of terraces in the narrow, chalk stream valleys of southern England, and Hosfield (1999) has explored this geomorphological trend with respect to vertical and horizontal artefact re-working. It is therefore possible that large quantities of the archaeological material occurring in the deposits south of Mottistone (the boundary between the

Terrace Unit	Findspots
T4	Mottisfont (Kimbridge); Romsey Extra (Chivers Gravel Pit); Romsey Extra (Belbin's Pit); Romsey Extra (Test Road Gravel Pit); Romsey Extra (Mile Hill); Romsey Extra (Luzborough Gravel Pits); Romsey Extra (Mountbatten School); Romsey Extra (Cupernham Lane)
T5	Romsey Extra (Great Woodley Farm); Romsey Extra (south of Ganger Wood)
T6	Mottisfont (Dunbridge Hill); Mottisfont (The Ready Mixed Concrete Gravel Pit);
T7	-
T8	Romsey Extra (Stanbridge)
Unknown	St. Mary Bourne; Longparish; Andover; Wherwell; King's Somborne; Michelmersh; Mottisfont (Hatt Hill, Dunbridge)

Table 66: assignment of River Test valley findspots to terrace gravel units (after Wessex Archaeology 1993a; Harding 1998)

Terrace	No. of artefacts (Bifaces and Levallois pieces)	Terrace area (km^2)	Artefact density/km^2	Urban growth 1861-1993 (km^2)	Artefact density over area of urban growth	Quarrying until 1993 (km^2)	Artefact density over area of quarrying
T8	5	0.40	12.50	0.05	100.00	0.00	-
T7	0	2.04	0.00	0.01	0.00	0.19	0.00
T6	1048	1.56	671.79	0.06	17466.67	0.07	14971.43
T5	1	1.50	0.67	0.22	4.55	0.36	2.78
T4	529	2.88	183.68	0.90	587.78	0.90	587.78

Table 67: standardised artefact densities for the River Test valley (after Ashton & Lewis 2002: Table 1)

Cretaceous chalk and the Tertiary sands and clays) have been derived from the upper reaches of the Test, and cover a wider span of chronological ages than just those associated with terrace units 4 and 6.

In conclusion, the application of the Ashton & Lewis' (2002) population modelling methodology to the regional data from the River Test valley is partially successful. It has suggested chronologically-discrete population peaks, interspersed with periods of extremely limited presence. However, the application of the model is problematic due to current weaknesses in the data and the nature of the results, specifically:

- The absence of an absolute geochronological framework, although current and future research should resolve this issue (this would benefit research by providing a chronology not only for the numbered terraces units used here but also for those deposits generically classified as river and terrace gravels).
- The patterns in the data (with artefact concentrations in the middle and bottom of the sequence) which highlight the potential for vertical re-working and recommend caution in the interpretation of any patterns.

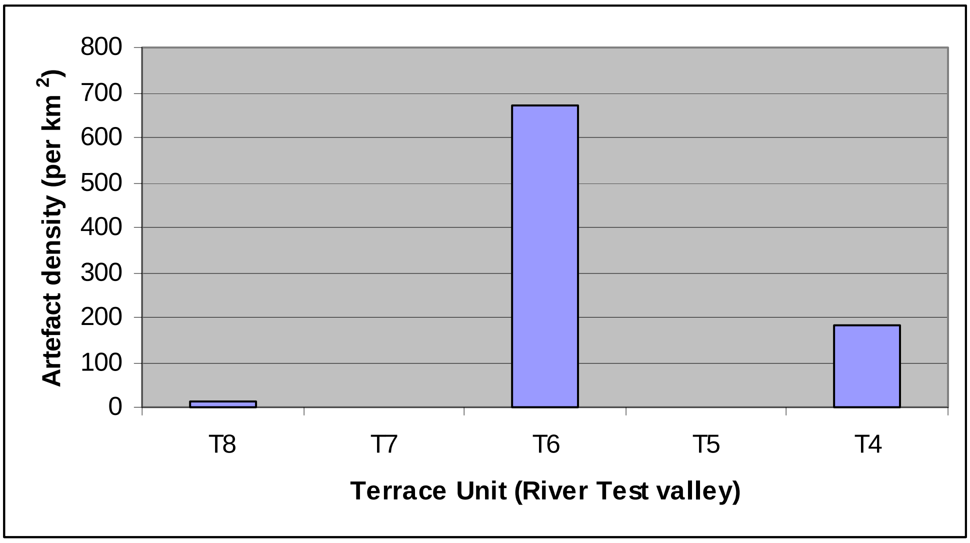

Figure 249: artefact densities (per km²) by terrace unit, in the River Test valley

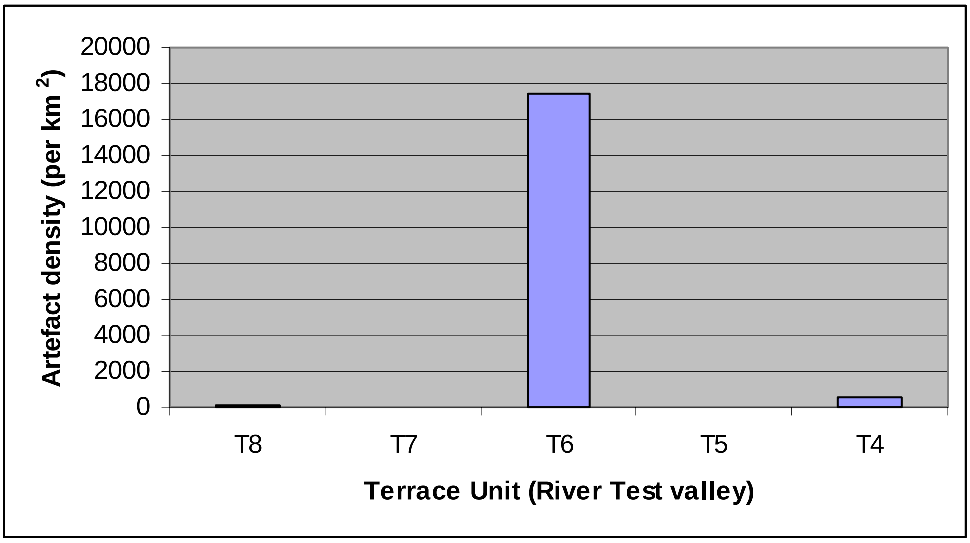

Figure 250: artefact densities (per km²) by terrace unit (standardised for variable quantities of urban expansion), in the River Test valley

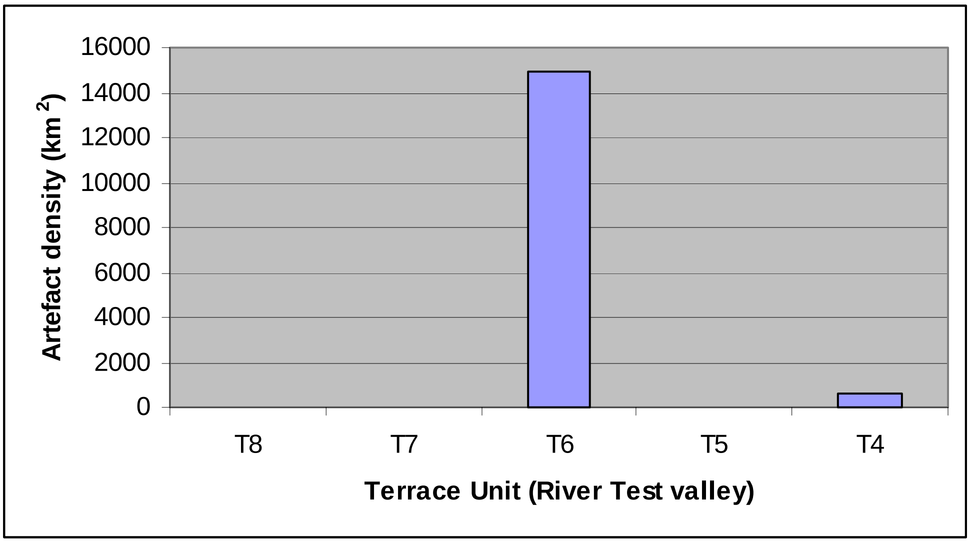

Figure 251: artefact densities (per km^2) by terrace unit (standardised for variable quantities of aggregates extraction), in the River Test valley

3.4 Island Britain Models

White & Schreve's (2000) biogeographical framework of human colonisation, settlement and abandonment of Britain during the Middle and Late Pleistocene is summarised above (Section 2.2). Central to the model are the impacts that Britain's fluctuating island/continental peninsular status would have had upon the opportunities for hominid colonisation and settlement. Based on sedimentological and palaeoenvironmental data sets from sites across southern Britain and northern France, a biogeographic framework outlining periods of insularity and peninsularity was established. This framework comprises three major phases (and 5 sub-phases) within each of the Middle Pleistocene's glacial/interglacial cycles, and the responses of hominid populations during each were modelled (*ibid*; Section 2.2). The model stresses the non-continuous nature of the hominid occupation of Britain, and proposes that repeated, separate, colonisation events may go some way towards explaining the lithic industrial variation preserved within the British Palaeolithic record.

Within the Island Britain model, the Clactonian is associated with the initial phases of re-colonisation from the non-biface regions of Germany, the Lowlands and Eastern Europe during MIS-11 and MIS-9. The Acheulean is considered to represent a subsequent colonisation pulse from the biface zones of Italy, Spain and France, occurring later within the interglacials. The model also argues that the severing of cultural and genetic contacts between Britain and the continent during island phases could lead to insular and endemic developments in technological practice, identifiable in the archaeological record as distinctive regional and sub-regional traditions of biface manufacture. This is illustrated by a discussion of the occurrence of twisted ovates, the temporal concentration of which in MIS-11 and early MIS-10 within the British record is argued to represent endemic cultural development during a period of island isolation (*ibid.*).

The Island Britain model addresses specific regional research questions, utilising the character and preservation of the Thames terrace sequences. The applicability of this framework to other regional data sets is examined below, through case studies of the River Axe and the River Test.

3.4.1 The River Axe Valley

a) The Clactonian and Island Britain

The apparently limited development and/or preservation of Pleistocene fluvial terraces and sediments within the Axe valley currently prohibits the development of a system wide geochronological framework, within which the six fluvial findspots of secure provenance (Table 63) could be correlated. This hampers even the relative dating of all the findspots within the valley that have not been directly dated in the manner of the Broom OSL program (Chapter 3). Additionally, the Lower and Middle Palaeolithic record of the Axe valley is dominated by the single (Acheulean) locality of Broom, and while other documented findspots in the region have produced artefact assemblages, these have typically been small (fewer than ten artefacts) and characterised by bifaces. While flake material has been recovered from several of these findspots, no assemblages that have been defined as Clactonian have been recovered from within the Axe valley. This is unsurprising, both because of the traditional south-eastern England distribution of Clactonian assemblages (e.g. Roe 1981; White 2000) and the difficulties of defining the Clactonian:

"the presence of a single handaxe or group of thinning flakes will automatically warrant an Acheulean designation, [however] *few would regard a site as Clactonian based on a small collection of hard-hammer flakes and cores."*
(White & Schreve 2000: 17)

In this regard, it may be worth noting that the small assemblage of artefacts recovered from the Kilmington findspot contains only retouched and non-retouched flake material, and therefore may not be demonstrably Acheulean in character. As this material has not been examined during the current research, it is not known whether these flakes are biface thinning flakes or hard hammer flakes, and it is not possible to ascertain the technological affinities of this assemblage. In general therefore, the overwhelming character of lithic technology in the Axe valley is Acheulean, with very limited evidence for non-biface technologies.

In conclusion, the findspot distribution, limited geochronology, and current understandings of the technological composition of the Lower and Middle Palaeolithic record of the Axe valley prohibits the application of the Clactonian component of the White & Schreve (2000) Island Britain model.

b) Bifaces and Island Britain

Any discussion of biface traits in the Axe Valley data is inevitably restricted to the material from Broom, as the remaining assemblages are too small to support any robust conclusions. The specific example of endemic biface traits in the Island Britain model concerns the evidence for twisted profiles on ovate forms. There are no pronounced twisted profiles in the Broom assemblage (see chapter 4 for further details). Given the age of the sediments (MIS-7 and MIS-8) this is perhaps unsurprising, if White & Schreve's (2000) assignment of twisted ovates to MIS-11 is followed.

However, the Broom assemblage is characterised by asymmetrical forms, which comprise 24% (n=232) of the recorded assemblage (n=977). These forms occur on all the types of raw materials from which the Broom artefacts were produced, and are associated with a wide range of types. This pronounced asymmetry is therefore not considered to be a product of raw material constraints, and there is also no supporting evidence that this pronounced asymmetry is related to the use of particular forms of blanks in biface production (e.g. side-struck flakes as suggested by Goodwin (1929)). The occurrence of the pronounced asymmetry on a wide range of biface types (shapes) indicates that it was not associated with a single form, and was therefore unlikely to have had a specific, utilitarian function. However, this interpretation does make the assumption that different biface forms were used for different utilitarian purposes, which has not yet been proven in Palaeolithic research (Winton 2001). Overall therefore, the data suggests that there is not a solely mechanical factor behind the production of bifaces with this pronounced asymmetry. It is not possible to rule out a functional element to the production of such asymmetrical artefacts, however it is suggested that these distinctive bifaces could also reflect the development of a highly specific knapping tradition, as argued for twisted ovates by White & Schreve (2000).

However, there are a number of issues which require further consideration with respect to whether there is evidence for the development of endemic traditions during periods of isolation:

- Do the proportions of pronounced asymmetrical bifaces at Broom (24%) allow the assemblage to be discussed in terms of the expression of a distinctive tradition of manufacture? White (1998a: Table 14.1) stresses that twisted ovates dominate either the entire assemblage or its ovate component at the sites of Swanscombe (Upper Loam, Barnfield Pit — 22%), Swanscombe (Rickson's Pit — at least 15%), Wansunt Pit (28%), Bowman's Lodge (27–31%), Elveden (36–40%), Allington Hill (46%), Hitchen Lake Beds (45% of the ovate element only), and Foxhall Road (40% of the ovate element)[12]. The Broom data clearly fit within the range of values from these sites.

- If this is a distinctive manufacturing tradition, can it be associated with a period of isolation? The dates from Broom suggest that this is possible, since at least part of the sequence appears to date to the MIS-7 interglacial. However, others parts of the sequence appear to date to the MIS-8 glacial, when Britain had a peninsular status. Since the stratigraphically-provenanced proportion of the Broom assemblage appears to indicate that asymmetrical bifaces occur throughout the sequence, this would suggest that the production of these artefacts did not solely occur as a result of endemic technological developments during a period of isolation.
- It is also not yet known whether this manufacturing tradition occurs in comparable frequencies in assemblages dating to other periods of the Middle Pleistocene. This is a clear avenue for further research.
- Finally, it is also not yet known whether assemblages dominated by this manufacturing tradition are geographically restricted to the southwest region, or whether they occur throughout Palaeolithic Britain.

In conclusion, the data from Broom in the Axe valley do permit an exploration of the Island Britain's model of endemic developments in biface traits, in response to periods of geographical isolation. The above discussion highlights an extremely interesting pattern in the Lower Palaeolithic record, and also illustrates how the concepts of the model can be applied to new regions, new assemblages, and different patterns of biface traits.

3.4.2 The River Test Valley

a) The Clactonian and Island Britain

The River Test valley provides the opportunity to test the applicability of the Clactonian component of the White & Schreve (2000) Island Britain model in a region of well-preserved Pleistocene fluvial terrace aggradations. Unlike the Axe valley, there is an extensive sequence of terrace landforms, particularly in the area south of Mottistone (Section 3.2). Unfortunately, the deposits are rather understudied and there is currently no widely accepted geochronological framework. Dating of the deposits and the terraces is therefore relative, based on the principle of increasing age with altitude.

While Lower and Middle Palaeolithic findspots occur in varying proportions within most of the River Test terrace deposits (mapped by the BGS), none of these assemblages has been specifically designated Clactonian (Table 65). The region is typified by the occurrence of biface dominated assemblages. However, as at Kilmington in the River Axe valley, flake assemblages do occur. At Near Brook Farm, Michelmersh, an assemblage comprising only of flakes and retouched flakes (scrapers) has been recovered from the Higher Terrace Gravels. While this material has not been examined within the scope of this project, from the available evidence the materials cannot be automatically designated as Acheulean. The recovery of this flake assemblage from the Higher Terrace Gravel may offer an intriguing suggestion of the presence of a non-biface component within the Palaeolithic record of the River Test valley, although this cannot be explicitly demonstrated at the current time.

In conclusion therefore, the findspot distribution, geochronological frameworks, and the current understandings of the technological composition of the Lower and Middle Palaeolithic record of the River Test valley does not allow for the application of the Clactonian component of the White and Schreve (*ibid.*) Island Britain model.

[12] The ranges in some of the estimates reflect differences between the observations of Roe (1968) and White (1998a).

b) Bifaces and Island Britain

Unlike the River Axe valley, there are a number of assemblages in the River Test valley from which patterns in biface assemblages can be investigated. Bifaces were examined from four assemblages: Yew Hill, King's Somborne (23 sampled bifaces[13]); Kimbridge, Mottisfont (17 sampled bifaces); Belbin's Pit, Romsey Extra (15 sampled bifaces); and Dunbridge Hill, Mottisfont (170 sampled bifaces). As with the River Axe data, there was no evidence in any of these assemblages for bifaces with pronounced twisted profiles. There was also no evidence for pronounced asymmetry in the manner of the Broom assemblage. The frequency of different Wymer biface types within the assemblages is not discussed, since:

"Gross measures of shape and technical sophistication are inadequate as these are too often reliant on factors such as raw material packages and basic functional requirements."

(White & Schreve 2000: 20)

It is possible that variations in tip type could be explored in primary context assemblages, although there is still considerable uncertainty as to the functionality of biface tips and the significance of variation in tip types and styles. However, the vulnerability of bifacial tips to breakage and damage during fluvial transport episodes limits the value of these data when dealing with secondary context assemblages, and they are therefore not analysed here (see chapter 4 for further discussion of this point).

Therefore there was no evidence for the development of distinctive manufacturing techniques within any of the secondary context assemblages that were examined from the River Test valley region. This would appear to indicate an absence of endemic technological traditions, as classified by White & Schreve (2000), in the area of the River Test during the time periods represented by the assemblages examined. Of course it must be stressed that this apparent absence may reflect our inability to identify those:

"Lesser features which can be demonstrated to vary independently of raw materials, which even if serving a specific function were clearly not used by all hominid populations under similar circumstances"

(White & Schreve 2000: 20)

3.5 Gamble's Social Model

Although many elements of Gamble's (1999) locales, rhythms and regions model are untestable with regional, secondary context data we have identified the following aspects of the model which can be explored:

- The proposal of generic rather than specialist skills, and its implications for the stability of Pleistocene populations.
- The concept of a social technology, constrained by local and immediate circumstances and creating bi-directional lithic artefacts (reflecting the constant interplay of material constraints, needs and opportunities, and technical skills), rather than predetermined, uni-directional products (driven by mental templates or production blueprints).
- The notion of paths and tracks as the spatio-temporal structures through which individuals move and act, and along which encounters and gatherings occur, and social occasions and places gradually become entrenched in the archaeological record.
- The framework of the landscape of habit, within which daily action occurs and which can be traced archaeologically through evidence of raw material transfers and usage.

[13] Although only 9 bifaces are listed in the Southern Rivers Palaeolithic Project (1993a), Chambers' (in prep.) doctoral research has documented 23 bifaces.

3.5.1 The River Axe Valley

a) Population Patterns

As discussed above (Section 3.3.1) there is no evidence for population fluctuations over time in the Axe valley, due to the poor geomorphological preservation of distinct terrace landforms and their deposits. Therefore the implications of generic and specialist skills (e.g. generic skills resulting in the ebb and flow of population in northern latitudes) cannot be tested from these data.

b) Social Technology

The biface data from Broom can be viewed in two ways. On one hand, there is evidence for considerable variation in the typology of the assemblage with respect to overall biface form (Figure 252), with significant proportions of ovate, cordate, sub-cordate and pointed types (and their various intermediate forms). Since none of these types show any preference for specific raw materials (Chapter 4), these data could be interpreted as suggesting a relatively bi-directional and fluid approach to tool-making. They are certainly not suggestive of the imposition of standardised mental templates or blueprints, given the highly unstandardised nature of the assemblage within the individual categories of the classificatory framework used in the analysis (see chapter 4).

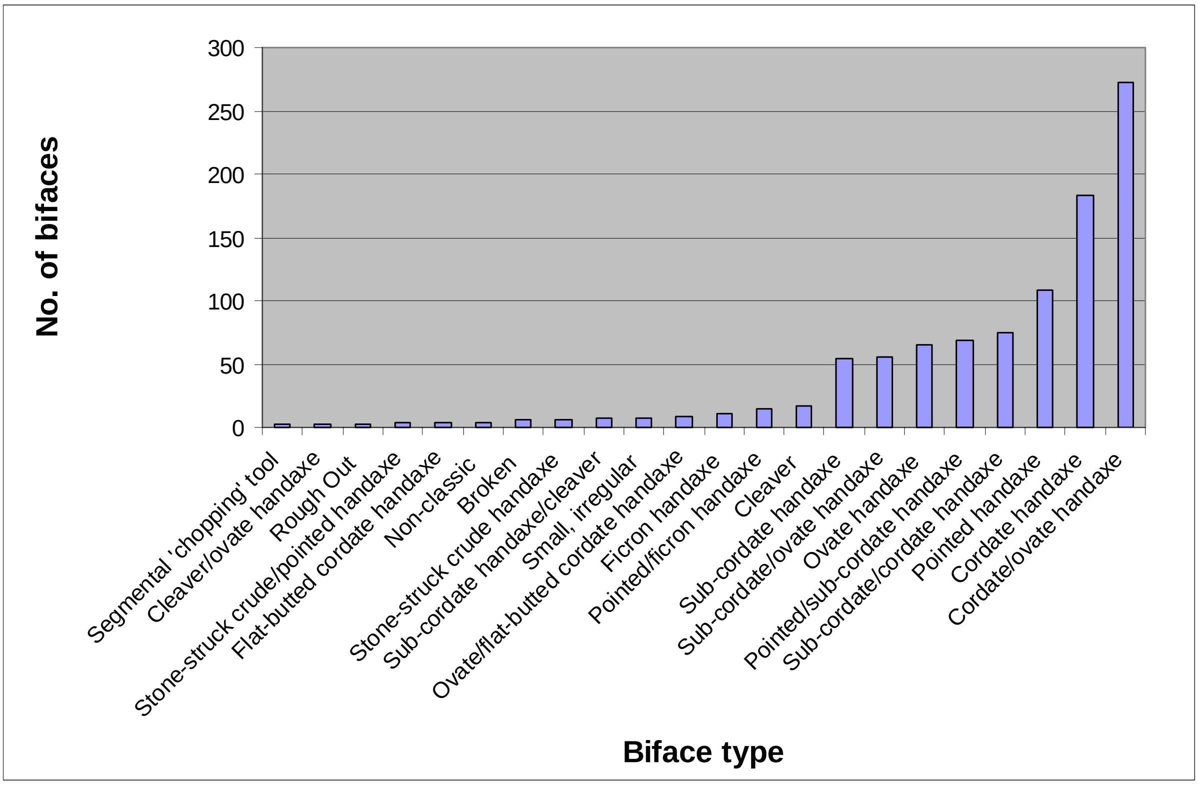

Figure 252: biface types present in the Broom assemblage (n=977)

However, moving beyond this classificatory framework it is clear that the assemblage is characterised by bifaces with pronounced asymmetry (24% — see Section 3.4.1). The distribution of asymmetrical bifaces across typological and raw material categories suggests that the asymmetry was not an unintentional by-product of particular manufacturing processes. This would suggest that the production of the asymmetrical forms was a deliberately sought after outcome of the knapping process. This interpretation of the data is less supportive of a model of bi-directional approaches to biface manufacture, and is more indicative of the imposition of notions of a particular outcome prior to the commencement of the process. This interpretation can be upheld irrespective of whether asymmetrical bifaces were being produced for utilitarian or social purposes.

In conclusion, it is possible to explore the concept of a social technology through typological patterning within derived, secondary context biface assemblages. However, considerations of assemblage derivation in time and space should always be paramount, since the above discussions make the assumption that the Broom assemblage represents a relatively discrete spatio-temporal entity.

c) Regional Spatial Patterning

In the context of the wider region of south-west England, the concentration of archaeology in the Axe valley suggests that this was a focal point in the landscape, through which hominid paths and tracks regularly crossed. However, this region has been severely under-studied in contrast to the other Pleistocene rivers of southern England (e.g. Bridgland 1994; Wenban-Smith & Hosfield 2001), and this apparent pattern may therefore be due to an absence of evidence in areas other than the Axe valley. Further work is therefore vital to validate this potential pattern. If it is genuine, this distribution could reflect the geographically marginal status of the south-west region at a north-westerly tip of the Middle Pleistocene world, and the proximity of the Axe valley to the headwaters of the Solent River (especially the modern day River Frome), a distance of approximately 10–15 km (Figure 253), well within the scale of Gamble's (1999) landscape of habit (see below). The potential role of the low sea-level stand Channel River network as a means of access into the Axe valley also requires further consideration.

However, within the Axe valley it is much more difficult to discuss local paths and tracks and the implications of the large Broom assemblage for interpretations of spatial patterning in hominid behaviour (e.g. the development of places and social occasions through repetitive encounters and gatherings). This is because the artefacts are fluvially derived and spatial information is therefore highly blurred, and the material is also severely time averaged. Therefore, to interpret the Axe valley and Broom as evidence of paths running up the valley floodplain, leading into and away from a significant place at Broom is to ignore the realities of the data from secondary context assemblages. The Broom assemblage *could* represent a repeatedly visited place that was the foci of social occasions, but it could also be the debris of a thousand gatherings, swept from the paths and tracks of the Axe valley during flooding and re-deposited at the sedimentary cache of Broom. Therefore, while apparent spatial clusters of artefacts appear in the archaeological record, it is not possible to demonstrate whether these clusters reflect places (e.g. locations that were repeatedly visited over generations) or the simple, re-worked debris of path and track gatherings. This is a fundamental issue of data resolution and scale. Regional, secondary context data can be used to illustrate spatial patterning at a broad level (e.g. the concentration of hominid activity in the river valleys of the Thames, the Solent River and the East Anglian basin — Figure 253), but cannot be taken as an unmodified spatial signature of hominid behaviour in a local landscape.

d) Raw Material Usage

The most striking feature of the archaeology of the Axe valley is the intensive use of chert at Broom. Given the local geology, this is highly suggestive of the procurement and use of immediately available, local raw materials. This pattern is also supported by the overall range and proportions of raw materials employed at Broom in the production of bifaces (921 chert, 55 flint and 1 quartz), which is in-keeping with recorded geological data (Section 3.1). These trends for local raw material use are also suggested by the absence of chert artefacts in the upper reaches of the Solent River (only *c.* 10–15 km away), which lie on flint-reach chalk uplands, although the appearance of chert artefacts in the assemblages from Warsash (Southampton Water — Marshall 2001) remains enigmatic.

There is currently no specific evidence of raw material transfer distances, the condition in which raw materials were transported, and whether raw material encounters resulted in the immediate creation of archaeological debris at that point in the landscape. Nonetheless, the raw material types and proportions recorded in the Broom assemblage provide no evidence for long distance transfers. The indication is therefore of a highly local landscape of habit, with respect to raw material procurement.

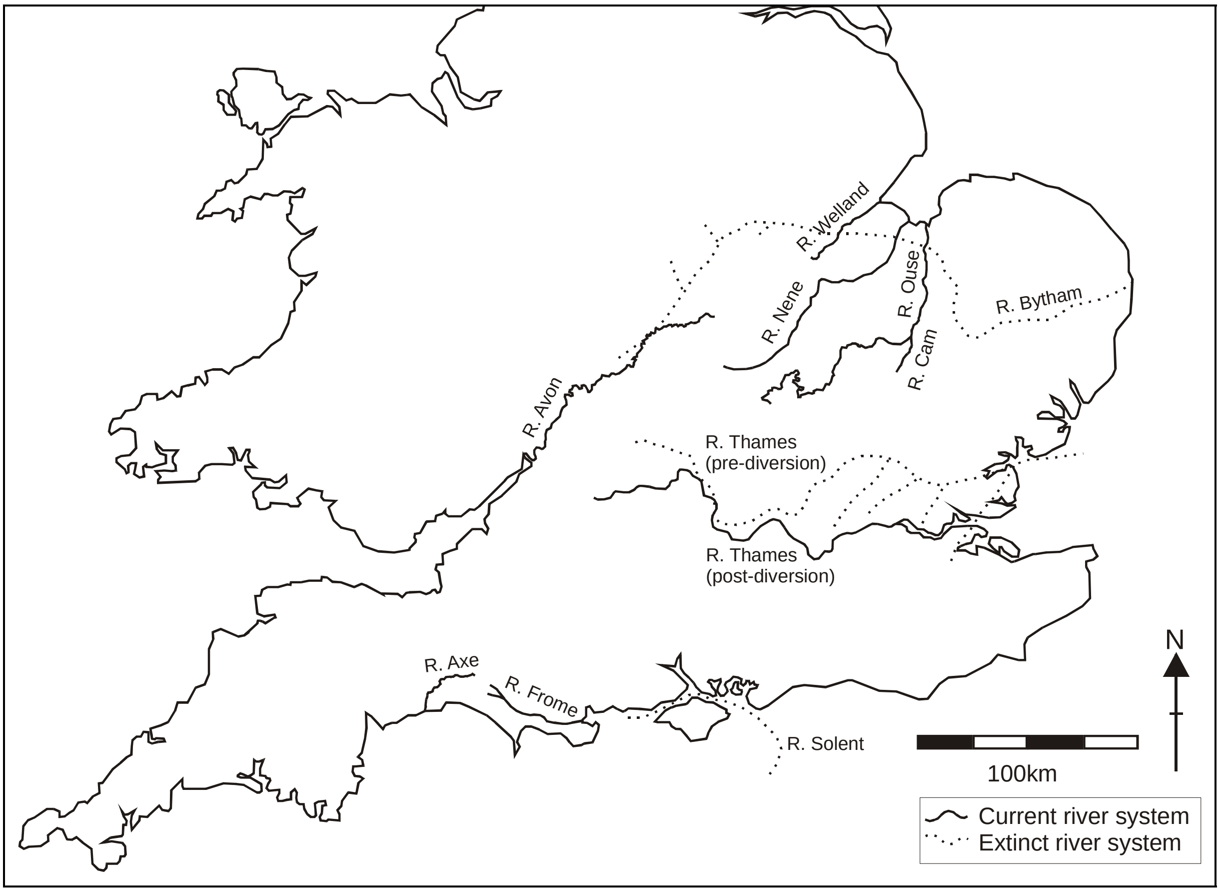

Figure 253: Middle Pleistocene river systems, including the Axe and the Frome (after Bridgland & Schreve 2001: Figure 1; Roberts et al. 1995: Figure 1; Allen & Gibbard 1993: Figures 1–3)

e) Conclusions

The archaeology of the River Axe valley does not support the wholesale implementation of the Gamble (1999) model. However, it has revealed a number of interesting patterns with respect to social technology, spatial distributions and raw material procurement. It has also indicated a number of areas for further research, including the regional distribution of Palaeolithic material and the palaeogeography of the western approaches region, and therefore re-emphasised the value of the secondary context archaeological resource.

3.5.2 The River Test Valley

a) Population Patterns

As discussed above (Section 3.3.2) there is evidence for population fluctuations through time in the River Test valley, although there are serious taphonomic issues with respect to the interpretation of the data. It is therefore recommended that the data should not be taken at face value, although the robust nature of the patterning does permit the general discussion of possible implications. The data appear to indicate a non-homogenous signature of occupation, with population peaks associated with terrace units 4 and 6, and apparently very low populations associated with the other terraces (Table 67; Figure 249–Figure 251). This pattern meets the predictions of Gamble's (1999) generic skills model, since it appears to indicate a population that ebbs and flows dramatically over time. The data suggest that the local hominid populations of the Solent River landscape (as represented by the Test valley) were either being driven to extinction during climatic downturn events or responding to the changing conditions by migration (presumably southwards).

Assuming that the terrace units equate to the marine isotope stages, the data suggest large-scale population fluctuations that occur between different stages, rather than over the course of a single cold/warm cycle. It is impossible to currently explore the causes of these patterns, particularly given the absence of an absolute geochronology for the terrace deposits. However, the patterns in the data indicate that the re-colonisation of individual regions of Britain was not inevitable during each climatic cycle (*c.f.* White & Schreve 2000), and was a discrete and distinctive process, within the context of local conditions and opportunities. This is provisionally supported by a comparison of the Test data (which suggests a fluctuating population that generally increased over time) with the Thames data (which clearly indicates population decline over the Middle Pleistocene). These contrasts may reflect their different geographical contacts with the continent during low sea-level stands, with the Thames/Rhine system linking south-eastern England to the North Sea Basin, the Low Countries and beyond, and the Channel River linking southern England to the channel plains and France. However, in order for these comparisons to be pursued further an absolute geochronology is required for the Test valley data, along with the extension of the analysis to the entire Solent River system.

Finally, it is stressed that the Test valley data may have originally indicated a far more homogenous signature, which has since been vertically blurred due to terrace deposit and artefact re-working through fluvial erosion. Detailed geoarchaeological studies are required to resolve these issues.

b) Social Technology

Unlike Broom, none of the sampled biface assemblages from the Test valley are characterised by distinctive features such as twisted profiles or pronounced asymmetry. Any assessment of technological practice can therefore only be based on the general typological characteristics of the assemblages, such as Wymer's (1968) framework for biface classification. Data from four findspots is presented: Belbin's Pit, Romsey Extra (n=14, Figure 254); Kimbridge, Mottisfont (n=16, Figure 255); Yew Hill, King's Somborne (n=22, Figure 256); and Dunbridge Hill, Mottisfont (n=168; Figure 257). In none of these cases is there clear evidence for the production of, for examples, points rather than ovates (or vice-versa), although pointed bifaces are the dominant typological form in the Dunbridge Hill assemblage. All of these bifaces were produced from flint, so it is not possible to draw any links between specific types and particular raw materials. Due to the difficulty of identifying blank forms (see the comments in chapter 4), the available data sets were also too small to analyse any potential relationships between biface form and blank type (following White's (1998b) hypothesis linking ovates to large flake blanks, and pointed forms to river cobble blanks)). At face value these data could therefore be interpreted as suggesting relatively bi-directional and fluid approaches to tool-making, resulting in the production of a range of different biface forms. The typological composition of these assemblages certainly provides no evidence for the imposition of standardised mental templates or blueprints.

However, there are two key caveats:

- The size of the sampled biface assemblage: the sample sizes for Dunbridge Hill (16.8%), Kimbridge (20.8%) and Belbin's Pit (7.0%) are all very small, especially in comparison with the comprehensive analysis of the Broom biface assemblage (81.6% (Chapter 4)). Therefore there is a possibility that these small samples are misrepresentative. Assessing the size of the Yew Hill sample was difficult, since investigation of the collections (Chambers in prep.) indicated 22 bifaces from Yew Hill, in contrast to the nine listed by The Southern Rivers Palaeolithic Project (Wessex Archaeology 1993a).
- These secondary context assemblages are derived, and therefore potentially represent an amalgamation of several individual assemblages from different sources. For example, it is hypothetically possible that the Belbin's Pit assemblage was derived from two sources, at the first of which pointed bifaces were discarded, and at the second, cordates and ovates (Figure 254). However, recent evaluations of the physical condition of the artefacts from all four assemblages have suggested that this type of interpretation is not tenable (Chambers in prep.).

Overall therefore, the biface evidence from the Test valley requires careful evaluation, due to the secondary context origins of the assemblages and the difficulty of demonstrating social technology. The data seem to suggest unstandardised approaches to tool production, but it is difficult to assess whether this is due to behavioural or taphonomic factors.

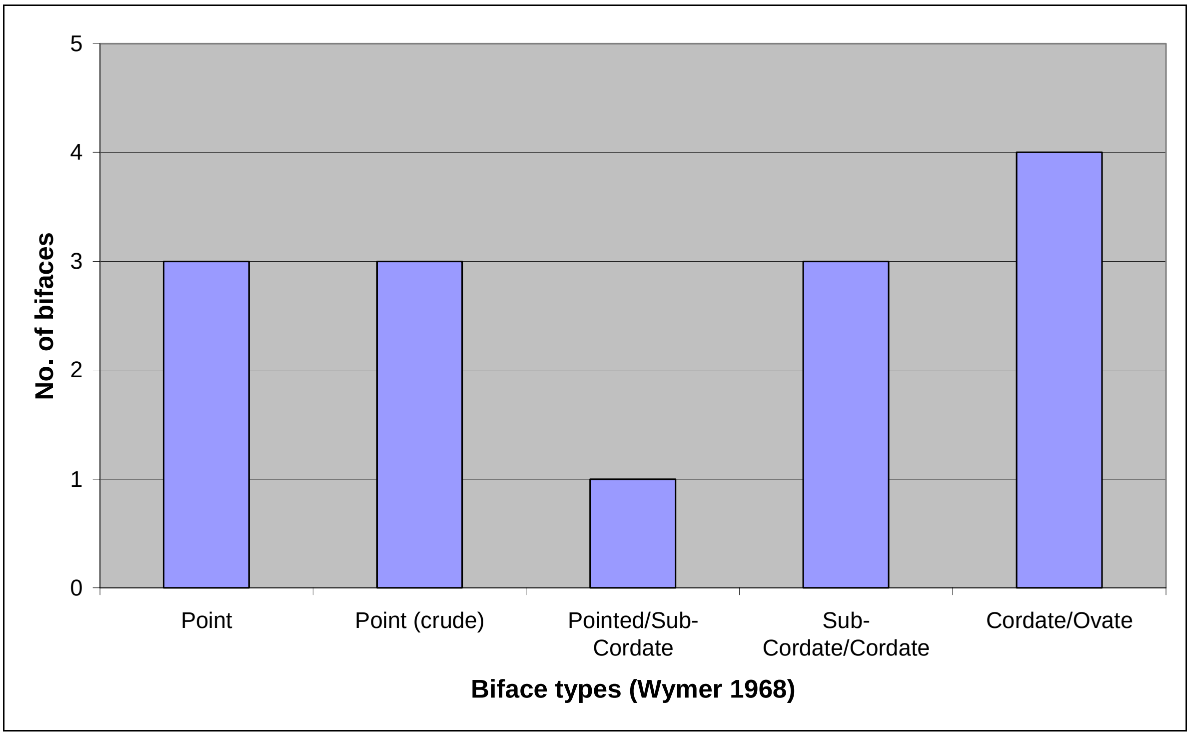

Figure 254: biface types from the Belbin's Pit assemblage sample (n=14)

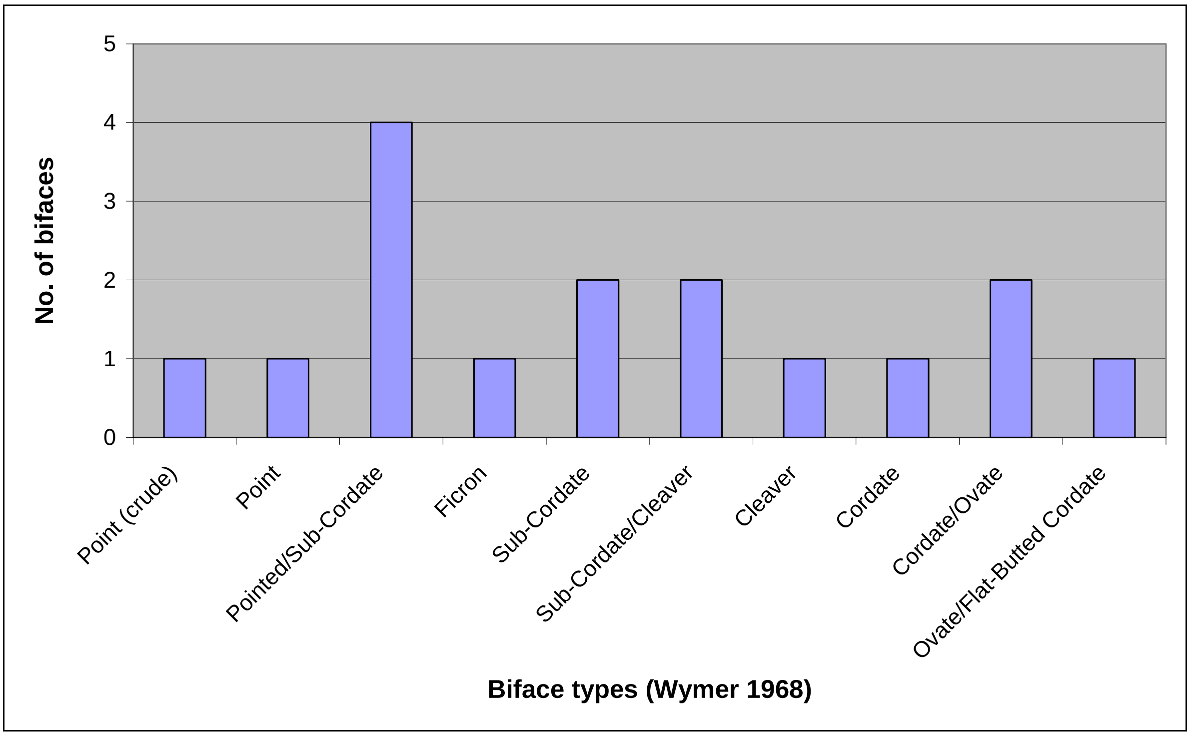

Figure 255: biface types from the Kimbridge assemblage sample (n=16)

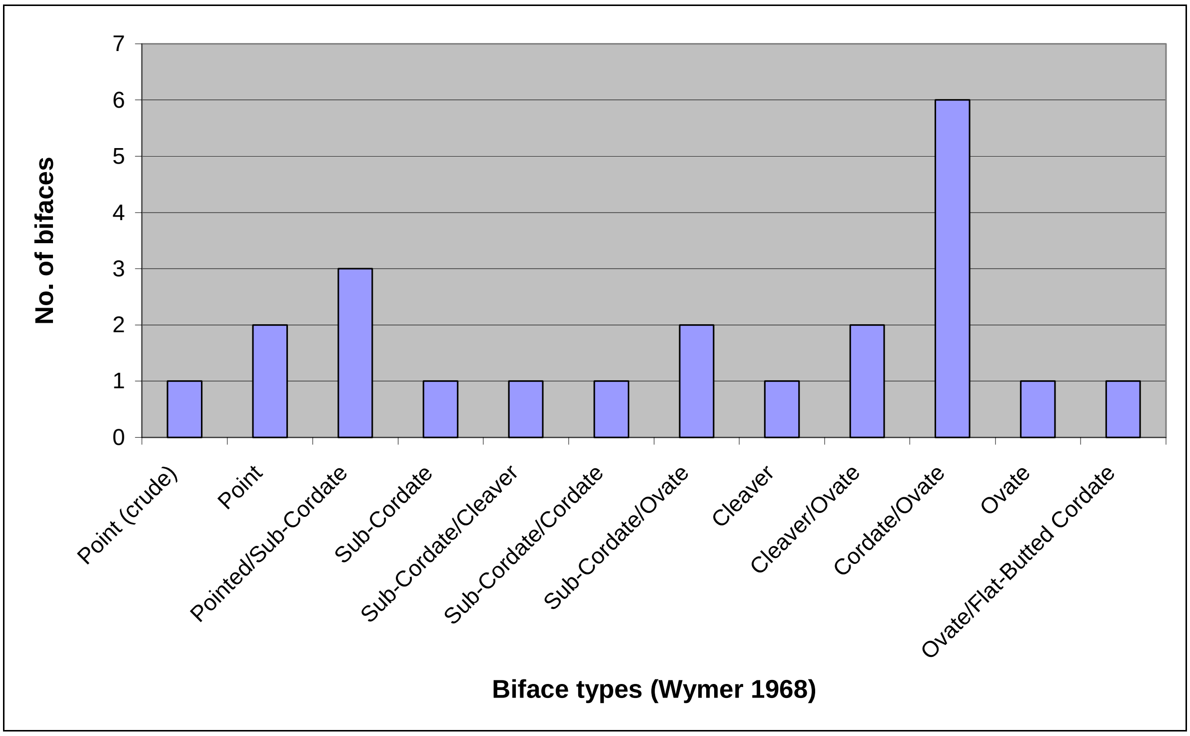

Figure 256: biface types from the Yew Hill assemblage sample (n=22)

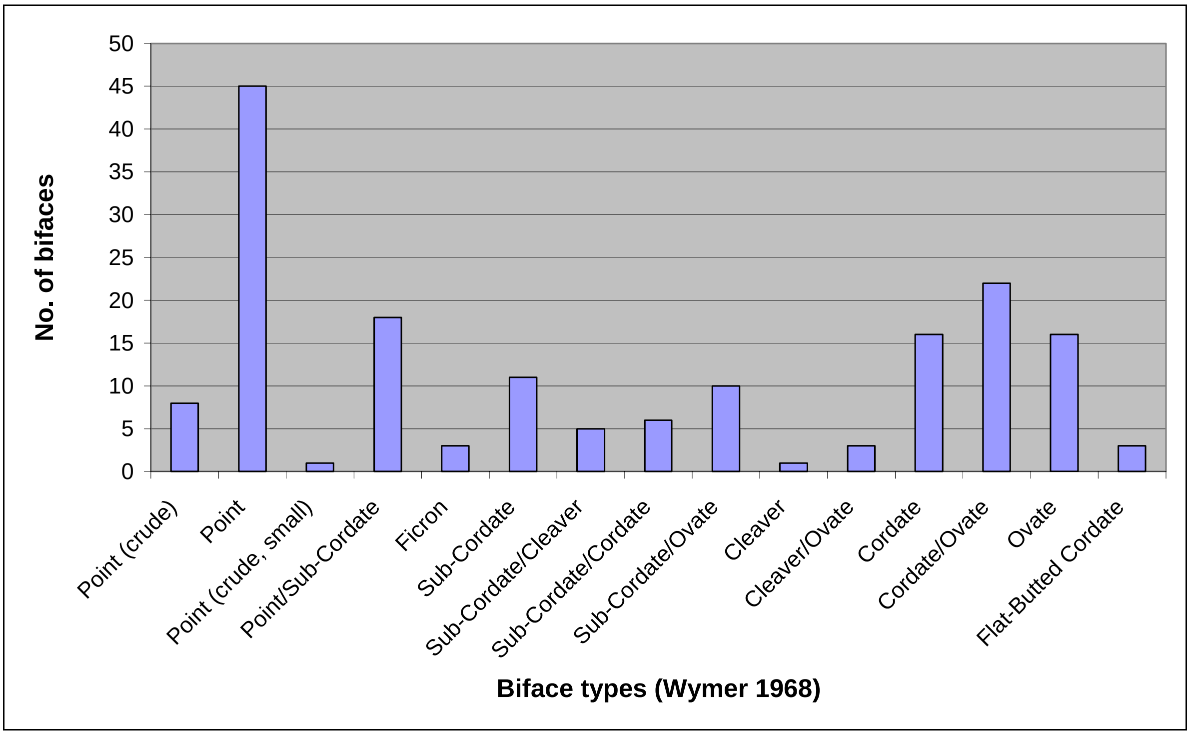

Figure 257: biface types from the Dunbridge Hill assemblage sample (n=168)

c) Regional Spatial Patterning

Unlike the River Axe, it is not possible to view the Test valley as a key focal point within the wider landscape of southern England, since it is an integrated part of the much wider fluvial and archaeological landscape of the Solent River system (Figure 258). This landscape is also bordered by the implementiferous deposits of the Sussex Coastal Plain to the east, the Upper Thames valley to the north, and clay-with-flints deposits to the north-east in the area of Basingstoke (Bridgland 1994; Roberts & Parfitt 1998; Scott-Jackson 2000; Pope 2001). Comparison of the archaeology of the River Test with other rivers in the Solent River system (e.g. the Itchen, Stour, Avon, Frome and the main Solent River) is also difficult due to the problems of deposit identification and the varying intensity of fieldwork and exposure of deposits across the region.

At a regional level of analysis therefore, the River Test archaeology can simply be seen as one component of a major hominid landscape, represented by the Solent River drainage. This is not intended to question the value of the data, but simply to emphasise that at a regional level of analysis discussing the concentration of archaeology in the Test valley is rather meaningless. Discussing the Test valley data within the context of the concentration of archaeology in the Solent River system (in comparison with the archaeology of the Upper Thames for example) is far more informative. This has been demonstrated by Wymer (1968), who stressed the distribution of the major regional concentrations of Lower and Middle Palaeolithic artefacts in England along the valleys of the Ouse (East Anglia), the Thames, and the Solent River system.

At the level of local paths and tracks the Test valley data is also problematic. Firstly, there is the issue of the fluvial derivation of the assemblages, resulting in the time and space-averaging of the archaeology. The implications of this were discussed in detail for the Axe valley data (Section 3.5.1) and are also relevant here. Indeed the issues of re-working are even more significant due to the effects of the chalk bedrock upon river terrace preservation and patterns of re-working. Secondly, and unlike the Axe valley, the proximity of other artefact-rich fluvial landscapes (e.g. the River Itchen and River Avon valleys) raises the question of whether local paths and tracks should be interpreted from a single valley system. Such an approach would argue that hominids went up the valley and down the valley, but never across the low hills to the next valley over. This type of interpretive framework runs the risk of simply re-iterating the notion that hominids were tethered to fluvial landscapes and could only navigate their world by following water courses. This may well have been the case, but it needs to be demonstrated rather than assumed as a default position.

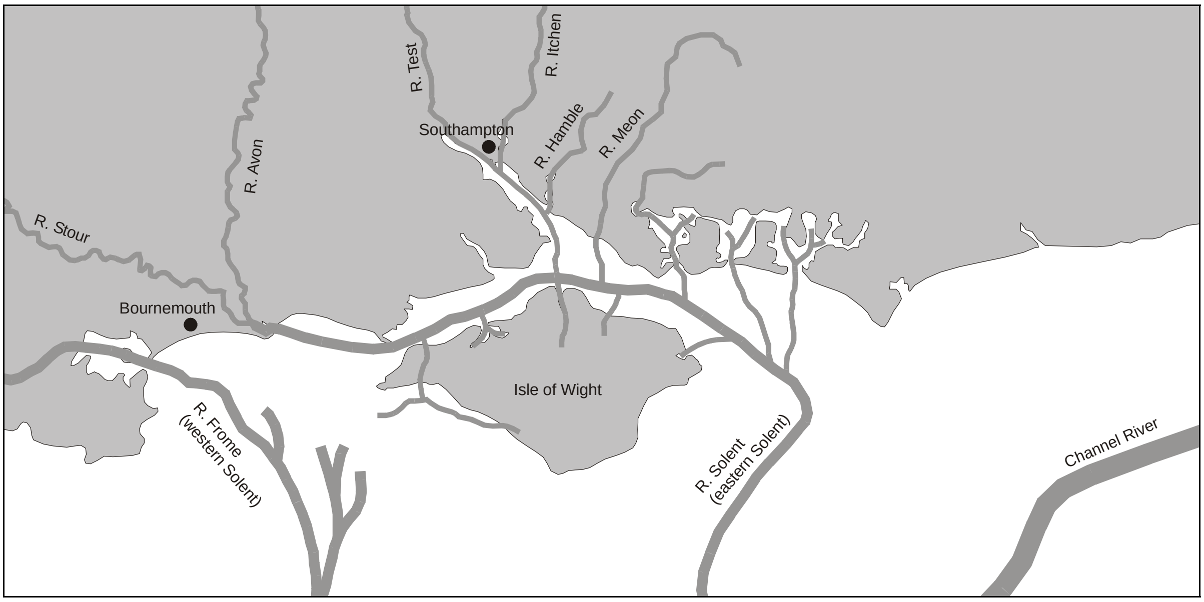

Figure 258: the Solent River system (after Bridgland 2001: Figure 1)

However, once taphonomic factors have been taken into account (see above), there is potential in a comparison of the quantities of artefacts occurring in the constituent valleys of the overall Solent River system. Specific patterns (e.g. the concentration of artefacts in the upper or lower reaches of the system) are valuable indicators of paths and tracks, gatherings and places, within an appropriately defined archaeological landscape. These data are available through the Southern Rivers Palaeolithic Project

(Wessex Archaeology 1993a) and are well-suited for further analyses utilising frameworks of the type proposed here and by Gamble (1999). However, such work requires the standardising of material densities from different valleys (potentially through an extended application of the Ashton & Lewis (2002) methodology), to take account of variations in deposit preservation, histories and traditions of collecting, and the exposure of potentially implementiferous sediments. Moreover, it is currently not possible to analyse the Solent River data in this manner, given the lack of absolute geochronological frameworks, which restricts the comparison of data from different valley systems. It is expected however that this situation will improve in the near future thanks to the current work of Bates & Wenban-Smith (in prep).

d) Raw Material Usage

Analysis of the sampled biface assemblages indicated the sole use of flint in artefact manufacturing. This is unsurprising considering the regional geology, in particular the dominance of Cretaceous chalk around the margins of the Hampshire Basin (Allen & Gibbard 1993: Figure 2). It is clear that fresh flint was not the sole source of raw materials, since river cobble cortex occurs on varying proportions of the bifaces with positively identified blank forms in each of the assemblages (4 (18%) from Yew Hill; 13 (81%) from Kimbridge; 8 (57%) from Belbin's Pit; and 92 (55%) from Dunbridge Hill). However, it should be stressed that the identification of cobble flint is disproportionately more common than the identification of other forms of biface blanks, since the former only requires the presence of ferruginously stained/patinated cortex. Nonetheless, these data indicate that the hominids were not exclusively travelling to fresh flint sources for raw material procurement, and were on other occasions utilising river cobbles that were presumably in close proximity to their current location. This presumption is made on the relative quality of the two raw material sources, and follows other workers (e.g. White 1998b).

This indication of the procurement of local, immediately available raw materials is also tentatively supported by the raw material evidence from the four assemblages. The lowest proportion of river cobble blanks (18%) is recorded at Yew Hill, located in an area of chalk bedrock, in which fresh flint may well have been locally present and available. By contrast, the other three assemblages (in which river cobble blanks are much more common) are located to the south, on the Tertiary sands and clays, where river cobbles would have been the primary source of immediately available raw material. However, this discussion assumes that the artefacts were only transported short distances by hominids between being manufactured and discarded. This is potentially supported by on-site data from sites such as Boxgrove (Roberts & Parfitt 1998) but it cannot be directly demonstrated with respect to the Test valley assemblages, although the small quantities of rough-outs suggest that raw material curation around the landscape was not a common strategy. This assumes however that the low representation of rough-outs in the Test valley assemblages is not due to collector bias. More fundamentally, the above discussion ignores the derived nature of the assemblages, since it is possible that some or all of the bifaces from Dunbridge Hill, Kimbridge and Belbin's Pit were fluvially transported from chalk-dominated regions of the landscape.

As with the Axe valley, there is currently no specific evidence in the Test valley data set of raw material transfer distances, the condition in which raw materials were transported, and whether raw material encounters resulted in the immediate creation of archaeological debris. Nonetheless, the raw material types recorded in the four assemblages provide no evidence for long distance transfers. While different generic raw material sources can be demonstrated (fresh chalk flint and river cobble flint), these generic sources both fall within the catchment of Gamble's (1999) local landscape of habit for all four assemblages. The derived nature of the assemblages also advocates caution when placing significance upon the proportions of different blank form types occurring in each assemblage. Overall therefore, the evidence is negative rather than positive, and does nothing to dispute the concept of a highly local landscape of habit, with respect to raw material procurement.

e) Conclusions

The regional archaeology of the River Test valley cannot be employed to test all of the elements of the Gamble (1999) model. However, it has revealed a number of interesting patterns with respect to population trends, social technology, and raw material procurement. It also indicated the importance of explicitly defining analytical scales when dealing with regional data sets, and the urgent need for improved geochronological models for fluvial sedimentary sequences.

3.6 Summary

It is clear from the applications described above that each of the reviewed models provides new mechanisms through which to explore secondary context archaeological assemblages and extract valuable information. However, none of the models can be applied wholesale, due to combination of factors:

- Current limitations in understanding, most notably with respect to the geochronological frameworks of the regional data sets (e.g. the River Test terraces). This can be resolved through the application of current dating techniques to fluvial sediments (optically stimulated luminescence) and biological material (amino acid ratios).
- The structure of the regional data sets, for example the absence of long terrace deposit sequences in the River Axe valley. This would appear to be an insoluble problem, although further geomorphological research (following the recent synthesis by Campbell 1998) and dating may reveal deposits from a wide range of ages, which have not formed in the classic terrace staircase manner of the River Thames.
- The structure of the secondary context assemblages, which limits the asking of certain research questions (e.g. specific raw material transfer distances), although it also clearly facilitates other research approaches (e.g. population models).
- Elements of the models are grounded in the archaeology of specific times and places (e.g. the Clactonian element of the Island Britain model) and are therefore of limited relevance when applied to the archaeology of other regions and periods.
- Elements of the models are dependent upon specific types of archaeology, namely primary context data sets.

The following section therefore summarises the models and the data in greater detail, highlighting their potential and their limitations, and proposing modifications where relevant.

4. OLD AND NEW FRAMEWORKS

In reviewing the models of Gamble (1999), White & Schreve (2000) and Ashton & Lewis (2002), the previous section highlighted the data and conditions upon which those models were based. These requirements are summarised here (Table 68), and compared against the realities of regional, secondary context data sets. Revised approaches are therefore proposed below for those situations where secondary context archaeological data fail to meet the requirements of the three models.

The most marked differences between the models are in their relative degrees of reliance upon secondary context data. Gamble (1999) and White & Schreve (2000) employ secondary context data, but primarily as supplementary support for evidence from primary context sites. For example, White & Schreve's (2000: 21) assessment of twisted ovate patterning in bifaces relies heavily upon data from primary context assemblages (e.g. Swanscombe (Upper Loam), Wansunt Pit, and Elveden), while mentioning secondary context sites primarily in passing. Gamble's (1999) model, although multi-faceted, tends to rely upon primary context data in his discussion of social technology (e.g. Boxgrove knapping sequences and the Schöningen spears); paths and tracks (e.g. lithic transfer data from Caune de l'Arago); and generic/specific skills and their demographic implications (e.g. the comparison of Swanscombe and Olduvai Gorge), although secondary context data is highlighted with respect to paths and tracks (e.g. the use of quartzite in the Upper Thames region) and modelling population trends. It is significant that both Gamble (1999) and White & Schreve (2000) utilise restricted elements of the secondary context record. This is not a cause for criticism in itself, but it does mean that they are not required to address the wider problems associated with secondary context data — namely, unsystematic sampling at the regional scale, fragmented preservation, and derivation of the artefacts.

Requirements (Regional, Secondary Context Data)	**Gamble (1999)**	**White & Schreve (2000)**	**Ashton & Lewis (2002)**
Chronology	Geochronology (either MIS-based (e.g. Bridgland 2001) or OSL/AAR dating)	Geochronology (either MIS-based (e.g. Bridgland 2001) or OSL/AAR dating)	Geochronology (either MIS-based (e.g. Bridgland 2001) or OSL/AAR dating)
Structure	Secondary context deposits (either isolated or within longer sequences) - although the model is most applicable to primary context data sets	Secondary context deposits (either isolated or within longer sequences) - although the model is most applicable to primary context data sets	Sequence of terrace landforms and associated deposits (e.g. Thames staircase terrace sequence)
Archaeology	No specific requirements	Bifaces and/or Clactonian artefacts	Bifaces and/or Levallois artefacts
Resources	Recording of artefact technology and typology; Geological and sediment mapping	Recording of artefact technology and typology	Mapping of: > sediments > archaeology > aggregates extraction > urban development

Table 68: data requirements for Gamble (1999); White & Schreve (2000) and Ashton & Lewis (2002)

4.1 Ashton & Lewis (2002) — revisited

By contrast however, the Ashton & Lewis (2002) model is explicit in its usage of regional, secondary context data. It therefore has to, and does, deal with the problems of secondary context data as outlined above:

- Unsystematic sampling at the regional scale: this is dealt with by focusing on a single stretch of the Middle Thames (to reduce the varied impacts of local antiquarian collectors — but see comments below) and standardising the artefact densities by aggregates extraction activity, and urban development.
- Fragmented preservation: this is dealt with through the standardisation of the artefact density by terrace area.
- Derivation of the artefacts: this is partially dealt with by examining data at a regional scale (to reduce the local impact of spatial derivation), but is also reliant upon the presence of specific trends in the data (namely a reduction in artefacts through time from the top to the base of the terrace sequence). This is the most problematic element of the methodology and the greatest hindrance to its usage in the analyses of other regional data sets. For example, if artefact densities had increased from the top to the base of the sequence it would be extremely difficult to assess how much of this pattern was due to post-depositional vertical re-working of artefacts, and how much to population increase over time.

A key legacy of the Southern Rivers Palaeolithic Project, the Welsh Lower Palaeolithic Survey and the English Rivers Palaeolithic Survey is the provision of data for all regions of Palaeolithic interest, thus enabling the problems of fragmented preservation and unsystematic sampling to be addressed. In this respect at least the data requirements of the Ashton & Lewis (2002) model can always be met. However, we contest the claim of Ashton & Lewis (2002) that variations in antiquarian activity can be minimised by adopting a single stretch of a river system as the focus for the model. Firstly this makes the comparisons of data from different regions (or from different river valleys within the same region) extremely difficult. One either has to assume that the intensity of collecting activity was uniform across southern England (this was and is clearly not the case (e.g. Roe 1981)), or rely upon the presence of very robust trends within the respective models. Secondly, it is dangerous to assume that collection activity was uniform in quality and quantity even within small regions such as the Middle Thames area. It is well documented that many collectors had favourite sites upon which they concentrated their efforts to the detriment of other exposures (Roe 1981). There is no simple, immediate solution to this problem. A previous attempt to resolve the issue (Hosfield 1999) was hindered by the statistical complexity of the methodology, and it may well be that simpler approaches (e.g. documenting the number of collectors that lived within the study area and adopting it as a simple proxy of the intensity of collection activity[14]) prove more effective. While this is not proposed as an ideal solution, it is stressed that consideration needs to be given to regional variations in antiquarian activity and that pan-regional comparisons of these types of data must be interpreted with caution.

The problem of vertical artefact derivation is also a serious one, since it is highly likely to have influenced the recorded patterns of artefact density to some degree. As argued by Ashton & Lewis (2002) the re-working process imposes limitations upon the types of questions that can be asked. It is re-stated here that the starting hypothesis for this type of modelling must be: is there evidence for population decline (as indicated by artefact densities) over time in this sequence? If the answer is yes, then it must be stressed that the genuine pattern may be more marked than that recorded. If the answer is no, then it must be made clear that there *may* be population decline, but it cannot be demonstrated. Any trends suggesting population *increase* through time must be considered with extreme caution.

Having discussed the methodological flexibility and transferability of this model, the final point is that the regional data set must be characterised by:

- Fluvial terrace sequences, with an absolute geochronological framework. Extensive terrace sequences are fundamental to the application of this methodology, as demonstrated by the Axe Valley case study (Section 3.3.1). In the absence of an absolute geochronological framework (e.g. the example from the Test Valley) it is impossible to assess the varying chronological duration associated with each terrace deposit (compare Table 67 with Table 62), to compare data from different valley systems, and to interpret the data in terms of the changing palaeogeography and climate of the Middle Pleistocene. In other words, data could be modelled but the interpretation would be without context and so abstract as to be virtually meaningless.
- Bifaces and/or Levallois archaeology. This highlights two other assumptions of the model which are transferable but can also be perceived as problematic: the equating of bifaces and Levallois artefacts; and the assumption that biface use and rates of discard remain standard over time. These issues are not explored fully here, but two fundamental points are emphasised:
    - It is proposed here that Levallois flakes and cores should not be used as a compensation for the lower prevalence of bifaces in Middle Palaeolithic assemblages. This is due to the tendency of not all collectors to recover cores and flakes from gravel pit sites and other secondary context exposures (Ashton & Lewis 2002: 389). Therefore we suggest that these population models should be restricted to the biface assemblages of the Lower Palaeolithic (*c.* 500–250,000 BP).
    - We agree with Ashton & Lewis (2002: 389) that changes in raw material availability, artefact function, and reliance on other raw materials are all unknowable sources of bias with respect to the assumption of constant rates of artefact discard over time. It is therefore stressed that the interpretation of data should only be based upon robust patterns.

In conclusion while faults can be found with specific elements of the model of Ashton & Lewis (specifically the assumptions with regard to antiquarian activity and the correlation of Levallois artefacts and bifaces), it is extremely successful in exploiting the scale and structure of the regional, secondary context archaeological resource, and extracting valuable data from it. Our only proposed modification would concern the limitation of the model's chronological duration to the period 500–250,000 years BP (although it is recognised that this ignores a period of considerable interest — the apparent abandonment of Britain from MIS-6 to MIS-3), to remove the bifaces/Levallois artefacts issue.

[14] These data could be documented from back issues of county and national journals (see Hosfield 1999: Chapter 3).

Since the models of Gamble (1999) and White & Schreve (2000) do not deal explicitly with the problems of secondary context data, their application to regional, derived data sets is therefore far less straightforward than for the Ashton & Lewis (2002) model.

4.2 White & Schreve (2000) — revisited

White & Schreve (2000) are primarily concerned with the resolution of two archaeological problems, through the perspective of their biogeographical framework of human colonisation, settlement, and abandonment throughout the course of the Middle Pleistocene:

- The significance of the Clactonian industry and its temporal relationship with the Acheulean.
- The significance of variability in the Acheulean biface industries of the Lower and Middle Palaeolithic. The identified variability cannot operate at the gross scales of shape and technical sophistication (as these can be reliant upon raw materials and functional requirements), but rather at the scale of lesser features (e.g. twisted profiles) that varied independently of raw materials and were not used by all hominid populations under similar conditions.

The model therefore focuses upon primary context sites, since these are perceived to consist of discrete, rather than derived, assemblages, and this is crucial given the well-documented disparity in the ease of identification of Clactonian and Acheulean assemblages respectively. The absence of temporal derivation is vital given the focus upon MIS sub-stages in the Clactonian/Acheulean element of the model (although see comments below), and therefore absolute geochronological frameworks are an integral element of the original model. In light of these requirements, the adaptation of the model to regional, secondary context data sets requires a number of modifications to be made. These are dealt with separately since the two archaeological problems (the Clactonian/Acheulean relationship, and patterning in the Acheulean) raise different considerations:

4.2.1 The Clactonian/Acheulean Problem

- Fundamental here is whether Clactonian archaeology is present within the specific region of the secondary context archaeology. The Clactonian is not a universal phenomenon across southern England, and appears to be concentrated in the south-east (White 2000). In many cases therefore, this element of the White & Schreve model is simply not transferable. However, in cases where Clactonian archaeology may be present, there is a second fundamental difficulty.
- Can the Clactonian be identified within archaeological secondary contexts? As White & Schreve have argued: firstly, a small number of derived flakes and cores would not automatically be taken as evidence for the Clactonian; secondly, a biface would automatically be taken as an indicator of the Acheulean; and thirdly, therefore there is very little potential for identifying the Clactonian within mixed, derived assemblages. For example, one that consisted of 4/5 Clactonian artefacts and 1/5 Acheulean bifaces would still be most likely interpreted as a single, re-worked Acheulean assemblage.
- The model also stresses the early appearance of the Clactonian within MIS-11 and MIS-9. This is based on the appearance of Clactonian artefacts in the basal sediments (including gravels) of the Lynch Hill/Corbets Tey Formation at Globe Pit, Little Thurrock; Cuxton; and Purfleet; in the lower part of the Boyn Hill/Orsett Heath Formation at Clacton (Freshwater Bed); Swanscombe (Phase I deposits); and conformably overlying Anglian till at Barnham. In these cases, assemblages have been described as unmixed, and presumably in primary context or only minimally derived, and this is accepted here. However, with respect to the extension of this model to new data sets, there is always a danger that artefacts occurring within basal terrace (ancient floodplain) sediments may have been derived from the eroded sediments of the previous, higher terrace. Artefacts could even be re-worked *en masse* within a raft of sediment and therefore remain unmixed but chronologically out of context. This would have fundamental implications for the chronology of the assemblages, which is a key element underpinning the Clactonian/ Acheulean model.

This combination of potential problems leads us to argue that this aspect of the White & Schreve (2000) model has limited applications with respect to regional, secondary context data.

4.2.2 Patterning in the Acheulean

- This model is reliant upon the dominance of twisted profile ovates either within overall biface assemblages or the ovate component of them. Both primary and secondary context assemblages can therefore be evaluated using this methodology, although in the case of secondary context data attention needs to be paid to the potential for derivation and the resultant mixing of artefacts from different sources. However, these factors can be evaluated through examination of artefact condition, and we therefore suggest that the likelihood of a false twisted ovate assemblage being created through taphonomic factors is limited.
- The problem of vertical re-working is more serious, since the model emphasises the development of endemic traditions during periods of isolation (i.e. the full interglacials of the Middle Pleistocene). Demonstrating the re-working of an assemblage dominated by twisted ovates from MIS-12 sediments (the Anglian glaciation) into MIS-11 deposits (the Hoxnian interglacial) would fundamentally influence the nature of the pattern and the resultant interpretations. However, this would require the *en masse* erosion and re-deposition of an assemblage and while this is potentially possible it is not considered likely.
- Finally, the model provides a potential framework through which to explore the occurrence of other manifestations of endemic traditions, expressed through biface production. This was demonstrated for the Broom assemblage, in terms of the dominance of bifaces with a pronounced asymmetry, potentially associated with the MIS-7 interglacial. These models could be explored through the re-investigations of extant secondary context assemblages and the re-dating of available fluvial sedimentary sections.

This discussion suggests that the second aspect of the White & Schreve (2000) model has extensive applications with respect to regional, secondary context data, and requires relatively little modification. We would propose that the model should be expanded to explore a fuller range of technological-typological features. It is also stressed that the issue of derivation must be evaluated for each assemblage, although in many cases it should not prohibit the application of the model. Finally, it is noted that this model could also be re-visited over the longer term, in response to the identification of new technological-typological patterns, as a result of on-going artefact studies.

4.3 Gamble (1999) — revisited

The Gamble (1999) model highlights both primary and secondary context data, although as with the work of White & Schreve (2000) it does not explicitly address the problems of secondary context data. Four facets of the model were identified here as being testable against such archaeological data:

- Generic and specific skills in the taskscape, and their implications for population trends in the northern latitudes. Gamble (1999: 140) argues that this can be documented both through *in situ* evidence of hominid behaviour, and long-term signatures of population fluctuation, although the means of investigating the latter are not made explicit.
- Social technology, the interpretation of the archaeological record, and the reconstruction of hominid societies. Gamble (*ibid*: 127–137) primarily explores these issues through primary context evidence for the manufacturing, use, maintenance, and discard of lithic and organic technology.
- Regional patterns in the distribution of archaeological data, and the modelling of the landscape of habit. Gamble (*ibid*: 142–143) summarises the taphonomic factors associated with regional, secondary context data (e.g. spatial blurring of data through fluvial and periglacial action), although there is not an explicit exploration of the relationships between data, analytical scales, methodology and research questions.
- Paths and tracks and raw material transfer data. The discussion primarily focuses upon explicit raw material transfer distance studies (e.g. Féblot-Augustins 1997), although there is also discussion of the role of broader scale patterns, which are sometimes preserved in secondary context assemblages (e.g. the work of MacRae (1988)).

These different areas of the Gamble model are dealt with separately here with respect to their application to regional, secondary context data sets, as the archaeological problems and the specific data components raise different considerations.

4.3.1 Population Models

Since Gamble (1999) does not explicitly outline a mechanism for the modelling of long-term population patterns, we propose the modified methodology of Ashton & Lewis (2002) highlighted above for the exploration of population trends. Despite their different goals and aims these models are highly complementary. On one hand, Gamble (1999) offered an over-arching conceptual framework for Palaeolithic research, while Ashton & Lewis (2002) produced a data-driven model addressing a specific issue (evidence for population decline during the Middle Pleistocene). It is therefore unsurprising perhaps, that the latter slots readily into the former.

4.3.2 Social Technology

Unlike primary context data, evidence for manufacturing sequences, and the use, maintenance and discard of artefacts is liable to be obscured beyond recognition in archaeological secondary contexts. Focus therefore needs to be turned to the end products of lithic manufacturing processes and whether they represent tool-making under rigid cultural constraints, typological traditions, and imposed standards, or the varied produce of a fluid, bi-directional social technology that differs with changing, immediate conditions. These conditions cannot be known, but the artefacts can preserve evidence of how they were manufactured (although the data will inevitably be less complete than that from complete production sequences), and the degree of variability in this sphere can offer a means of evaluating the two different interpretations summarised above. This approach does not necessarily need to be anchored in an explicit geochronological framework, although any wider regional comparisons would obviously be untenable without it.

The Gamble model pays relatively little attention to traditional typological notions, principally because of its concern with operational sequences and the issues of the fallacy of the finished artefact. The rejection of rigid typological frameworks is commendable; however there are two key points:

- On methodological grounds, artefact typology remains the basis for characterising and comparing assemblages. It is now generally conceived of as providing labels rather than as having any interpretive significance, but it remains the basis for the majority of Palaeolithic research.
- White & Schreve (2000) and recent work at Broom (Chapter 4) have indicated that finished artefacts bear evidence of technological practice and the context of production, in the shape of features (e.g. twisted profiles and pronounced asymmetry) whose identification and description would have been impractical outside of a standard typological framework.

We would therefore propose that there is a large body of valuable data available through the analysis of regional, secondary context data sets, pertinent to the exploration of Palaeolithic technology. It is also stressed that the analysis of secondary context assemblages must highlight both the exploration of manufacturing evidence and models of technological practice, *and* variability as expressed through broad-scale patterns in artefact typology and form. Obviously these investigations are dealing with derived assemblages, and therefore attention needs to be paid to the geoarchaeology of the sediments and their assemblages, and the potential for spatial and temporal re-working. This will vary on a case-by-case basis, and it is clear that certain assemblages (e.g. Broom) may be more amenable to this type of analysis than others (e.g. Dunbridge, and Corfe Mullen on the River Stour (Wessex Archaeology 1993a)).

4.3.3 Regional Patterning

The exploration of regional patterning in archaeological secondary contexts can be characterised at two contrasting spatial scales:

- Pan-regional comparisons of artefact densities and typologies between river valleys and river systems.
- Local investigation of artefact density and typological variations within individual river valleys or river

systems.

There is clearly a wide body of data available for this type of analyses, synthesised by the Southern Rivers Palaeolithic Project, the Welsh Lower Palaeolithic Survey and the English Rivers Palaeolithic Survey. However, there are a number of methodological issues that need to be addressed:

- Robust geochronological frameworks are fundamental, regardless of the scales of analysis. This need is gradually being met, but much work remains to be done. The issue is also complicated by the fact that not only can terrace sequences in adjacent valley systems (e.g. the Test and Itchen) not be presumed to be chronologically equivalent, but nor can altitudinally-equivalent terrace deposits within a single valley.
- The evaluation of unsystematic sampling of the archaeological record, with respect to antiquarian collecting, and the differential exposure of Pleistocene sediments through aggregates extraction and the urban growth. This was discussed in more detail with respect to Ashton & Lewis' (2002) population modelling (see above), and is critical at all scales of analysis.
- The differential preservation of deposits in different locations also requires consideration, and is once again a factor at all analytical scales.
- At the pan-regional scale, emphasis is upon the large-scale, long-term exploitation of landscapes, occurring through the criss-crossing of paths and tracks and the resulting accumulation of material debris. At these scales (e.g. testing whether the Thames valley was more intensively colonised than the Solent River), the issue of local spatial derivation of assemblages is insignificant. However, at the local scale, the *unmodelled* distribution of secondary context assemblages cannot be employed to reconstruct the specific paths, tracks and places of Gamble's (1999) landscapes of habit, because such an approach ignores the realities of spatial blurring. Nonetheless, geoarchaeological investigations (e.g. Chambers in prep; Chapter 4) do allow *relative* patterns in artefact discard across landscapes to be explored.
- At both scales of analysis, the issue of temporal derivation is critical for explorations of changing patterns through time and data trends for specific periods. This must be considered through geoarchaeological explorations of artefacts, sedimentary preservation, and related geomorphological factors (e.g. bedrock conditions). As discussed above, the degree of temporal derivation will vary on a case-by-case basis, and some data sets will be more applicable to analysis than others (for the example the long, well-preserved terrace sequences of the Thames compare favourably with the heavily re-worked deposits of the chalk streams in the upper reaches of the Solent River's northbank tributaries).

In summary, there is a large, available body of data in the regional, secondary context data sets that can yield valuable data with respect to regional and sub-regional patterning of landscape use. However, it is stressed that such investigations require a greater consideration of taphonomic factors, prior to the drawing of conclusions based upon blurred spatial data. The raw data for such considerations are widely available, and there is an increasing body of literature that addresses the methodological requirements of such research (e.g. Bridgland 1985; Hosfield 1999; Ashton & Lewis 2002; Chambers in prep).

4.3.4 Raw Material Transfers

The spatial derivation of secondary context assemblages precludes the generation of specific raw material transfer distance data. Nonetheless, the spatial structure of behaviour seen through raw material procurement (e.g. local or regional) can be explored through evidence of raw material proportions in derived assemblages and the regional background geology. There are two key issues:

- The spatial derivation of the assemblages requires that opportunities for raw material procurement are analysed at a river basin-wide scale, rather than on the basis of specific geological outcrops occurring at individual localities. This approach therefore requires comprehensive geological data and these are widely available.
- The analyses should deal in robust patterns, represented by broad proportions of raw materials rather than absolute values, e.g. the dominance of chert in the geology and artefact assemblages of the Axe valley. Small proportions of exotic raw materials in artefact assemblages should be considered

cautiously, but can potentially support the proposal of larger landscapes of habit, although the role of erratics should always be evaluated.

Overall, there is data available in the regional, secondary context archaeology, but it is generic and cannot be explicitly compared to the well-known raw material transfer data (e.g. Féblot-Augustins 1997). However it can be effectively utilised to support existing models for the scale of the landscape of habit.

4.3.5 Summary

Overall, the Gamble (1999) model can be applied to regional, secondary context data sets, although in a piecemeal rather than wholesale manner. A number of small modifications have been proposed here, to account for the structure and character of the secondary context resource. As with the other models, this review of Gamble (1999) has illustrated that the most directly transferable models are those explicitly designed to work with secondary context data sets (e.g. Ashton & Lewis 2002). Models principally concerned with primary context data sets inevitably require greater degrees of adaptation. It is also clear that: firstly, the secondary context archaeological resource has a wealth of potential value; and secondly, for this value to be exploited fully the development of specific and appropriate methodologies are required. Examples of these are therefore presented in the final section.

5. CONCLUSIONS: INTERPRETIVE FRAMEWORKS FOR SECONDARY CONTEXT ARCHAEOLOGY

These conclusions do not present a conceptual, interpretive framework in the style of Gamble (1999). The intention is rather to highlight a series of key research questions in Lower and Middle Palaeolithic archaeology, and indicate whether those questions can or cannot be explored through regional, secondary context data sets. A series of specific interpretive frameworks are therefore discussed, alongside methodological examples of work undertaken as part of this project. Where relevant, links between the frameworks are identified, and preliminary connections are also drawn between the secondary context frameworks and the primary context archaeological resource. Finally, it is emphasised that the interpretive frameworks are intended to profitably exploit the structure of the data, and not to underpin a specific perspective of Palaeolithic societies.

The key research questions addressed here are adopted from the *Research Frameworks for the Palaeolithic and Mesolithic of Britain and Ireland* document (The Prehistoric Society 1999), and are divided between three themes (only the research questions considered to be relevant to the Palaeolithic were included here):

1. Colonisation and recolonisation:
    - 1.1. Establishing the pattern of human interaction with, and possible impact on, the faunas and vegetation of Britain and Ireland. This involves determining the earliest occupation in the Middle Pleistocene and relating this to well-dated and stratigraphically secure deposits in Britain, Ireland and Northern Europe.
    - 1.2. Tracing through the archaeology, and where available the physical anthropology and bio-molecular evidence, the relations between Britain, Ireland and NW Europe. This should be done at various periods to determine the variety of source populations.
    - 1.3. Establishing with greater precision the arrival of anatomically modern humans in Britain and tracing the patterns of Neanderthal extinctions in our data.
    - 1.4. Establishing the pattern of recolonisation at various time periods but particularly following the Last Glacial Maximum at 18,000 uncalibrated years BP and throughout the Mesolithic as population expanded.

2. Settlement patterns and settlement histories:
    - 2.1. How much of the Pleistocene actually saw human occupation in Britain and Ireland?
    - 2.2. Were there, through time, appreciable shifts in the length of occupation as humans coped better with the recurrent challenges of climate change?
    - 2.3. To what extent did successive populations in the Palaeolithic and Mesolithic intensify their

subsistence behaviour and so develop new niches for adaptation?
2.4. Does the British and Irish evidence indicate a full settlement system within our current geographical limits? Alternatively how far are the settlement data illustrative of a logistic system of special task sites, where major base camps were located either on the continental shelf or on the continent?
2.5. What changes in landscape use and the organisation of technology are indicated by the provenancing and quality of lithic raw materials?
2.6. How soon after areas of Britain and Ireland became available for settlement (following glacial retreat and the establishment of useable food resources) were they in fact recolonised?
2.7. How do we compare activities which took place at cave and open sites and place them within a differentiated settlement system?

3. Social organisation and belief systems:
   3.1. Apply the *chaîne opératoire* concept to the analysis of a social technology rather than just to the mechanics of manufacture. The opportunity to incorporate experimental studies, including use-wear analysis, promises to make this a key area in the archaeological study of the production and consumption of material culture.
   3.2. Animal bones need to be assessed as symbolic resources used in the reproduction of society as well as sources of calories.
   3.3. The transference of social organisation into spatial patterning on camp sites needs to be systematically considered.
   3.4. What was the regional scale of Palaeolithic and Mesolithic social systems as revealed in such concepts as Grahame Clark's social territories (1975) and measured through artefact studies?

It is clear that many of these research questions cannot be answered from regional, secondary context data sets (Table 69). This is due to a number of factors, including:

- The lack of geochronological tools of sufficiently high resolution. This is particularly pertinent to the issues of the recolonisation delay after glacial retreat (2.6), and in combination with the problems of artefact re-working, the issues of recolonisation following the Last Glacial Maximum (1.4). In the case of issue 1.4, although high resolution geochronological tools are available for the last 40,000 years (e.g. Accelerator Mass Spectrometry dating), these refinements are of limited application due to the persistent problem of temporal artefact re-working. For earlier periods, the error ranges associated with coarser resolution geochronologies (e.g. OSL) and temporal artefact re-working were of comparable magnitudes (Chapter 7). This is not the case for later periods, and the resultant disparity limits the applications of secondary context data to the understanding of high resolution processes of re-colonisation, in which centennial timescales are of considerable significance (e.g. Housley *et al.* 1997).
- The loss through derivation of spatial information with respect to potential associations between different elements of the artefact record. This is particularly relevant to the issues of spatial patterning and social organisation (3.3), animal bones and symbolism (3.2), and the intensification of subsistence behaviour (2.3). In the case of issue 2.3, derived faunal elements frequently bear no evidence of either the agent of death (e.g. carnivore/hominid/natural causes) or whether hominid involvement was as a primary hunter or a secondary scavenger. Equally importantly, derived faunal remains cannot be used to construct age profiles which might indicate intensification or specialisation of subsistence behaviours, since all the remains cannot be assumed to be contemporary. With respect to issue 3.2, if unmodified animal bones were being used as symbolic resources, there is no preserved contextual evidence within secondary contexts to demonstrate this.
- Inability to classify sites and settlements, due to re-working. This is relevant to the issues of contrasts between cave and open sites (2.7), and the nature of settlement systems (2.4), and is due to the inherent fact that derived artefact assemblages are not sites. Moreover, the selective recovery of different artefact types from secondary contexts has severely restricted our ability to quantitatively measure differences between assemblages in space and time.

Research Questions	Secondary Context Data Sets	Spatial Scales	Temporal Scales	Data Limitations
1.1 Earliest Occupation	✓	Local Regional	Sub-MIS MIS	-
1.2 Britain/Europe Links	✓	Local Regional	Sub-MIS MIS	-
1.3 Modern Human Arrival	✓	Local Regional	Sub-MIS	-
1.4 LGM Recolonisation Patterns	×	Not applicable	Not applicable	Geochronological resolution & temporal derivation
2.1 % of Occupation	✓	Regional	MIS	-
2.2 Occupation Change over Time	✓	Regional	MIS	-
2.3 Intensification of Subsistence Behaviours	×	Not applicable	Not applicable	Lack of spatial associations & spatio-temporal derivation
2.4 Settlement Systems	×	Not applicable	Not applicable	Recovered assemblages are not sites
2.5 Raw Material Provenancing	✓	Regional	MIS	-
2.6 Recolonisation Delays	×	Not applicable	Not applicable	Geochronological resolution & temporal derivation
2.7 Cave & Open Sites	×	Not applicable	Not applicable	Recovered assemblages are not sites
3.1 Chaîne Opératoire & Social Technology	✓	Local	Sub-MIS MIS	-
3.2 Animal Bones & Symbolism	×	Not applicable	Not applicable	Lack of spatial associations
3.3. Social Organisation & Spatial Patterning	×	Not applicable	Not applicable	Lack of spatial associations
3.4 Regional Scales of Social Systems	✓	Regional	MIS	-

Table 69: Palaeolithic research questions and regional, secondary context data

However, despite the inapplicability of regional, secondary context data sets to the research questions outlined above, there remain a wide range of issues that can be profitably addressed through these data sets. These questions highlight the key characteristic of the data, namely its extensive spatio-temporal coverage. This facilitates the investigation of:

- The earliest occupation of Britain (1.1), as exemplified recently by the assignment of derived artefacts from the pre-Anglian sands and gravels at Warren Hill to MIS-13 (Wymer *et al.* 1991; Wymer 1999: 140), thus supporting other evidence for the earliest occupation of Britain, for example from Boxgrove (Roberts & Parfitt 1998).
- Links between Britain and northwest Europe, as traced through the archaeology (1.2), and recently explored by White & Schreve (2000) for the Middle Pleistocene.
- The modern human arrival in Britain (1.3). Although there is inevitably an issue of geochronological resolution (see the comments above), the difference here is that the focus is upon identifying the earliest dated example, rather than tracing a diachronic process through a number of dated occurrences. It is for this reason that the data cannot be used to address the second aspect of the research question (the pattern of Neanderthal extinctions in Britain).
- How much of the Pleistocene saw human occupation of Britain (2.1)? It is stressed that the data will provide a measure that operates at the regional scale, and at the MIS-level of temporal resolution. Yet while this is not generating a high resolution model, it is the scope and abundance of the secondary

context data that allow this work to undertaken at all. Estimates of occupation during the Pleistocene cannot be based on the small number of primary context sites currently available.
- Changes over time in the length of occupation (2.2). These changes can only be mapped at the MIS-level, reflecting the highest level of geochronological resolution that can currently be applied to regional data sets. Nonetheless, these data still indicate trends through time, as with the evidence for population decline over the Middle Pleistocene, modelled by Ashton & Lewis (2002) for the Middle Thames valley.

Despite the time- and space-averaging of the data, it is also possible to explore other questions that have traditionally been addressed through primary context data sets:

- Raw material provenancing (2.5). Although the derived nature of the assemblages prevents the identification of specific raw material transfer distances, the structure of the data (e.g. the association between the assemblage and the fluvial system) supports a generic modelling of raw material procurement strategies based upon regional bedrock geology, the lithology of fluvial sediments, and the proportions of lithic types evident in the artefact assemblages. The tendency will be for the data to provide negative evidence with respect to long distance transfers and procurement, although the potential remains for the highlighting of geographically distant sources through the presence of exotics.
- The chaîne opératoire and social technology (3.2). While there is obviously no evidence for operational sequences within secondary contexts, there is an extensive body of material evidence that can provide indicators of the manufacturing process, and document distinctive aspects of artefacts (e.g. twisted profiles on ovate bifaces). The interpretation of these data will be dependent upon the specific interpretive and conceptual frameworks (e.g. compare McNabb & Ashton 1992; McNabb 1996; White 1998a, 1998b; Gamble 1999; Wymer 1999; Wenban-Smith *et al.* 2000), but all of these investigations do not need to be solely based upon the archaeology of primary contexts.
- The regional scales of social systems (3.4). This is assumed here to refer to the scale of the alliances and contacts that formed a part of hominid and social systems in the Palaeolithic. Since this is most commonly expressed through evidence for shared symbolic material culture (e.g. the Venus figurines of the Upper Palaeolithic), this has currently relatively little applicability to the Lower and Middle Palaeolithic. However, shared patterns of specific material culture in fluvial basins from different regions could still indicate generic scales of contact and interaction, although they cannot be tied to a specific time and place. Unfortunately, the probability of many of these symbolic artefacts surviving derivation and re-working is relatively limited.

Based upon these applications for regional, secondary context data sets, an interpretive framework is proposed. It is not intended to support a particular perspective with respect to the understanding and interpretation of Palaeolithic societies, but is rather designed to identify the structure of the resource, map relevant questions onto appropriate data, highlight linkages, and illustrate connections between primary and secondary context archaeology. The framework is illustrated schematically in Table 70, and is summarised below.

The framework's analytical units are defined in terms of the maximum spatial or temporal resolution that can be currently achieved. Spatial units are discussed in terms of regions, which are defined here as the setting of the secondary context archaeological record — individual river systems. It is therefore recognised that regions will differ in size (e.g. compare the Thames and the Ouse), but stressed that as fluvial drainage systems they are structurally comparable. Temporal units are defined on the basis of the MIS record, either as single marine isotope stages or as sub-stages (e.g. Schreve 2001a). The resolution of the analytical units varies in response to the behavioural domain that is being investigated. For example, in the case of the Colonisation & Occupation domain, it is proposed that the population trends can only be modelled at the regional level (e.g. comparing population trends of the Thames region with the Solent River region) and on the basis of MIS-stages (e.g. comparing MIS-12 with MIS-10). This reflects the fact that regional populations should not be modelled on the basis of selected assemblages within that region, and that the sedimentary deposits representing portions of an individual MIS cannot be equated (and often not even identified) between different locations or regions on the basis of current geochronological tools.

There are not a limited set of specific methodologies associated with this framework, indeed it is hoped that this report will encourage the development of new approaches. However, and based on the earlier discussions of the three models, three sample methodologies are briefly outlined below, to illustrate some of the key considerations that need to be born in mind when dealing with these types of data (these considerations are not presented in any order of significance).

		Behavioural Domains		
		Colonisation & Occupation	*Landscapes*	*Technologies*
Analytical Units (maximum resolution)	*Time*	MIS	MIS & MIS sub-stages	MIS & MIS sub-stages
	Space	Multi-regional & regional	Regional & sub-regional	Regional & sub-regional
	Themes	Population models; Identifying breaks in occupation; Dating first occupation	Distribution patterns; Raw material procurement	Assemblage characterisation

Table 70: an interpretive framework for regional, secondary context archaeology

5.1 Population Modelling/Regional Distribution Patterns

There should be considerable overlap between population modelling and the analysis of regional distribution patterns, although there will inevitably be variations in terms of the focus of the interpretation of the results. Key considerations should include:

1. The availability of a robust geochronological framework.
2. Mapping of the secondary context deposits (e.g. fluvial sediments), aggregates extraction sites, urban development areas, and archaeological assemblages.
3. With respect to population modelling, explicit definition of the model's assumptions regarding the links between artefact density values, rates of artefact discard, and population data, and how (or if) these change over time.
4. Standardisation of the data to take account of local and regional variations in deposit preservation, aggregates extraction activity, urban development, and antiquarian collector activity.
5. Investigation of the impact of temporal (vertical) re-working of archaeological materials, and the impact of the process upon the recorded results. Key factors in the assessment of the degree of re-working should include the relative preservation of the deposits associated with each terrace unit, and the physical condition of the artefacts.

5.2 Assemblage Characterisation

There is potential for considerable variation in approaches to assemblage characterisation, and the following points are therefore restricted to generic observations:

1. The availability of a robust geochronological framework.
2. Assessing the degree of spatial reworking of what is inevitably a palimpsest assemblage. Key factors would include the physical condition of the artefacts, and the sedimentary contexts.
3. Assessing the potential for vertical re-working (based on the location of the assemblage, the preservation of associated deposits, and the regional solid geology) and recognising the problems

inherent in the analysis of a heavily time-averaged assemblage. This should be undertaken on case-by-case basis, and the option of rejecting an assemblage for analysis should always be available.
4. Documentary evidence (where available) relating to the collection of the assemblage and the potential presence of sample bias influencing the composition of the extant material.
5. Awareness of the range of data that can be recorded, which includes overall typology, evidence of the manufacturing process, physical condition (the *état physique*), raw material use (see also below), and non-standard typological variants (e.g. twisted profiles and pronounced asymmetry).

5.3 Raw Material Distributions

These approaches are dependent on an explicit understanding of the scalar elements of the analysis. Key points include:
1. The availability of a robust geochronological framework.
2. Modelling the theoretical spatial catchment of the assemblage or assemblages (e.g. Chambers in prep.).
3. If vertical derivation of the assemblage is demonstrated or suspected, then an evaluation of the potential for changing raw material availability over time must be undertaken (see White 1998b for a detailed example of this issue with respect to the Swanscombe bifaces).
4. Characterisation of the potential raw material sources, based on the regional solid geology and the lithology of the drift deposits.
5. Assessment of the proportions of different raw materials (where relevant) within the assemblage or assemblages (see also above).

5.4 Summary

It is emphasised that there are number of feedback loops between the different components of the interpretive framework. These loops illustrate the linkages between the themes, and demonstrate how results in one area will assist in the analysis and interpretation of other data. Generic examples might include how changes through time in population data (e.g. the decline in Middle Pleistocene populations documented by Ashton & Lewis (2002) in the Middle Thames) could be used to explore shifts in technological practice (e.g. the first appearance of Levallois technique in MIS-9/8). Alternatively, regional variations in the chronology of population peaks and troughs (e.g. the contrasts between the Solent River data (Hosfield in prep.) and the Thames data of Ashton & Lewis (2002)) could be considered in terms of variations in one or more elements, ranging from local differences in technology or raw material procurement to landscape location within the wider context of Palaeolithic northwest Europe.

Following the tacking concept of Gamble (1996; Figure 239 & Figure 240), linkages can also be drawn between secondary context data and their interpretive frameworks, and the on-site investigations that have tended to dominate Palaeolithic research. One of the best explicit examples of this has been Ashton & Lewis' (2002) use of data from European Middle Palaeolithic sites (e.g. La Borde, La Cotte de St. Brelade and Wallertheim) to explore their long-term population patterns in the Thames valley. However, this does not have to be a one-way relationship, as Gamble reminds us:

"Population would ebb and flow into and out of the northern environments, as represented by Swanscombe, and this process [only observable through regional, secondary context data] *will provide the strongest archaeological signature of variation in behaviour* [traditionally the preserve of on-site studies] *at the regional scale."*

(Gamble 1999: 140)

In more general terms, this should therefore remind us that our well preserved snapshots of behaviour from Boxgrove (Roberts & Parfitt 1998) and Lynford (Boismier *et al.* 2003) are just a few days in millions, and that the long-term patterns of fluctuating populations in Britain (Ashton & Lewis 2002; Hosfield in prep.) are an equally valuable indicator of hominid adaptation, occupation and potential mobility during the Middle Pleistocene.

In conclusion therefore, this chapter began with a review of three recent models of Palaeolithic archaeology and hominid behaviour. The review has indicated that regional, secondary context data sets are best investigated through the development of specifically-tailored frameworks and methodologies, although all three of the models did indicate profitable areas of research. Modified frameworks and methodologies have therefore been proposed, and it is hoped that these clearly demonstrate the considerable potential of archaeological secondary contexts and stimulate further research with these unique data.

CHAPTER 10
CONCLUSIONS

1. INTRODUCTION

The focus of this project has been the UK's archaeological secondary context resource, with specific reference to the Lower and Middle Palaeolithic periods (*c.* 500–40,000 years BP). The archaeological value and potential of this resource has been demonstrated through a series of investigations exploring:

- The spatio-temporal structure of the resource, emphasising the chronology of the secondary contexts (fluvial sedimentary deposits) and the derivation of the archaeology (stone tool assemblages).
- The range and types of archaeological data which can be extracted from secondary context assemblages.
- The relationships between archaeological secondary contexts and extant analytical and interpretive frameworks.
- The management of the secondary context resource.

2. SUMMARY

The key points raised by this project in the preceding report are summarised below:

2.1 The temporal structure of fluvial sedimentary deposits (Chapters 2 & 3)

1. Fluvial activity during the Middle and Late Pleistocene (787–11,000 years BP) is associated with periods of climatic change.
2. These periods of climatic change operate both at high magnitudes and low frequencies (the 100,000 year glacial/interglacial (Milankovitch) cycles) and at low magnitudes and higher frequencies (sub-Milankovitch climatic variations, occurring over centennial or millennial timescales).
3. Fluvial studies from the last glacial/interglacial cycle (127–11,000 years BP) and the Holocene (11,000–present) indicate that:
    a. phases of fluvial activity occurring in response to climatic change are relatively rapid, typically lasting hundreds rather than thousands of years.
    b. all rivers typically respond to the 100,000 year Milankovitch cycle climatic events, while fluvial response to the sub-Milankovitch climatic variations is less universal.
4. Fluvial activity is not *continuous* during these periods (e.g. sedimentation is likely to have occurred only in response to spring floods during an annual cycle), but current geochronological tools do not permit such high resolution dating.
5. There is only partial preservation of fluvial sedimentary features from the Middle and Late Pleistocene periods. Typically, the larger-scale features associated with the Milankovitch cycles are favourably preserved, while the small-scale features associated with the sub-Milankovitch events are vulnerable to subsequent erosion.
6. Sedimentary units can be dated to individual marine isotope stages and it is *predicted* that they represent short periods of time (probably hundreds of years). However, current geochronological tools do not permit the dating of sedimentary units to specific episodes of climatic change.

2.2 The temporal structure of archaeological assemblages occurring within fluvial sedimentary deposits (Chapter 5 & 7)

1. The artefacts are derived and have therefore been removed from their original place of discard by processes of soil erosion, solifluction and flooding. The artefacts were incorporated into fluvial

sedimentary deposits by stream flow. These processes have two implications:

   a. the artefacts are older than the formation of the sedimentary deposit. The sediments therefore only provide a *terminus ante quem* age. Assessing the relative magnitude of the age discrepancy between the archaeology and the fluvial sediments was therefore a major focus of this research (see also points 2–5 in this section).
   b. the findspot locations associated with secondary context assemblages cannot be regarded as 'sites' in the same way as *in situ* contexts from the Palaeolithic (e.g. Boxgrove) and later archaeological periods.

2. The frequency of sub-Milankovitch climatic variations (interstadial events occurred every 3–4,000 years over the last 80,000 years) indicates that artefacts discarded upon floodplain surfaces would have been regularly exposed to significant fluvial activity. While preservation of the fluvial sediments associated with high frequency climatic events is variable (see above), their widespread occurrence within European Late Glacial and Holocene river systems indicates that artefacts are unlikely to have lain upon *unmodified* floodplains for tens and hundreds of thousands of years.
3. Once artefacts have been incorporated into fluvial sedimentary deposits they are potentially vulnerable to subsequent erosion of those deposits. This can result in the artefacts being re-worked into younger deposits. The age discrepancy between the younger and older deposits can range between hundreds of years (reflecting localised erosion in response to sub-Milankovitch climatic events) and hundreds of thousands of years (reflecting river downcutting in response to Milankovitch cycles).
4. A model is therefore presented for assessing the degree of temporal re-working undergone by artefact assemblages. The model emphasises:
   a. the fluvial morphology and its implications for the preservation/erosion of sedimentary (river terrace) deposits.
   b. the local and regional geological bedrock controls and their implications for preservation/erosion of the deposits.
   c. the stratigraphic position of the artefact assemblage, its relationship to fluvial activity across a Milankovitch-scale glacial/interglacial cycle, and its probable chronology of re-working.
   d. the physical condition of the artefacts (Section 2.3 below).
5. The model provides a *relative* measure of the degree of re-working undergone, and the importance of sedimentary evidence from the field is emphasised for the evaluation of the model.

2.3 The spatial structure of archaeological artefact assemblages (Chapters 4, 5 & 7)

1. The physical condition of all the stone tool assemblages examined from archaeological secondary contexts indicates that they have undergone degrees of fluvial transport.
2. Experimental flume research has documented distinctive patterns of artefact damage, sustained during fluvial transport. Damage was assessed in terms of the *état physique* of the artefacts, incorporating arête ridge widths, edge micro-flaking and gross factors of artefact morphology. The distinctive patterns indicate different modes of bed-load transport and enable the differentiation of damage sustained during phases of movement and damage sustained during static periods.
3. Modelled transport distances were based upon comparisons between the damage sustained by experimental artefacts over known transportation distances and that displayed by artefacts from archaeological secondary contexts.
4. The modelling allowed the source areas of derived artefact assemblages to be mapped and inter-assemblage comparisons to be undertaken.

2.4 The range and types of archaeological data in secondary context assemblages (Chapters 4, 6 & 7)

1. The vast majority of data consists of fluvial sedimentary deposits and stone tools.
2. Although palaeoenvironmental material occurs within archaeological secondary contexts, the contrasting spatio-temporal scales of the data do not permit their *direct* equation with the derived

artefact assemblages. When dealing with derived, secondary contexts, it cannot be assumed that the artefacts, fauna and flora were ever associated in time and/or space prior to their deposition within the same sedimentary deposit. Reconstructed palaeoenvironments are therefore only specific examples of some of the range of habitats that existed prior to and during fluvial depositional events, but they cannot be explicitly populated with either hominids or artefacts.

3. The spatio-temporal models of the structure of the archaeological secondary contexts indicated nine distinct analytical scales for the interpretation of the artefact data. Chronological scales ranged from sub-MI stages (100's and 1,000's of years) to MIS cycles (100,000's years). Spatial scales ranged from local (10's and 100's of metres) to regional, river system basins (1,000's of metres).
4. Research questions and techniques vary between the spatio-temporal scales (e.g. the analysis of technological trends at local, sub-MI stage scales, and demographic modelling at regional, MIS-cycle scales). Case studies were presented for the secondary context assemblage at Broom (Chapter 4) and the Axe and Test valley basins (Chapter 9).

2.5 Relationships between archaeological secondary contexts and extant analytical and interpretive frameworks (Chapter 9)

1. Archaeological research operates at a variety of data scales and resolutions. The project therefore sought to map the secondary context archaeological resource against appropriately scaled research questions.
2. It was clear that there are specific research questions that cannot be answered from archaeological secondary contexts (e.g. on-site analysis of spatial patterning in artefact distributions and subsistence practices).
3. It was also clear that there are specific research questions that are best addressed through archaeological secondary contexts (e.g. demographic patterns over MIS cycles and regional variations in artefact densities).
4. In order to fully investigate hominid behaviour, it is necessary to integrate primary and secondary context data. The frameworks proposed here have therefore highlighted the scope of secondary context investigations and demonstrated their incorporation within existing research frameworks more traditionally associated with primary context data-sets.

2.6 With respect to the management of the secondary context resource (Chapter 8)

1. The aggregates industry has facilitated the recording of the majority of UK Palaeolithic data, due to the deeply buried nature of the resource.
2. Therefore, archaeological watching briefs are the principal available mechanism for the monitoring of archaeological secondary contexts and the recording of data.
3. Current archaeological watching brief practice offers a range of contingency measures should *in situ* archaeology be discovered and suggests that monitoring is primarily concerned with such discoveries. This practice is unhelpful as it both downplays the value of the secondary context resource and presents an unfavourable image of archaeological intervention to the aggregates industry.
4. The spatio-temporal models have highlighted the importance of geochronological and sedimentary data from archaeological secondary contexts. It is therefore proposed that archaeological watching briefs need to:
    a. Explicitly state that Palaeolithic archaeological data from secondary contexts is not restricted to lithic artefacts. This principle should be explicit within both project design and practice.
    b. Develop cost-effective strategies for the systematic geochronological sampling of fluvial sedimentary sequences, utilising recent developments in OSL and amino-acid techniques. Developing securely dated geochronological sequences is important both for regions with and without a rich artefact heritage.
    c. Develop cost-effective strategies for the systematic lithostratigraphic recording of fluvial

   sedimentary sequences. These recording processes can be streamlined using new technologies (e.g. digital data-capture devices).
   d. In regions with rich artefact assemblages, reduce the focus upon the collection of lithic artefacts.
   e. However, in regions without demonstrated Palaeolithic occupation, sampling for lithic artefacts should be afforded a higher priority.
5. It is stressed that these proposals for watching brief practice would need to be developed in conjunction with the aggregates industry, and that the archaeological community needs to emphasise:
   a. That the primary goal of the watching brief process must still be preservation by record, given the destructive nature of the aggregates extraction process.
   b. That the principle foci of this preservation by record are the secondary context data (sedimentary sequences, geochronological sampling, and artefact recovery from exposed sections).
   c. That the secondary goal of the watching brief process must be the streamlining of on-site time and the minimising of disruption to industrial process.
   d. That primary context, *in situ* discoveries are extremely rare and that the profitable recovery of valuable secondary context data can be rapid and cost-efficient.

3. FUTURE DIRECTIONS

The project has also highlighted a number of areas towards which future research should be profitably directed:

- The development of regional geochronological frameworks for fluvial sedimentary sequences.
- Refinement of geochronological techniques with respect to their application and resolution over Pleistocene timescales.
- Experimental research exploring artefact behaviour within fluvial systems and the formation of secondary context assemblages.
- Re-investigation of historic secondary context artefact assemblages, utilising current models, recording methodologies and techniques.

4. CONCLUSION

In conclusion, this investigation into the archaeological potential of secondary contexts has demonstrated that:

- Due to their extensive geographical and temporal coverage, archaeological secondary contexts from the British Palaeolithic are a unique resource.
- The taphonomic processes associated with the spatio-temporal structure of the resource can be successfully modelled using extant data and new techniques.
- Valuable data for the reconstruction of early human behaviour can be extracted from secondary context artefact assemblages, at a range of different spatio-temporal scales.
- The development of appropriate strategies for the continuing management and recording of the secondary context resource during aggregates extraction are therefore vital.
- The integration of the primary and secondary context resource is critical to gaining a fuller understanding of early human behaviour during the British Palaeolithic.

REFERENCES

Adamiec, G. & Aitken, M.J. 1998. Dose-rate conversion factors: new data. *Ancient TL* 16: 37–50.

Allen, L.G. & Gibbard P.L. 1993. Pleistocene evolution of the Solent River of southern England. *Quaternary Science Review* 12: 503-528.

Anklin, M., Barnola, J-M., Beer, J., Blunier, T., Chappellaz, J., Clausen, H.B., Dahl-Jensen, D., Dansgaard, W., Angelis, M de., Delmas, R J., Duval, P., Fratta, M., Fuchs, A., Fuhrer, K., Gundestrup, N., Hammer, C., Iversen, P., Johnsen, S., Jouzel, J., Kipfstuhl, J., Legrand, M., Lorius, C., Maggi, V., Miller, H., Moore, J C., Oeschger, H., Orombelli, G., Peel, D.A., Raisbeck, G., Raynaud, D., Schott-Hvidberg, C., Schwander, J., Shoji, H., Souchez, R., Stauffer, B., Steffensen, J.P., Suevenard, M., Sveinbjornsdottir, A., Thorsteinsson, T. & Wolff, E.W. 1993. Climate instability during the last interglacial period recorded in the GRIP ice core. *Nature* 364: 203–207.

Ashton, N., Dean, P. & McNabb, J. 1991. Flaked flakes: what, where, when and why? *Lithics: The Newsletter of the Lithic Studies Society* 12: 1–11.

Ashton, N.M., Cook, J., Lewis, S.G. & Rose, J. (ed's). 1992. *High Lodge: Excavations by G. de G. Sieveking 1962–1968 and J. Cook 1988*. British Museum Press, London.

Ashton, N., McNabb, J., Irving, B., Lewis, S. & Parfitt, S. 1994. Contemporaneity of Clactonian and Acheulian flint industries at Barnham, Suffolk. *Antiquity* 68: 585–589.

Ashton, N.M., Lewis, S.G. & Parfitt, S.A. (ed's). 1998. *Excavations at the Lower Palaeolithic site at East Farm, Barnham, Suffolk 1989–94*. British Museum Occasional Paper No. 125. British Museum, London.

Ashton, N., Lewis, S.G. & Parfitt, S.A. 2000a. East Farm, Barnham, Suffolk. In S.G. Lewis, C.A. Whiteman & R.C. Preece (ed's) *The Quaternary of Norfolk & Suffolk: Field Guide*: 165–175. Quaternary Research Association, London.

Ashton, N., Lewis, S.G., Keen, D. & Parfitt, S.A. 2000b. Excavations at Elveden, Suffolk (TL 809804). In S.G. Lewis, C.A. Whiteman & R.C. Preece (ed's) *The Quaternary of Norfolk & Suffolk: Field Guide*: 165–175. Quaternary Research Association, London.

Ashton, N. & Lewis, S. 2002. Deserted Britain: Declining Populations in the British Late Middle Pleistocene. *Antiquity* 76 (2002): 388–396.

Bagnold, R.A. 1980. An empirical correlation of bedload transport rates in flumes and natural rivers. *Royal Society of London Proceedings* A372: 453–473.

Bailey, G.N. 1980. Concepts of time in Quaternary prehistory. *Annual Review of Anthropology* 12: 165–192.

Bailey, R.M. In press. The analysis of measurement-time dependent single aliquot equivalent dose estimates from quartz: implications for the identification of incompletely-bleached sediments. *Radiation Measurements.*

Bates, M.R. & Wenban-Smith, F.F. In prep. *The Palaeolithic Archaeology of the Sussex/Hampshire Coastal Corridor*. English Heritage Project Report (Project No. 3279).

Best, J. L. & Bristow, C.S. 1993. *Braided Rivers*. Geological Society Special Publications, Volume 75. Geological Society, London.

Best, J., Bennett, S., Bridge, J. & Leeder, M. 1997. Turbulence Modulation and Particle Velocity over Flat Sand Beds at Low Transport Rates. *Journal of Hydraulic Engineering* 123(12): 1118–1129.

Bibus, E. & Wesler, J. 1995. The middle Neckar as an example of fluvio-morphological processes during the Middle and Late Quaternary period. In J. Hagedorn (ed.) *Late Quaternary and present-day fluvial processes in Central Europe*: 15–26. Gebrüder Borntraeger, Berlin.

Binford, L.R. 1980. Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45: 1-17.

Binford, L.R. 1987. Searching for Camps and Missing the Evidence?: Another Look at the Lower Palaeolithic. In O. Soffer (ed.) *The Pleistocene Old World: Regional Perspectives*: 17-31. Plenum Press, New York.

Binyon, F.M. 2002. *Modern methods on ancient axes: a study of the Broom bifaces*. Unpublished MA Dissertation, University of Southampton.

Boëda, E., Geneste, J-M. & Meignen, L. 1990. Identification de chaînes opératoires lithiques du Paléolithique ancien et moyen. *Paléo* 2: 43–80.

Boggs, S. 1987. *Principles of Sedimentology and Stratigraphy*. Merrill, Columbus.

Boismier, W.A., Schreve, D.C., White, M.J., Robertson, D.A., Stuart, A.J., Etienne, S., Andrews, J., Coope, G.R., Field, M.H., Green, F.M.L., Keen, D.H., Lewis, S.G., French, C., Rhodes, E., Schwenninger, J.-L., Tovey, K., Donahue, R.E., Richards, M.P. & O'Connor, S. 2003. A Middle Palaeolithic Site at Lynford Quarry, Mundford, Norfolk: Interim Statement. *Proceedings of the Prehistoric Society* 69: 315–324.

Bowen, D.Q., Hughes, S., Sykes, G.A. & Miller, G.H. 1989. Land–sea correlations in the Pleistocene based on isoleucine epimerization in non-marine molluscs. *Nature* 340: 49–51.

Brewer, P.A., Maas, G.S. & Macklin, M.G. 2000. A fifty year history of exposed riverine sediment dynamics on

Welsh rivers. In J.A.A. Jones, K. Gilman, A. Jigorel & J. Griffin (ed's) *Water in the Celtic World: Managing Resources in the 21st Century*: 245–252. British Hydrological Society, Wallingford.

Brewer, P.A., Macklin, M.G. & Jones, A. 2002. Channel change and bank erosion on the Afon Rheidol: the Felin Rhiwarthen and Lovesgrove meanders. In M.G. Macklin, P.A. Brewer & T.J. Coulthard (ed's) *River systems and environmental change in Wales: Field Guide*: 40–50. British Geomorphological Research Group, Aberystwyth.

Bridgland, D.R. 1985. Uniclinal shifting: A speculative reappraisal based on terrace distribution in the London Basin. *Quaternary Newsletter* 47: 26-33.

Bridgland, D.R. 1994. *Quaternary of the Thames*. Geological Conservation Review Series 7. Chapman and Hall, London.

Bridgland, D.R. 1995. The Quaternary sequence of the eastern Thames basin: problems of correlation. In D.R. Bridgland, P. Allen & B.A. Haggart (ed's) *The Quaternary of the Lower Reaches of the Thames: Field Guide*: 35–52. Quaternary Research Association, Durham.

Bridgland, D.R. 1996. Quaternary River Terrace Deposits as a Framework for the Lower Palaeolithic Record. In C.S. Gamble & A.J. Lawson (ed's) *The English Palaeolithic Reviewed*: 23–39. Wessex Archaeology Ltd., Salisbury.

Bridgland, D.R. 1998. The Pleistocene history and early human occupation of the River Thames valley. In N. Ashton, F. Healy & Pettitt, P. (ed's) *Stone Age Archaeology: Essays in honour of John Wymer*: 29–37. Lithic Studies Society Occasional Paper 6. Oxbow Books, Oxford.

Bridgland, D.R. 2000. River terrace systems in north-west Europe: an archive of environmental change, uplift and early human occupation. *Quaternary Science Review* 19: 1293–1303.

Bridgland, D.R. 2001. The Pleistocene Evolution and Palaeolithic Occupation of the Solent River. In F.F. Wenban-Smith & R.T. Hosfield (ed's) *Palaeolithic Archaeology of the Solent River*: 15–25. Lithic Studies Society, London.

Bridgland, D.R. & Harding, P.A. 1987. Palaeolithic sites in tributary valleys of the Solent River. In K.E. Barber (ed.) *Wessex and the Isle of Wight: Field Guide*: 45–58. Quaternary Research Association, Cambridge.

Bridgland, D.R. & Harding, P.A. 1993. Preliminary Observations at the Kimbridge Farm Quarry, Dunbridge, Hampshire: Early Results of a Watching Brief. *Quaternary Newsletter* 69: 1–9.

Bridgland, D.R., Allen, P. & Haggart, B.A. (ed's). 1995. *The Quaternary of the Lower Reaches of the Thames: Field Guide*. Quaternary Research Association, Durham.

Bridgland, D.R. & Allen, P. 1996. A revised model for terrace formation and its significance for the lower Middle Pleistocene Thames terrace aggradations of north-east Essex, U.K. In C. Turner (ed.) *The Early Middle Pleistocene in Europe*: 121–134. Balkema, Rotterdam.

Bridgland, D.R., Keen, D.H. & Maddy, D. 1989. The Avon terraces: Cropthorne, Ailstone and Eckington. In D.H. Keen (ed.) *West Midlands: Field Guide*: 51–67. Quaternary Research Association, Cambridge.

Bridgland, D.R. & Schreve, D.C. 2001. River terrace formation in synchrony with long-term climatic fluctuation: supporting mammalian evidence from southern Britain. In D. Maddy, M. Macklin & J. Woodward (ed's) *River Basins Sediments Systems: Archives of Environmental Change*: 229–248. Baltema, Rotterdam.

Briggs, D.J., Coope, G.R. & Gilbertson, D.D. 1985. *The Chronology and Environmental Framework of Early Man and the Upper Thames Valley. A New Model.* British Archaeological Report, British Series 137. BAR, Oxford.

Briggs, D.J., Gilbertson, D.D. & Harris, A.L. 1990. Molluscan taphonomy in a braided river environment and its implications for studies of Quaternary cold-stage river deposits. *Journal of Biogeography* 17: 623–637.

Bristow, C. 1996. Reconstructing Fluvial Channel Morphology from Sedimentary Sequences. In P.A. Carling & M.R. Dawson (ed's) *Advances in Fluvial Dynamics and Stratigraphy*: 351–371. John Wiley & Sons Ltd, Chichester.

Brown, A.G., Cooper, L., Salisbury, C.R. & Smith, D.N. 2001. Late Holocene channel changes of the Middle Trent: channel response to a thousand-year flood record. *Geomorphology* 39: 69–82.

Bryant, I.D. 1983. The utilization of arctic river analogue studies in the interpretation of periglacial river sediments from southern Britain. In K.J. Gregory (ed.) *Background to Paleohydrology*: 413–431. Chichester, Wiley.

Büdel, J. 1977. *Klima-Geomorphologie*. Gebrüder Borntraeger, Berlin.

Bunn, H., Harris, J.W.K., Isaac, G., Kaufulu, Z., Kroll, E., Schick, K., Toth, N. & Behrensmeyer, A.K. 1980. FxJj50: An Early Pleistocene Site in Northern Kenya. *World Archaeology* 12(1): 109–136.

Callow, P. 1986. A Comparison of British and French Acheulean bifaces. In S.N. Collcutt (ed.) *The Palaeolithic of Britain and its Nearest Neighbours: Recent Trends*: 3–7. Department of Archaeology and Prehistory, University of Sheffield, Sheffield.

Campbell, S.S. 1998. *Quaternary of South-West England*. Chapman Hall, London.

Chambers, J.C. In prep. *The spatial modelling of Palaeolithic secondary context assemblages: case studies from the Solent River System and Axe River Valley, UK.* Unpublished PhD Thesis, University of Southampton.

Charman, D.J. 2001. Biostratigraphic and palaeoenvironmental applications of testate amoebae. *Quaternary Science Reviews* 20: 1753–764.

Church, M. & Hassan, M.A. 1992. Size and distance of unconstrained clasts on a streambed. *Water Resources Research* 28: 299–303.

Clark, J.D. 1974. *Kalambo Falls prehistoric site. Volume 2.* Cambridge University Press, Cambridge.

Clark, J.G.D. 1975. *The Earlier Stone Age Settlement of Scandinavia.* Cambridge University Press, Cambridge.

Clayton, K.M. 1977. River Terraces. In F.W. Shotton (ed.) *British Quaternary Studies: Recent Advances*: 153–168.

Clarendon Press, Oxford.
Cleveringa, P., De Gans, W., Huybrechts, W. & Verbruggen, C. 1988. Outline of river adjustments in small river basins in Belgium and the Netherlands since the Upper Pleniglacial. In G. Lang & C. Schluchter (ed's) *Lake, Mire and River Environments During the Last 15000 Years*: 123–132. Balkema, Rotterdam.
Collins, M. 2003. *Amino acid racemization dating of Quaternary sediments*. Paper presented at the ALSF Meeting on Techniques and Technical Developments in Aggregate-Related Archaeology, Keyworth (British Geological Survey), October 2003.
Collins, P.E.F., Fenwick, I.M., Keith-Lucas, M.D. & Worsley, P. 1996. Late Devensian river and floodplain dynamics and related environmental change in northwest Europe, with particular reference to a site at Woolhampton, Berkshire, England. *Journal of Quaternary Science* 11(5): 357–375.
Conway, B.W. 1969. Preliminary geological investigation of Boyn Hill Terrace deposits at Barnfield Pit, Swanscombe, Kent, during 1968. *Proceedings of the Royal Anthropological Institute for 1968*: 59–61.
Conway, B., McNabb, J. & Ashton, N. (ed's). 1996. *Excavations at Barnfield Pit, Swanscombe 1968–1972*. British Museum Occasional Paper No. 94. British Museum, London.
Coope, G.R. 1977. Quaternary Coleopteran as aids in the interpretation of environmental history. In F.W. Shotton (ed.) *British Quaternary Studies — recent advances*: 55–68. Oxford University Press, Oxford.
Coope, G.R. 1987. The response of Late Quaternary insect communities to sudden climatic changes. In J.H.R. Gee & P.S. Giller (ed's) *Organisation of Communities, Past and Present*: 421–438. Blackwell Scientific, Oxford.
Coope, G.R. 2001. Biostratigraphical distinction of interglacial coleopteran assemblages from southern Britain attributed to Oxygen Isotope Stages 5e and 7. *Quaternary Science Reviews* 20: 1717–1722.
Coope, G.R. & Lister, A.M. 1987. Late glacial mammoth skeletons from Condover, Shropshire, England. *Nature* 330: 472–474.
Cotswold Archaeological Trust. 2000. *Squabb Wood, Romsey, Hampshire. Project Design for an Archaeological Watching Brief.* Cotswold Archaeological Trust.
Coulson, S.D. 1986. The Bout Coupé Handaxe as a Typological Mistake. In S.N. Collcutt (ed.) *The Palaeolithic of Britain and its Nearest Neighbours: Recent Trends*: 53–54. Department of Archaeology and Prehistory, University of Sheffield, Sheffield.
Crossley, A.J., Wright, N.G. & Whitlow, C.D. 2003. Local time stepping for modelling open channel flows. *Journal of Hydraulic Engineering* 129(6): 455–462.
Currant, A.P. 1989. The Quaternary origins of the modern British mammal fauna. Biological *Journal of the Linnean Society* 38: 22–30.
Currant, A. & Jacobi, R. 2001. A formal mammalian biostratigraphy for the Late Pleistocene of Britain. *Quaternary Science Reviews* 20: 1707–1716.
Dale, W. 1896. The Palaeolithic Implements of the Southampton Gravels. *Papers and Proceedings of the Hampshire Field Club and Archaeological Society* 3: 261–264.
Dale, W. 1912a. On the Implement-bearing gravel beds of the lower valley of the Test. *Proceedings of the Society of Antiquaries* 24: 108–116.
Dale, W. 1912b. Discussion. In E. Hull. On the Interglacial gravel beds of the Isle of Wight and the South of England, and the conditions of their formation (Abstract). *Quarterly Journal of the Geological Society of London* 68: 21–22.
Dale, W. 1918. Report as Local Secretary for Hampshire. *Proceedings of the Society of Antiquaries* 30: 20–32.
Dancey, C.L., Diplas, P., Papanicolaou, A. & Bala, M. 2002. Probability of individual grain movement and threshold condition. *Journal of Hydraulic Engineering* 128(12): 1069–1075.
Davidson, I. & Noble, W. 1993. Tools and language in human evolution. In K.R. Gibson & T. Ingold (ed's) *Tools, language and cognition in human evolution*: 363–388. Cambridge University Press, Cambridge.
Department of the Environment. 1989. *Minerals Planning Guidance 6: Guidelines for aggregates provision in England.* Department of the Environment, HMSO.
Department of the Environment. 1990. *Planning Policy Guidance Note 16: Archaeology and Planning*. Department of the Environment, HMSO.
Dincauze, D.F. 2000. *Environmental Archaeology: principles and practice*. Cambridge University Press, Cambridge.
Dominguez-Rodrigo, M., Serrallonga, J., Juan-Tresserras, J., Alcala, L. & Luque, L. 2001. Woodworking activities by early humans: a plant residue analysis on Acheulian stone tools from Peninj (Tanzania). *Journal of Human Evolution* 40: 289–299.
Einstein, H.A. 1942. Formula for the transportation of bed-load. *Transactions of the American Society of Civil Engineers* 107.
Einstein, H.A. 1950. *The bed-load function for sediment transportation in open channel flows*. United States Department of Agriculture, Soil Conservation Service, Technical Bulletin No 1026.
Engelund, F. & Fredsøe, J. 1967. A sediment transport model for straight alluvial channels. *Nordic Hydrology* 7: 293–306.
English Heritage. 1998. *Identifying and protecting Palaeolithic remains: Archaeological guidance for planning authorities and*

developers. English Heritage, London.
Evans, J. 1872. *The ancient stone implements, weapons and ornaments of Great Britain* (1st edition). Longmans, London.
Evans, J. & O'Connor, T. 1999. *Environmental Archaeology: Principles and Methods*. Sutton, Stroud.
Evans, P. 1971. Towards a Pleistocene time scale. The Phanerozoic time scale: a supplement. *Geological Society Special Publication* 5(2): 123–356.
Féblot-Augustins, J. 1997. *La circulation des matières premières au Paléolithique*. Études et Recherches Archéologiques de l'Université de Liege No. 75. ERAUL, Liege.
Fluck, H. 2002. *The Victoria West: an investigation into the prepared core technology of South Africa*. Unpublished MA Dissertation, University of Southampton.
Foley, R. 1981. A model of regional archaeological structure. *Proceedings of the Prehistoric Society* 47: 1–17.
Gamble, C.S. 1996. Hominid Behaviour in the Middle Pleistocene: an English Perspective. In C.S. Gamble & A.J. Lawson (ed's) *The English Palaeolithic Reviewed*: 61–71. Wessex Archaeology Ltd, Salisbury.
Gamble, C.S. 1997. Review. The Skills of the Lower Palaeolithic World. *Proceedings of the Prehistoric Society* 63: 407–410.
Gamble, C.S. & Roebroeks, W. 1999. The Middle Palaeolithic: a point of inflection. In W. Roebroeks & C.S. Gamble (ed's) *The Middle Palaeolithic Occupation of Europe*: 3–21. University of Leiden Press, Leiden.
Gamble, C.S. 1999. *The Palaeolithic Societies of Europe*. Cambridge University Press, Cambridge.
Gibbard, P.L. 1985. *The Pleistocene History of the Middle Thames Valley*. Cambridge University Press, Cambridge.
Gibbard, P.L. 1994. *The Pleistocene History of the Lower Thames Valley*. Cambridge University Press, Cambridge.
Gibbard, P.L. & Lewin, J. 2002. Climate and related controls on interglacial fluvial sedimentation in lowland Britain. *Sedimentary Geology* 151: 187–210.
Giddens, A. 1984. *The constitution of society*. University of California Press, Berkeley.
Gittins, S.R.D., Brewer, P.A. & Macklin, M.G. 2002. Exposed riverine sediment dynamics in mid-Wales rivers. In M.G. Macklin, P.A. Brewer & T.J. Coulthard (ed's) *River systems and environmental change in Wales: Field Guide*: 51–57. British Geomorphological Research Group, Aberystwyth.
Gomez, B. & Church, M. 1989. An assessment of bedload sediment transport formulae from gravel bed rivers. *Water Resources Research* 25: 1161–1186.
Goodwin, J.H. 1929. Part III. The Victoria West Industry. In J.H. Goodwin & C. van Riet Lowe. The Stone Age Cultures of South Africa. *Annals of the South African Museum* 27: 53–71.
Gowlett, J.A.J. & Hallos, J. 2000. Beeches Pit: Overview of the Archaeology. In S.G. Lewis, C.A. Whiteman & R.C. Preece (ed's) *The Quaternary of Norfolk & Suffolk: Field Guide*: 197–206. Quaternary Research Association, London.
Graf, W.H. & Cellino, M. 2002. Suspension flows in open channels: experimental study. *Journal of Hydraulic Research* 40(4): 435–447.
Green, C.P. 1974. Pleistocene gravels of the River Axe in south-western England, and their bearing on the southern limit of glaciation in Britain. *Geological Magazine* 111: 213–220.
Green, C.P. 1988. The Palaeolithic site at Broom, Dorset, 1932–41: from the record of C.E. Bean, Esq., F.S.A. *Proceedings of the Geologists' Association* 99: 173–180.
Green, C.P. & McGregor, D.F.M. 1980. Quaternary evolution of the River Thames. In D.K.C. Jones (ed.) *The Shaping of Southern England*: 177–202. Academic Press, London.
Green, C.P. & McGregor, D.F.M. 1987. River Terraces: a stratigraphic record of environmental change. In V. Gardiner (ed.) *International Geomorphology 1986 Part 1*: 977–987. Wiley, Chichester.
Green, H.S. 1984. *Pontnewydd Cave: a lower Palaeolithic hominid site in Wales: the first report*. National Museum of Wales, Cardiff.
Griffiths, H.I. 2001. Ostracod evolution and extinction – its biostratigraphic value in the European Quaternary. *Quaternary Science Reviews* 20: 1743–1751.
Ham, D.G. & Church, M. 2000. Bed-material transport estimated from channel morphodynamics: Chilliwack River, British Columbia. *Earth Surface Processes and Landforms* 25: 1123–1142.
Hardaker, T. 2001. New Lower Palaeolithic Finds from the Upper Thames. In S. Milliken & J. Cook (ed's) *A Very Remote Period Indeed: Papers on the Palaeolithic Presented to Derek Roe*: 180–198. Oxbow Books, Oxford.
Hardaker, T. & MacRae, R.J. 2000. A Lost River and Some Palaeolithic Surprises: New Quartzite Finds from Norfolk and Oxfordshire. *Lithics: Newsletter of the Lithic Studies Society* 21: 52–59.
Harding, P.A. 1998. An Interim Report of an Archaeological Watching Brief on Palaeolithic Deposits at Dunbridge, Hants. In N. Ashton, F. Healy & P. Pettitt (ed's) *Stone Age Archaeology: Essays in Honour of John Wymer*: 72–76. Oxbow Monograph 102 & Lithic Studies Society Occasional Paper No. 6. Oxbow Books, London.
Harding, P., Gibbard, P.L., Lewin J., Macklin, M.G. & Moss, E.H. 1987. The transport and abrasion of flint handaxes in a gravel-bed river. In G. de G. Sieveking & M.H. Newcomer (ed's) *The Human Uses of Flint and Chert: Proceedings of the Fourth International Flint Symposium Held at Brighton Polytechnic, Oct 15th April 1983*: 115–126. Cambridge University Press, Cambridge.
Harvey, A. M., Oldfield, F. & Baron, A.F. 1981. Dating of post-glacial landforms in the Central Howgills. *Earth Surface Processes and Landforms* 6: 401–412.

Harvey, A.M. & Renwick, W.H. 1987. Holocene alluvial fan and terrace formation in the Bowland Fells, Northwest England. *Earth Surface Processes and Landforms* 12: 249–257.
Hassan, M.A. & Church, M. 2001. Sensitivity of bed load transport in Harris Creek: Seasonal and spatial variation over a cobble-gravel bar. *Water Resources Research* 37(3): 813–825.
Hassan, M.A., Church, M. & Ashworth, P.J. 1992. Virtual Rate and Mean Distance of Travel of Individual Clasts in Gravel-Bed Channels. *Earth Surface Processes and Landforms* 17: 617–627.
Hassan, M.A., Church, M. & Schick, A.P. 1991. Distance of Movement of Coarse Particles in Gravel Bed Streams. *Water Resources Research* 27(4): 503–511.
Health & Safety Executive. 2003a. *A Review of Safety Passport Training Schemes*. Health & Safety Laboratory, Sheffield.
Health & Safety Executive. 2003b. *Passport schemes for health, safety and the environment: a good practice guide*. Health & Safety Executive, Sheffield.
Hosfield, R.T. 1999. *The Palaeolithic of the Hampshire Basin: a regional model of hominid behaviour during the Middle Pleistocene*. BAR British Series 286. Archaeopress, Oxford.
Hosfield, R.T. 2001. The Lower Palaeolithic of the Solent: site formation and interpretive frameworks. In F.F. Wenban-Smith & R.T. Hosfield (ed's) *Palaeolithic Archaeology of the Solent River*: 85–97. Lithic Studies Society Occasional Paper 7. Lithic Studies Society, London.
Hosfield, R.T. 2002. *The Archaeological Potential of Secondary Contexts (Project Design)*. Submitted to English Heritage (Aggregates Levy Sustainability Fund).
Hosfield, R.T. In prep. Individuals among palimpsest data: a case study from southern England. In C.S. Gamble & M. Porr (ed's) *The Individual Hominid in Context: Archaeological Investigations of Lower and Middle Palaeolithic landscapes, locales and artefacts*. Routledge (Taylor & Francis).
Hosfield, R.T., Chambers, J.C., Macklin, M.G., Brewer, P. & Sear, D. 2000. Interpreting Secondary Context Sites: A Role for Experimental Archaeology. *Lithics: The Newsletter of the Lithic Studies Society* 21: 29–35.
Hosfield, R.T. & Chambers, J.C. 2002a. Processes and Experiences — Experimental Archaeology on a River Floodplain. In M.G. Macklin, P. A. Brewer & T .J. Coulthard (ed's) *River Systems and Environmental Change in Wales: Field Guide*: 32–39. British Geomorphological Research Group, Aberystwyth.
Hosfield, R.T. & Chambers, J.C. 2002b. The Lower Palaeolithic site of Broom: geoarchaeological implications of optical dating. *Lithics: The Newsletter of the Lithic Studies Society* 23: 33–42.
Hosfield, R.T. & Chambers, J.C. 2003. *Rivers gravels, flakes and handaxes: Experiments in site formation, stone tool transportation and transformation*. Paper presented at the 1st Conference of the European Association for the Advancement of Archaeology by Experiment (Vienna, 10–12th October 2003).
Hosfield, R.T. & Chambers, J.C. 2004. Experimental Archaeology on the Afon Ystwyth, Wales, UK. *Antiquity* 78 (299): http://antiquity.ac.uk/ProjGall/chambers/chambers.html
Hosfield, R.T. & Chambers, J.C. In prep. Secondary Contexts: Interpretive frameworks for the derived artefacts of the British Lower Palaeolithic. *Proceedings of the Prehistoric Society*.
Hosfield, R.T., Toms, P., Chambers, J.C. & Green, C.P. In prep. Late Middle Pleistocene dates from the Broom Palaeolithic sites. *Journal of Quaternary Science*.
Houben, P., Nolte, S., Rittweger, H. & Wunderlich, J. 2001. Lateglacial and Holocene environmental change indicated by floodplain deposits of the Hessian Depression (Central Germany). In D. Maddy, M.G. Macklin & J.C. Woodward (ed's) *River Basin Sediment Systems: Archives of Environmental Change*: 249–264. Balkema, Lisse.
Houben, P. 2003. Spatio-temporally variable response of fluvial systems to Late Pleistocene climate change: a case study from central Germany. *Quaternary Science Reviews* 22: 2125–2140.
Housley, R.A., Gamble, C.S., Street, M. & Pettitt, P. 1997. Radiocarbon evidence for the Lateglacial Human Recolonisation of Northern Europe. *Proceedings of the Prehistoric Society* 63: 25–54.
Howard, A.J. & Macklin, M.G. 1999. A generic morphological approach to archaeological interpretation and prospection in British river valleys: a guide for archaeologists investigating Holocene landscapes. *Antiquity* 73: 527–541.
Howard, A.J., Keen, D.H. & Hollin, J.T. 1999. Amino acid dating of a molluscan fauna from Bassingham Fen, Lincolnshire: implications for the chronology of the Trent terraces. *Proceedings of the Geologists Association* 110 (3): 233–239.
Hubbard, R.N.L.B. 1982. The environmental evidence from Swanscombe, and its implications for Palaeolithic archaeology. In P.E. Leach (ed.) *Archaeology in Kent to AD 1500*: 3–7. Council for British Archaeology Research Report 48.
Hunziker, R.P. & Jaeggi, M.N.R. 2002. Grain Sorting Processes. *Journal of Hydraulic Engineering* 128(12): 1060–1068.
Hütt, G., Jaek, I. & Tchonka, J. 1988. Optical dating: K-feldspars optical response stimulation spectra. *Quaternary Science Reviews* 7: 381–386.
Ingold, T. 1993. The temporality of the landscape. *World Archaeology* 25: 152–173.
Institute of Field Archaeologists. 2001. *Standard and Guidance for an archaeological watching brief*. Institute of Field Archaeologists, London.
Isaac, G.L. 1989. Towards the interpretation of occupation debris: some experiments and observations. In B. Isaac

(ed.) *The Archaeology of Human Origins: Papers by Glynn Isaac*: 191–205. Cambridge University Press, Cambridge.
Jacobi, R.M., Rowe, P.J., Gilmour, M.A., Grün, R. & Atkinson, T.C. 1998. Radiometric dating of the Middle Palaeolithic tool industry and associated fauna of Pin Hole Cave, Creswell Crags, England. *Journal of Quaternary Science* 13: 29–42.
Johnstone, E., Macklin, M.G. & Brewer, P.A. 2002. Late Quaternary river terrace development in the Dyfi valley. In M.G. Macklin, P.A. Brewer & T.J. Coulthard (ed's) *River systems and environmental change in Wales: Field Guide*: 6–16. British Geomorphological Research Group, Aberystwyth.
Jones, A.P., Tucker, M.E. & Hart, J.K. 1999. Guidelines and Recommendations. In A.P. Jones, M.E. Tucker & J.K. Hart (ed's) *The Description and Analysis of Quaternary Stratigraphic Field Sections*: 27–76. Technical Guide 7. Quaternary Research Association, London.
Keen, D.H. 1990. Significance of the record provided by Pleistocene fluvial deposits and their included molluscan faunas for palaeontological reconstruction and stratigraphy: cases from the English Midlands. *Palaeogeography, Palaeoclimatology, Palaeoecology* 80: 25–34.
Keen, D.H. 2001. Towards a late Middle Pleistocene non-marine molluscan biostratigraphy for the British Isles. *Quaternary Science Reviews* 20: 1657–1665.
Kerney, M.P. 1968. Britain's fauna of land mollusca and its relation to the post-glacial thermal optimum. *Symposia of the Zoological Society, London* 22: 273–291.
King, W.B.R. & Oakley, K.P. 1936. The Pleistocene succession in the lower part of the Thames valley. *Proceedings of the Prehistoric Society* 1: 52–76.
Koenigswald, W. von & Kolfschoten, T. van. 1996. The Mimomys-Arvicola boundary and the enamel thickness quotient (SDQ) of Arvicola as stratigraphic marker in the Middle Pleistocene. In C. Turner (ed.) *The Early Middle Pleistocene in Europe*: 211–226. Balkema, Rotterdam.
Kozarski, S., Gonera, P. & Antczak, B. 1988. Valley floor development and paleohydrological changes: The Late Vistulian and Holocene history of the Warta River (Poland). In G. Lang & C. Schluchter (ed's) *Lake, Mire and River Environments During the Last 15000 Years*: 185–203. Balkema, Rotterdam.
Lee, H.Y., Chen, Y.S., You, J.Y. & Lin, Y.T. 2000. Investigations of continuous bed load process. *Journal of Hydraulic Engineering* 126/9: 691–700.
Lee, H.Y., Jiing-Yun, Y. & Tien Lin, Y. 2002. Continuous saltating process of multiple sediment particles. *Journal of Hydraulic Engineering* 128: 443–450.
Lemdahl, G. 1991. A rapid climatic change at the end of the Younger Dryas in southern Sweden — palaeoclimatic and palaeoenvironmental reconstructions based on fossil insect assemblages. *Palaeogeography, Palaeoclimatology, Palaeoecology* 83: 313–331.
Lewis, S.G. & Maddy, D. 1999. Description and Analysis of Quaternary Fluvial Sediments: a case study from the Upper River Thames, UK. In A.P. Jones, M.E. Tucker & J.K. Hart (ed's) *The Description and Analysis of Quaternary Stratigraphic Field Sections*: 111–135. Quaternary Research Association, London.
Lewin, J. & Brewer, P.A. 2002. Laboratory Simulation of Clast Abrasion. *Earth Surface Processes and Landforms* 27: 145–164.
Lister, A.M. 1992. Mammalian fossils and Quaternary biostratigraphy. *Quaternary Science Reviews* 11: 329–344.
Lowe, J.J. & Walker, M.J.C. 1997. *Reconstructing Quaternary Environments* (2nd Edition). Pearson Education Limited, Harlow.
Macklin, M.G. & Lewin, J. 1993. Holocene river alluviation in Britain. In I. Douglas & J. Hagedorn (ed.) *Geomorphology and Geoecology*: 109–122. Gebrüder Borntraeger, Berlin.
Macklin, M.G. 1995. Archaeology and the river environment of Britain: a prospective review. In A.J. Barham & R.I. Macphail (ed's) *Archaeological sediments and soils: analysis, interpretation and management*: 205–220. Institute of Archaeology, London.
Macklin, M.G., Brewer, P.A. & Coulthard, T.J. (ed's) 2002. *River systems and environmental change in Wales: Field Guide*. British Geomorphological Research Group, Aberystwyth.
MacRae, R.J. 1988. The Palaeolithic of the Upper Thames Valley and its Quartzite Implements. In R.J. MacRae & N. Moloney (ed's) *Non-Flint Stone Tools and the Palaeolithic Occupation of Britain*: 49–65. British Archaeological Reports British Series 189. BAR, Oxford.
MacRae, R.J. 1990 New Finds and Old Problems in the Lower Palaeolithic of the Upper Thames Valley. *Lithics: Newsletter of the Lithic Studies Society* 11: 3–15.
MacRae, R.J. 1991 New Lower Palaeolithic Finds from Gravel Pits in Central Southern England. *Lithics: newsletter of the Lithic Studies Society* 12: 12–19.
MacRae, R.J. 1999. New Lower Palaeolithic Finds in Norfolk. *Lithics: Newsletter of the Lithic Studies Society* 20: 3–9.
Maddy, D. 1997. Uplift driven valley incision and river terrace formation in Southern England. *Journal of Quaternary Science* 12: 539–545.
Maddy, D. & Bridgland, D.R. 2000. Accelerated uplift resulting from Anglian glacioisostatic rebound in the Middle Thames valley, UK? Evidence from the river terrace record. *Quaternary Science Review* 19: 1581–1588.
Maddy, D., Bridgland, D.R. & Westaway, R. 2001. Uplift-driven valley incision and climate-controlled river terrace

development in the Thames Valley, UK. *Quaternary International* 79: 23–36.

Maddy, D., Keen, D.H., Bridgland, D.R. & Green, C.P. 1991. A revised model for the Pleistocene development of River Avon, Warwickshire. *Journal of the Geological Society of London* 148: 473–484.

Maddy, D., Green, C.P., Lewis, S.G. & Bowen, D.Q. 1995. Pleistocene geology of the Lower Severn valley, UK. *Quaternary Science Reviews* 14: 209–222.

Maddy, D., Lewis, S.G., Scaife, R.G., Bowen, D.Q., Coope, G.R., Green, C.P., Hardaker, T., Keen, D.H., Rees-Jones, J., Parfitt, S. & Scott, K. 1998. The Upper Pleistocene deposits at Cassington, near Oxford, England. *Journal of Quaternary Science* 13 (3): 205–231.

Malmaeus, J.M. & Hassan, M.A. 2002. Simulation of Individual Particle Movement in a Gravel StreamBed. *Earth Surface Processes and Landforms* 27: 81–97.

Markey, B.G., Bøtter-Jensen, L. & Duller, G.A.T. 1997. A new flexible system for measuring thermally and optically stimulated luminescence. *Radiation Measurements* 27: 83–89.

Marshall, G.D. 2001. The Broom pits: a review of research and a pilot study of two Acheulean biface assemblages. In F.F. Wenban-Smith & R.T. Hosfield (ed's) *Palaeolithic Archaeology of the Solent River*. Lithic Studies Society Occasional Paper 7: 77–84. Lithic Studies Society, London.

Martin, Y. & Church, M. 2000. Re-examination of Bagnold's empirical bedload formulae. *Earth Surface Processes and Landforms* 25: 1011–1024.

Mayhew, D.F. 1977. Avian predators as accumulators of fossil mammal material. *Boreas* 6: 25–31.

Mayle, F.E. & Cwynar, L.C. 1995. Impact of the Younger Dryas cooling event upon lowland vegetation of Maritime Canada. *Quaternary Science Reviews* 12: 295–306.

McNabb, J. & Ashton, N. 1992. The Cutting Edge: Bifaces in the Clactonian. *Lithics: The Newsletter of the Lithics Studies Society* 13: 4–10.

McNabb, J. 1996. More from the cutting edge: further discoveries of Clactonian bifaces. *Antiquity* 70(268): 428–436.

Meinke, K. 1995. The development of the middle and lower course of the Weser river during the Late Pleistocene. In J. Hagedorn (ed.) *Late Quaternary and present-day fluvial processes in Central Europe*: 1–13. Gebrüder Borntraeger, Berlin.

Mellars, P. 1996. *The Neanderthal Legacy*. University of Princeton Press, Princeton.

Miall, A. D. 1996. *The Geology of Fluvial Deposits: Sedimentary Facies, Basin Analysis and Petroleum Geology*. Springer-Verlag, Berlin.

Mitchell, G.F., Penny, L.F., Shotton, F.W. & West, R.G. (ed's). 1973. A correlation of Quaternary deposits in the British Isles. *Special Report of the Geological Society of London* 4: 1–99.

Mithen, S. 1996. *Social learning and cultural tradition.* In J. Steele & S. Shennan (ed's) The Archaeology of Human Ancestry: 207–229. Routledge, London.

Murphy, P.J. & Hooshiari, H. 1982. Saltation in water dynamics. *Journal of the Hydraulics Division of the American Society of Civil Engineers* 108: 1251–1267.

Murray, A.S. & Roberts, R.G. 1997. Determining the burial time of single grains of quartz using optically stimulated luminescence. *Earth and Planetary Science Letters* 152: 163–180.

Murray, A.S. & Wintle, A.G. 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* 32: 57–73.

Murray, J. 1985. *Modification of Experimental Flint Scatters by Fluvial Processes*. Unpublished BA Dissertation. Institute of Archaeology, University College London.

Muste, M. 2002. Sources of bias errors in flume experiments on suspended-sediment transport. *Journal of Hydraulic Research* 40(6): 695–708.

Nanson, G.C. & Croke, J.C. 1992. A genetic classification of floodplains. Geomorphology 4: 459–486.

Newcomer, M.H. 1971. Some quantitative experiments in handaxe-axe manufacture. *World Archaeology* 3: 85–94.

Nichols, G. 1999. *Sedimentology and Stratigraphy*. Blackwell Science Ltd., London.

Niño, Y. & García, M. 1998. Experiments on saltation of sand in water. *Journal of Hydraulic Engineering* 124(10): 1014–1025.

Ovey, C.D. (ed.). 1964. *The Swanscombe Skull. A survey of research on a Pleistocene Site*. Royal Anthropological Institute Occasional Paper No. 20. Royal Anthropological Institute of Great Britain & Ireland, London.

Petit, J.R., Jouzel, J., Raynaud, D., Barkov, N.I., Barnola, J-M., Basile, I., Benders, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyakov, V.M., Legrand, M., Lipenkov, V.Y., Lorius, C., Pepin, L., Ritz, C., Saltzman, E. & Stievenard, M. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* 399: 429–436.

Pike, K. & Goodwin, H. 1953. The interglacial at Clacton-on-Sea, Essex. *Quarterly Journal of the Geological Society of London* 108: 261–272.

Ponel, P. & Coope, G.R. 1990. Lateglacial and early Flandrian Coleoptera from La Taphanel, Massif Central, France: climatic and ecological implications. *Journal of Quaternary Science* 5: 235–250.

Pope, M. 2001. New Investigations at Slindon Bottom Palaeolithic Site, West Sussex: An Interim Report. *Lithics: The Newsletter of the Lithic Studies Society* 22: 3–10.

Preece, R.C. 1995. Mollusca from interglacial sediments at three critical sites in the Lower Thames. In D.R. Bridgland, D. Allen & B.A. Haggert (ed's) *The Quaternary of the Lower Reaches of the Thames: Field Guide*: 53–62. Quaternary Research Association, London.
Preece, R.C. 2001. Molluscan evidence for differentiation of interglacials within the 'Cromerian Complex'. *Quaternary Science Reviews* 20: 1643–1656.
Prehistoric Society, The. 1999. *Research Frameworks for the Palaeolithic and Mesolithic of Britain and Ireland*. English Heritage, London.
Prescott, J.R. & Hutton, J.T. 1994. Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. *Radiation Measurements* 23: 497–500.
Read, C.J. 1885. The Flint Implements of Bemerton and Milford Hill, near Salisbury. *Wiltshire Archaeological and Natural History Magazine* 22: 117–123.
Reid Moir, J. 1936. Ancient Man in Devon. *Proceedings of the Devon Archaeological Exploration Society* 2: 264–275.
Renfrew, C. & Bahn, P. 1996. *Archaeology: Theories, Methods, and Practice* (2nd edition). Thames & Hudson, London.
Rhodes, E. 2003. *Luminescence dating: recent advances, new results*. Paper presented at the Palaeolithic-Mesolithic Day Meeting (London, 10th–11th April 2003).
Roberts, R.G., Galbraith, R.F., Olley, J.M., Yoshida, H. & Laslett, G. M. 1999. Optical dating of single and multiple grains of quartz from Jinmium rock shelter (northern Australia): Part II, Results and implications. *Archaeometry* 41: 365–398.
Roberts, M.B., Gamble, C.S. & Bridgland, D.R. 1995. The earliest occupation of Europe: the British Isles. In W. Roebroeks & T. van Kolfschoten (eds) *The Earliest Occupation of Europe (Proceedings of the European Science Foundation Workshop at Tautavel (France) 1993)*: 165–192. Institute of Prehistory, Leiden.
Roberts, M.B. & Parfitt, S.A. 1998. *Boxgrove: a Middle Pleistocene hominid site at Eartham Quarry, Boxgrove, West Sussex*. English Heritage, London.
Roe, D.A. 1968a. *Gazetteer for British Lower and Middle Palaeolithic Sites*. Council for British Archaeology, London.
Roe, D.A. 1968b. British Lower and Middle Palaeolithic handaxe groups. *Proceedings of the Prehistoric Society* 34: 1–81.
Roe, D.A. 1981. *The Lower and Middle Palaeolithic periods in Britain*. Routledge and Kegan Paul: London.
Roe, H.M. 2001. The Late Middle Pleistocene biostratigraphy of the Thames Valley, England: new data from eastern Essex. *Quaternary Science Reviews* 20: 1603–1619.
Roebroeks, W. 1996. The English Palaeolithic Record: Absence of Evidence, Evidence of Absence and the First Occupation of Europe. In C.S. Gamble & A.J. Lawson (ed's) *The English Palaeolithic Reviewed*: 57–62. Wessex Archaeology Ltd, Salisbury.
Roebroeks, W., Conard, N.J. & van Kolfschoten, T. 1992. Dense forests, cold steppes and the Palaeolithic settlement of northern Europe. *Current Anthropology* 33: 551–586.
Roebroeks, W. & Kolfschoten, T. van. 1995. The earliest occupation of Europe: the reappraisal of artefactual and chronological evidence. In W. Roebroeks & T. van Kolfschoten (eds) *The Earliest Occupation of Europe*: 297–315. University of Leiden, Leiden.
Rose, J. 1979. River terraces and sea level change. *Brighton Polytechnic Geographic Society Magazine* 3: 13–30.
Rose, J., Moorlock, B.S.P, Hamblin, R.J.O. 2001. Pre-Anglian fluvial and coastal deposits in Eastern England: lithostratigraphy and palaeoenvironments. *Quaternary International* 79: 5–22.
Rose, J., Turner, C., Coope, G.R. & Bryan, M.D. 1980. Channel changes in a lowland river catchment over the last 13,000 years. In R.A. Cullingford, D.A. Davidson & J. Lewin (ed's) *Timescales in Geomorphology*: 159–175. John Wiley & Sons Ltd, Chichester.
Rousseau, D-D. 1991. Climatic transfer function from Quaternary molluscs in European loess deposits. *Quaternary Research* 36: 195–209.
Samaga, B.R. Ranga Raju, K.G. & Garde, R.J. 1986. Velocity Distribution in Alluvial Channel Flow. *Journal of Hydraulic Research* 24: 297–308.
Sampson, C.G. (ed.). 1978. *Palaeoecology and Archaeology of an Acheulean Site at Caddington, England*. Department of Anthropology, Institute for the Study of Earth and Man, Southern Methodist University, Dallas.
Scaife, R. Unpublished manuscript (2002). *Preliminary palynological analysis of the Railway Ballast Pit, Broom, UK*.
Schick, K.D. 1986. *Stone Age Sites in the Making: Experiments in the Formation and Transformation of Archaeological Occurrences*. British Archaeological Reports (International Series 319). BAR, Oxford.
Schick, K.D. & Toth, N. 1993. *Making Silent Stones Speak: Human Evolution and the Dawn of Technology*. Phoenix, London.
Schirmer, W. 1988. Holocene valley development on the Upper Rhine and Main. In G. Lang & C. Schluchter (ed's) *Lake, Mire and River Environments During the Last 15000 Years*: 153–160. Balkema, Rotterdam.
Schirmer, W. 1995. Valley bottoms in the late Quaternary. In J. Hagedorn (ed.) *Late Quaternary and present-day fluvial processes in Central Europe*: 27–51. Gebrüder Borntraeger, Berlin.
Schmidt, K.-H. 1994. River Channel Adjustment and Sediment Budget in Response to a Catastrophic Flood Event (Lainbach Catchment, Southern Bavaria). In P. Ergenzinger & K.-H. Schmidt (ed's) *Dynamics and Geomorphology of Mountain Rivers*: 109–127. Springer-Verlag, Berlin.

Schmidt, K-H. & Ergenzinger, P. 1992. Bedload entrainment, travel lengths, step lengths, rest periods studied with passive (iron, magnetic) and active (radio) tracer techniques. *Earth Surface Processes and Landforms* 17: 147–165.
Schreve, D.C. 1997. *Mammalian biostratigraphy of the later Middle Pleistocene in Britain*. Unpublished Ph.D. thesis. University of London.
Schreve, D.C. 2001a. Mammalian evidence from Middle Pleistocene fluvial sequences for complex environmental change at the oxygen isotope sub-stage level. *Quaternary International* 79: 65–74.
Schreve, D.C. 2001b. Differentiation of the British late Middle Pleistocene interglacials: the evidence from mammalian biostratigraphy. *Quaternary Science Reviews* 20: 1693–1705.
Schreve, D.C., Bridgland, D.R., Allen, P., Blackford, J.J., Fazakerley, R., Gleed-Owen, C.P., Griffiths, H.I., Keen, D.H. & White, M.J. 2002. Sedimentology, palaeontology and archaeology of late Middle Pleistocene River Thames terrace deposits at Purfleet, Essex, UK. *Quaternary Science Reviews* 21: 1423–1464.
Schreve, D.C. & Bridgland, D.R. 2002. Correlation of English and German Middle Pleistocene fluvial sequences based on mammalian biostratigraphy. *Netherlands Journal of Geosciences* 81 (3–4): 357–373.
Schreve, D.C. & Thomas, G.N. 2001. *Critical Issues in European Quaternary Biostratigraphy*. Quaternary Science Reviews 20: 1577–1582.
Scott-Jackson, J.E. 1992. Lower Palaeolithic Finds at Wood Hill, East Kent: A Geological and Geomorphological Approach to an Archaeological Problem. *Lithics: The Newsletter of the Lithics Studies Society* 13: 1–16.
Scott-Jackson, J.E. 2000. *Lower and Middle Palaeolithic artifacts from deposits mapped as clay-with-flints*. Oxbow Books, Oxford.
Scourse, J.D. Unpublished manuscript (1982/1983). *Palaeobotany of the Railway Pit, Broom*.
Scourse, J.D. 1984. Appendix. In R.A. Shakesby & N. Stephens. The Pleistocene gravels of Axe Valley, Devon. *Report of the Transactions of the Devon Association for the Advancement of Science* 116: 77–88.
Sekine, M. & Kikkawa, H. 1992. Mechanics of Saltating Grains. *Journal of Hydraulic Engineering* 118(4): 536–558.
Shackley, M.L. 1973. A contextual study of the Mousterian industry from Great Pan Farm, Isle of Wight. *Proceedings of the Isle of Wight Natural History and Archaeological Society* 6: 542–554.
Shackley, M.L. 1974. Stream abrasion of flint implements. *Nature* 248: 501–502.
Shackley, M.L. 1975. *A Study of the Mousterian of Acheulian Tradition Industries of Southern Britain*. Unpublished Ph.D. Thesis, University of Southampton.
Shakesby, R.A. & N. Stephens, N. 1984. The Pleistocene gravels of Axe Valley, Devon. *Report of the Transactions of the Devon Association for the Advancement of Science* 116: 77–88.
Shipman, P. 1981. *Life History of a Fossil*. Harvard University Press, Harvard.
Singer, R., Wymer, J., Gladfelter, B.G. & Wolff, R.G. 1973. Excavation of the Clactonian Industry at the Golf Course, Clacton-on-Sea, Essex. *Proceedings of the Prehistoric Society* 39: 6–74.
Singer, R., Gladfelter, B.G. & Wymer, J.J. 1993. *The Lower Palaeolithic site at Hoxne, England*. Chicago University Press, Chicago.
Smith, R.A. 1926. *Guide to Antiquities of the Stone Age in the Department of the British and Medieval Antiquities*. British Museum, London (3rd edition).
Smith, R.A. & Dewey, H. 1913. Stratification at Swanscombe: report on excavations made on behalf of the British Museum and H.M. Geological Survey. *Archaeologia* 64: 177–204.
Smith, R.A. & Dewey, H. 1914. The High Terrace of the Thames: report on excavations made on behalf of the British Museum and H.M. Geological Survey in 1913. *Archaeologia* 65: 187–212.
Sörgel, W. 1921. *Die Ursachen dur diluvialen Aufschotterung und Erosion*. Berlin.
Sparks, B.W. & West, R.G. 1970. Late Pleistocene deposits at Wretton, Norfolk. 1. Ipswichian interglacial deposits. *Philosophical Transactions of the Royal Society of London*, B258: 1–30.
Starkel, L. 1988. Tectonic, anthropogenic and climatic factors in the history of the Vistula river valley downstream of Cracow. In G. Lang & C. Schluchter (ed's) *Lake, Mire and River Environments During the Last 15000 Years*: 161–170. Balkema, Rotterdam.
Starkel, L. 2002. Change in the frequency of extreme events as the indicator of climatic change in the Holocene (in fluvial systems). *Quaternary International* 91: 25–32.
Stephens, N. 1974. The Chard Area and Axe Valley Sections. *Quaternary Research Association Field Handbook*: *Exeter Meeting*: 46–51.
Stephens, N. 1977. The Axe Valley. In D.N. Mottershead (ed.) *INQUA Congress Guidebook for Excursions. A6 and C6. South-West England*: 24–29. Geo Abstracts Ltd., Norwich.
Stern, N. 1993. The Structure of the Lower Pleistocene Archaeological Record. *Current Anthropology* 43(3): 201–224.
Stern, N. 1994. The implications of time-averaging for reconstructing the land-use patterns of early tool-using hominids. In J.S. Oliver, N.E. Sikes & K.M. Stewart (ed's) *Early Hominid Behavioural Ecology*: 89–105. Academic Press Limited, London.
Stuart, A.J. 1979. Pleistocene occurrences of the European pond tortoise (Emys orbicularis Linnaeus) in Britain. *Boreas* 8: 359–371.
Stuart, A.J. 1982. *Pleistocene Vertebrates in the British Isles*. Longman, London & New York.

Sturge, W.A. 1912. The patina of flint implements. *Proceedings of the Prehistoric Society of East Anglia* 1: 140–157.

Sumer, B.M., Kozakiewicz, A., Fredsøe, J. & Deigaard, R. 1996. Velocity and Concentration Profiles in Sheet-Flow Layer of Moveable Bed. *Journal of Hydraulic Engineering* 122: 549–558.

Sumer, B.M., Chua, L.H.C., Cheng, N.S. & Fredsøe, J. 2003. Influence of turbulence on bed load sediment transport. *Journal of Hydraulic Engineering* 129(8): 585–596.

Sutcliffe, A.J. 1976. Reply to R.G. West on The British Glacial–Interglacial Sequence. *Quaternary Newsletter* 18: 1–7.

Sutcliffe, A.J. & Kowalski, K. 1976. Pleistocene Rodents of the British Isles. *Bulletin of the British Museum (natural History), Geology* 27/2.

Thomas, G.N. 2001. Late Middle Pleistocene pollen biostratigraphy in Britain: pitfalls and possibilities in the separation of interglacial sequences. *Quaternary Science Reviews* 20: 1621–1630.

Toms, P.S. 2002. *The acquisition of equivalent dose estimates from natural sedimentary quartz using optically stimulated luminescence*. Unpublished PhD thesis, University of London.

Toms, P. 2003. *OSL Dating*. Paper presented at the ALSF Meeting on Techniques and Technical Developments in Aggregate-Related Archaeology, Keyworth (British Geological Survey), October 2003.

Toms, P.S., Hosfield, R.T., Chambers, J.C. & Green, C.P. In prep. *Optical dating of the Broom Palaeolithic sites*. English Heritage Centre for Archaeology Report.

Tuffreau, A. & Antoine, P. 1995. The earliest occupation of Europe: Continental Northwestern Europe. In W. Roebroeks & T. van Kolfschoten (ed's) *The Earliest Occupation of Europe: Proceedings of the European Science Foundation Workshop at Tautavel (France), 1993*: 147–163. University of Leiden, Leiden.

Tyldesley, J.A. 1987. *The bout coupé handaxe: a typological problem*. British Archaeological Report (British Series 170). BAR, Oxford.

Ussher, W.A.E. 1906. *The geology of the country between Wellington and Chard*. Memoir of the British Geological Survey, Sheet 311. HMSO, London.

Vandenberghe, J. 1993. Changing fluvial processes under changing periglacial conditions. In I. Douglas & J. Hagedorn (ed's) *Geomorphology and Geoecology: proceedings of the Second International Conference on Geomorphology, Frankfurt/Main 1989*: 17–28. Gebrüder Borntraeger, Berlin.

Vandenberghe, J. 1995. Timescales, Climate and River Development. *Quaternary Science Reviews* 14: 631–638.

Vandenberghe, J. 2001. A typology of Pleistocene cold-based rivers. *Quaternary International* 79: 111–121.

Vandenberghe, J. 2002. The relation between climate and river processes, landforms and deposits during the Quaternary. *Quaternary International* 91: 17–23.

Vandenberghe, J. 2003. Climate forcing of fluvial system development: an evolution of ideas. *Quaternary Science Reviews* 22: 2053–2060.

van Andel, T.H. 2003. Glacial Environments I: the Weichselian Climate in Europe between the End of the OIS-5 Interglacial and the Last Glacial Maximum. In T.H. van Andel & W. Davies (ed's) *Neanderthals and modern humans in the European landscape during the last glaciation*: 9–19. McDonald Institute for Archaeological Research, Cambridge.

T.H. van Andel & W. Davies (ed's). 2003. *Neanderthals and modern humans in the European landscape during the last glaciation*: 9–19. McDonald Institute for Archaeological Research, Cambridge.

van Huissteden, J. 1990. Tundra rivers of the last glacial: sedimentation and geomorphological processes during the Middle Pleniglacial (Eastern Netherlands). *Mededelingen Rijks Geologische Dienst* 44(3): 1–138.

van Huissteden, J., Gibbard, P.L. & Briant, R.M. 2001. Periglacial fluvial systems in northwest Europe during marine isotope stages 4 and 3. *Quaternary International* 79: 75–88.

Van Rijn, L.C. 1984. Sediment transport, Part 1: bed load transport. *Journal of Hydraulic Engineering* 110/10: 1431–1456.

Walker, M.J.C., Coope, G.R. & Lowe, J.J. 1993. The Devensian (Weichselian) Lateglacial palaeoenvironmental record from Gransmoor, East Yorkshire, England. *Quaternary Science Reviews* 12: 659–680.

Watts, W.A. 1978. Plant macro-fossils and Quaternary Palaeoecology. In D. Walker & J.C. Guppy (ed's) *Biological and Quaternary Environments*: 53–68. Australian Academy of Science, Canberra.

Watts, W.A., Allen, J.R.M. & Huntley, B. 1996. Vegetation history and palaeoclimate of the last glacial period at Lago Grande di Monticchio, southern Italy. *Quaternary Science Reviews* 15: 133–153.

Wenban-Smith, F.F. 1990. The Location of Baker's Hole. *Proceedings of the Prehistoric Society* 56: 11–14.

Wenban-Smith, F.F. 1992. Early Palaeolithic cultural facies and the Levalloisian at Baker's Hole. *Papers from the Institute of Archaeology* 3: 1–10.

Wenban-Smith, F.F. 1996. *The Palaeolithic Archaeology of Baker's Hole: a case study for focus in lithic analysis*. Unpublished PhD Thesis, University of Southampton.

Wenban-Smith, F.F. 1998. Clactonian and Acheulean Industries in Britain: Their Chronology and Significance Reconsidered. In N. Ashton, F. Healy & P. Pettitt (ed's) *Stone Age Archaeology: Essays in Honour of John Wymer*: 90–97. Oxbow Monograph 102 & Lithic Studies Society Occasional Paper No. 6. Oxbow Books, London.

Wenban-Smith, F.F., Gamble, C.S. & ApSimon, A. 2000. The Lower Palaeolithic Site at Red Barns, Porchester: Bifacial technology, Raw Material Quality, and the Organisation of Archaic Behaviour. *Proceedings of the Prehistoric*

Society 66: 209–256.
Wenban-Smith, F.F. & Hosfield, R.T. 2001. *Palaeolithic Archaeology of the Solent River*. Lithic Studies Society Occasional Paper No. 7. Lithic Studies Society, London.
Wessex Archaeology. 1993a. *The Southern Rivers Palaeolithic Project: Report No. 1, 1991–1992. The Upper Thames Valley, the Kennett Valley and the Upper Solent Drainage System*. Wessex Archaeology & English Heritage, Salisbury.
Wessex Archaeology. 1993b. *The Southern Rivers Palaeolithic Project Report No. 2. 1992–1993. The South West and South of the Thames*. Wessex Archaeology & English Heritage, Salisbury.
Wessex Archaeology. 1994. *The Southern Rivers Palaeolithic Project. Report No. 3. 1993–1994. The Sussex Raised Beaches and the Bristol Avon*. Wessex Archaeology & English Heritage, Salisbury.
Wessex Archaeology. 1996a. *The Welsh Lower Palaeolithic Survey. 1996*. Wessex Archaeology & CADW, Salisbury.
Wessex Archaeology. 1996b. *The English Rivers Palaeolithic Project. Report No. 1. 1994–1995. The Thames Valley and the Warwickshire Avon*. Wessex Archaeology & English Heritage, Salisbury.
Wessex Archaeology. 1996c. *The English Rivers Palaeolithic Project. Report No. 2. 1995–1996. The Great Ouse Drainage and the Yorkshire and Lincolnshire Wolds*. Wessex Archaeology & English Heritage, Salisbury.
Wessex Archaeology. 1997. *The English Rivers Palaeolithic Project. Report No. 3. 1996–1997. East Anglia Rivers and the Trent Drainage*. Wessex Archaeology & English Heritage, Salisbury.
West, R.G. 1956. The Quaternary deposits at Hoxne, Suffolk. *Philosophical Transactions of the Royal Society of London B* 239: 265–356.
West, R.G. 1957. Interglacial deposits at Bobbitshole, Ipswich. *Philosophical Transactions of the Royal Society of London B* 241: 1–31.
West, R.G. 1977. Early and Middle Devensian flora and vegetation. *Philosophical Transactions of the Royal Society of London*, B280: 229–246.
West, R.G., Andrew, R., Catt, J.A., Hart, C.P., Hollin, J.T., Knudsen, K.-L., Miller, G.F., Penney, D.N., Pettit, M.E., Preece, R.C., Switsur, V.R., Whiteman, C.A. & Zhou, L.P. 1999. Late and Middle Pleistocene deposits at Somersham, Cambridgeshire, UK: a model for reconstructing fluvial / estuarine depositional environments. *Quaternary Science Reviews* 18: 1247–1314.
Westlake, E. 1902. *Note on Recent Discoveries of Palaeolithic and Eolithic Implements in the Valley of the Avon*. W. H. King and Son, Fordingbridge.
Whatley, R.C. 1993. Ostracoda as biostratigraphical indices in Cainozoic deep-sea sequences. In E.A. Hailwood & R.B. Kidd (ed's) *High Resolution Stratigraphy*: 155–167. Geographical Society Special Publications No. 70. Geographical Society, London.
White, H.J.O. 1912. *The Geology of the Country around Winchester and Stockbridge*. Memoir of the Geological Survey of Great Britain. H.M.S.O, London.
White, M.J. 1998a. Twisted Ovate Bifaces in the British Lower Palaeolithic: Some Observations and Implications. In N. Ashton, F. Healy & P. Pettitt (ed's) *Stone Age Archaeology: Essays in Honour of John Wymer*: 98–104. Oxbow Monograph 102 & Lithic Studies Society Occasional Paper No. 6. Oxbow Books, London.
White, M.J. 1998b. On the significance of Acheulean biface variability in southern Britain. *Proceedings of the Prehistoric Society* 64: 15–45.
White, M.J. 2000. The Clactonian Question: On the Interpretation of Core-and-Flake Assemblages in the British Lower Palaeolithic. *Journal of World Prehistory* 14(1): 1–63.
White, M.J. & Jacobi, R.M. 2002. Two sides to every story: bout coupe handaxes revisited. *Oxford Journal of Archaeology* 21(2): 109–133.
White, M.J. & Pettitt, P. 1995. Technology of early Palaeolithic western Europe: innovation, variability and a united framework. *Lithics: The Newsletter of the Lithic Studies Society* 16: 27–40.
White, M.J. & Schreve, D.C. 2000. Island Britain – Peninsula Britain: Palaeogeography, Colonisation and the Lower Palaeolithic Settlement of the British Isles. *Proceedings of the Prehistoric Society* 66: 1–28.
Wiberg, P.L. & Smith, J.D. 1985. A Theoretical Model for Saltating Grains in Water. *Journal of Geophysical Research* 90: 7341–7354.
Wiberg, P.L. & Smith, J.D. 1989. A model for calculating bed load transport of sediment. *Journal of Hydraulic Engineering* 115(1): 101–123.
Wilcock, P.R. 1997. Entrainment, displacement and transport of tracer gravels. *Earth Surface Processes and Landforms* 22: 1125–1138.
Wilcock, P.R. 2001. Towards a practical method for estimating sediment-transport rates in gravel bed rivers. *Earth Surface Processes and Landforms* 26: 1395–1408.
Wilkinson 2001. Prospecting the Palaeolithic: strategies for the archaeological investigation of Middle Pleistocene deposits in Southern England. In F.F. Wenban-Smith & R.T. Hosfield (ed's) *Palaeolithic Archaeology of the Solent River*: 99-110. Lithic Studies Society Occasional Paper 7. Lithic Studies Society, London.
Winton, V. 2001. Unexpected results from experimentation with handaxes. Paper presented at the *Palaeolithic–Mesolithic Day Meeting*, British Museum, London, September 2001.
Wymer, J.J. 1968. *Lower Palaeolithic Archaeology in Britain, as Represented by the Thames Valley*. John Baker, London.

Wymer, J.J. 1974. Clactonian and Acheulean industries in Britain: their chronology and significance. *Proceedings of the Geologists Association* 85: 391–421.

Wymer, J.J. 1977. A chert hand-axe from Chard, Somerset. *Proceedings of the Somerset Natural History and Archaeological Society* 120: 101–103.

Wymer, J.J. 1999. *The Lower Palaeolithic Occupation of Britain.* Wessex Archaeology, Salisbury.

Wymer, J.J., Lewis, S.G. & Bridgland, D.R. 1991. Warren Hill, Mildenhall, Suffolk (TL 744743). In S.G. Lewis, C.A. Whiteman & D.R. Bridgland (ed's) *Central East Anglia and the Fen Basin*: 50–58. Quaternary Research Association, London.

Yang, S-Q. & Lim, S-Y. 2003. Total load transport formula for flow in alluvial channels. *Journal of Hydraulic Engineering* 129(1): 68–72.

Zeuner, F.E. 1958. *Dating the Past: An Introduction to Geochronology* (4th edition). Metherun and Co. Ltd., London.

Zeuner. F.E. 1959. *The Pleistocene Period* (2nd edition). Hutchinson, London.