The Palaeolithic of the Avon valley

A geoarchaeological approach to the hominin colonisation of Britain

Volume I of II

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Abstract

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This thesis presents the results of a geoarchaeological investigation into the Palaeolithic occupation of the Avon valley, Hampshire. In this area, the Palaeolithic archaeological record is dominated by three large concentrations of lithic artefacts, found at Bemerton, Milford Hill and Woodgreen, against a background scatter of isolated finds. These prolific assemblages are amongst the largest concentrations of Palaeolithic finds in Britain. Their contribution to the understanding of hominin presence and behaviour in northwest Europe has though remained largely obscured due to the complex depositional context of Pleistocene fluvial terraces and limited age constraints of these sites. This thesis discusses the current knowledge of the Pleistocene palaeogeography and hominin occupation of Britain and how a geoarchaeological reinvestigation into the Avon valley archaeological record can contribute to the understanding of the British Palaeolithic. The study of seven Pleistocene fluvial terrace exposures, sedimentological analysis, and examination of environmental indicators provide information about terrace formation and Pleistocene landscape evolution in the valley and the depositional context of the three main Palaeolithic sites. Optically stimulated luminescence dating of fine-grained sediments from a sequence of six different terraces is used to create a chronometric framework for landscape evolution and the archaeological record. The results indicate that hominins were present in the Avon valley between MIS 10 and 8, in a period that has previously been characterised by a general decline in Palaeolithic sites in Britain relative to MIS 13-10. The work demonstrates that hominins continued to reach the Avon valley, suggesting adaptive and cognitive developments to cope with colder climates and palaeogeographic changes in the Channel region. Furthermore, a comparison of the assemblages from Bemerton, Milford Hill and Woodgreen based on primary data gathered, shows that these assemblages are in ‘proximal context’ and represent the accumulation of lithic artefacts produced, used and left at these sites during repeated revisits over a considerable length of time, throughout all habitable phases of a glacial-interglacial or stadial-interstadial cycle. The location of these focal places within the river valley changed over time, either through transformations in the local environment and resource availability, through a difference in hominin landscape use and behaviour or through an interplay between these factors.

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List of abbreviations

AST	Altitudinally separated terraces
BGS	British Geological Survey
D_e	Equivalent dose
D_r	Dose rate
dGPS	Differential global positioning system
DEM	Digital elevation model
DTM	Digital terrain model
ESEM	Environmental scanning electron microscope
GIS	Geographic information system
HER	Historic environment record
IBAG	Image-based automated grain-sizing
ka	Kiloannus (one thousand years)
LiDAR	Light detection and ranging
Ma	Megaannus (one million years)
MIS	Marine oxygen isotope stage
MPT	Mid Pleistocene transition
O5-O1	Terrace numbers of 'older river gravels'
OD	Ordnance datum
OS	Ordnance Survey
OSL	Optically stimulated luminescence dating
STM	Superficial geology thickness model
T14-T1	Terrace numbers

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Chapter 1 Introduction

1.1 Introduction

The understanding of the earliest arrival of hominins in Europe has changed significantly over the last decade and has been strongly influenced by recent Palaeolithic finds in Britain. Before the discoveries of stone tools at Pakefield, Suffolk and Happisburgh, Norfolk in sediments dated to >780ka and ~0.98Ma respectively (Parfitt et al. 2005, 2010), the scarcity of well-dated and well-provenanced Palaeolithic material from northwest Europe led many archaeologists to consider this area as uninhabited by hominins before 500ka (Roebroeks 2001). Climatic, physio-geographical and behavioural reasons were put forward to explain the apparent absence of hominins northwest of the Alps and Pyrenees (ibid.). The discoveries from Britain, together with the increasing body of evidence of early hominin presence from elsewhere in the continent, significantly contribute to the current day understanding of the timing and environmental context of the first arrival of hominins in Europe (Antoine et al. 2014, 2007; Despriée et al. 2011).

In this context, Britain forms a particularly interesting research area due to its palaeogeographic history. Fluctuating sea-levels in response of Pleistocene climatic change transformed Britain from peninsula to island several times during the last 1.7Ma (Funnel 1996). The British Palaeolithic occupation as it appears today differs from that seen on the continent in the fact that it is discontinuous and possibly, after a wider hominins presence during marine oxygen isotope stages (MIS) 13-11, becomes gradually less populated with a total absence between MIS 6 and 4 (Lewis and Ashton 2002; Ashton and Hosfield 2010 but see Wenban-Smith et al. 2010). This pattern has been linked to the changing palaeogeography during the Pleistocene, in which Britian becomes increasingly difficult to reach after the establishment of the Channel River and prolonged periods of high sea-level stands. This history emerged from the current understanding of the chronology of the British Palaeolithic record. However, historically collected, significant sites found in complex depositional contexts with limited age constraints, are poorly integrated in this wider narrative of hominin presence. A geoarchaeological reinvestigation of such assemblages allows these to contribute to the understanding of the British Palaeolithic through an improved chronology. The Palaeolithic record from the Avon valley, Hampshire, is an example of such largely unexplored potential.

Hominin presence in Britain seems to have concentrated along river systems such as the Solent and the Thames which might have provided routes through the landscape along which hominins reached Britain from the continent (Ashton and Hosfield 2010). The River Avon is the main northern tributary to the ancient Solent river system and the rich Palaeolithic record in the Avon valley indicates hominin presence in this area. The limited understanding of the timing and nature of hominin occupation in the Avon valley has hampered the integration of the Avon's Palaeolithic into the wider Palaeolithic occupation of Britain. The Avon valley, as tributary to the main Solent river system however, could offer a local perspective on the regional patterns proposed for the hominin occupation of Britain.

The Avon valley Palaeolithic record is characterised by three large concentrations of artefacts, discovered at Bemerton, Milford Hill and Woodgreen. These prolific sites have been recognised for their significance since the second half of the 19th century (Blackmore 'Locked notebook', Salisbury Museum; Read 1885). At these locations large quantities of Palaeolithic artefacts have been found interbedded in Pleistocene fluvial sediments. This superficial geology in the Avon consists of terrace deposits which formation is correlated to Pleistocene climatic change that caused disequilibria in sediment aggradation and valley incision. In the Avon valley this has resulted in a flight of terraces that, with decreasing altitude, decrease in age and are thought to reflect the relative chronology of Pleistocene landscape evolution. This complex depositional environment causes the artefacts to be in 'proximal context'. The wide existence of large artefact concentrations in fluvial contexts, and the recognition of the reworked nature of such sites, has instigated a debate on the significance of these records for the understanding of hominin behaviour (Ashton and Hosfield 2010; Brown et al. 2013). The main question has been whether such sites represent hominin behaviour in the landscape or whether they reflect fluvial processes, collection or discovery bias. The difficulties presented by the depositional environment and collection history of the Avon valley sites have led to a limited exploration of their information potential. This has further been hampered by the absence of chronometric dating of these Pleistocene sediments and a dating framework for the sites. As a result, the study of the artefact assemblages from Bemerton, Milford Hill and Woodgreen has been minimal.

Overcoming the challenges presented by the Pleistocene fluvial context of the Avon valley would allow the assessment of the significance of these sites in the understanding of hominin landscape use and behaviour. Analysis of artefact assemblages could reveal information about site integrity and hominin activities at these locations, and the establishment of a dating framework for the Avon Palaeolithic record would permit these sites to be situated in time. This would not only permit the integration of these sites in the wider pattern of the hominin occupation of Britain, but could also reveal diachronic changes in hominin behaviour and landscape use within the Avon valley and as such provide a local perspective on hominin presence in northwest Europe.

1.2 Aims and objectives

This research aims to improve the understanding of the Pleistocene landscape evolution and fluvial depositional environment of the Avon valley and its chronology to provide a context and dating framework for the Palaeolithic record it preserves. This will provide the basis for answering questions regarding hominin presence and behaviour in the Avon valley and its timing in relationship to the Pleistocene landscape and wider understanding of the British Palaeolithic. This research applies a geoarchaeological approach to the Avon Palaeolithic record through the combination of geomorphological and sedimentological research, the establishment of a chronometric dating framework for the Pleistocene landscape and archaeological record, and a study of the Palaeolithic assemblages. The objectives of this study are:

1. To review the current understanding of the palaeogeography of Britain in general and the Pleistocene landscape of the Avon valley in particular and discuss the main principles of Pleistocene fluvio-geomoprhological processes that led to valley and terrace formation in the Avon valley.

2. To review the current understanding of the Palaeolithic occupation of Europe and Britain and the significance of patterns in this archaeological record, especially from fluvial contexts.

3. To assess the Palaeolithic record of the Avon valley, and assess the potential of this for improving our understanding of hominin behaviour and approaches to disclose this.

4. To reconstruct the processes that led to terrace formation in the Avon valley to understand how fluvio-geomorphological processes formed the Pleistocene landscape and influenced the Palaeolithic record; through the study of terrace sediment structures, clast lithology, terrace modelling, the investigation

of environmental indicators, and the application of novel techniques in the recording of sediments and stratigraphic structures.

5. To develop a geochronological framework for Pleistocene landscape evolution and hominin occupation in the Avon valley through OSL dating the sequence of river terraces.

6. To reconstruct hominin presence and behaviour in the Avon valley through the assessment of taphonomic processes and artefact analysis of the Avon Palaeolithic record, using information from objectives 3, 4, and 5.

7. To reconstruct a chronometric history of Pleistocene landscape change and hominin presence and behaviour in the Avon valley and relate this to the understanding of the British Palaeolithic occupation.

1.3 Outline of the research

Pleistocene landscapes and hominin evolution and dispersal are intimately related and studied in the interdisciplinary field of Quaternary science. This has offered a contextual and chronological framework for Palaeolithic research. **Chapter 2** will therefore start with a brief discussion of the principle climatic-chronological framework of the Pleistocene. This sets the scene for discussing the palaeogeography of Britain. An important part of the Pleistocene landscape, and major source of Palaeolithic and environmental evidence, are fluvial terraces. Understanding the processes that led to their formation is vital to the interpretation of the Pleistocene landscape and Palaeolithic record of the Avon valley and is therefore also discussed in this chapter before assessing how these principles apply to the fluvio-geomorphology of the research area. **Chapter 3** discusses the current understanding of hominin presence in Britain after a brief overview of the emergence of *Homo* and arrival in Europe. This chapter also deals with the question of how to relate observed patterns in the Palaeolithic record to preservation, hominin preference and timing of their presence. This is then related to the spatial distribution of the Avon Palaeolithic record and the current understanding of its chronology. **Chapter 4** details and critiques the applied methods used to address the objectives of this research. **Chapter 5** presents the field sites that were studied for this thesis to gain insights in the sedimentology of the Avon terraces and in the processes that led to their formation. The fieldwork also provides information on the sedimentological context of Palaeolithic finds, and includes exposing a sequence of terraces (undifferentiated terrace, terrace 10 and terrace 7-4) to obtain sediment samples for optically stimulated luminescence (OSL) dating to allow a chronometric framework to be developed. The results of the sediment analysis of the deposits of the Avon terraces are presented in **Chapter 6**. Additional indications of the climate during terrace deposition are obtained from laser diffractometry and palynological analysis of sediments that had the potential for micro-fossil preservation. This chapter also describes the results and applicability of novel methods for recording sedimentology and stratigraphy in the field. The results of the OSL analysis are presented and critically assessed in **Chapter 7**. **Chapter 8** presents the results of the artefact analysis of the assemblages from Bemerton, Milford Hill and Woodgreen and discusses how this informs site formation processes, hominin landscape use and behaviour. The results of the previous chapters are combined in **Chapter 9** which provides a reconstruction of Pleistocene landscapes and landscape change and the timing of hominin presence in the valley. This is then related to regional Palaeolithic record and demonstrates that reinvestigation and dating of rich assemblages can make an important contribution to the current understanding of the British Palaeolithic. Chapter 9 also discusses future work that could further advance the understanding of Pleistocene landscape change and hominin behaviour in the Avon valley. **Chapter 10** presents the conclusions of this study, and identifies directions for further work.

Chapter 2 The Pleistocene landscape of southern Britain

2.1 Introduction

The Pleistocene (now incorporating the formerly late Pliocene) extends from 2.58Ma to 11.7ka and includes all recent glaciations (Gibbard et al. 2010; Hambrey and Harland 1981). It is this cyclic climatic change that characterises the Pleistocene world and forms the framework of Quaternary science. The glacials and interglacials shaped the surface of the earth and influenced the distribution of flora and fauna (including humans) (Preece 1995; White and Schreve 2000) leaving geomorphological, lithological and biological evidence the study of which forms the core of Quaternary research (Lowe and Walker 1997). The glacial and interglacial cycles form the basic subdivision of the Quaternary and correlation of environmental records and archaeological evidence to a particular climate stage provides a chronology of events that allows a reconstruction of the Pleistocene to be made (Lowe and Walker 1997). The following chapter summarises the climatic, chronologic and palaeogeographic context of hominin presence in Britain.

2.2 Climate and chronology

The division of the Pleistocene into glacials and interglacials was first initiated by Penck and Brückner (1909, in Lowe and Walker 1997) based on a sequence of river terraces along an Alpine river, which they suggested were the result of four Pleistocene glaciations. Evidence of these glaciations could be used as a chronological framework. The following independent development of glacial chronological schemes in Europe, Britain and North America led to a divergence in stratigraphic frameworks that, until improved dating techniques became available, were difficult to correlate (Ehlers and Gibbard 2003). Subsequent Quaternary research focussing on stratigraphy, palaeoecology, geomorphology and dating techniques provided evidence for additional glaciation events indicating a more complex Quaternary climate history (e.g. De Jong 1988, Kohl 1986, Zeuner 1946). This could be further refined with the discovery and development of the marine oxygen isotope record that revealed more climate fluctuations than originally recognised in the terrestrial records (Emiliani 1955). Fluctuations in the oxygen isotope ratios of ^{18}O:^{16}O in foraminifera from deep-ocean sediments reflect the amount of sea-water stored in the polar ice caps and on land and therefore global climate change (Shackleton 1987). This high-resolution oxygen isotope stratigraphy provides an isotopic profile that can be divided in isotopic stages (Marine Oxygen Isotope Stages or MIS). This profile revealed a detailed record of the major and minor climate fluctuations of the past 2.5Ma years. The MIS stages are counted from the current interglacial, the Holocene (MIS 1), backwards such that increasing MIS numbers reflect an increase in age and that even numbers represent cold stages and uneven numbers warm stages (Lowe and Walker 1997). The correlation of MIS to Milankovitch cycles (orbital forces that influence the insolation of the earth (Imbrie et al. 1992; 1993) has offered a way to 'orbitally tune' the stages and provide a chronometric framework for Quaternary climate change to which proxy data, with the use of other, improved and extended (relative) dating techniques, can be related (Bassinot et al. 1994; Penkman et al. 2011; Shackleton et al. 1990). This chronology is presented in Figure 2.1 showing the age of the MIS and the correlated chronostratigraphic units in Britain and northwest Europe. In Britain three major lowland glaciations are recognised during MIS 12 (the Anglian glaciation), during MIS6 (Saalian/Wolstonian) and MIS 2 (Devensian) (Clark et al. 2004). The Pleistocene climate fluctuations influenced relative global sea-levels changing the palaeogeography of Britain (Rohling et al 2009).

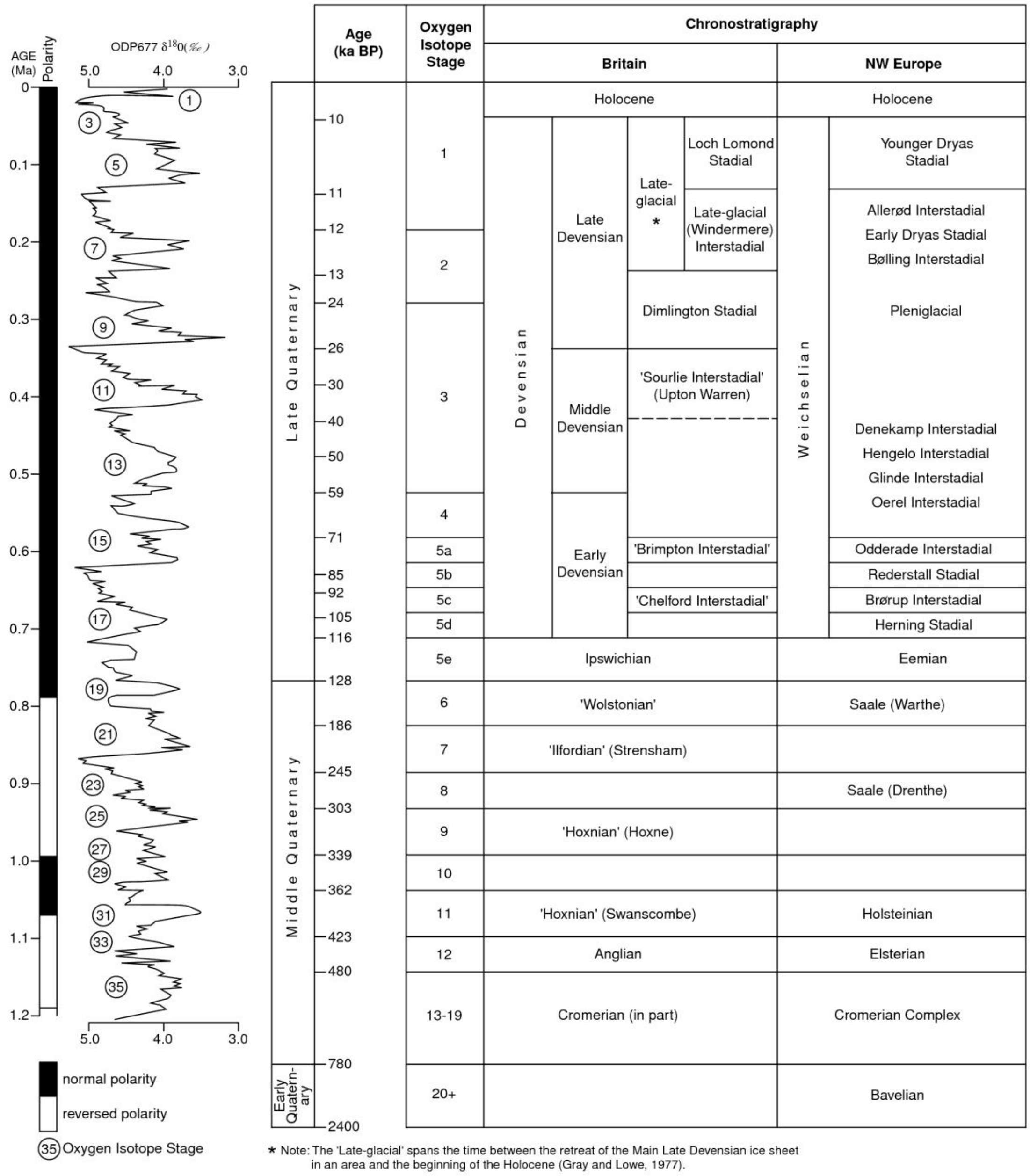


Figure 2.1 British and north-west European chronostratigraphy (British Geological Survey, catalogue reference number: P915253).

2.3 Palaeogeography of southern Britain

By the end of the Pliocene global sea levels dropped as a result of the first Northern hemisphere glaciation. This caused a connection between Britain and mainland Europe for the majority of the period between 2.4/2.5Ma until 1.7Ma (Funnell 1996; White and Schreve 2000). From 1.7Ma to 0.5Ma, sea levels stayed sufficiently low during both warmer and colder periods for Britain to remain connected to the continent. An important feature in the physical geography of this connection is the Weald-Artois anticline, a Chalk ridge that crosses the Strait of Dover and separates the North Sea and Channel basin. This ridge remained dry when sea-levels rose (Gibbard 1995). During low sea level stands both basins fell dry. The North Sea basin formed an extensive delta into which the Thames, Scheldt, Meuse and Rhine Rivers drained (Funnel 1996, Hijma et al. 2012). The Channel basin emerged as alluvial plain through which the Rivers Solent, Somme and Seine drained southwest. The confluence of these rivers was situated south of what is now Weymouth and together formed the Channel River (Fleuve Manche). This large river drained through Hurd Deep into the Atlantic ocean (Gibbard 1988; Lagarde et al. 2003; Lericolais et al. 2003) (Figure 2.2).

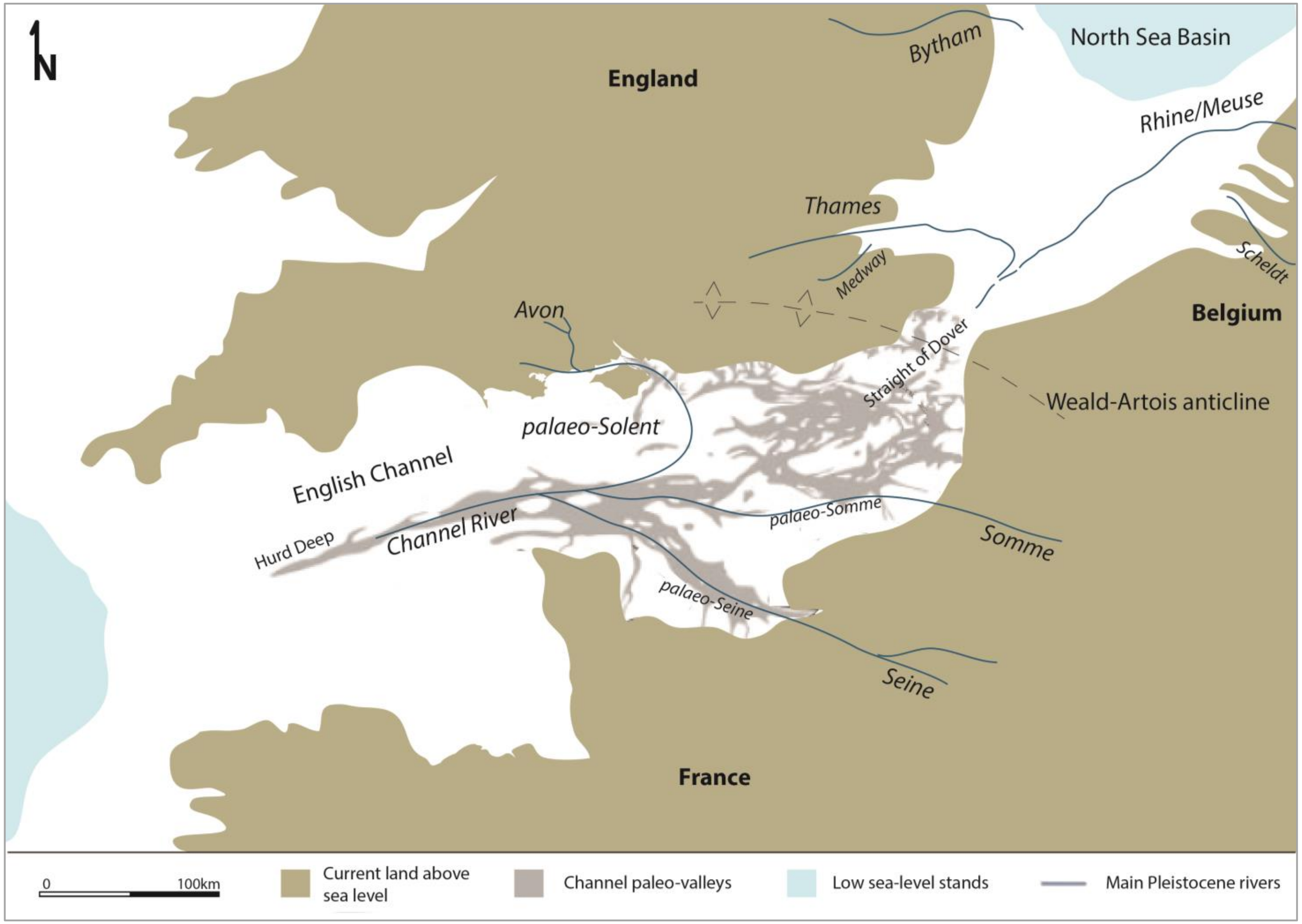


Figure 2.2 Schematic representation of the palaeogeography of the English Channel region during low sea-level stands (based on Antoine et al. 2003a,b; Hijma et al. 2012).

The Anglian glaciation, 0.48Ma (MIS 12), initiated a new geographic configuration (Figure 2.3). It is likely that the great, and previously un-paralleled ice extent during this period dammed the water in the North Sea, preventing it from draining north. The accumulating water formed a pro-glacial lake that extended over East Anglia, the Netherlands and Germany as is indicated by glacio-fluvial sediments found in these regions (Gibbard 1995). The overspill of this lake breached the Weald-Artois land bridge between Britain and the mainland (Gupta et al. 2007). This is dated to 450ka (MIS 12) based on evidence of extremely increased sediment influx into the eastern North Atlantic dated to this period (Toucanne et al. 2009). The flood cut a broad valley into the Channel floor and joined the confluent Channel River of the Solent, Somme and Seine in the southwest. This breaching of the anticline probably deflected the course of the Thames, Medway and Scheldt which subsequently started to drain to the southwest through the newly incised valley (Gibbard 1988). Whether the Meuse and Rhine were also deflected southward remains to be established (Hijma et al. 2012). This process extended the course of the Fleuve Manche to the north, connecting the northern (Thames-Medway-Sheldt) and southern river systems

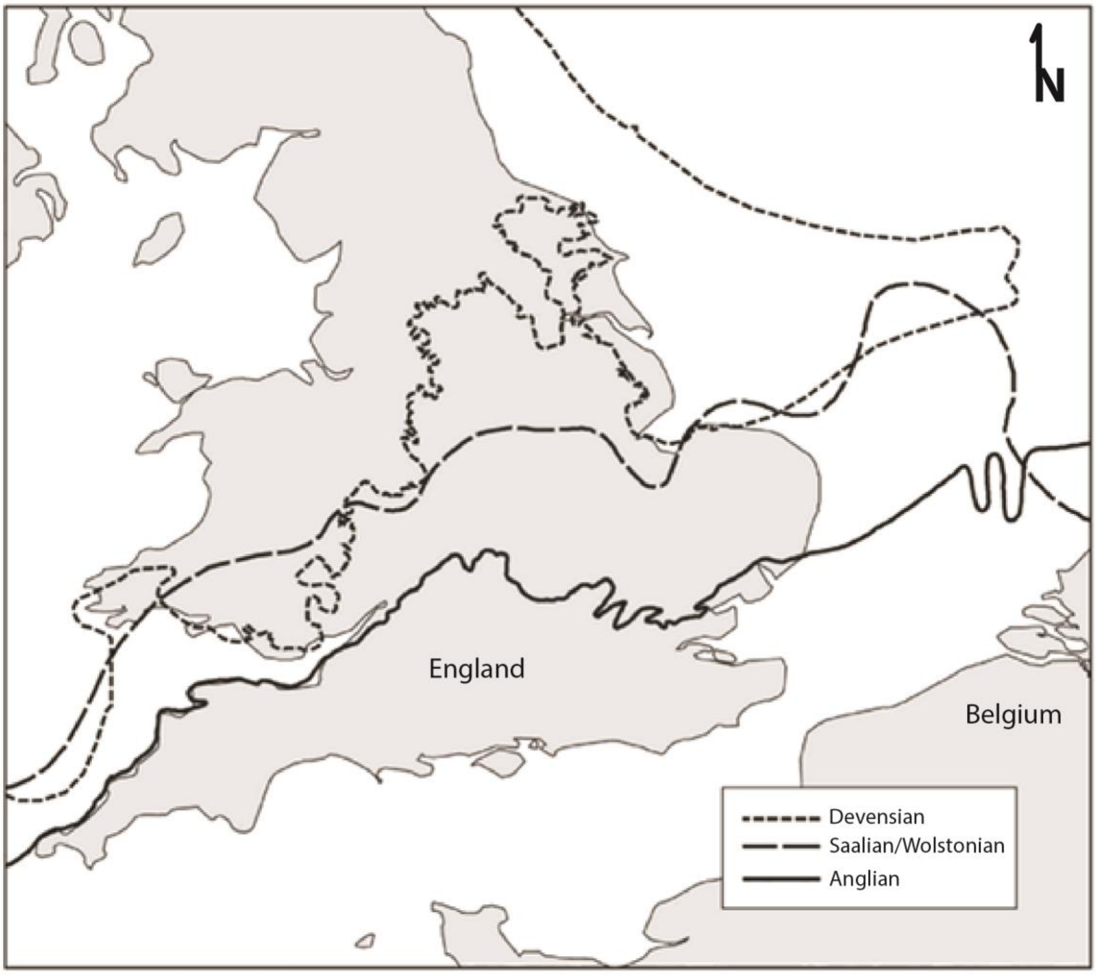


Figure 2.3 Extent of British ice sheets during the Anglian (MIS 12), Saalian/Wolstonian (MIS 6) and Devensian (MIS2). The coastline reflects the current configuration of exposed land mass above sea level (after Gibbard and Clark 2011).

(Solent-Somme-Seine) to form '*one of the largest palaeodrainages of Europe during late Quaternary low-sea-level stands*' (Gupta et al. 2007, p.344). During low-sea level stands this river system may have formed a barrier for hominins to reach Britain (Ashton and Hosfield 2010), especially towards the end of MIS 10, MIS 8, MIS 6 and MIS 2 when river discharge increased due to the melting of the Northern hemisphere ice sheet (Toucanne et al. 2009). After the initial breach of the Weald-Artois anticline, high sea levels resulted in the connection of the North Sea and Atlantic Ocean, isolating Britain completely (Meijer and Cleveringa 2009; White and Schreve 2000). A second flooding (Gupta et al. 2007) or more gentle denudation (Mellett et al. 2013) of the Channel area is possibly related to MIS 6. This led to a widening of the English Channel and the addition of the Meuse to the Fleuve Manche (Gupta et al. 2007). Ice sheets deflected the course of the Rhine to form a Rhine/Meuse river during MIS 6. As deglaciation proceeded the Rhine diverted north again and only the Meuse kept its south-west orientation (Busschers et al. 2008; Hijma et al. 2012). Thus the connection of Britain to the mainland was already deteriorating between MIS 7 and MIS 6, but rising sea-levels during MIS 5 caused complete isolation of Britain (Keen 1995). The low sea-level stands associated with MIS 4 and MIS 2 reconnected Britain once more before the sea-level rise during the current warm stage of the Holocene shaped the geography of Britain largely as we know it today. During the last glaciation all rivers from the North Sea fluvial systems joined the Fleuve Manche (Toucanne et al. 2009). The Pleistocene rivers are an important aspect of the Pleistocene landscape and helped shape the landscape through complex fluvio-geomorphologic processes. Characteristic Pleistocene landscape features, also recognised in the Avon valley and therefore of particular interest to this research, are river terraces.

2.4 River terrace formation in southern Britain

2.4.1 Introduction

Pleistocene river terraces form the terrestrial evidence of climatic change recognised in marine isotope records (Bridgland 2000). Understanding the relationship between climate change and terrace formation offers a model of relative chrono-geomorphological landscape evolution that, with the aid of chronometric dating techniques, can form a chronostratigraphic framework for landscape change that can be linked to that of the wider region and the marine record (Bridgland 2000). This is essential for the understanding of the Palaeolithic period in Britain as the majority of the Lower and Middle Palaeolithic archaeology has been found in association with fluvial terrace deposits (Roe 1968, 1981, Wymer 1999a, 1999b). Therefore establishing the chronology of the terraces provides a dating framework for hominin presence in Britain. Additionally, modelling terrace formation offers insights in the taphonomy of Palaeolithic sites in such depositional contexts (e.g. Brown et al. 2009b; Brown et al. 2015). The following section summarises general processes of terrace formation before discussing the principles that apply to terraces in southern Britain.

2.4.2 River terrace formation

River terraces are landforms that can be underlain by alluvial deposits (Pazzaglia 2013). 'Terrace' refers to the topographic structure, whilst 'fluvial deposits' describe the sediment deposits (Leopold et al. 1964). The term 'morpho-sedimentary units' has been proposed to define river terraces (Brown et al. 2010). The formation of river terraces is complex and similar looking topographic features can be the result of different processes. When terraces are cut in bedrock, possibly covered by fluvial deposits, they are referred to as strath terraces. Cut-and-fill terraces are formed through the erosion of former alluvial valleys and subsequent deposition ('filling') of new fluvial sediments (Fairbridge 1968; Leopold et al. 1964). Unidirectional, lateral shifting, without pronounced incision of a river can lead to row-terraces that are not separated by elevation but reflect a lateral age sequence (Lewin and Gibbard 2010). Also the reversed of terrace formation can occur, for example in subsidising areas, where the youngest deposit overlies its predecessors, creating a stacked terrace (ibid.) although other reasons for the formation of stacked sequences are possible (Brown et al. 2015).

The presence of terraces in a river valley indicates that disequilibria in erosion and aggradation processes occurred. Incision takes place when the fluvial transport capacity exceeds sediment supply. This results in net sediment removal, channel incision and floodplain abandonment. Inversely, aggradation occurs when sediment yield exceeds transport capacity. Changes in sediment supply and/or transport rate (the available energy) will result in aggradation or incision (Blum and Törnqvist 2000). Factors that can cause disequilibria in the fluvial system can be divided in external and internal factors. Internal fluvial system dynamics are influenced by landform evolution, topographic relief, bedrock lithology and vegetation cover, affecting channel geometry, discharge and sediment supply (Vandenberghe 2003; Vandenberghe 1995). Such processes occur on smaller spatio-temporal scales, e.g. seasonal flooding and can often be studied through the sedimentology within river terraces (Bridge 2005; Maddy et al. 2001; Vandenberghe 1995). Internal factors are influenced by external factors such as climate change (e.g. through precipitation and vegetation cover), tectonic activity (relief, sediment supply) and eustatic sea-level fluctuations. These processes occur on a basin wide (10-1000km) and over temporary large scales (10-1000ka) and are revealed as features in the landscape, like river terraces (Bridge

2005; Maddy et al. 2001). The external factors may be intimately related as climate change and tectonics can influence sea-levels and tectonic processes such as glacio-isostatic adjustment and denudational isostasy are related to climatic change (Bridgland and Westaway 2008a; Bridgland 2000; Maddy et al. 2000; Maddy and Bridgland 2000; Maddy et al. 2001).

Following these principles Quaternary river terraces are generated through changes in sediment supply and transport, which are governed by internal and external processes within the river system. These are in turn influenced by climatic change that, often against a backdrop of tectonic uplift, leads to river terrace formation. Terraces can be found along rivers all around the world (Bridgland and Westaway 2008a, b). However, how climatic change exactly influences sediment supply and transport may vary in different directions in different regions (Blum and Törnqvist 2000). '*Climatic change produces time parallel discontinuities in alluvial successions over broad areas, even though the directions of change may differ between regions*' (Blum and Törnqvist 2000, p.5). The genesis of terraces can best be understood through the study of their geomorphology, internal sediment structures and valley characteristics (Lewin and Gibbard 2010). The type, structure and altitudinal separation of terraces can vary within a single fluvial system (Brown et al. 2009a; Brunnacker et al. 1982 in Bridgland 2000), reflecting the complex processes that control their formation.

2.4.3 Quaternary river terraces in southern Britain

Within Britain there is a considerable variation in terrace form and the number of identifiable levels (Brown et al. 2009a). The main river systems in southern Britain are characterised by flights of up to 15 altitudinally separated terraces, mainly aggradational, possibly overlying strath, with cut-and-fill often forming the altitudinally lowest terraces (Brown et al. 2009a). The age of the fluvial deposits of these terrace staircases increases with height above the floodplain (Bridgland and Westaway 2008a). The high number of terraces in this region can be partly related to the position of the valleys south of the extent of maximum glaciation in Britain which has warranted their preservation (Bridgland 2000; Brown et al. 2009a).

The region-wide presence of rivers with a high number of terraces, (with occasional exceptions e.g. adjacent Exe and Axe valleys with respectively high and low numbers of terraces (Brown et al. 2015; Gallois 2006)), indicates a region-wide terrace generating force, superimposed on local valley characteristics (Hancock and Anderson 2002). Their formation has been subject of long and considerable research concerned with the influence of sea-level change, tectonics and climate change and interplay between these (Bridgland and Westaway 2008a; Bridgland 2001; Calkin and Green 1949; Clarke and Green 1987; Lewin and Gibbard 2010; Maddy et al. 2000; Reid 1898, 1902; Westaway et al. 2006).

In southern Britain the effect of sea-level change on river terrace formation is thought to be limited (Bridgland 2000). The influence of sea-level change depends on the slope of the continental shelf in relation to the river gradient (Bridge 2005). In areas, such as in northwest Europe and especially in southern Britain where the continental shelf is wide, the influence of sea-level change is limited. Lowering sea-levels caused rivers to extend to their previous course in the Channel region without encountering a significant break of slope until the shelf-edge (Bridgland 2000; Maddy et al. 2000). The on-shore preserved terraces lie in the upstream reaches of the Pleistocene extent of these rivers, where the influence of sea-level change was likely limited (Schumm 1993). However, the complex palaeogeographic history of the Channel region (section 2.3) illustrates that the continental shelf between Britain and Europe itself is a changeable environment. Raised beach deposits of the Isle of Wight, southern England and the Sussex coastal plain suggest Quaternary crustal uplift in this region (Bowen 1994; Bates et al. 2010; Preece et al. 1990). Although discontinuous tectonic uplift alone can generate the formation of fluvial terraces (Pazzaglia 2013), on the time scale of Quaternary fluvial systems these processes rather facilitated climatically generated terrace formation (Bridgland and Westaway 2008a; Bridgland 2000; Lewin and Gibbard 2010; Maddy et al. 2000; Maddy et al. 2001). This indicates the cyclic fluctuation of Quaternary climate change has driven terrace formation in southern Britain. However, the high number of terraces, especially in river systems that drain in relatively erodible Palaeogene-Neogene basins (Brown et al. 2009a) indicate a complex relationship between terrace formation and Quaternary climate change.

2.5 Quaternary climate change and the timing and mechanisms of terrace formation

The relationship between Quaternary climate change and terrace formation has been widely studied (e.g. Antoine et al. 2007; Blum and Törnqvist 2000; Bridgland 2000; Brown et al. 2010; Lewin and Gibbard 2010; Vandenberghe 2003; Vandenberghe 1995). Main issues in modelling this relationship are the timing of and mechanisms behind terrace formation within a climatic cycle. This section discusses the various mechanisms that may lie behind terrace formation in fluvial systems and how the timing and frequency may vary in different geological and geographical contexts. This provides a theoretical framework for the discussion of terrace formation in the Avon valley, addressed in section 2.6.

The simplest correlation between Quaternary climate change and terrace formation is that incision and aggradation occur once in a climatic cycle. Depending on the regional manifestation of global climatic change, aggradation and incision may be related to different phases within a climate cycle (Blum and Törnqvist 2000). In lowland regions a disequilibrium in transport and deposition of sediments can be instigated during the warming phase when the melting of the permafrost leads to high water discharges causing down-cutting of the valley floor and the abandonment of the previous floodplain (Vandenberghe 1995; Bridgland 2000). Sediment aggradation can fill the newly cut floodplain when water velocities decrease towards the end of the climatic transition. Fine sediments are deposited during interglacial conditions which can be partly removed and/or reworked when water supply increases again when the climate cools (Bridgland 2000). During the continuing transition into glacial conditions further climatic deterioration and vegetation decline can lead to increased discharge, slope instability and enhanced sediment supply resulting in aggradation (Vandenberghe 1995). The following glacial period can be a relative stable stage with restricted fluvial activity only reactivated by seasonal melt-water pulses (Bridgland 2000). In this model of terrace formation fluvial sand and gravels are deposited during the transitional phases that, if preserved, can be separated by organic deposits such as seen in some terraces in the Thames (Bridgland 2000; Bridgland 2006). Coarse-grained sediments can also be deposited *during* the glacial period after which incision takes place throughout the cold-warm climatic transition (Vandenberghe 2008). In such a model a meandering/anastomosing river incises the floodplain relatively deeply but over a limited lateral extent during climate transition. The alluvial plain is stable during the following warm period. The river changes from a low energy single channel to a high energy braided river at the warm-cold transition when the climate deteriorates. The incising braided river has a wide lateral extend and removes the morphology and sediments of the preceding meandering system in the middle of the floodplain through periodically high energy events. Valley incision during the first transitional period can be relatively small and be overwritten by the second major incision during the cooling phase of the climate cycle (Vandenberghe 2008).

An alternative model is that almost all aggradation and incision occurs during full glacial conditions (Lewin and Gibbard 2010). In this scenario incision occurs during the early phase of full glacial conditions, when sediment is transported and the substrate eroded (ibid.). Later in the glacial period aggradation occurs, depositing sand and gravels in a braided river system. Early in the interglacial the channel stabilises and interglacial sediments are deposited (Lewin and Gibbard 2010). This continues during full interglacial conditions. At the interglacial-glacial transition the cooling climate results in a decline of woodland vegetation that is substituted by herbs and early glacial grasslands (ibid.). The diminishing evapotranspiration, together with cold climate weather regimes, results in increased discharge leading to the removal of fine sediments and remobilisation of coarse debris (Lewin and Gibbard 2010). During this transitional phase the floodplain is incised and reworked forming gullies, clay and silt drapes and an enlarged channel. Glacial periods bring permafrost conditions that influence soil permeability, inhibiting infiltration and leading to increased surface water run-off and slope erosion and solifluction processes adding coarse sediments to the river (ibid.). In full glacial conditions valley floor erosion and bedrock incision is reactivated, fines are removed from the floodplain and lateral planation occurs. Later during the glacial period gravel transport is reactivated and the incised bedrock becomes swamped by cold climate sediments (Lewin and Gibbard 2010).

In addition to the models described above Brown et al. (2010) have emphasised the importance of erosional processes during cold aggradation periods. They propose a cascade response model in which lateral erosion creates the bedrock strath onto which terrace sediments are subsequently deposited. This lateral erosion results in the accommodation space for the next terrace gravels to be deposited on. It also results in the generation of fluvial sediments from the erosion of fringing (older) terrace deposits. In other words, lateral erosion leads to the undercutting of preceding terrace deposits and the redeposition of these sediments on the 'new' strath surface (Brown et al. 2010). Valley incision can occur due to a lack of lateral erosion, instigated by re-vegetation of the floodplain or permafrost conditions (ibid.).

River valleys with more terraces than climate cycles since the start of the Pleistocene, such as often found in southern Britain, indicate that multiple terraces can form over the duration of a single glacial-interglacial cycle. It has been proposed that terraces are generated during both the warming and cooling transition of a climate cycle (Bridgland and Westaway 2008a). The increased water supply during the cooling period could lead to a second phase of incision and deposition. When the second transitional period is more severe than that at the start of the interglacial, two terraces can be formed (Bridgland and Westaway 2008a). This results in paired terraces which exhibit minimal altitudinal separation. Alternatively, terraces could be formed under sub-Milankovitch climate fluctuations (Bridgland 2000; Westaway et al. 2006).

Climate oscillations would need to be of significant magnitude in duration and temperature to change river form and depositional patterns to a recognisable degree and internal thresholds must be crossed before climate change can influence river morphology

(Lewin and Gibbard 2010). The values of those thresholds depend on basin characteristics which vary according to each fluvial system (Vandenberghe 2002). Lewin and Gibbard (2010) stress the importance of considering bedrock incision and terrace aggradation more independently to explain both ‘over’ and ‘under’ representation of terraces. For example, they argue that when either erosion or aggradation exceeds the lateral extent and depth of earlier incisions or depositions several bedrock benches (terraces) can be eliminated or buried by erosion or aggradation, respectively leading to an under representation of terraces. When sediment deposition events are alternated with periods of minimal erosion and incision, terraces will be minimally separated in altitude and can form compound terraces (Lewin and Gibbard 2010). Over representation may occur when lateral planation and down-cutting does not reach the valley side every time. This would result in bedrock steps that, covered by aggradation, form the template for multiple terraces. Similarly, the geomorphology observed in aggraded sediments not necessarily matches the bedrock steps (ibid.). The importance of lateral planation and bedrock incision for terrace formation in southern Britain is also demonstrated by Brown et al. (2009). They show that sediment mass in the River Exe is stable over the formation of several terraces. This suggests that the loss of coarse material from the system has been limited and that it was incision in erodible bedrock that allowed the formation of terraces (ibid.). Sediment entered the system through lateral erosion and planation of former terraces during cold aggradational phases that occurred during climatic transitions (Brown et al. 2010).

In sum, river terrace formation in response to Quaternary climatic change is subject to complex mechanisms and feedback effects which all should be taken into account when investigating the fluvio-geomorphology of a river. The above discussed models and mechanisms are not mutually exclusive and could apply to different rivers and different parts of rivers at different times.

2.6 River terraces in the Avon valley

The Quaternary deposits in the Avon valley include clay-with-flints, head, gravelly head, river terrace deposits, brickearth, alluvium and occasional peat. Clay-with-flint is a residual deposit created by modification of Palaeogene sediments and the solution of the underlying chalk, deposited considerably earlier than the river terrace deposits. The exact age is uncertain but clay-with-flint deposits in south-west England are likely of Pleistocene age (Gallois 2009). Clay-with-flint is mainly found on the flats of hilltops. Older head deposits, associated with clay-with-flint sediments, formed through solifluction and solution of the latter and the underlying bedrock. It is often found on the upper valley slopes. Further down the valley 'head gravel', 'gravelly head' and 'head' are found, deposited by fluvial transport, hill wash, hill creep and soliflution (Barton et al. 2003; Hopson et al. 2007).

The fluvial deposits in the area form a flight of 14 river terraces. The highest terraces, up to 100m above the Avon valley floor, spread up to 12km wide from the present day river axis. The lower terraces in the Avon catchment are 6 to 3km wide and are found alongside and below the present day river (BGS 1991, 2004, 2005). The massive extent and limited altitudinal separation between the highest terraces point to the draped deposition of these terraces over the landscape (Clarke and Green 1987). The difference between these terraces and later well-separated steps may be due to a change in uplift regime as the result of increased denudational isostasy or a change in the cyclicity of climate change from 41ka to 100ka cycles during the Mid Pleistocene Revolution (Maddy et al. 2000). The middle terraces, T10-T5, are formed through bedrock incision and fluvial sediment aggradation (Clarke and Green 1987). The altitudinally lowest terraces in the modern valley are formed through cut and fill processes (Clarke and Green 1987). The terraces are of relatively constant thickness along the valley. This is typical for systems where sediment overloading from upstream and input from tributaries to the main valley occurs (Blum and Törnqvist 2000). This is probably combined with lateral erosion and redeposition of fluvial sediments (Brown et al. 2009a, b). This mechanism could explain the progressive restriction of floodplain width between each erosion-aggradation phase (Brown et al. 2010).

The high number of terraces may indicate that terrace formation in the Avon valley cannot directly be linked to MIS cycles as suggested in the model of terrace formation developed by Bridgland (2000). Instead, terraces in the Avon valley might reflect sub-Milankovitch climate fluctuations or multiple terrace formations within one climatic cycle. The fluvial sediments are indicative of deposition under cold climate conditions (Kubala 1980; Clarke 1981). However, to understand how terrace formation in the Avon valley is linked to Quaternary climate change the sedimentology and chronology of the terraces must be understood. Some attempts have been made to correlate the Avon terraces to develop an improved understanding of the age of the deposits, in part because of the Avon's significant Palaeolithic record and its position in relation to the River Solent (the Avon dissects the terraces of the Solent) (Maddy et al. 2000; Westaway et al. 2006). The following sections provide an overview of terrace schemes, correlations and proposed chronologies for the Avon terraces and its shortcomings (see sections 2.6.2 and2.6.3). The pervious overview as shown that valley characteristics such as bedrock can importantly influence terrace formation (e.g. Brown et al. 2010). Therefore, before looking at the chronology of the Avon terraces, the pre-Quaternary geology is briefly discussed.

2.6.1 Bedrock geology in the Avon valley

Today, the Avon River flows north to south through the Hampshire Basin. This structural depression extends from Dorchester in the west to Chichester in the east. The Chalk hills of the North Downs, Salisbury Plain and Cranborne Chase form the northern boundary of the basin. The south is defined by the Wight-Purbeck monocline that runs from Old Harry Rock to the Needles at the Isle of Wight and continues as the Wight-Bray monocline under the English Channel (Gibbard and Lewin 2003) (Figure 2.4). This bedrock, its structural evolution and resulting topography influenced the lithology and distribution of the overlying deposits, including the river terraces.

The base strata in the area are of Palaeozoic age, which were deformed during the Variscan orogeny towards the end of the Carboniferous (299Ma). These structures were reactivated at various times during the early Cretaceous, resulting in a Variscan Basement. Marine transgressions during the Late Triassic through to the Jurassic caused this depositional basin to be infilled by marine sediments (Penarth Group). A period of marine regression from the end of the Late Jurassic into the Cretaceous times caused the depositional environment to change from offshore marine (Kimmeridge Clay Formation) through shallow marine (Portland Group) to brackish water and evaporite precipitation (Purbeck Group) and the establishment of fluviatile precipitation is represented in the deposits of the Wealden Group (Barton et al. 2003; Hopson et al. 2007). Regional subsidence during the Late Cretaceous (99-65Ma) led to a renewed marine transgression depositing the Lower Greensand Group, Gault Formation and Upper Greensand Formation and Chalk Group. These are largely formed of sand, sandstone, mudstone, and chalk (Barton et al. 2003; Hopson et al. 2007). Falling sea levels, caused by uplift associated with the opening of the North Atlantic region, resulted in erosion of parts of the Upper Chalk. The 'Tertiary' Basin saw periods of marine transgression and regression caused by global eustatic sea level change. This resulted in the deposition of the Lambeth Group, Thames Group, Bracklesham Group, Barton Group and Solent Group (Barton et al. 2003; Hopson et al. 2007). Deposits which are thought to date to the beginning of the Quaternary directly overly the Palaeogene strata, indicating a considerable period to be unrepresented in the geological record (Barton et al. 2003; Hopson et al. 2007). The absence of the deposits from this time is caused by extensive deformation and erosion of the area during the mid-Miocene Alpine Orogeny. These tectonic processes compressed the Cretaceous strata and led to the formation of a series of east-west and northwest-southeast anticlines and synclines across the Hampshire basin (Hopson et al. 2007). The formation of the Purbeck-Wight monocline and the Weald-Artois anticline and the North Downs, separating the London and Hampshire basins, are thought to have formed during this period (Hopson 2009). In the Avon valley these processes formed the east-west running Wardour anticline and associated Mere fault to the southwest of Salisbury, the Dean Hill anticline (Hopson et al. 2007) and the Bowerchalke anticline (Barton et al. 2003). The orientation of these structures is probably initiated by deeper faults of Variscan Orogeny origin, that were reactivated during the mid-Miocene Orogeny leading to the inversion of previous basins and highs (Melville and Freshney 1982), initiating extensive erosion that unroofed the inverted basins that is "represented" in the time gap between the Palaeocene and Quaternary deposits (Barton et al. 2003).

The fault structures in the Avon valley and the general structure of the Hampshire basin have a northwest-southeast orientation. The Avon flows at right angles with these geological structures possibly suggesting a super-imposed drainage system, thus a different landscape when the river was initiated (Wessex Archaeology 1993) and a Hampshire (?proto-Avon) river may have existed throughout the Cenozoic (Gibbard and Lewin 2003). This bedrock, its structural evolution and resulting topography influenced the lithology and distribution of the overlying deposits, including the river terraces.

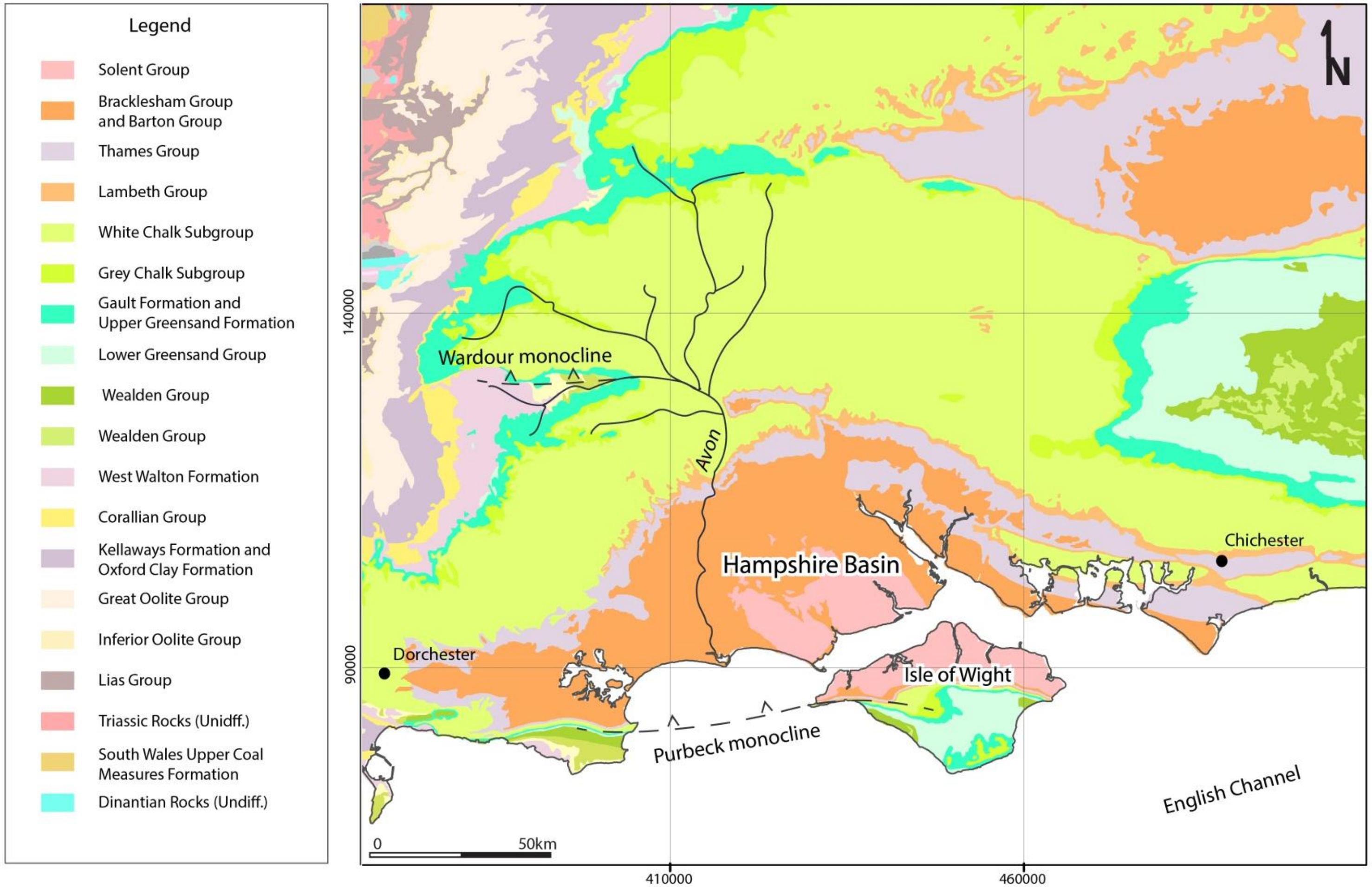


Figure 2.4 Bedrock geology map of the Avon valley and surrounding areas (based upon 1:625000 scale geology data, with permission of the British Geological Survey).

2.6.2 Avon valley terrace schemes

Two interrelated aspects of the Avon valley Quaternary record have generated interest in the area for decades: the timing of river terrace formation and the age of Palaeolithic artefacts discovered in these deposits. This has led the area to be subject to geological research over the last 150 years resulting in a variety of terrace schemes (Blackmore 1864, 1865, 1867; Bristow et al. 1991; Clarke 1981; Clarke and Green 1987; Green 1946; Kubala 1980; Reid 1903, 1898, 1902; Sealy 1955; Westlake 1889, 1902).

The first geological survey of the Avon area was made by Bristow and Trimmer between 1855 and 1857 and published on 'Old Series' sheets. Although the earliest geological mapping did not include 'drift' deposits (now known as superficial geology), Pleistocene sediments in the region were of interest to geologists and antiquarians right from the beginning due to their association with Palaeolithic artefacts, which great antiquity was appreciated through their stratigraphic position high above the current river valley (Blackmore 1865, 1867; Evans 1864; Westlake 1889, 1902) and the discovery of remains of extinct fauna in brickearth found at Fisherton, near Salisbury (Lyell 1827).

Following the initial geological survey, Reid and colleagues resurveyed the three sheet areas during the period 1892-1900 (Reid 1898, 1902, 1903). This resulted in the first geological memoirs of the region and the maps of Quaternary deposits (Reid 1898, 1902, 1903). Reid divided the superficial deposits into: clay-with-flints, plateau gravels, valley gravels, and alluvium. Based on the observed break in slope and their height above Ordnance Datum he further divided the plateau and valley gravels, where possible, in terraces. In the Salisbury area the valley gravels could be subdivided in an 'upper lower terrace' and a 'lower lower terrace' (Reid 1903). In the Bournemouth area Reid recognised two distinct sheets of 'plateau gravel', the lower of which included '*numerous Palaeolithic implements*' (Reid 1903, p.10). He identified the most complete set of terraces in the Ringwood area where he described the 'high plateau gravels' or 'higher terraces', a 'second terrace' (or *Eolith terrace*), a 'first terrace' (or *Palaeolithic terrace*) and 'valley gravels' (Figure 2.5). Although using similar nomenclature for the three studied areas, no clear correlations were suggested.

Green (1946) recognised eight river terraces and a number of graded reaches in the Bournemouth area. These terraces have been traced northwards along the Avon River by Sealy in an attempt to provide a more integrated terrace system for the valley (Sealy 1955) See Table 2.1 for an overview and correlation of the discussed terrace schemes. Profile studies, based on new data available from the assessment of boreholes, enabled Kubala (for the Fordingbridge area) and Clarke (for the area north of Bournemouth) to reclassify the terrace deposits and identify five Older River Gravels (O5-O1) and nine (T9- T1) lower river terraces (Clarke 1981; Kubala 1980). In the area around Bournemouth the number of recognisable terraces increases (Bristow et al. 1991) but clear correlations between the schemes have thus far not been published. Correlations between terrace schemes throughout the valley are essential for understanding the geomorphological history of the Avon valley and the integration of environmental and archaeological data present in the terrace deposits. Recent research on the terraces has been concerned primarily with correlating the Avon terraces with the Solent terraces (Westaway et al. 2006), issues of chronology in terms of landscape change (Maddy 1997; Maddy et al. 2000), and the age of the artefacts (Westaway et al. 2006; Ashton and Hosfield 2010).

Historic terrace schemes				BGS scheme
Westlake 1889	Reid 1902	Green 1946	Sealy 1995	Clarke 1981
175 ft Terrace ?	High Plateau/Higher terraces		Higher surfaces	O5
				O4 a+b
				O3
				O2
				O1
		Upper Ambersham	VIII	T10
		Ambersham	VII	T9
150 ft Terrace -	Eolith Terrace	Sleight Terrace	VI	T8
100 ft Terrace -	Palaeolithic Terrace	Boyn Hill	V	T7
50 ft Terrace -		Upper Taplow	IV	T6
		1st Lower Taplow	III	T5
	Valley Gravels	2nd Lower Taplow	II	T4
		Mustcliff Terrace	I	
		Christchurch Terrace		
				T3
				T2
				T1

Table 2.1 Overview of historic terrace schemes in the Avon Valley. O= 'Older river gravels' and T= Terrrace. The BGS scheme is added to aid comparison with the currently used schemes (Clarke 1981; Green 1946; Reid 1902; Sealy 1955; Westlake 1889).

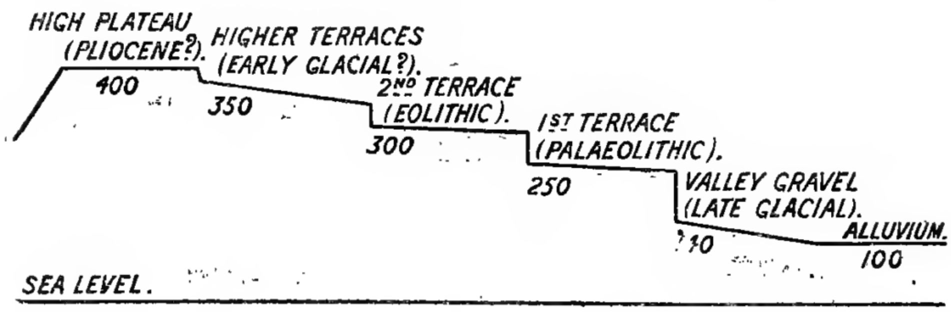


Figure 2.5 The terrace sequence of the Avon valley around Ringwood as illustrated by Reid (1902, p. 34).

An examination of current BGS maps, earlier published schemes and terrace heights, conducted for this research, have resulted in an overview of the published schemes (Table 2.2). T10 on the currently used BGS maps corresponds to the 'Older river gravels' recognised by Kubala (1980) and Clarke (1981). These deposits are not represented in the terrace scheme of the area around Bournemouth (Bristow et al. 1991). The highest terraces in this area (T14-T10) correlate to T8-T10 terraces as identified by Clarke (1981). The BGS map of the area is based on the terrace numbering proposed by Bristow et al. (1991). Correlation of the lower terraces in the Bournemouth area is not much clearer. T9, as mapped on the current BGS map, correlates to both T7 and T8 deposits as identified by Clarke (1981). T8 in the Bournemouth area and as currently used on the BGS maps (Bristow et al. 1991), correlates to T6 and T5 deposits in the area north of Bournemouth (Clarke 1981). Some T5 deposits (as identified by Clarke 1981), are currently numbered T7 in the Bournemouth area (Bristow et al. 1991). T6 is not clearly correlated, T3 of Clarke's scheme corresponds to deposits currently mapped as T5, and T2-T1 in the area north of Bournemouth (Clarke 1981) correlate to T4-T1 in the Bournemouth terrace scheme (Bristow et al. 1991). Correlation between the lower terraces as recognised by Kubala (1980) and Clarke (1981) is clearer (Table 2.2). Some anomalies exist between the schemes proposed by them and the terrace numbering presented on current BGS maps. T6 in the scheme of Kubala (1980) is designated T5 on the BGS map. Kubala identified two terraces on the floodplain, T5 and T4, on the BGS map these deposits are number T4 and T3 but these do not geographically correspond exactly with T5 and T4 on the map published by Kubala (1980). This research used the terrace numbering as published on the most recent BGS maps and the correlations proposed in Table 2.2. A map of the superficial geology is presented in Figure 2.6.

BGS TERRACE SCHEMES IN THE AVON VALLEY					
Middle Valley				Lower Valley	
Fordingbridge (Kubala 1980)	BGS map 2004		North of Bournemouth (Clarke 1981)	BGS map 1991	Bournemouth (Bristow et al. 1991)
O5			O5		
O 4 a+b	T10		O4 a+b		
O3			O3		
O2			O2		
O1			O1		
T10	T9-T10		T10	T14	T14
			T9	T10-T13	T10-T13
T8-T9	T9		T8		
	T8	T8	T7	T9	T9
T7	T7				
T6	T5		T6	T8	T8
T5			T5		T7
	T3-T4				
T4			T4		T6
T3		T1-T4	T3	T5	T5
T2			T2		T1-T4
T1			T1		

Table 2.2 Overview of different terrace schemes currently used for the Avon valley and their correlations as proposed in Hopson et al. (2007), Barton et al. (2003) and based on current BGS maps (2004; 1991). O = ‘Older river gravel’s, T = terrace.

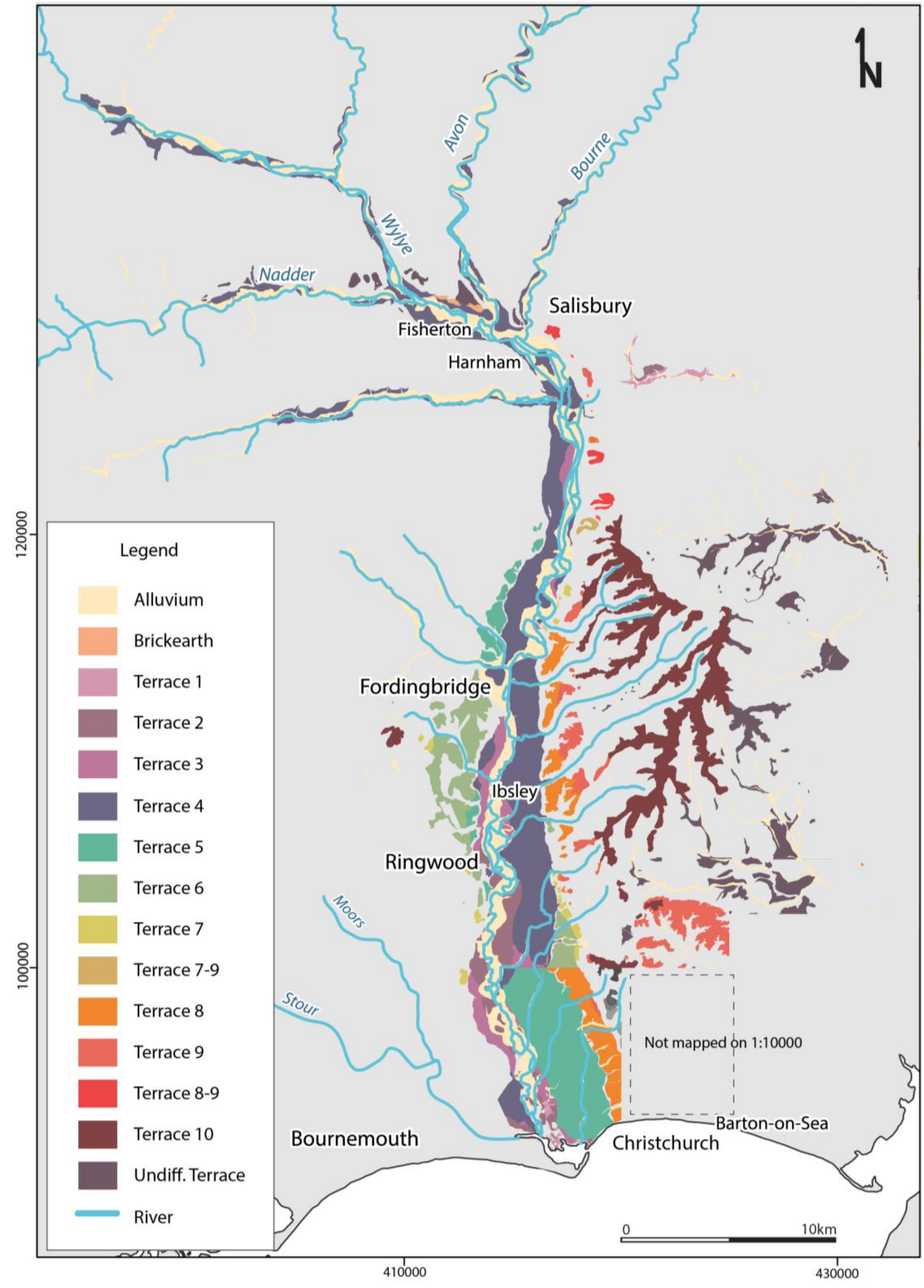


Figure 2.6 Superficial geology map of Pleistocene river terraces in the Avon valley (based upon 1:10000 scale geology data, with permission of the British Geological Survey and 1:10000 scale OS VectorMap Local [water line shape file], Digimap Licence).

2.6.3 Geochronology of the Avon valley terraces

The highest gravel deposits in the Avon valley, found on the Avon-Test interfluve, are the oldest Pleistocene deposits in the catchment representing the early confluence between the Avon and Solent River and probably date to the Pliocene or early Pleistocene (Allen and Gibbard 1993; Westaway et al. 2006). Attempts to improve the chronological understanding of the geomorphological history of the Solent River system have been based on chronometric and biostratigraphic dating of terrace deposits and the correlation of those with deposits of unknown age based on a comparable height above the floodplain (Briant et al. 2012; Briant et al. 2006; Davis 2013; Harding et al. 2012; Hatch 2014; Westaway et al. 2006). Evidence for the timing of terrace formation in the Avon valley is limited, hence the chronology of the Avon terraces is poorly understood and currently based on scarce fossiliferous sediments found only in association with the altitudinally lowest terraces, correlations with dated terrace deposits elsewhere in the Solent system and the application of Palaeolithic artefacts from the terrace deposits as 'index fossils' (Barber and Brown 1987; Bates et al. 2014b; Delair and Shackley 1978; Westaway et al. 2006). A better understanding of the age of the terraces depends on the application of chronometric dating techniques. The absence of fossiliferous sediments from these deposits has hindered the application of for example biostratigraphic, C^{14} or amino acid racemisation dating techniques. The following section discusses the evidence for the timing of river terrace formation in the Avon valley, based on chronological evidence and terrace correlations and its problems and shortcomings. The terrace numbering used in the following discussion is based on the schemes of Kubala (1980) and Clarke (1981) for the Ringwood and Salisbury area and that of Bristow et al. (1991) for the area around Bournemouth. The correlated numbering used on current BGS maps is presented in Table 2.2.

2.6.3.1 Chronological evidence

From the Avon valley itself three fossiliferous deposits are known. Just northwest of Salisbury in the Nadder valley, are the Fisherton brickearths which overly T4 contain a rich fossil assemblage (Blackmore 'Locked notebook', Salisbury Museum; Delair and Shackley 1978; Lyell 1827) (see Figure 2.6). The faunal assemblage is indicative of an environment associated with the extreme end or very beginning of an interglacial, probably the end of the Ipswichian (MIS 5) (Delair and Shackley 1978) or early middle Devensian (MIS 4-3) (Green et al. 1983). This led Westaway et al. (2006) to suggest a MIS 4 age for gravel deposition and a MIS 3 age for the overlying fossiliferous deposits based on Green et al.'s (1983) attribution of the latter to the Devensian (Westaway et al. 2006).

Secondly, at Ibsley peat from beneath terrace 3 has been dated to ~41ka by radiocarbon dating (Barber and Brown 1987) (see Figure 2.6). Alternatively the deposit may be linked to the Ipswichian IIb based on its specific pollen spectrum which is dominated by herbaceous plants of temperate affinity (Allen et al. 1996). This could indicate that the overlying gravel deposit from terrace 3 post-dates MIS 5, related to one of the cold stages or stadials that followed this period.

A third location of interest is Harnham, located just down-stream of Salisbury in the main Avon valley. Here four depositional phases have been recognised. The first phase comprises the deposition of gravel under cool to cold conditions (Bates et al. 2014b). This is overlain by sand with occasional tufa, rare flint clasts, abundant molluscs and rare but fresh artefacts and mammalian remains (ibid.). The third phase is a weathering horizon of the surface of the phase two sand. Here 'mint', refitting waste debitage has been found (Bates et al. 2014b). The final phase of deposition is represented by solifluction causing mass movements of chalk rubble, pebbles and fresh artefacts including high concentations of production waste and bifaces (ibid.). The limited faunal assemblage from phase II and IV is indicative of a pre-Ipswichian/post-Hoxnian date. OSL dating on quartz sand and amino acid racemisation on two *Bithynia tentaculata* opercula, both from phase II, was carried out (Bates et al. 2014b). The AAR results suggests an MIS 8 or early MIS 7 age; the OSL results suggest the accumulation of phase II sediments during the later part of the cold phase of MIS 8 or the very beginning of MIS 7, between *c*. 276ka and 235ka. The authors suggest a MIS 8 age for the phase I gravel deposition (Bates et al. 2014b). Unfortunately however, it is difficult to relate this gravel deposit with certainty to the numbered terrace scheme. Based on the comparable height above the floodplain the authors tentatively suggest that the Harnham and Milford Hill assemblages are of broadly similar age (Bates et al. 2014b).

2.6.3.2 Terrace correlations

Another approach to understanding the chronology of the Avon terraces is terrace correlation with dated deposits from the Solent River system. The Avon valley and the Solent River system (including its head waters as represented by the Frome and its northern tributaries the Stour, Test and Avon) were, for large parts of the Pleistocene, part of the same system and subject to similar geomorphological processes. It is therefore reasonable to assume the terraces of the tributaries and the main river are the result of the same events affecting the system (Allen and Gibbard 1993). Important tools for correlating terraces from the Solent and its tributaries are terrace long profile projections (e.g. Briant et al. 2012). Particular areas have become important in integrating the terrace systems. For example the western Solent region is known as the 'classic' Solent terrace staircase, lying between the

Test and the Avon confluence zones. The latter is located between Barton-on-Sea and Christchurch and it is here that Solent and Avon terraces can be related. This is dependent on the terrace correlations within and between the individual regions (here the Avon and Solent). Correlations in turn are dependent on the gradient deployed for correlating terraces. This has led to many, often incompatible, terrace schemes for the Solent (Allen and Gibbard 1993; Green 1946; Hatch 2014; Westaway et al. 2006). Table 2.3 summarises the different schemes in the Avon-Solent confluence. Such confusion hampers extrapolation of the age of dated terraces from adjacent areas to undated deposits of interest. Table 2.4 provides terrace correlations across the Solent region proposed in recent literature. Correlations however are not straight forward as there is a lack of precise terrace elevation data and insufficient field verifications (e.g. Westaway et al. 2006). This approach to assessing the age of undated terrace deposits should therefore be used with caution and rather as guidance.

This section has demonstrated that the timing of terrace formation in the Avon valley is poorly understood. In order to improve the integration of the terrace sequence and landscape evolution of the Avon valley with that of the wider region direct dating of the stratigraphy of the Avon valley is needed. An improved understanding of the chronology of landscape evolution and terrace formation would also provide a chronological framework for the significant Palaeolithic record associated with the Avon river terraces. The paucity of fossiliferous sediments in the Avon valley hinders the application of dating techniques based on organic material. Optically stimulated luminescence offers a dating technique that allows the age of inorganic sediments to be established based radiometric properties of minerals (Murray et al. 1995) and is now widely used for the dating of inorganic Pleistocene fluvial sediments (Briant et al. 2006; Schwenninger et al. 2007;. Toms et al. 2008; Toms et al. 2005).

The next chapter will present the current understanding of hominin presence in Britain. This sets the research context of the Palaeolithic record from the Avon valley and how an improved understanding of the latter can contribute to the understanding of hominin behaviour in northwest Europe.

Lower Avon Valley					Solent	
Bournemouth (Bristow et al. 1991)	Hatch 2014	Allen&Gibbard 1993	Westaway et al. 2006 (west)		Allen&Gibbard 1993	Westaway et al. 2006 (Southampton area)
T14	Whitefield Hill		16	Whitefield Hill	Whitefield Hill	
T13	Holm Ridge		15	Wootton Gravel (Holmsley Ridge Gravel?)	Holmsley Ridge	Wootton Gravel
T12	Sway		14	Sway Gravel	Sway	Sway Gravel
			13	Tiptoe Gravel	Tiptoe	Tiptoe Gravel
					Beaulieu Heath	
T11	Setley Plain		12	Setley Plain Gravel	Setley Plain	Setley Plain Gravel
	Mount Pleasant		11	Mount Pleasant Gravel	Mount Pleasant Gravel	Mount Pleasant Gravel
T10	Stanwoodbay		10	Old Milton	Old Milton	Old Milton Gravel
					Tom's Down Gravel	Tom's Down Gravel
T9	Milford-on-Sea	High Cliff Gravel	9		Taddiford Farm	
					Stanswood Bay	
T8	Pennington	Bransgore Gravel	8		Milford-on-Sea	
T7						
T6						
					Lepe Gravel	Lepe
T5						
T4		Burton Rough Gravel			Pennington Gravel	
T3						
T2		North End Copse Gravel				
T1						

Table 2.3 Overview of currently used terrace schemes and correlations proposed in the literature (Bristow et al. 1991; Allen and Gibbard 1993; Westaway et al. 2006; Hatch 2014).

Western Solent				Test valley				Correlated Avon terraces	
Terrace (Allen&Gibbard 1993)	Date	MIS	Source for OSL dates	Terrace (Edwards&Freshney 1987)	Date	MIS	Source for OSL dates	Clarke 1981	Bistow et al. 1991
5									
4b									
4a									
3									
2									
1									
Whitefield Hill									
Holmsley Ridge				6	413±26 (±1σ)/280±19 (±1σ)	11 (12-11)/8(8)	Bates et al. 2004/Briant et al. 2012	8	? 15
Sway				5	233±37 (±1σ)/292±20 (±1σ)	7d (8-7a)/8 (9-8)	Bates et al. 2004/Briant et al. 2012		? 14
Tiptoe									
Beaulieu Heath									
Setley Plain									
Mount Pleasant Gravel				4					
Old Milton	351±35 (±2σ)	10 (11-9)	Briant et al. 2006					6	10
Tom's Down Gravel	329±33 (±2σ)	9 (11-8)	Briant et al. 2006						
Taddiford Farm	254±18 (±2σ)	8 (8-7b)	Schwenninger et al. 2007	3	305±25 (±2σ)	9(9-8)	Harding et al. 2012	-	9
Stanswood Bay	245±15 (±2σ)	8 (8-7b)	Briant et al. 2006	2	217±22 (±1σ)	7 (8-6)	Bates et al. 2004/Briant et al. 2012	-	-
Milford-on-Sea									
Lepe Lower Gravel	149±14 (±2σ)	6 (6)	Briant et al. 2006						
Stone Point (organic)		5e							
Lepe Upper Gravel	65±14 (±2σ)	4 (5a-3)	Briant et al. 2006						
Pennington Lower Gravel								4 - 1	5 - 1
Pennington Marshes		5e							
Pennington Upper Gravel	46±8 (±2σ)	3 (3)							

Table 2.4 Overview of dated terraces from western Solent and Test and suggested correlations in the literature based on height OD and long profile projections (Edwards and Freshney 1987; Allen and Gibbard 1996; Bates et al. 2004; Briant et al. 2006, 2012; Harding et al. 2012).

Chapter 3 Hominin presence in Britain

3.1 Introduction

Having discussed the chronological framework for Pleistocene climate and palaeogeographic change, this chapter reviews current knowledge of hominin evolution and dispersal. It deals briefly with the emergence of the species *Homo*, its dispersal out of Africa and arrival in Europe. The presence of *Homo* in Europe is discussed in more detail as this provides the immediate context for the British Palaeolithic. As part of Europe, Britain offers a particularly interesting area to study hominin behaviour, being at the north-western margins of the landmass. Recent research has suggested that hominin presence here follows somewhat different patterns than those observed on mainland Europe (Ashton and Hosfield 2010; Ashton and Lewis 2002; Davis 2013). Contrasting the information between Britain and mainland Europe offers new insights in hominin behaviour and adaptation in Britain. However, within the British Palaeolithic record, the potential information from several significant assemblages has not yet been realised and integrated into the broader understanding of the British Palaeolithic due to a lack of contextual and chronological information. Such assemblages are often recovered from fluvial deposits and the significance of rivers in the Palaeolithic is briefly discussed before assessing the potential of 'proximal context' assemblages. The chapter concludes with a description of the Palaeolithic record from the Avon valley, its current understanding and future potential.

3.2 The emergence of *Homo*

Hominins in the genus *Australopithecus* evolved into early *Homo* between 3Ma and 2.5Ma (Berger et al. 2010; Jurmain et al. 2012), but some argue that traits that define *Homo* (anatomically and behaviourally) probably evolved over longer time (Antón et al. 2014; Harmand et al. 2015). The earliest current evidence for the appearance of the genus *Homo* is in Ethiopia, where a mandible assigned to *Homo* was found in sediments dated to 2.8Ma ago (Villmoare et al. 2015). Following emergence, the morphometric traits of *Homo* diversified. Some argue this variety represents within species variation (Antón et al. 2014; Lordkipanidze et al. 2013) while others have used it to define different *Homo* species (Leakey et al. 2012; Spoor et al. 2015). The earliest evidence of *Homo* outside Africa is found in Dmanisi (Georgia), dated to 1.85Ma (Lordkipanidze et al. 2007). *Homo* fossils found in Indonesia and China dated to ~1.65Ma indicate a rapid eastern spread (Antón et al. 2014; Zhu et al. 2008). The earliest evidence of *Homo* reaching western Eurasia comes from Pirro-Nord (Italy) dated to ~1.6-1.3Ma, (Arzarello and Peretto 2010) and sites in Sierra de

Atapuerca (Spain), where fossils from Sima del Elefante are dated to ~1.2Ma, and fossils from Gran Dolina TD3-4 are dated to 1.0Ma (Mosquera et al. 2013). Populations possibly spread east and west from a 'central area of dispersals of Eurasia' perhaps located in the Levantine corridor (Bermúdez de Castro and Martinón-Torres 2013).

3.3 The European Palaeolithic record

Hominin dispersal into Europe may have appeared in two phases. Early, sporadic occupation between ~1.6Ma-700ka by hominins using core flake technology are thought to have been followed by more persistent hominin presence after ~600ka (Roebroeks 2006; Pettitt and White 2012). The basis for this suggestion of a continental wide depopulation event (or events) are the gaps in otherwise continuous records of hominin occupation in Atapuerca and the Loire valley (Despriée et al. 2011; Mosquera et al. 2013). At both sites the use of core flake technology ceases before the introduction of Acheulean stone tools to the site (Despriée et al. 2011; Mosquera et al. 2013). Mosquera et al. (2013) suggest small groups of new hominins arrived in Europe before ~650ka carrying Acheulean technology, represented at French sites such as "Rue du Manege" and "Carriere Carpentier" in the Somme Valley (Antoine et al. 2014) and the Brinay and Gievres sites in the Cher valley (Despriée et al. 2011). Many Acheulean sites are found from ~500ka onwards. These are considered to be related to the arrival of *Homo heidelbergensis* whose fossil remains have been found at several sites from this period onwards (Mosquera et al. 2013).

Two archaeological sites in Britain, Pakefield and Happisburgh, have contributed significantly to the understanding of early hominin presence in northwest Europe (Parfitt et al. 2005, 2010) and before their discovery it was widely thought that hominins did not reach these areas prior to 500-600ka (Roebroeks 2001). The discovery of flint artefacts at Pakefield, Suffolk, England, in sediments dated to ~700ka, questioned the former dispersal model (Parfitt et al. 2005). Environmental data from the site, suggest warmer conditions than those known in England today, and led to the proposal of an 'ebb and flow' model of hominin dispersal (Roebroeks 2006). In this scenario hominins would migrate in synchrony with specific habitats (habitat-tracking) which expanded and contracted north in response to interglacial/interstadial-glacial cycles (ibid.). The discovery of stone tools at Happisburgh site 3, dated by biostratigraphy and palaeomagnetism to ~0.99-0.78Ma, changed this perspective again (Parfitt et al. 2010). Based on a wide range of environmental data the authors reconstructed a habitat they suggest to be similar to the southern edge of the boreal zone thus instigating new questions about hominin habitat preferences and tolerances (ibid.). Hominin presence at Pakefield and Happisburgh site 3 has been explained as an 'Atlantic' phenomenon in which early hominin migration might have been facilitated by the milder Atlantic climate prevailing in coastal regions and lower reaches of rivers (Cohen et al. 2012). These areas would have formed a corridor for dispersal; at the junction of different ecotones the coast and lower reaches of rivers offer a wide variety of food resources (ibid.).

As an alternative to the ebb and flow model, in which populations expand and retreat, Dennell et al. (2011) suggest that the archaeological record might reflect source and sink populations. A 'source' would be core populations in glacial refugia. Hominins migrating outside glacial refugia during interglacials and interstadials form population sinks that depended on an influx from core populations in refugia to sustain their presence. When conditions deteriorated sink populations outside glacial refugia would experience local extinctions rather than retreating to refugia (ibid.). Glacial refugia of source populations were probably located in southern Europe or, during periods of extreme climatic deterioration, in southwest Asia, when the whole of Europe would have formed a population sink (Bermúdez de Castro and Martinón-Torres 2013; Dennell et al. 2011). Hominins probably developed biological, behavioural and technological adaptations to survive in specific environments in refugia (Basell 2008). This scenario might be reflected in the European archaeological record as we know it today.

3.4 The Palaeolithic in Britain

The majority of Palaeolithic artefacts in Britain are found in the south, southwest and southeast of the country (Roe 1981). This distribution has been directly affected by the extent of Pleistocene glaciations (Figure 2.3) (Wymer 1999a). The northern regions of Britain would have been habitable for shorter times, limiting the duration of hominin presence and consequently the archaeological record. In addition, this record would have been obscured through landscape modification and sediment deposition from the expanding ice sheets (ibid.).

The pattern of hominin occupation in Britain is similar to that of Europe. The earliest occupation (e.g. Pakefield and Happisburgh) is sporadic, represented technologically by cores, flakes, and hammer stones, and is probably linked to milder Atlantic climates in coastal areas (Cohen et al. 2012). The first groups using Acheulean stone tools arrived around MIS 15 (~565ka) (Davis 2013; Pettitt and White 2012) and there is evidence for increasing numbers of hominins reaching Britain during subsequent interglacials, and possibly some interstadials. A key difference in the British record of hominin occupation compared to Europe is the suggested decline of hominin presence in Britain from MIS 11 onwards and their probable absence between MIS 6-4 (Ashton and Hosfield 2010; Ashton and Lewis 2002; Ashton et al. 2015; Davis 2013 but see Wenban-Smith et al. 2010). This pattern has been linked to the changing palaeogeography of Britain (Ashton et al. 2015; Gupta et al. 2007) (see section 2.3). The opportunities for hominins to reach Britain were influenced by changing sea levels, Channel River dynamics and local tectonics, and the proposed population decline might reflect a decrease in the connectedness of Britain to the continent (Gupta et al. 2007). It is difficult to predict the interplay between sea-level change, local tectonics, river dynamics and habitable conditions but it has been reasoned that only specific combinations of low sea-levels but relatively mild climates allowed hominins to reach Britain (Ashton and Hosfield 2010).

This is possibly reflected in the archaeological records from the Middle Thames and Solent river systems, where, based on artefact densities, a population peak during MIS 11 (or between MIS 13 and 10) and a subsequent polulation decline has been suggested (Ashton and Hosfield 2010; Ashton and Lewis 2002). However, a better understanding of the influence of behaviour (artefact discharge patterns or habitat preferences) and technology on artefact densities is needed to convert numbers of artefacts to demographic estimates (Ashton and Hosfield 2010; Ashton and Lewis 2002; Scott et al. 2011). A dearth of archaeological evidence dated to between MIS 6 and early MIS 4 could reflect a total absence of hominins in Britain (Ashton and Hosfield 2010; Ashton and Lewis 2002) and new populations possibly only returned again during late MIS 4 or early MIS 3 (Pettitt and White 2012). However, the alleged absence of hominins in Britain can be a function of the lack of deposits of this period that preserve hominin evidence, taphonomy and research history (Lewis et al. 2011), and some possible evidence exists of hominin presence during MIS5d-5b (Wenban-Smith et al. 2010).

In Britain, as on the continent, there is a temporal divide in the occurrence of Oldowan and Acheulean (Pettitt and White 2012). In addition a further temporal division in the occurrence of lithic technologies has been proposed for Britain (Bridgland and White 2014; Westaway et al. 2006; White and Schreve 2000). Twisted ovate bifaces seem to be related to MIS 11 and at sites dated to MIS 9 cleavers and ficrons frequently dominate lithic assemblages. Levallois artefacts first appear in the British Palaeolithic during MIS 9-8 and *bout coupé* bifaces are clearly related to the arrival of Neanderthals in Britain during MIS 3 (Ashton and Scott 2015; White and Schreve 2000; White and Jacobi 2002).

Differential spatial distributions of artefact technologies (including biface and non-biface assemblages or Clactonian technology and the occurrence of Levallois) can be seen in the Thames and Solent Palaeolithic records (Ashton and Hosfield 2010). In the Solent area relatively few Levallois artefacts are found as opposed to the rest of Britain where it generally occurs around MIS 9-7 (Ashton et al. 2011) and a similar paucity is seen in southwest Britain (Ashton et al. 2015). Many questions persist regarding the reasons why hominins employed Levallois technique and what its presence or absence tells us (Basell and Brown 2011; Pettitt and White 2012; Scott 2011). However, the east-west divide in lithic technology in Britain could be the result of contrasting dispersal opportunities along the North Sea rivers (Thames, Rhine and Meuse) and the Channel Rivers (Solent, Somme and Seine) (see Figure 2.2) mirroring the divide as seen on the continent where Levallois is dominant in northern France, Belgium and the Netherlands and bifaces persist in western France (Ashton and Hosfield 2010; Scott and Ashton 2011). However, evidence of late (MIS 8) Acheulean sites in southwestern England could also reflect the persistence of an Acheulean industrial tradition from MIS 9 through to MIS 8 in this region (Bates et al. 2014b).

3.5 Hominins in the landscape: preservation, preference and time

Key issues in interpreting patterns in the archaeological record to understand hominin dispersal routes, landscape use and the environmental context of dispersal, are: 1) the disentanglement of taphonomic influences from hominin preference; and 2) the establishment and refinement of reliable chronological frameworks (Cohen et al. 2012; MacDonald and Roebroeks 2012; Roebroeks 2006). Importantly, the current interpretation of the British Palaeolithic (section 3.4) is based on the records from the main Pleistocene river systems. This spatial distribution of sites is a widely observed phenomenon and 90% of the total Lower and Middle Palaeolithic finds in Britain and northern Europe are associated with rivers (Brown 1997; Wymer 1999). This has led many authors to suggest river valleys were important dispersal routes and the preferred ecological niches of hominins (Cohen et al. 2012; Kahlke et al. 2011; Wymer 1999a,b). It has been argued that river mouths and the lower reaches of valleys and coastal plains offer a wider range of food and raw material resources and obviously access to fresh water (Cohen et al. 2012; Hosfield 2011). The observed pattern and therefore assumed preference for river valleys may however be (partly) the result of differential preservation conditions, increased chances of discovery or the result of taphonomic processes (Brown 1997; Cohen et al. 2012; Hosfield 1999; Roebroeks 2006).

The Palaeolithic record from terrace deposits is predominantly found in fluvially disturbed environments. Sites from such contexts have been regarded as of limited stratigraphic and chronological integrity (Roe 1981). Consequently, much research concerned with these data was limited to the description of artefact typologies within a relative chronological framework grounded in the terrace sequences (Roe 1981; Wymer 1969). However, the concept of site integrity is relative to the research questions one seeks to address (Hardesty and Little 2009). Disturbed assemblages might not be suitable to answer specific questions regarding aspects of, for example, the spatial organisation of activities within a site. When addressing issues on a much broader (e.g. regional or continental) scale, such sites gain new significance to address large scale questions (ibid), for example, of spatio-temporal patterns in hominin behaviour. Disturbed and undisturbed contexts are therefore complementary and offer different interpretive scales (site specific, individual or regional, general), depending on the understanding of the depositional and post-depositional processes that have affected the remains. Site formation and its relative integrity can be investigated through the analysis of the records' sedimentary context (e.g. Hewitt and Allen 2010), and the physical appearance of the artefacts (e.g. Burroni et al. 2002). A case by case study and the application of modern methods can now be used to provide much more contextual and chronological information than previously possible. In addition, theoretical concerns in Palaeolithic archaeology are now less concerned with describing and categorising such assemblages but focus on the relationship between the Quaternary environment and landscape change and hominin behaviour, applying a geoarchaeological approach to the Palaeolithic record as integral aspect of Quaternary science. Fluvial terraces as context for the majority of the Palaeolithic record could be seen as providing an opportunity for a further integration of the Palaeolithic within its Pleistocene context.

The link between Pleistocene fluvial sediments (especially river terrace deposits) and Palaeolithic artefacts and its chronological implications for the understanding of hominin presence has long been appreciated (Blackmore 1864, 1865; Evans 1864; Reid 1902; Westlake 1889). Understanding the British Palaeolithic within its Pleistocene context developed alongside progresses made in Quaternary science. The recognition of the correlation between Pleistocene climate cycles and the formation of river terraces offered a relative chronological framework for these 'fluvial archives' (containing Palaeolithic and environmental records) from the river systems in Britain and northern Europe (Bridgland 2000; Bridgland and White 2014; Mishra et al. 2007).

The development of new techniques for dating fluvial deposits has provided chronometric age tie-points for hominin presence (Despriée et al. 2011; Moncel et al. 2013; Penkman et al. 2011; Toms et al. 2008). The establishment of these chronometric frameworks and the recognition that the rich but often reworked Palaeolithic records from fluvial archives could provide a different interpretive scale to study long-term hominin behaviour (Gamble 1996) has led to a reassessment of such fluvial records and contributions to the understanding of hominin presence in Britain in time and in the landscape.

This renewed interest in the Palaeolithic record from river systems not only led to the recognition of general patterns of hominin presence in Britain. The existence of notably rich sites against a general background scatter of Palaeolithic find-spots has instigated a debate on the behaviour significance of large artefact concentrations (Ashton and Hosfield 2010; Brown et al. 2013; Hosfield 1999; McNabb 2007; White et al. 2006). The distribution of Palaeolithic artefacts in river valleys in Britain has been linked to differential preservation of terrace deposits, fluvial processes and collection history but also to hominin behaviour and preference (Hosfield 1999; Hosfield and Chambers 2005; Wymer 1999). This is relevant to the question of hominin presence in the landscape but the distribution of sites over different terraces also has a chronological aspect, as these provide the relative chronological framework for the archaeological record. This has led to the argument that temporal patterns, based on the relative chronology of the river terrace from which artefacts are derived, may be biased by the differential preservation of certain terraces over others (Ashton and Hosfield 2010; Ashton and Lewis 2002). This could result in an increased potential of artefact recovery from the better preserved deposits leading to an apparent archaeological richness interpreted as reflecting increased hominin presence (Ashton and Hosfield 2010; Ashton and Lewis 2002).

The existence of rich sites within terrace deposits has been related to fluvial processes. Hosfield (1999; 2001) proposed that fluvial reworking could lead to artefact accumulation in confluence zones and breaks of slope, mimicking areas of behavioural significance (ibid.). Wymer (1999a,b; Wessex Archaeology 1993) has argued that fluvial processes would have the opposite effect on artefact distribution, as reworking would result in a dispersal rather than accumulation of initial artefact concentrations. Brown et al. (2010) have emphasised the importance of lateral erosion in river systems causing the reworking and redeposition of sediments from fringing, older terrace deposits. This results in the cascade like contribution of artefacts from previous terraces to the new floodplain. In this process down-stream transport of artefacts is regarded minimal and artefacts will remain in proximity to their initial discard location (ibid.) and represent hominin presence within the landscape (Brown et al. 2013). However, their vertical reworking down the terraces changes the stratigraphic position and therefore chronological understanding of the finds (Brown et al. 2009a, 2010) (see section 2.5).

Opportunities to recover Palaeolithic finds are influenced by the exposure of Pleistocene deposits as this evidently increases their visibility (Brown 1997; Wymer1999a). Pleistocene deposits can be exposed in quarries, through urban expansion (e.g. excavation of cellars) and the development of infrastructure (Hosfield 1999, 2001.). This would mean that more intensely commercially worked terraces could appear richer in Palaeolithic finds than smaller exposures. Such a pattern could wrongly be interpreted as a change in hominin presence through time. Aggregate extraction and urban expansion could also lead to a bias in spatial distribution of Palaeolithic find-spots, where locations can appear richer due to increased chances of artefact recovery (Hosfield 1999). If this were the case, numbers of Palaeolithic artefacts should be highest in urban areas or areas where there are significant exposures of and quantities of Pleistocene deposits such as cliffs. However, subsurface discoveries (archaeological or other) are often stochastic (increased by urban development, infrastructure, mining/quarrying) and it could be argued that this is a bias present in the entire archaeological record.

A further theory is that the activity of local antiquarians could have biased to observed find-spot distribution (Hosfield 1999). It has been suggested that antiquarians would have focused their collection activities on rich sites and therefore exaggerated the richness of these over other areas (ibid.). The collection history also likely biased the artefact assemblages with a preference for bifaces (Ashton and Hosfield 2010; Hosfield 1999). The relative influence of the above-discussed factors on the spatial distribution of Palaeolithic find-spots in the Avon valley is discussed below to assess the hominin behavioural significance of prolific sites in the area.

3.6 Artefact distribution in the Avon valley

3.6.1 Spatial distribution of the Avon Palaeolithic record

Figure 3.1 shows a map of the distribution of Palaeolithic finds throughout the Avon valley based on Historic Environment Records from Dorset, Hampshire and Wiltshire, which derived their information form historic sources, surface finds and the Southern Rivers Palaeolithic Project (SRPP; Wessex Archaeology 1993). In the Avon valley over 1490 artefacts are recovered from 145 different locations (for 8 sites the exact number of artefacts is unknown). Some discrepancies do exist between terrace mapping and find location.

Historic maps and analysis of grey literature can contribute to the refinement of the locations of finds and their attribution to specific terrace deposits through localising quarries, buildings or old field names.

Similarly as observed for the wider British Palaeolithic record the majority of sites are associated with fluvial deposits and have attracted interest for over 150 years (Blackmore 1864, 1865, 1867; Read 1885; Reid 1902, 1903, Westlake 1889, 1902). Most of the terrace finds are concentrated in the middle and upstream part of the catchment. Further upstream only a few artefacts have been recorded, often related to clay-with-flint or undifferentiated terrace deposits (Wessex Archaeology 1993). Some isolated finds have been derived from the valleys of the tributaries Nadder, Wylye and Bourne. At the confluence of these rivers at Salisbury large concentrations of artefacts are found at Bemerton and Milford Hill, and are associated with the higher, undifferentiated terrace deposits on the interfluves between the valleys. At Bemerton 98 artefacts were recovered from a few small gravel pits between the middle of the 19th century and the beginning of the 20th century (Read 1885; HER). Opposite Bemerton is Milford Hill, located on the spur between the valleys of the Avon and the River Bourne. Milford Hill, with 467 artefacts, is one of the most prolific Palaeolithic sites in the Avon valley (Roe 1968; Wessex Archaeology 1993; Wymer 1999a). The majority of the artefacts found here were collected during the second half of the 19th century when the digging of cellars, basements and the exploitation of many small gravel pits led to the exposure of undifferentiated terrace deposits and the artefacts within (Read 1885). The superficial geology at both sites is undifferentiated terrace deposit which is considered to be part of the same deposit and is related to the same depositional event. However, Bemerton is *ca*. 6m higher than Milford Hill which could have implications for the relative chronology of these deposits and the artefact assemblages they contain.

South of Salisbury the river valley widens, and consequently the number of preserved terraces increases. Here very small numbers of artefacts are associated with almost each terrace (Table 3.1). Against this spread of isolated finds, larger concentrations are found around Fordingbridge and Christchurch. The most prolific site in the valley is that of Woodgreen (Roe 1968; Wymer 1999a). Here a gravel pit in T7 (in use between 1849 and 1943 based on OS mapping and possibly at other times) has been the source of 635 artefacts. The first biface was found *in situ*, 1.5m in the gravel, on 28 April 1876 by Westlake (1902).

Thus the largest numbers of finds are related to undifferentiated terrace deposits and T7 and T4. Additionally 181, artefacts from 45 sites are not related to superficial geology. 134 of these artefacts come from 6 sites in the vicinity of Milford Hill and can possibly be associated with the undifferentiated terrace deposit there (Blackmore 1865; Read 1885; Wessex Archaeology 1993). An additional cluster of sites around Milford Hill is associated with head deposits downslope of the undifferentiated terrace deposit or is found down in the valley gravels (T4). It is possible that these artefacts have been reworked through fluvial and solifluction and erosion processes (Brown et al. 2010; Wessex Archaeology 1993; Wymer 1999a). Such processes may have occurred throughout the valley, resulting in vertical artefact reworking.

The lithic distribution density over the river terraces shows that a few terraces, T4, T7 and undifferentiated terrace, are the richest sources of artefacts. The latter two terraces are limited in extent and more significantly, have the smallest volumes (see Chapter 6 for a more detailed discussion on terrace volume calculations). The large number of finds from these terraces is related to a small number of sites indicating the concentration of artefacts within these terraces. Milford Hill and Bemerton produced 99.2% of the finds from undifferentiated terrace deposits and 99.3% of the artefacts from T7 come from one site, Woodgreen (Table 3.1). A relatively high number of finds are associated with T4, but they are distributed in lower quantities over a relatively high number of sites in.

Higher numbers of artefacts are found in proximity to urban areas in the Avon valley, possibly indicating a recovery bias instigated by increased aggregate extraction and building activities in these areas. The high number of artefacts recovered from quarries and urban/infrastructure work (Table 3.2) also shows the importance of such activities for the discovery of Palaeolithic artefacts in the area. This could indicate that the spatial distribution of finds reflects terrace exposures through aggregate extractions or building activities and holds limited information regarding hominin behaviour (Hosfield 1999). However, many small pits were exploited throughout the Avon valley as can be seen on historic maps, offering numerous and geographically well-distributed artefact discovery opportunities. Nonetheless the largest concentrations of artefacts are found in restricted areas. For example the large assemblage found at the Woodgreen gravel pit may be related to urban development, but the site is the only one of its size in the urbanised region of Fordingbridge. Similarly, the concentrations at Bemerton and Milford Hill could be related to the expansion of Salisbury; however the extent of the sites is restricted in an overall much urbanised area where building and infrastructure works would have resulted in the discovery of finds if more widely present in the area.

The numbers of artefacts per terrace are presented in Table 3.1 and demonstrate that the largest concentrations are related to T4, T7 and undifferentiated terrace deposits from a limited number of sites. Artefacts related to T4 are mainly derived from the Christchurch area from terraces related to the River Stour. The large numbers of finds related to T7 are all found at Woodgreen even though this terrace has been exploited throughout the valley. The large numbers of artefacts recovered from undifferentiated terraces are all found in the Salisbury area. Due to the concise valley narrow spreads of terraces developed resulting in poorly separable terraces. The higher terrace deposits are often found 30m above the modern river. In the valley two spreads of gravel can be identified, correlated to T4 and T1 downstream. It can be concluded that in the Avon valley the large artefact concentrations are not a relic of urbanisation yet the latter *was* the initiation of their discovery.

It has been suggested that even though many discovery opportunities presented themselves during urban development, without someone to know what to look for, Palaeolithic artefacts would not have been found. In other words, in areas where antiquarians were active, larger concentrations of artefacts are recovered (McNabb 2007; Ashton and Hosfield 2010). The Avon valley has been studied by active, well informed antiquarians. Important collectors were Blackmore, Stevens and Westlake, and based on their notebooks it can be concluded that they obtained a deep interest in geological exposures and associated artefacts both within the Avon valley and beyond (Blackmore 'Locked notebook', Salisbury Museum; Westlake 1900). Westlake filled sixteen geological field notebooks, covering quarries, coastal exposures, wells, collections, railway and road cuttings, in Dorset, Hampshire, Isle of Wight, Wiltshire, amongst many other counties. Just in Hampshire he recorded as many as 28 gravel and sand pits. It is important to recognise that different collecting histories of sites may hinder comparisons of assemblages from individual sites (Ashton and Hosfield 2010). The assemblages used in this study are mainly collected by Blackmore (Bemerton and Milford Hill) and Westlake (Woodgreen). The recovery bias introduced by the behaviour of individual collectors (Ashton and Hosfield 2010) is minimal for the comparison of Bemerton and Milford Hill but potentially more influential in the comparison between the Salisbury sites and Woodgreen. However, both Blackmore and Westlake were scientifically trained and active collectors, suggestive of comparable collecting behaviour.

This assessment of the Avon Palaeolithic record indicates that the spatial distribution of artefacts in the valley is characterised by three large artefact concentrations which do not reflect terrace preservation or urbanisation. The active antiquarians in the area were well-informed about all geologic exposures and Palaeolithic discoveries and covered the entire valley, noting exposures in the many pits extracting gravels, sand and bedrock in the area. This suggests that the observed find-spot distribution was neither biased by its collection history. The influence of fluvial processes on site formation is assessed in this research based on a combination of field observations of sediment structures, clast lithology and artefact analysis (Chapter 5, 6 and 8).

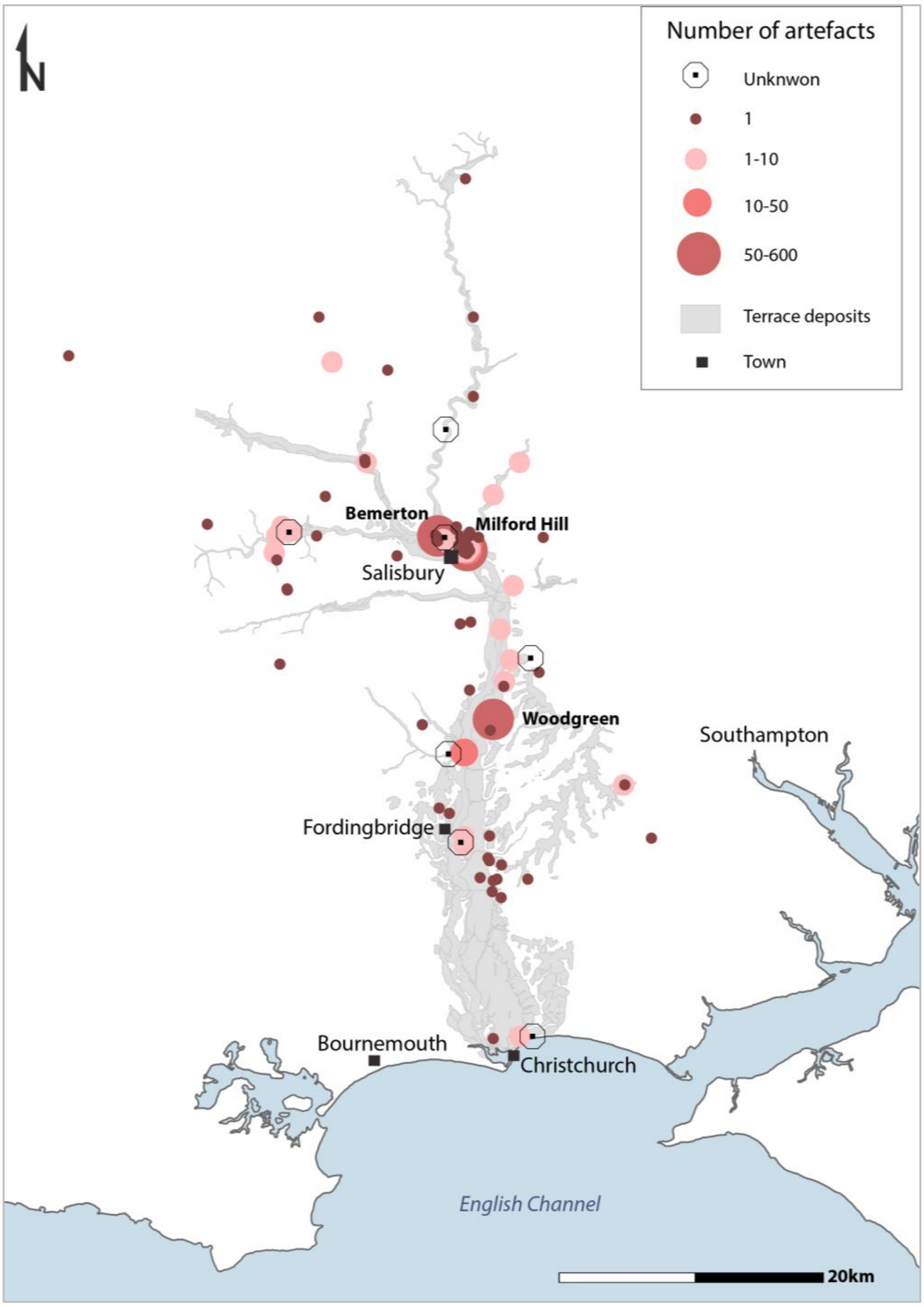


Figure 3.1 Map of the distribution of Palaeolithic find-spots and Pleistocene terrace deposits in the Avon valley (Based on HER data from Dorset, Hampshire and Wiltshire. Geology data is based on 1:10000 scale geology data, with permission of the British Geological Survey).

Geology	Sites	Artefacts	Sites with exact number of artefacts unknown
Brick earth	4	8	2
Terrace 3	3	5	1
Terrace 4	20	147	1
Terrace 5	6	22	1
Terrace 6	3	3	-
Terrace 7	2	639	-
Terrace 8	4	3	1
Terrace 9	1	4	-
Terrace 10	2	2	-
Terrace 11	2	1	1
Older River Gravel	2	3	
Undifferentiated terrace deposits	20	618	1
Clay-with-flint	10	12	-
Head	15	35	-
Stour terrace	6	5	1
Not related to superficial geology	45	181	1
Total	**145**	**1490**	**10**

Table 3.1 Overview of superficial geology deposits in the Avon valley and the number of associated Palaeolithic sites and finds (Based on HER data from Dorset, Hampshire and Wiltshire. Geology data is based on 1:10000 scale geology data, with permission of the British Geological Survey).

Recovery type	Sites	Artefacts
Excavation	3	7
Quarry	24	892
Surface find	60	145
Urban/Infrastructure	9	91
Unknown	49	355
Total	**145**	**1490**

Table 3.2 Table showing the number of Palaeolithic artefacts and sites recovered from excavations, aggregate extractions, surface finds and building activities (based on HER data from Dorset, Hampshire and Wiltshire).

3.6.2 Chronological understanding of the Avon Palaeolithic record

The stratigraphy of fluvial terraces provides a relative chronology for the archaeological record it contains (Bridgland 2000). Terrace formation models indicate that altitudinally separated terrace decrease in age with decreasing height, thus the highest terrace represents the oldest river deposits and every next terrace down will be relatively younger (see section 2.4.3). Table 3.1 summarises the number of artefacts recovered per terrace in the Avon valley.

Milk Hill, north of Salisbury, is at *ca*. 290m OD the highest find spot of a biface in Britain (Wessex Archaeology 1993). In this area a few other isolated Palaeolithic artefacts are found. Their geological context of undifferentiated terrace or clay-with flint deposits makes it difficult to relate the finds to the relative chronology of the terrace stratigraphy in the south. The highest locations of Palaeolithic artefacts found in association with the well-developed terrace sequence in the middle of the Avon valley are Minstead (Older River gravel), Bransgore House and Hinton Admiral (T11 of Bristow et al.'s terrace scheme), Vereley Hill and Ringwood Charles (T10), East of Lightslane Plantation (T9), Ringwood Hightown, Crow Hill and Rockford Common (T8). This small number of artefacts possibly represents the earliest hominin presence in the area. However, the limited contextual information is difficult to verify. The assessment of the spatial distribution of finds has shown that the majority of the finds in the Avon valley are related to undifferentiated terrace deposits, and T7 and T4. Using this spatial distribution of artefacts over the different, altitudinally separated terraces can be applied to propose a relative chronological history of hominin occupation in the Avon valley. The earliest hominin presence is indicated by the artefacts from Ringwood Hightown, Crow Hill and Rockford Common (T8) or even from Minstead (Older River gravel), Bransgore House and Hinton Admiral (T11 of Bristow et al.'s terrace scheme), Vereley Hill and Ringwood Charles (T10) and 'East of Lightslane Plantation' (T9). The high number of artefacts from undifferentiated terrace and T7 deposits may indicate an increase in hominin presence in the valley.

It has been suggested that the first appearances of certain lithic technologies in Britain have chronological significance (section 3.4). The Avon record has yielded 12 Levallois artefacts and 3 *bout coupé* bifaces. Possible Levallois technology has been found at Bemerton, Milford Hill and Woodgreen, suggesting a MIS 9/8 age based on the timing of its general occurrence in the Thames region (Bridgland and White 2014, 2015). However, the scarcity of the technique in the Solent region makes its use as an chronological marker in this area less appropriate (Ashton and Hosfield 2010). Two of the three *bout-coupé* bifaces in the Avon valley are found at Fisherton. At this location brickearth containing mammal and molluscan remains has been related to MIS 4 or early MIS 5 (Delair and Shackley 1978; Green et al. 1983, Lyell 1827). Another *bout-coupé* biface is found in the Christchurch area, but its exact provenance is unclear (Chalkin and Green 1949, Wymer 1999). The youngest Middle Palaeolithic presence is therefore likely represented by the artefacts from the lowest terraces and the *bout-coupé* bifaces possibly date to MIS 3 (Westaway et al. 2006). The scarcity of these technologies, the risk of circular reasoning in using artefact technology/typology as a chronological tool for archaeological assemblages, and the possibility of reworking restricts their effectiveness as chronological marker for the Avon archaeological record and/or river terraces.

Nonetheless, based on this coarse relative chronology the Avon Palaeolithic record has been related to the wider British Palaeolithic occupation despite the risks of circular reasoning and tentative correlations between archaeological records (Maddy et al. 2000; Westaway et al. 2006). For example, the chronological framework for the Avon valley proposed by Westaway et al. (2006) was based on the assumed age for the first appearance of Levallois technology and *bout-coupé* bifaces. This has subsequently been used to integrate the Avon 'super sites' into the wider pattern of the British Palaeolithic (Ashton and Hosfield 2010; Hosfield 2011). Hosfield (2011) used the chronology given by Westaway et al. (2006) to propose a MIS 13 date for the first arrival of hominins in the Avon valley based on a limited number of artefacts related to T8, and the relation of the latter to MIS 13b. In this chronology of the Avon Palaeolithic record the large concentration of artefacts from Bemerton, Milford Hill and Woodgreen were related to the "population peak" seen in the rest of Britain (Ashton and Hosfield 2010).

In summary, the Avon Palaeolithic record has received some attention but the complex depositional context of Pleistocene terrace deposits and limited chronological control have not been appropriately addressed. Only limited analyses of the lithics has been conducted and what began as tentative correlations based on the available data have been repeatedly used to situate the record within the broader interpretations of the Palaeolithic. It could be argued that this has given a false impression of a well understood sequence, and hindered a proper and full analysis of the Avon's geoarchaeological potential. The following chapter will outline the methods employed for this research to reinvestigate the Pleistocene landscape and hominin presence and behaviour in the Avon valley.

Chapter 4 Methodology

4.1 Introduction

Geoarchaeological approaches to the study of the Palaeolithic are essential to address large landscape scale questions and offer a framework for the study of the Avon valley Palaeolithic record (see section 3.5). This chapter addresses the methodological approach used to do this, which encompasses the study of the Pleistocene landscape, the development of a chronostratigraphy for Pleistocene sediments and its containing Palaeolithic record, and the study of hominin presence and behaviour.

The current understanding of the Avon valley Pleistocene landscape evolution has been discussed in section 2.6. The Avon valley superficial geology is characterised by a sequence of fluvial terraces. These have formed in response to Quaternary climatic change (see section 2.5) and form a relative chronology of Pleistocene landscape evolution in the valley. The formation of terraces is complex and it is the combination of the study of the geomorphological features and internal sedimentological structures which provide insights in the processes that led to their formation (see section 2.4). Therefore, in order to improve the understanding of terrace formation and Pleistocene landscape evolution in the Avon valley, fieldwork was carried out on a sequence of altitudinally separated terraces to study their internal sedimentological structures and obtain lithological and environmental samples to reconstruct the depositional environment and investigate environmental indications through particle size and palynological analysis (Objective 4).

The dating of Pleistocene terrace sequences to improve the understanding of their chronology, formation and age of environmental and archaeological evidence within them has provided a framework for research concerned with the study of terrestrial records of Quaternary climate change and the timing of hominin presence in Europe and Britain (see sections 2.4 and 3.4). Additional fieldwork aims were to obtain fine-grained sediments suitable for the application of optically stimulated luminescence (OSL) dating to improve the understanding of the timing of terrace deposition and develop a chronometric framework for Pleistocene landscape evolution and Palaeolithic archaeology in the Avon valley (Objective 5).

Pleistocene river terraces have formed the main source of Palaeolithic discoveries in Britain (see section 3.4), consisting of isolated finds and some exceptionally large concentrations of artefacts. The significance of such large sites for the understanding of hominin behaviour and landscape use has been debated. It has been argued that their formation can be contributed to fluvial processes and/or collection and discovery bias (see section 3.5). The Palaeolithic archaeology of the Avon valley is characterised by the existence of three main artefact concentrations against a background scatter of isolated finds (see section 3.6). Assessment of the distribution of finds, their collection and discovery history has indicated that the presence of the large artefact concentrations at Bemerton, Milford Hill and Woodgreen cannot be related solely to collection and recovery bias and their geographic location and distribution is likely to have a behavioural significance. These sites were therefore selected for detailed artefact analysis to further reconstruct site formation processes, and hominin landscape use and behaviour (Objective 6). Results from the fieldwork, clast lithology analysis and OSL dating provide information on the sedimentological and chronological context of the archaeological record. Together this contributes to the overarching aim of this research which is to reconstruct the history of Pleistocene landscape change and hominin presence and behaviour in the Avon valley and relate this to the understanding of the British Palaeolithic occupation (Objective 7).

This chapter will start with outlining the applied fieldwork methods (section 4.2) and follows with the description of the methodology of clast lithology analysis (section 4.3), palynological analysis (section 4.4) and OSL dating (section 4.5). The artefact analysis methodology is discussed in section 4.6. Methods for the collation and manipulation of geographic information from the fieldwork, bedrock and superficial geology, and artefact distribution are discussed in section 4.7.

4.2 Fieldwork

4.2.1 Identification of fieldwork sites

Fieldwork was conducted to collect data that would permit: reconstructions of the Pleistocene Avon valley; investigations of the depositional context of the region's key Palaeolithic artefact assemblages; dating of the terrace stratigraphy and related environmental and archaeological records.

A chronological framework for the Pleistocene fluvial deposits in the Avon valley can be built through the dating of a sequence of river terraces (cf. Penkman et al. 2013) (see section 2.4.2). Techniques suitable for dating the Avon terraces are limited by the poor preservation of organic materials to methods that can be applied to dating mineral material. Optically stimulated luminescence dating (OSL) is particularly suitable for dating fluvial sediments (Murray and Olley 2002; Wallinga 2002) (and will be discussed in detail in section 4.5). A range of fieldwork sites were identified which were defined as altitudinally separated fluvial terrace deposits, likely to contain fine grained sediment suitable for the application of OSL. This was accomplished by targeting active and disused gravel pits in which suitable deposits could be identified prior to excavation, providing time and cost effective access (see section 4.7.3). Seven sites were selected for investigation, and full details of these are presented in Chapter 6. All fieldwork and reports were conducted in compliance with the standards outlined in the Chartered Institute for Archaeologists (CIfA). The work was undertaken considering the Health and Safety regulations and codes of practice as outlined by Bournemouth University, the CIfA and the Health and Safety at Work Act 1974.

4.2.2 Excavation and recording

This section outlines the techniques used to clean, study, and record the exposed sections at each fieldwork site (see Chapter 6).

Each site was given a site code incorporating the name of the site and a number for each section. After initial investigation of the site a mechanical excavator was used where possible to clean the targeted sections. Where necessary sections were stepped to ensure stability and safe access. Final section cleaning was carried out by hand using pick axes, mattocks, hand picks and trowels.

The locations were recorded using Leica GS15 Viva differential Global Positioning System (dGPS) and a Leica TS06 Total Station. The sections were sedimentologically logged, photographed, drawn to scale and scanned using a georeferenced Leica C10 Scan Station. The description and analysis of sediments was conducted following Jones et al. (1999), Bridgland (1986) and Miall (1996). Photographs were taken using centimetre and colour scales for detailed images and 1 and 2m ranging poles for general shots. In addition photographs and scans were taken to use for analysis in image-based automated grainsizing (4.3.6). Spoil was visually scanned for finds and deposited on terram, on a safe distance from the sections and/or pits. Upon completion of the work the sections were back filled.

4.2.3 Sediment sampling

From each site gravel samples of ~ 40cm^3 for grain size distribution, laser diffractometry and clast lithological analysis were taken from the relevant sediment units and stored in woven rubble bags (4.3). OSL samples were taken from selected sand layers following English Heritage guidelines (Duller 2008). At all sites except Bemerton and Bickton (see Chapter 6) a portable gamma-ray spectrometer was used to measure the environmental dose rate of the individual samples (the former were excluded due to time restrictions). Sediment directly surrounding the OSL sample was sampled for laboratory-based gamma spectrometry at all sites (see section 4.5). Wherever sediments with potential for preservation of pollen were encountered, the unit was sampled *en bloc* in order to allow subsampling in a laboratory environment. The samples were stored in cling film and airtight sample bags (for OSL sampling see section 4.5). All sample locations were recorded using a combination of the dGPS, Total Station, Scan Station and drawing.

4.2.4 Coring

At Bemerton cores were used to establish the height of the top of the river terrace deposit below the Loess, and the height of the underlying chalk bedrock. For the former a Dutch auger and Shell auger were used. For the latter a spiral auger and a gouge auger were used. The spiral auger was used to core through the gravel deposit; as soon as the sediment became less gravelly the gouge auger could be used. This also allowed for sampling clay from the interface with the bedrock. A Dutch auger was used for coring the chalk.

4.3 Clast lithological analysis

Sediment samples were collected from the field sites to analyse grain size distribution, apply laser diffractometry,and conduct clast lithological analysis and clast angularity-roundness analysis. These methods were used to differentiate and classify stratigraphic units (Bridgland 1986; Jones et al. 1999). Grain size analysis informed on processes of sediment transport and deposition and therefore on the (palaeo)-environment (Bridge and Demicco 2008; Leeder 1982). Laser diffractometry provided information on the particle size distribution of <63µm sediments (e.g. Sperazza et al. 2004). Clast lithological analysis provided numerical data permitting more objective differentiation and correlation of sediment units (Briggs 1977; Leeder 1982). Analysis of the rudaceous clast content of Pleistocene river gravels was used to reconstruct sediment provenance and drainage history (Bridgland 1986). Clast angularity/roundness (or shape analysis) can potentially be used for palaeo-environmental reconstructions as clast shape is related to sediment transport, weathering frost action and other environmental factors (Bridgland 1986; Lukas et al. 2013). Method development focused on the use of novel techniques for grain size and stratigraphic analysis (image-based automated grainsizing and scan-based sediment analysis).

4.3.1 Sample collection for clast lithological analysis

Sediment samples for clast lithological analysis were taken from different sediment units identified in the field. The sample size was based on analytical requirements for grain size distribution analysis and clast lithology analysis, discussed below.

For grain size distribution analysis the minimum required sample size is expressed as minimum dry weight that varies according to the proportion of various clast sizes (a high proportion of large clasts in the sediment will require larger sample sizes) (Bridgland 1986; Briggs 1977). The lithological composition of sediments is based on stone count. To obtain statistically valid analyses a minimum number of 300-500 clasts is generally accepted. This provides a reasonable standard error (with a 95% confidence level) but maintains efficiency and practicality (Bridgland 1986; Briggs 1977). However, this quantity still results in large standard errors for infrequent rock types. To accurately represent the proportion of infrequent rock types in the source population, a prohibitively large amount of stones would need to be counted (Bridgland 1986). Percentages of the less frequent rock types should therefore be treated with caution when comparing assemblages. Still, the presence of rare lithologies in sediments is of potential significance for provenance analysis (ibid.).

Clast lithological analysis requires varying sample sizes depending on the clast size fraction. To obtain 300-500 clasts the sample size increases proportional to the size fraction used (Bridgland 1986). The size range used for stone counts may be chosen based on compatibility with previous work and the type of analysis conducted and can differ per project and per type of sediment. Which size fractions are used may be dictated by difficulties in obtaining sufficient clasts in a manageable sample, transport and storage and a size range that allows precise identification. Bridgland (1986, p.18) argues that sophisticated analysis of finer gravel (smaller than 8mm) is not possible due to limitations of classification/identification through weathering, loss of recognisable features and the impracticality of breaking very small clasts for obtaining a clean surface. Counting the lithology of more than one size range can provide a characterisation of the sediment and informs the selection of a size fraction for lithological comparison between deposits (Lefèbvre 1974; McGregor and Green 1986). Comparison between different deposits is best based on one or two size ranges as different size groups may have different lithological compositions leading to a skewedness towards the lithology of the dominant clast size rather than a relevant comparison between samples (Bridgland 1986). Therefore Bridgland (1986) recommended the 11.2-16mm and 16-32mm size ranges for clast lithological analysis of gravel deposits. These fractions were also used in previous work (Allen and Gibbard 1993; Bridgland 1986; Clarke 1981; Kubala 1980) and selected for clast lithological analysis in this research. For the 11.2-16mm fraction and the 16-32mm fraction sample sizes of 20-25kg and 30-50kg respectively, are suggested (Bridgland 1986).

Samples for clast lithological analysis were collected from the relevant stratigraphic units from each exposed section and labelled using the site code and unit number. After cleaning the section approximately $40cm^3$ (between 15 and 30kg, depending on the deposit) of sediment was removed from the unit using a hand pick assuring no clasts were broken. The sediment was collected directly into woven rubble bags.

4.3.2 Grain size distribution

Data for particle size distribution were obtained by wet-sieving the sediment samples using brass Endecotts Ltd., 300mm diameter, laboratory test sieves of fractions >45mm to 63µm. The sediments were passed through a set of sieves above a bucket using water until the entire sample was sieved down to 710µm. Different size fractions were stored in plastic trays, dried in an oven at 50°C and weighed using a Salter Brecknell ESA 6000 (6000x0.1g capacity and resolution) electronic balance. The <710µm fraction was left in buckets to settle. A siphon covered with a 23µm mesh sized filter was used to drain the superfluous water without disturbing the settled sediments. The total remaining sediment of two of the samples (ASH1.11 and BEM2.4) was sieved down to 63µm. 1000g of the <710µm fraction of the other samples was subsampled for sieving to 63µm. The <710µm fraction of sample WG2.7 was 1147g and therefore not subsampled but sieved totally. The total remaining fraction of <710µm of sample TAR1 was 518g, and entirely sieved to 63µm. The remaining <63µm fraction of all the samples was left to settle to remove superfluous water by using a siphon covered with a 23µm mesh filter without disturbing the settled sediments. 2x20ml of the remaining wet <63µm fraction was subsampled by bringing the sediment in suspension and filling two 20ml tubes for laser diffraction analysis (4.3.3), before drying and weighing the remaining sediment.

The particle size distribution over the size groups is calculated as the weight of that fraction as % of the total dry weight of the sample. For the size classes <710µm the dry weight is calculated as % of the dry weight of the entire <710µm fraction and can be used to calculate its percentage of the total sample by computing the percentage of the percentage:

$$\%\text{ of total sample} = \frac{\%\text{ of fraction X of total } <710\mu m}{100} * \frac{\%\text{ of } <710\mu m\text{ of total sample}}{100}$$

Sediment statistics were calculated using GRADISTAT (Blott and Pye 2001). The calculations and assignment of Folk and Ward parameters are based on the combined sieving and laser diffraction data (4.3.3). Percentage calculations of the particle size distribution data from laser diffraction relative to the sieving data provide an integrated data set. Errors can occur when the size distribution of more than 5 percent of the sample is undetermined, for example when the sample contains more than 5% sediments in the <63μm fraction. The combination of sieving data and laser diffraction data can account for this, providing the basis for the sediment statistics presented in table Chapter 7 (Blott and Pye 2001).

4.3.3 Laser diffraction particle size analysis

Grain size analysis of the <63μm fraction of sediments shows its silt and clay component that can be valuable in understanding which types of environment contributed to sediments in this fraction (An et al. 2012; Liu et al. 2016; Sun et al. 2002; Vandenberghe 2013; Vandenberghe et al. 1997; Xiao et al. 2009).

A Malvern Mastersizer 3000 laser diffraction particle size analyser was used to obtain particle size distributions of the <63μm fraction of all the sediment samples. Methods applied here followed those proposed by Sperazza et al. (2004) and Ryzak and Bieganowski (2011). Aliquots of 2ml were subsampled from the 20ml tubes using a pipette and introduced in the diffractometer. All aliquots were submitted to 4min 100% sonication to deflocculate clay particles. Optimal machine settings were adopted from Ryzak and Bieganowski (2011) combined with, for this research, experimentally identified preferences. 2110 rpm pump speed and 20% obscuration was selected. The absorption index (AI) and refractive index were set to 1 and 1.5 respectively, using the Mie theory as mathematical model for calculating the relation between the observed light scatter and the size of spherical particles (Ryzak and Bieganowski 2011; Xiao et al. 2009). Each sample and every aliquot was measured five times.

4.3.4 Clast lithological analysis

Clast lithological analysis was applied to two gravel samples from each site and three from Ashley, following Bridgland (1986) who recommends counting the lithology of 300-500 stones in the 16-32mm and 11.2-16mm size groups. This corresponds with the 22.4-31.5mm and 16-22.4mm and 11.2-16mm size classes used in this analysis. The lithology of the larger size classes and that of 8-11.2mm and 5.6-8mm was also counted for to provide an initial characterisation of the sediment and to select the appropriate size class for comparison between the terraces (cf. Lefèbvre 1974). The larger size groups generally provided an undersized count and are therefore less suitable for the comparison between sediments, for which the recommended size groups are used. Samples yielding over 500 clasts in the >31.5mm size classes were split avoiding preferential selection of certain clast types. The various lithological components in the Avon terraces identified in this analysis are described and defined in Table 4.1. Flint is by far the most abundant and further division has been used in the Thames system (Bridgland 1986b) and the Trent (Bridgland et al. 2014). This classification is adapted in this research and defined in Table 4.1. An additional subdivision was used in this research to differentiate between 'Tertiary flint' and 'Broken Tertiary flint' as has been used in the Solent system (Allen and Gibbard 1993). This division has potential significance for the discussion of sediment transport and (local) weathering frost action in the angularity-roundness analysis (4.3.5). Clast data is calculated as % of the total stone count per size group.

4.3.5 Angularity-roundness of clasts

The angularity or roundness of sediments is a secondary order characteristic super imposed on a first order characteristic. The latter describes clast shape (three axial dimensions of length, breadth and thickness) that is related to the initial shape of a fragment derived from a parent rock. Edge sharpness and rounding of a clast are secondary order characteristics and are related to depositional and weathering history (Bridgland et al. 2014).

Bridgland (1986) proposed that angularity-roundness of a clast is determined by: 1) the initial shape of the clast when derived from the parent rock, 2) the chemical and mineralogical properties of the rock, 3) the amount of abrasion and attrition to which the clast is submitted during transport and, 4) the effects of chemical and mechanical post-depositional weathering processes.

Of interest in reconstructing the depositional environment of the gravel under study is the degree of abrasion and attrition of the clasts as an indication for sediment transport, and the amount of post-depositional weathering (point 3 and 4). As these aspects are superimposed on characteristics dictated by the parent rock type and its mineralogical properties (1 and 2), angularity-roundness is analysed per lithological group per size fraction as identified in the clast lithological analysis. This also accounts for possible morphological differences of clasts per size range (Sneed and Folk 1958). Clasts identified as Tertiary flint in the clast lithological analysis are an example of the possible inheritance of clast shape from earlier deposits. Rounded to well-rounded flint pebbles are probably derived from Tertiary deposits (Kubala 1980). Their shape is likely the result of the beach and marine environments present in the Hampshire basin during the Palaeogene (Barton et al. 2003; Bridgland et al. 1997). To account for this inheritance the angularity-roundness of the pebbles and its subgroups of unbroken and broken pebbles are analysed separately. The angularity-roundness of unbroken pebbles describes characteristics the clast acquired predominantly during its Palaeogene depositional history. The angularity-roundness analysis of the broken surfaces of the 'broken Tertiary flint' category informs of depositional and weathering processes influencing the clast after it being reworked out of older deposits like described for the other clasts (cf. Bridgland et al. 2014).

Category	Characteristics
NODULAR FLINT	Hard, fine-grained homogeneous siliceous rock with complete absence of bedding; retaining part of the original nodular surface as white cortex
BROKEN FLINT	Like nodular flint but bounded entirely by broken surfaces
WEATHERED FLINT	Thoroughly weathered and patinated, obscuring characteristics
TERTIARY FLINT	Well rounded to rounded, chatter marked surface
BROKEN TERTIARY FLINT	Like Tertiary flint but broken
CHERT	Siliceous rock with flint like appearance but unlike the latter some crystalline structure is present and chert may appear bedded
OTHER	Other lithologies. Described in the results

Table 4.1 Definition of lithologies described in the clast lithology analysis modified from Allen and Gibbard (1993), Bridgland et al. (2014) and White (1998).

To objectify and quantify the description of clast shape, many methods have been developed (cf. Blott and Pye 2008). Despite the development of quantitative approaches to the description of clast shape, for its ease and efficiency the use of a chart for visual comparison to assign clasts to categories of angularity/roundness and sphericity is the most widely used method (Blott and Pye 2008; Bridgland 1986). This method was adapted in this research for compatibility and efficiency. Power's (1982) comparison chart for estimating roundness and sphericity (Figure 4.1) was used in combination with verbal descriptions of roundness/angularity classes following that adapted by Bridgland et al. 2014 from Schneiderhöhn (1954) (Table 4.2). Roundness describes “the relative rounding or angularity (sharpness) of corners and edges” and is independent of form (length, breadth and thickness) (Blott and Pye 2008, p.31). Sphericity is the degree with which the clast shape approximates that of a true sphere (a constant radius in all dimensions) and depends both on form and roundness (Blott and Pye 2008). Clasts where assigned to a roundness-angularity category per size class and lithology type, and calculated as a % thereof.

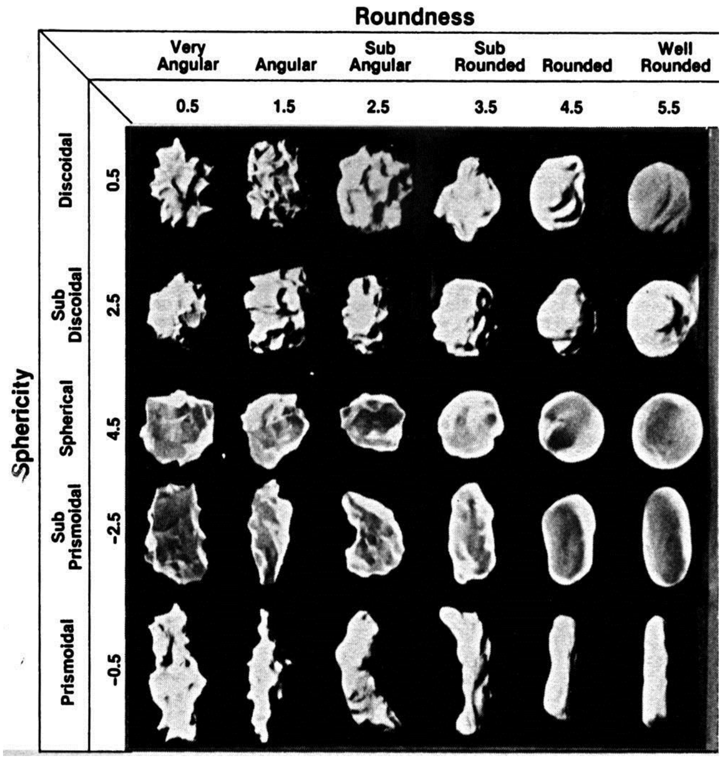


Figure 4.1 Power’s scale of roundness (1982) used for the categorisation of clasts in roundness/angularity classes.

Category (abbreviation)	Characteristic features
WELL ROUNDED (WR)	No flat faces, corners or re-entrants discernible; a uniform convex clast outline
ROUNDED (R)	Few remnants of flat faces, with corners all gently rounded
SUBROUNDED (SR)	Poorly to moderately developed flat faces with corners well rounded
SUBANGULAR (SA)	Strongly developed flat faces with incipient rounding of corners
ANGULAR (A)	Strongly developed faces with sharp corners, although not cutting edges
VERY ANGULAR (VA)	As angular, but corners and edges very sharp, with no discernible blunting (cutting edges)

Table 4.2 Criteria employed in the categorisation of clasts in roundness/angularity classes after Bridgland et al. (2014).

4.3.6 Imaged-based automated grain sizing

In addition to traditional grain size analysis, sediments were photographed in the field for the application of image-processing-based grain size analysis. Sedimetrics software was used to conduct image-processing, analysis and the derivation of size distribution data (Graham et al. 2005a; Graham et al. 2005b) (Basell in prep.).

4.3.7 3D laser scan-based sediment analysis

Laser scan data provide a combination of all traditional recording methods and offers a way of virtually preserving the excavated section. High resolution 3D scans can also be used to determine surface roughness and can be applied to grain roughness analysis of river beds (Heritage and Milan 2009; Siewczynska 2012). The use of scan data has also proven to be suitable for rapid recording of sediment faces and derivation of proxy stratigraphic and proxy grain size data (Basell in prep.).

A Leica C10 Scan Station was used to scan the sediment sections excavated for this research. All sections were scanned, with the exception of Bickton where limited site access prevented full scan recordings. Low resolution scans (5cm resolution over 100m distance) were taken for overviews of the fieldwork location. High resolution scans (2mm resolution over 100m distance) were taken from the sections and framed sediments used for image-based grain size distribution. The laser scan data provides a high resolution surface model of the scanned sections. This can be analysed in the same way as LiDAR data and DTMs in GIS programs. Initial manipulation of the scan data was carried out in Cyclone 9.1.2 after which the surface was analysed in ERSI ArcGIS 10.1. The work flow is summarised in Table 4.3.

SCAN DATA ANALYSIS	
1	Import data in Cyclone
2	Crop and clean scans
3	Adjust the orientation to make Z correspond to distance away from the section (thus representing roughness of scanned surface)
4	Export the point cloud as txt file
5	Import data in ArcGIS
6	Create a shape file of the point cloud
7	Create a raster of the shape file
8	The raster can be subjected to a variety of topographic analysis

Table 4.3 Work-flow for scan-based sediment structure analysis.

4.4 Palynological analysis

Fine-grained sediments with a potential for pollen preservation were sampled for palynological analysis to investigate the broader environment in the region during sediment deposition.

4.4.1 Sediment sampling

Sediments with the potential for pollen preservation were sampled *en bloc* from the stratigraphic sections. Locations were drawn and recorded using standard recording methods (see section 0). Subsamples of 1cm were taken in the pollen laboratory in the Geography and Environment Department at the University of Southampton.

4.4.2 Sample preparation

The minerogenic and organic matrix was removed from the pollen samples by applying a number of chemical and physical methods following standard procedures proposed by (Moore et al. 1991). Samples were treated with 10% hydrochloric acid (HCl) to dissolve any chalk, and deflocculated by boiling in 10% potassium hydroxide (KOH). At this stage 2x3862 lycopodium tablets were added to each residue. The samples were sieved through a 180 µm mesh size strainer, and washed with distilled water to remove the KOH and HCl. 40% hydrofluoric acid (HF) was used to remove silicates. The residues were treated with 96% acetic acid (CH_3CO_2H). Acetolysis (9/10 acetic anhydride ($(CH_3CO)_2O$) and 1/10 sulphuric acid (H_2SO_4)) was used to remove organic material. The samples were boiled in a dry bath after which they were washed subsequently with acetic acid, 1ml distilled water and 5ml 100% ethanol (C_2H_6O). At this stage a stain was added to colour the pollen after which the sample was once more washed with 100% ethanol. 1ml of *Tert*-butyl alcohol (TBA) was added and residues were centrifuged at 700 rpm for 10min after which excess TBA could be removed. Silicon fluid (viscosity MS 200/2,000 cs.) was added and residues were left in a 25°C oven for 24 hours to allow excess TBA to evaporate. Microscope slides were prepared for analysis by mounting a drop of residue onto the slide and covering it with a cover slip. Nail polish was used to secure the cover slips.

4.4.3 Counting procedure and taxonomy

Pollen, spores, non-pollen palynomorphs and any other environmental indications such as insect remains and charcoal particles were studied under a Leica light microscope using 100-400 times magnification. The microscope slides were systematically examined, in closely spaced transverse sections. The entire microscope slides were examined to overcome the non-randomness of the pollen distribution over the microscope slide (Brookes and Thomas 1967 in Fægri and Iversen 1989; Peck 1974). The entire slide was examined to estimate the pollen content of the sampled sediments to inform further sample selection and processing. Between 300-500 marker grains were counted per sample. Samples with low pollen concentrations necessitated the preparation and analysis of multiple slides.

A pre-existing modern taxonomy was used to classify the fossil pollen. In this extrinsic taxonomic classification individual fossils are identified on the basis of reference to modern counterparts (Birks and Birks 1980). Identification of pollen and spores was assisted by the use of the identification key in Fægri and Iversen (1989). Additional references were made to Beug (2004), Moore et al. (1991) and Punt et al. (1976-1995) for comparison and identification. Confidently identified pollen were counted. Unknown pollen grains (Cushing 1967) were given a code, drawn and described and coordinates noted for further study and discussion. Indeterminable pollen (due to their position and/or physical state), where present, were counted as an indication of the preservation of the fossil material (Cushing 1967). The identification of non-pollen palynomorphs followed the key presented by Blackford et al. (*in press*) and the special issue of Review of Palaeobotany and Palynology on non-pollen palynomorphs (Van der Linden et al. 2012).

4.5 OSL dating

Optically stimulated luminescence (OSL) techniques were used for dating a sequence of terraces in the Avon valley to construct a chronostratigraphic framework to which environmental and archaeological data can be related. Techniques suitable for dating the terraces are limited by the poor preservation of organic materials to methods that can be applied to dating mineral material. OSL is particularly suitable for dating fluvial sediments (Murray and Olley 2002; Wallinga 2002). Samples were obtained from altitudinally separated fluvial terrace deposits (section 4.2).

4.5.1 Mechanisms and principles

Optically stimulated luminescence (OSL) dating is a radiometric dating technique based on the ability of minerals to absorb and store energy from naturally occurring ionising radiation within its direct surroundings and a small contribution from cosmic radiation. Especially dielectric materials containing many minerals such as quartz, feldspar, zircon or calcite have the capability to accumulate energy from ionising radiation that has resulted in the development and wide use of this method for dating Quaternary deposits (Huntley et al. 1985; Murray and Olley 2002). OSL dating has proven particularly useful in environments where no carbon bearing materials are present or preserved (Munyikwa 2014; Murray and Olley 2002). Reviews of OSL dating are provided by Duller (2008), Preusser et al. (2008) and Wallinga (2002) and its principles were recently detailed by Yukihara and McKeever (2011) and Munyikwa (2014). The accumulation of energy is related to the amount of time a material has been irradiated. In OSL dating the energy is released, and the signal ‘zeroed’ through stimulation by light. This means that the OSL signal in sediment will build up since the last moment it was exposed to light and subsequently buried. In a fluvial environment this principle can be applied to date sediment aggradation and provides a minimal age for material incorporated in the sediments.

The decay of unstable isotopes of Uranium (U), Thorium (Th) and Potassium (K), widely present in the natural world, causes the emission of energy as alpha and beta particles and gamma rays resulting in ionising radiation that 'charges' minerals with energy by travelling through material and dispatching electrons from atoms or molecules on their way. Alpha and beta particles and gamma rays have different penetration rates from 0.02mm, 0.02cm and 20cm respectively, limiting their ionising influence (Munyikwa 2014). Cosmic radiation comprises a soft and hard component of which the former is absorbed by the surface of the earth in the first 50cm. The influence of the hard component reaches deeper but decreases with depth and depends on the location on the earth. In luminescence dating this radiation is corrected for through the application of formulae based on the longitude, latitude and altitude of the sample location (Perscott and Hutton 1994).

Energy accumulation through ionising radiation occurs when electrons within the mineral lattice are exiled from the valance band of their parent nuclei to the conduction band. The displaced electron diffuses in the surrounding lattice until it becomes trapped in a defect in the crystal. A defect is a violation of the periodicity of the crystal lattice such as displaced or missing atoms or impurity atoms. The ionisation (displacement) of the electron results in a hole in the crystal lattice near the valence band. Between the conduction and valence bands recombination centres exist in which an electron and a hole can recombine resulting in the release of energy in the form of light: luminescence (Yukihara and McKeever 2011). When this recombination is halted because electrons and holes are trapped by defects, and thermal or optical stimuli to release them are absent, trapped electrons and holes can be stable for thousands of years (ibid.). The depth of a trap below the conduction band is an indication of its efficacy, dictating the amount of energy needed to release the electron. Sufficient stimulation of the mineral by light (OSL) or heat (thermoluminescence [TL]) evicts the trapped electrons and holes, allowing recombination causing the emission of light (Yukihara and McKeever 2011). The number of trapped electrons increases with the duration and intensity of irradiation, resulting in a stronger luminescence signal upon release. The number of traps however is not infinite, limiting the energy storage capacity until the point of saturation. This implies an age limit for the application of OSL dating, which depends on the duration and intensity of radiation received, with a high dose rate resulting in a younger age limit (Munyikwa 2014).

The strength of the luminescence signal released from a mineral upon stimulation is therefore a function of the time the mineral has been ionised and the rate of ionisation. The luminescence signal is called the natural dose or palaeo dose (Munyikwa 2014). After applying laboratory measurements to calculate the absorbed dose, it is referred to as the equivalent dose (D_e) (see section 4.5.2). The rate of ionisation, the amount of radiation received per unit of time, is called the dose rate (ibid.). The age of a sample can thus be determined by the following equation:

$$\text{Age} = \frac{\text{Mean equivalent dose } (D_e, \text{Gy})}{\text{Mean dose rate } (D_r, \text{Gy.ka}^{-1})}$$

4.5.2 Equivalent dose determination

In OSL dating the equivalent dose of a sample is determined by stimulating the mineral by light and measuring the released energy. This is defined in Gray (Gy) where 1Gy=1joule per kg, captured by a photomultiplier tube after going through optical filters that separate the luminescence signal from the stimulating light. Light of particular wavelength (blue, green, near-infra red) is used to expel the trapped electrons. Continuous stimulation evicts all electrons from the traps sensitive to light until the mineral is zeroed (Munyikwa 2014) (see Appendix 33 for specifications of D_e acquisition).

Minerals exhibit naturally different sensitivity resulting in marked inter-sample variability in luminescence per unit dose. This requires calibration of the natural dose by applying known amounts of laboratory radiation to find the equivalent of the naturally received radiation during burial. The currently most used technique to establish the equivalent dose in quartz is the single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2003; Wintle and Murray 2006). In this method the sample is divided in aliquots (subsamples) of consistent size, which are subjected to a series of measurements and tests. The natural signal of a single aliquot is measured after which that aliquot's signal is regenerated using known laboratory doses (laboratory regenerative doses). Five different regenerative-doses were administered to each aliquot to create a dose response curve onto which the natural dose was interpolated to obtain the D_e values (see figure 5 in Appendices 34 and 35).

4.5.3 Dose rate determination

The second component that allows luminescence to be used as a dating technique, in addition to the equivalent dose, is the dose rate (D_r). To determine the age of a sample in years the measured energy (dose) must be divided my de rate of radiation it received over a unit time. It is the radioactive decay of Uranium (U), Thorium (Th) and Potassium (K) that cause minerals to be ionised and charged. The dose rate can therefore be defined through the measurement of U, Th and K radionuclide concentrations to quantify α, β and γ values. α and β contributions were estimated from sub-samples by laboratory-based γ spectrometry using an Ortec GEM-S high purity Ge coaxial detector system, calibrated using certified reference materials supplied by CANMET. Unless stated otherwise, γ dose rates were estimated from in situ gamma spectrometry using the EG&G µNomad portable NaI gamma spectrometer (calibrated using the block standards at RLAHA, University of Oxford). Estimates of radionuclide concentrations were converted to D_r values (Adamiec and Aitken 1998) accounting for the influence of grain size (Mejdahl 1979) and present moisture content (Zimmerman 1971). Contribution of cosmic radiation was calculated on the basis of the longitude, latitude and depth of the sample location and matrix density (Perscott and Hutton 1994). Sample locations were recorded using a dGPS, providing the longitude, latitude and altitude. Five variables are considered when evaluating the validity of obtained D_r values (Toms et al. 2008):

1. *In situ* gamma spectroscopy is essential for obtaining reliable D_r values for samples taken from units exhibiting heterogeneous texture or that are close to strata of different texture and/or mineralogy. When *in situ* gamma spectroscopy is not available the D_r values can be evaluated based on laboratory-based measurements. Consistent D_r values throughout the stratigraphic profile evidence homogeneity of the gamma field and the D_r can be considered accurate.
2. Disequilibrium of Uranium and Thorium content can result in temporal instability U and Th emissions and therefore variations in D_r over time. This can result in higher D_r estimations based on *in situ* gamma spectroscopy, then the radiation that has dominated during the majority of the burial period, leading to an under estimation of the age of the sample.
3. The matrix composition, its radionuclide and/or mineral content, can vary over time due to pedogenesis altering energy emission and/or absorption. The influence of this evaluated and minimised through investigating the profile for evidence of pedogenesis and the selection of sample locations with minimal disturbance.
4. The moisture content of the sample influences radiation. This accounted for by assessing the moisture content in the laboratory. However, its spatiotemporal variation is difficult to evaluate based on the present day moisture content. Its influence is weighed by calculating D_r for maximum and minimum moisture content.
5. A similar problem occurs when evaluating overburden thickness, which may not have been stable throughout the burial history, altering the contribution of cosmic radiation to D_r values. Its proportional contribution to the total D_r is often negligible but can be evaluated by recalculating D_r values for maximum and minimum cosmic radiation.

4.5.4 OSL sampling

OSL samples were taken from fluvial sand deposits exposed in stratigraphic sections of six different terraces. The selection of sample locations was based on the following criteria:

1. The identification of fine fluvial deposits (presence of bedding, sorting, etc.) consisting of either sand (~90-250μm) or fine silt (~5-15μm)
2. Homogeneity of the fine deposit, with the absence of inclusions, roots and turbation
3. Sufficient thickness of the deposit
4. Minimum depth of 300mm beneath the present land surface

From deposits that met these criteria a sample was taken from the middle of the unit where gamma dose rate can be assumed most homogeneous. By maintaining the recommended minimal depth beneath the present land surface for sample locations the influence of cosmic radiation on the sample could be assumed limited and accounted for in the analytical process based on formulae (Perscott and Hutton 1994). Samples were collected in daylight using opaque plastic tubing (200x45mm) forced into the selected deposits. Tubes where carefully removed from the section and sealed using cellophane and parcel tape to preserve moisture content. Approximately 100g of non-light-sensitive sediment was sampled from around the samples for laboratory –based assessment of radioactivity. *In situ* gamma dose rates were estimated using a portable gamma spectrometer (for specifications see section 4.5.3) placed in the cavity left by the sample tube, measuring for minimum 45min. Where possible multiple samples were taken from the same stratigraphic unit or stratigraphically related units to attain intrinsic metric reliability. Sample locations where recorded, drawn and photographed as detailed in section 4.2.2.

4.5.5 Laboratory preparation

Laboratory preparations and OSL analyses were carried out at the University of Gloucestershire. Sample preparation was conducted under controlled laboratory illumination provided by Encapsulite RB-10 (red) filters. After opening the samples the material within 20mm of each tube-end, potentially exposed to daylight during sampling, was removed. The remaining sample was weighed wet and weighed dried to establish its moisture content. The dry sample was, in the case of sandy sediments, directly sieved. Clayey samples were first deflocculated in calgon. The >5μm fraction of the clayey samples was separated through centrifuging and dried. If this contained sufficient quantities of sand the same procedure as for sandy samples was followed. In case the amount of sand was limited, the silt fraction (5-15μm) was selected for OSL analysis.

Sandy samples were sieved and separated in fractions of 250-212μm, 212-180μm, 180-125μm and 125-90μm using Endecotts Ltd. brass laboratory test sieves. Depending on the samples grain size distribution, quartz within the fine sand (63–90μm, 90–125μm, 125–180μm) fraction was selected. Organic and carbonate components were removed through acid and alkaline digestion (10% HCl, 15% hydrogen peroxide ((H_2O_2)). Treatment with HF (40%, 60min for 125–180μm; 40%, 40min for 90–125μm; 20% 15min for 63-90μm) etched the outer 10-15μm layer affected by alpha radiation and degrades the feldspar content of the samples. During HF treatment continuous magnetic stirring makes sure etching of the grains happens uniformly. Acidic soluble fluorides were removed by adding 10% HCl. Upon re-sieving the sample, quartz grains were segregated from the remaining heavy mineral content by density separation using sodium polytungstate density separation at 2.68g.cm^{-3}. After washing and drying, the remaining quartz grains were mounted on 12 aluminium discs providing 12 multi-grain aliquots of circa 3-6mg.

Fine silt sized quartz was extracted by sample sedimentation in acetone (<15μm in 2 min 20 s, >5μm in 21mins at 20ºC). Other minerals were removed from the fraction through acid digestion (35% H_2SiF_6 for 2 weeks (Jackson et al. 1976; Berger et al. 1980)). Acid soluble fluorides were removed through addition of 10% HCl. Grains degraded to <5μm as a result of acid treatment were removed by acetone sedimentation. Twelve multi-grain aliquots (ca. 1.5mg) were then mounted on aluminium discs for D_e acquisition.

All drying was conducted at 40°C to prevent thermal erosion of the signal. All acids and alkalis were Analar grade. All dilutions (removing toxic-corrosive and non-minerogenic luminescence-bearing substances) were conducted with distilled water to prevent signal contamination by extraneous particles.

4.5.6 Estimation of age

The estimated ages reported are based on weighted (geometric) mean D_e values from 12 aliquots, calculated using the central age model outlined by Galbraith et al. (1999) and are quoted at 1σ confidence. Inaccuracies in age estimation can have been introduced through systematic and experimental errors in D_e and D_r. Systematic errors for D_e are confined to laboratory β calibration. Experimental errors are related to the success of D_e interpolation using sensitisation corrected dose responses. For D_r systematic errors include factors such as uncertainty in radionuclide conversion factors, matrix density, variations in moisture content and overburden thickness. Experimental errors include factors such as radionuclide quantification. The accuracy of the acquired D_e and D_r values depends on a set of laboratory factors and environmental factors that are assessed and corrected for through the addition of a series of tests to the luminescence measurement procedure providing an analytical assessment of reliability (Appendices 34 and 35). The intrinsic assessment of reliability of the results is based on intra-site stratigraphic consistency and concordance of stratigraphically equivalent units with different dosimetry (Toms et al. 2005).

4.5.7 Feldspar luminescence dating

Quartz and Feldspar are the most widely used minerals for OSL dating because of their generally good luminescence properties and global abundance in sediments (Munyikwa 2014). OSL signal saturation for quartz lies around 200Gy (Wintle and Murray 2006). With an average dose rate of 1 and 1.5 Gy ka^{-1} this would give an upper age limit of around 100-200ka (ibid.). The saturation point of feldspar lies around 2000Gy and therefore has a much higher upper age limit (Thiel et al. 2011). However, where quartz has stable luminescence properties, feldspar tends to fade anomalously leading to a possible age underestimation (Wintle 1973). With the development of corrections for signal loss (Kars et al. 2008; Kars and Wallinga 2009; Wallinga et al. 2000), the testing of fading rates (Thomsen et al. 2008) and method development (Buylaert et al. 2009), feldspar luminescence dating has now proven to be successful back to 600ka (Buylaert et al. 2012; Thiel et al. 2011). Quartz sand and silt sized quartz were used for the OSL analysis presented here. Further work is carried out to apply feldspar luminescence to the same samples and provide a comparison between quartz and feldspar dating from deposits of various antiquity in Britain.

4.6 Artefact analysis

The artefact assemblages from Woodgreen, Bemerton and Milford Hill were analysed to investigate site taphonomic processes, reconstruct hominin behaviour at key sites in the Avon valley and investigate its spatio-temporal context. These sites were selected based on the assessment of the Palaeolithic record from the Avon valley discussed in section 3.6. The recording methods are detailed in Appendices 1 and 2.

4.6.1 Description of the artefact assemblages

The artefact assemblages were described according to raw material, blank type, roundedness of the natural surface, cortex retention, artefact type and metric measurements. These aspects of the assemblage were recorded in order to investigate hominin behaviour at the site. The roundedness of the natural surface (cf. clast lithology), raw material and blank type provides information about where hominins sourced their raw material. Cortex retention on artefacts and artefact types (bifaces vs flakes) has relevance to questions of site use, knapping- and reduction intensity, knapping skills, artefact curation, refinement and tool function and a combination of these factors (Dibble et al. 2005; Machin 2009; McPherron 1999; Newcomer 1971; Roe 1968; Roth and Dibble 1998; White 1998). It has been argued that biface-flake ratios of assemblages can provide an indication of the taphonomic processes an assemblage underwent (Isaac 1989). However, in unsystematically collected assemblages such as those from historically quarried river terrace deposits, recovery biases may have led to preferential collection of bifaces over flakes (Ashton and Lewis 2002) in which case this ratio instead provides an indication of collection history.

Metric measurements and weight of all artefact types were recorded in order to assess minimum raw material size (Shaw et al. 2003). In addition, the size and weight of the artefacts was used to apply principles of clast size analysis in sedimentology to analyse the depositional environment of the host material (river terrace deposits) and that of the artefacts. Sieving of the terrace deposits provided detailed clast size distributions of the sediments that was contrasted with the recorded size and weight distribution of the artefacts. Clast size distribution varies with depositional environment and sediment sorting (Briggs 1977; Leeder 1982) and a comparison of that of sediment clasts and of archaeological clasts is used to discuss site formation processes. The grain size distribution of the artefacts was calculated by assigning each artefact to a phi size category based on its length. The sum of the weight of all artefacts per size group was converted to a percentage of the total size of all artefacts. This method most closely resembles that applied to the grain size distribution calculations applied to the sediments (see section 4.3.2 and Chapter 5).

4.6.2 Description of the condition of artefacts

Considering post-depositional processes of an archaeological record is key to understanding the significance of an assemblage as an indication of hominin behaviour. Yet distinguishing post-depositional processes and relating them to particular environmental contexts remains most challenging.

The description of the condition of the artefacts, including abrasion, patination and staining, as related to context-dependent, post-depositional processes, has been suggested to provide indications on the (post) depositional history of an assemblage (Ashton 1998; Ashton and Hosfield 2010; Chambers 2004; Glauberman and Thorson 2012; Harding et al. 1987; Hosfield 1999; Isaac 1989; Shackley 1974). However, the description of such characteristics is not well-defined and their formation and relationship to post-depositional processes not well understood (Andrefsky 2005; Chambers 2004; Glauberman and Thorson 2012; Purdy and Clark 1987; Thiry et al. 2014). The following section defines these terms as used in this research and their relevance for the discussion of site taphonomy in 'proximal contexts'.

4.6.2.1 Abrasion and breakage

The degree of abrasion has often been applied as a measure of artefact transport (Harding et al. 1987; Hosfield 1999; Shackley 1974). However, difficulties exist in the equation of experimentally derived abrasion and spatial derivation (Lewin and Brewer 2002). Chambers (2004) aimed to improve the assessment of spatial derivation of artefacts through further experimental research closer to 'real world fluvial conditions'. This showed that: artefact abrasion can occur both *in situ* (burial) and during transport, when immobile artefacts can be bombarded by mobile clasts causing abrasion; artefact transport is sporadic; river-bed morphology influences artefact transport; transport is affected by artefact shape but not clearly related to size; there is no typical transportation under fluvial conditions (Chambers 2004). Although she related damage to artefact derivation distance, it was stressed that the latter was not indicative of specific transportation distances (ibid.). It is clear that artefact abrasion can occur under different and sometimes highly localised processes (Leeder 1982). Here it is therefore argued that the abrasion of an artefact provides an indication of its depositional environment but is not necessarily correlated to downstream or long-distance reworking and that the interpretation of assemblage-integrity should be based on an understanding of the geomorphological context as well as artefact condition (Brown et al. 2009b). Artefact abrasion is described on a qualitative scale from fresh to very-rolled (following Ashton 1998). It should be taken into account that artefact abrasion and breakage can also be the result of its collection, storage and handling history.

As geomorphological research on clast rounding has suggested that the rate of rounding is proportional to clast shape (Lewin and Brewer 2002). Broken artefacts and the location of breakage can be an indication of artefact transport. It is argued that the location and frequency of breakage can be used in conjunction with abrasion to examine post-depositional processes and the applicability of abrasion as an indication of 'transport distance'. The breakage of artefacts and the location of the damage were therefore recorded. The appearance of the broken surface was described considering patination, staining and abrasion as an indication of the timing of the breakage.

4.6.2.2 Patination, staining, manganese, and cortex

The use of the term patina differs in geology and archaeology. In the latter it usually refers to the alteration of the outer part of an object after knapping, therefore implying a temporal factor; namely that patina always develops later than the cortex (Inizan et al. 1999).

In geology, cortex is used to describe the weathering rind of stones. Thiry et al. (2014) use 'weathering rind' or 'cortex' in reference to the alteration of the outermost part of siliceous materials (these terms are also used for other materials), and 'patina' to describe the very thin layer of weathering or alternation at the surface of siliceous artefacts. Glauberman and Thorson (2012) make a similar distinction and use cortex or true weathering rind to describe the outer surface of flint nodules or Tertiary flint and restrict the use of patina to the alternation of humanly worked flint surfaces. This distinction is followed here. However, Glauberman and Thorson (2012, p.22) also use patina as referring 'to any process of alternation of any type of flint taking place anywhere at any time'. Artefacts from fluvial contexts are often described in terms of patination *and* staining (e.g. Ashton 1998; Davis 2013). But staining is also often described as *part* of the patination process (Whittaker 1994). The location of patina, staining and/or iron-manganese concretion may indicate that the different faces of bifaces have been exposed to differential weathering, suggesting that they could have lain on the surface for a significant amount of time before burial. The degree of patination and staining and its location on the tool has therefore been described as part of this research. Iron-manganese concretion was only described according to its location as little vitiation in the degree of concretion was observed. In this research these descriptive concepts are used as follows:

Cortex is defined as the un-knapped 'natural' surface of an object. This can be the white, porous rind found on flint nodules from the chalk, or the mechanically and chemically weathered surfaces like seen on Tertiary pebbles. Thus cortex refers to the natural surface (that can show patination) and patina is only applied to describe the alternation of the knapped surface. The presence of cortex on a flint tool can offer important clues to raw material source (Shaw et al. 2003). Cortex on chert is less easily identified, especially when it concerns 'slabs'. The unworked surface, where present and identifiable, was regarded as cortex on chert artefacts.

Patination is the alternation of the crystalline structure of flint caused by processes of silica leaching and continuous chemical alteration may result in a friable, porous rind (Thiry et al. 2014). The change in crystalline structure alters the reflective properties of the material, often causing flint to turn white (Hurst and Kelly 1961) . Patina can be a guide to interpret the sequence of natural and intentional flake removals, e.g. recent edge damage, but not as dating technique (Inizan et al. 1999). Although the conditions under which patination is formed are not well understood and may vary, it is suggested that differences in patination intensity may indicate different depositional histories (Thiry et al. 2014). It has been suggested that the localised occurrence of patination on a single artefact could be related to its position on a surface and in relation to soil water (Sturge 1911, Stapert 1976). Although the exact significance of patination as an indication of the depositional environment remains poorly understood, it is suggested that reworking of an artefact will increase its chances to undergo processes leading to patination.

Staining can overlay patination (cf. Ashton 1998) and cortex, and can be of different colour. In river terraces this is almost exclusively ferruginous orange (colour descriptions may vary between yellow to brown), caused by the iron-oxide and manganese present in river terraces. The colour of the staining might provide some suggestion of the provenance of the artefact but can only be used as a general indication (Butler 2005). Staining can penetrate the flint and can occur across the intentionally knapped, broken and cortical surface of a tool. Thus its appearance is influenced by the characteristics of the flint, patination and cortex. The location and degree of staining was recorded for all artefacts. On heavily stained artefacts patination may be obscured and more difficult to identify. (Stapert 1976).

Iron and manganese can accrete on the surface of the flint/artefact and follow specific patterns related to the dominant water table during burial history. Deposits of manganese concretion can often be identified in terrace exposures and the presence and the location of bands of manganese across the artefact may indicate their provenance and orientation within the deposit (Blackmore, 'Locked notebook', Salisbury Museum). Iron and manganese concretion were therefore described according to their location on the artefact. When severe, manganese accretion could conceal the patina (Stapert 1976).

4.6.2.3 Clast size distribution of artefacts

To assess and compare the depositional processes of the artefacts with their sedimentological context, clast size distribution analysis was applied to both. The clast size distribution of the artefacts was calculated by assigning each artefact to a phi size category based on its length. The sum of the weight of all artefacts per size group was converted to a percentage of the total weight of all artefacts. This method most closely resembles that applied to the grain size distribution calculations applied to the sediments (see section 4.3.2 and Chapter 5).

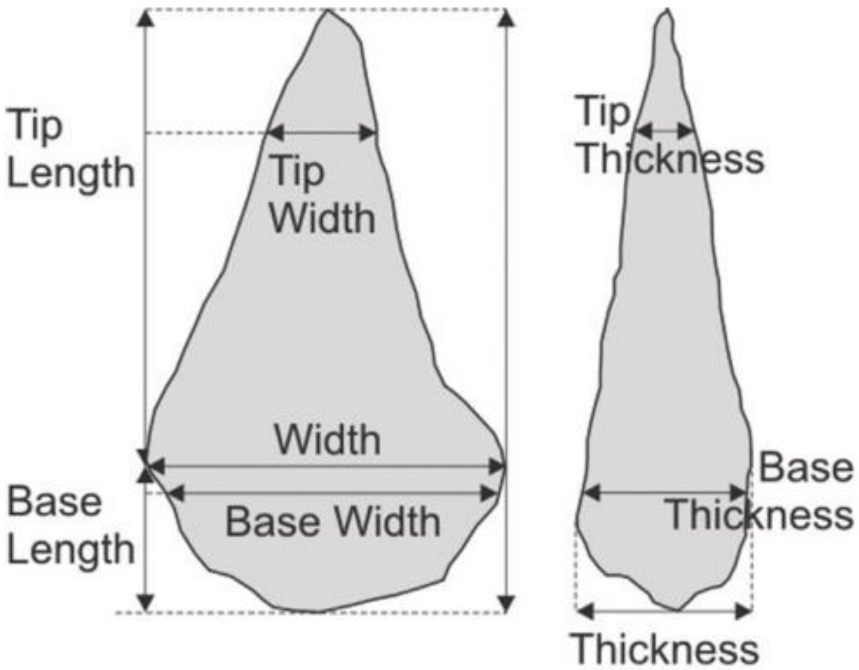
4.6.3 Biface variability

To circumvent recovery bias likely introduced in the assemblages through selective recovery of bifaces over flakes (Ashton and Lewis 2002), the analysis of the variability of artefact shapes was restricted to bifaces. The comparison of biface variability within and between sites was based on unbroken artefacts.

Characterising and describing biface assemblages facilitates the comparison of artefact groups and can be based on broad categories or minute differences (Odell 2004). The most influential categorisations focus on morphology (e.g. Bordes 1961) or technology (e.g. Binford 1973), but other explanations for artefact variability also exist (Mellars 1970). Categories recognised in material culture can be interpreted as inherent in prehistorically made objects or as constructs of the archaeologist (Odell 2004). It can be argued that the recognition of groups in biface assemblages is mainly the product of the archaeologists as this artefact category is often made of the comparable raw material, possibly used for a wide variety of tasks, and used over a long period of time by different groups and species of hominins (Soressi and Dibble 2003), hindering the recognition of inherent groups. Divisions made are therefore more arbitrary and made along a continuum of options, resulting in numerous biface classification systems and a wide variety of types (McPherron 2006). This kind of classification facilitates characterisation and comparison of assemblages but does not explain what the variation means (McPherron 1999, 2006). Shape variation in bifaces has been explained as a result of raw material availability (Ashton and McNabb 1994, White 1998a), reduction strategies (Ashton 2008, McPharron 2006), spatio-temporal variations (White 1998b, Bridgland and White 2014), social, cultural and aesthetic dynamics, cognitive capacities, and tool function (Key and Lycett 2015).

The main Avon valley assemblages provide a unique opportunity to test the validity of these possible explanations for biface variability. The situation in the Avon valley, where two of the sites (Bemerton and Milford Hill) are located on the Chalk bedrock in close proximity to each other at the main river confluence, and one site (Woodgreen) situated downstream on Tertiary bedrock close to a small tributary, provides a study area that allows raw material availability and spatio-temporal explanations to be tested. The influence of raw material availability and used blank type on biface shape can be examined by comparing Woodgreen (Tertiary bedrock, secondary context flint likely more widely available than fresh nodules) with Bemerton and Milford Hill on the Chalk (possibly easier access to flint nodules). Variations between the latter two may refine or reject the ‘raw material’ scenario. The dating results presented in this research allow temporal explanations of site variability to be explored, both within catchment, and between valleys across southern Britain. The geological setting, spatial distribution and chronology of the sites in the Avon valley combined make this an ideal data set for exploring above mentioned theories and making inferences about hominin behaviour.

The most widely used systems to classify bifaces in Britain over the last decades are those developed by Roe (1968) and Wymer (1968). Wymer's typology encompasses a wide variation in types, whereas Roe's metric approach provides a more objective categorisation of assemblages that allows large groups of artefacts to be distinguished and sites to be compared. The method developed by Roe (1968) records basic measurements that are used to calculate shape ratios that allow an objective description and comparison of biface shapes (Figure 4.2 and Figure 4.3). Using the most commonly recorded attributes facilitates comparisons with other sites (e.g. Marshall et al. 2002). In addition, all artefacts were systematically photographed. This offers a record of all artefacts that could be studied for this research and the possibility for future image-based morphometric analysis.



Length	Maximum length	L
Breadth	Maximum breadth	B
Thickness	Maximum thickness	T
Refinement	Thickness/Breadth	T/B
Tip refinement	Tip thickness/breadth	T1/B
Elongation	Breadth/Length	B/L
Edge Shape	Tip breadth/butt breadth	B1/B2
Profile shape	Tip thickness/butt thickness	T1/T2
Pointedness	Base length/maximum length	L1/L

Figure 4.2 Measurement system for recording biface variability developed by Roe (1968b) (after McPherron 2006).

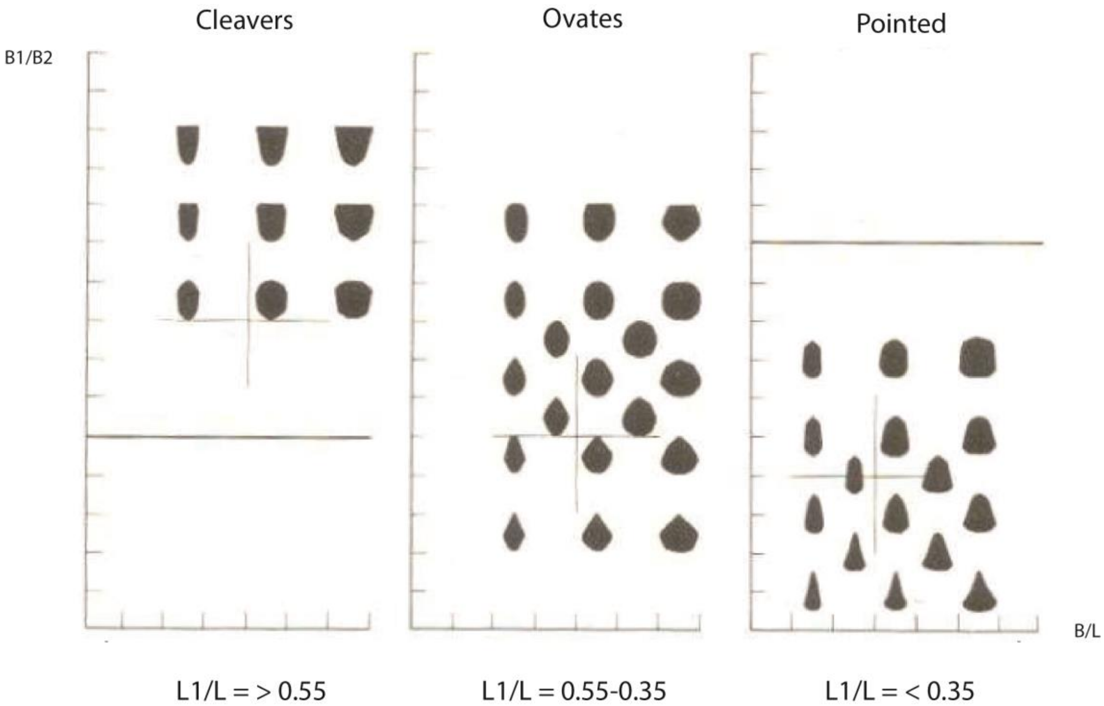


Figure 4.3 Tripartite diagram developed by Roe (1968b). Metric definition of biface types plotted against elongation (B/L) and edge shape (B1/B2) (after Roe 1981).

4.7 Geographic information

Geographic information used in this research included modern and historic maps, geomorphological data, geological and subsurface geological data, Palaeolithic find-spots. These data were combined, analysed and manipulated in ESRI ArcGIS 10.1 and RockWorks 16. This enabled the identification of geomorphological features, the 3D reconstruction of subsurface geology, analysing the spatial distribution of Palaeolithic find spots, selection of field sites, and integrating these with (historic) OS maps.

4.7.1 Geomorphological and geological data

LiDAR and digital terrain models (DTMs) can reveal previously unidentified geomorphological landscape features, or clarify the definition of existing ones (French 2003; Jones et al. 2007). The LiDAR data of the Avon valley was kindly shared by the New Forest National Park Authority (NFNPA) for the Hampshire region, east of the Avon River. LiDAR data for the Dorset and Wiltshire regions was available via the Geomatics Group (Environment Agency 2013). The digital elevation model was obtained through Edina Digimap (Bournemouth University licence). These data were manipulated in ArcGIS to highlight features, relate terrace deposits and obtain cross-sections. Geological data were obtained from British Geological Survey maps available through Edina Digimap

(Bournemouth University licence) and geological assessment reports and memoirs of the area (Bristow et al. 1991; Clarke 1981; Kubala 1980; Reid 1898, 1902, 1903).

4.7.2 Archaeological data

Palaeolithic find-spot data from the Avon Valley was acquired through Historic Environment Records (HERs) of Wiltshire, Hampshire and Dorset, combined with the Portable Antiquities Scheme, Archaeological Investigations Project and Oasis databases and available literature and gazetteers (e.g. Roe, 1968,1981; Wessex Archaeology, 1993; Wymer, 1999a,b) (see section 3.6).

4.7.3 Field site selection

Geographic information including: (historic) maps; BGS superficial geological mapping; and Lidar, was combined in ArcGIS to facilitate the identification of active and disused gravel pits exposing terrace deposits, as potential sites (see section 4.2.1).

4.7.4 Subsurface geology

To provide an improved regional understanding of the internal structure of the Avon terraces and their formation, information from 1129 BGS borehole and well records were obtained from the BGS GeoRecords+ Borehole browser (http://shop.bgs.ac.uk/georecords/) in combination with the BGS GeoIndex Onshore (http://www.bgs.ac.uk/geoindex/). In BGS GeoIndex Onshore all borehole and well records within the spatial extend of the Avon superficial terrace deposits mapping were selected. In ESRI ArcGIS 10.1 using 'Selection by location' 1129 boreholes related to the Avon river terrace deposits on the 1:10000 BGS geology map were selected. 94 of these records were confidential and therefore could not be used. Scans of the BGS borehole reports of the remaining 1035 records were obtained through BGS GeoRecords+ and digitised in Excel in the format presented in Table 4.4. These data was then imported in RockWorks 16. RockWorks is a software program developed by RockWare that facilitates subsurface geology data visualisation, modelling and analysis.

LOCATION

BGS ID	EASTING	NORTHING	ELEVATION	NAME	TERRACE	DEPTH	BEDROCK GEOLOGY
	415510	*109410*	*25*	*Near Ibsley House*	*4*	*9.4*	*Poole Formation*

STRATIGRAPHY

BGS ID	DEPTH 1	DEPTH 2	STRATIGRAPHY
	0	*0.4*	*Made ground*
	0.40	*7.40*	*Gravel*
	7.40	*10.4*	*Bedrock*

LITHOLOGY

BGS ID	DEPTH 1	DEPTH 2	LITHOLOGY
	0	*0.4*	*Made ground*
	0.4	*1.2*	*Sandy gravel*
	1.2	*2.0*	*Sand*
	2.0	*7.40*	*Gravel*
	7.40	*10.4*	*Fine sand*

Table 4.4 Lithological and stratigraphic data recorded in Rockworks database.

Chapter 5 Field sites

5.1 Introduction

The Quaternary deposits of the Avon valley provide valuable information on river system development and forms the sedimentological (and potentially landscape) context of the majority of the Palaeolithic archaeology in the region. The Avon valley dissects the terraces of the upper (Bournemouth terraces) and middle Solent (western Solent terraces). Correlation between the Avon and Solent terrace system allows integration of the geomorphological history in both systems and the reconnection of the Bournemouth and western Solent terrace deposits. The development of dating techniques that allow fluvial deposits to be dated has made a significant contribution to renewed investigations into and interpretations of the geomorphological history of the Solent and its tributary rivers. OSL dating is one of such methods that allows dating the deposition of fine, mineral rich sediments. To apply this technique to the terrace sequence in the Avon valley, terrace deposits were searched to contain bedded fine grained sediments. Disused gravel pits were the primary focus of investigations, providing cost and time efficient access to the terrace deposits and allowing targeted excavations at locations where sand lenses suitable for OSL dating could be identified prior to excavations. This led to the selection of 7 field sites (see Figure 5.1) over 6 different river terraces.This chapter discusses the field site locations, geological context, research history and results. The aim of the fieldwork was to investigate the internal sedimentological structure of the terraces, obtain OSL samples, and gain insight in the depositional context of main Palaeolithic artefact concentrations.

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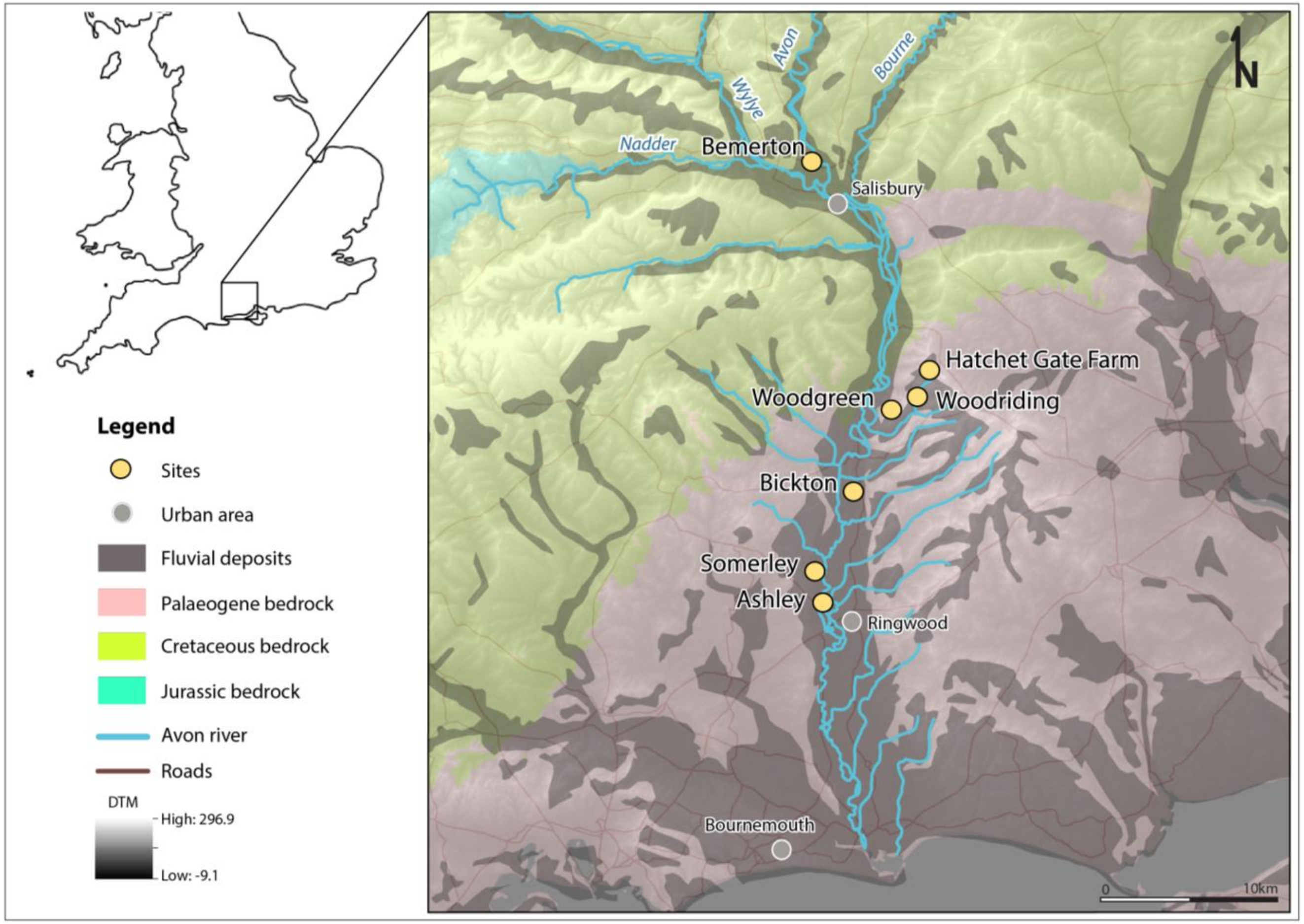

Figure 5.1 Map showing the Avon valley and distribution of the field sites, in relation to superficial fluvial deposits and bedrock, draped over a DTM (derivation 2.5) of the area (based upon 1:625000 scale geology data, with permission of the British Geological Survey and 1:10000 scale OS VectorMap Local [shape files water line; main roads], Digimap Licence).

5.2 Bemerton (undifferentiated terrace)

Bemerton gravel pit (E 412610 N 130945, SU 12610 30945; 77m OD) is located at Roman Road, west of Salisbury, between Wilton Road and Devizes Road (see Figure A3.1 in Appendix 3). It is a disused quarry now surrounded by houses built between 1880 and 1982. An area of about 2580m^2 has been extracted. The site was first mentioned by Read in 1885. He described the discovery of over 450 bifaces in the area around Salisbury, of which 55 were found in the river terrace at Bemerton through quarrying (Read 1885). The map included in Read (1885) facilitated the relocation of the site, which was found to be still accessible with gravel still present. The pit is currently owned by Mark Maidment who gave consent for the excavation which was carried out between 14 July 2014 and 7 August 2014.

5.2.1 History and archaeology of Bemerton

The gravel pit was active prior to 1881 as indicated on the County Series 1:2500 map published in 1881, where it was marked as 'Gravel pit Folly'. A note by Read (1885, p.117) confirms earlier gravel extraction in this location as he writes that Mr H.P. Blackmore found the first bifaces in the quarry on the 14th of September in 1863. Evans also noted in 1864: '*It is an old gravel pit, for a portion of it that has been worked out is planted with fir-trees, now of considerable size*.' (Evans 1864, p. 190). Based on this and the County Series map of 1881 it is calculated that a surface of 2580m^2 had been excavated by 1881. Later maps show no further extension of the pit, possibly suggesting gravel extraction had ceased by 1881 or that extraction continued by deepening the pit rather than by lateral extension. The quarried area to the east of the current pit has been built over; so that what is accessible today covers a smaller part of the original gravel pit.

Historically, artefacts have been recovered from several terrace exposures around Bemerton, and Read states: '*wherever it* [the gravel] *has been excavated these implements have appeared*.'(1885, p. 118). The pit at Roman Road seems to have been the most prolific findspot (Read 1885). More recently, in 1971, an ovate Acheulean biface was found in the garden of 32 New Zealand Avenue, southeast of the gravel pit at Roman Road. 151 artefacts from Bemerton were analysed, which results are presented in Chapter 8.

5.2.2 Geology and topography at Bemerton

The bedrock geology at Bemerton is Cretaceous Chalk of the Newhaven Chalk formation (BGS 2013) (see Figure A3.1 in Appendix 3). Around the site the Avon and its tributaries have cut steep valleys into the Chalk bedrock also contributing to the patchy nature of the overlying river gravels.

Bemerton is assigned to an undifferentiated terrace of the Avon and lies at a height of *c*. 77 m OD and *c*. 30m above the modern floodplain (BGS 2005). BGS mapping defines the terrace as lying 750m to the north and 165m to the south of the gravel pit. It stretches west and east for 235m and 560m respectively. Further patches of undifferentiated terrace deposits are located on the hills surrounding Salisbury. In the Nadder valley, a tributary of the Avon, to the south of the Bemerton gravel pit, the undifferentiated terrace deposit is bordered by gravels assigned to Terrace 1. The hill to the north of the pit is covered by head and clay-with-flint. The terrace deposits are generally covered by a layer of Loess ('Brickearth') of varying thickness (Antoine *et al*. 2003; Delair and Shackley 1978).

5.2.3 Excavation at Bemerton

Two sections and one pit were excavated at Bemerton (see Figure A3.1-A3.5 in Appendix 3). Access to the site was limited by the surrounding buildings, preventing the use of a mechanical excavator. The first section revealed made ground directly deposited on top of the chalk bedrock. This initiated the excavation of a second section to the northeast. To reach the bedrock a trench was dug directly below section 2. The sediments consist of 4.58m of orange brown, poorly sorted becoming moderately sorted, clayey flint gravel overlying Newhaven Chalk. On top of the terrace, to the northwest of section 2, a pit was dug in order to establish the height of the terrace surface. In the pit, 190cm of massive, well-sorted silt was found overlying the gravel. The clay content of the silt increased towards the bottom of the pit. The sediment included rare grit and granules and was capped by 20-60cm of gravelly topsoil. The well sorted silt was identified as brickearth.

5.3 Hatchet Gate Farm (Terrace 10)

The Hatchet Gate Farm gravel pit (E 419310 N 119280, SU 19310 19280; 105m OD) is a privately used pit located in the southeast corner of the field behind Hatchet Gate Farm on Hale Lane in Hale, about 6.5 km northeast of Fordingbridge, Hampshire (see Figure A5.1 in Appendix 5). The extracted area currently comprises 125m^2. The quarry is located on land owned by Mr A.H. Pasmore who had noted a silty sand lens during gravel extraction. Mr Pasmore gave consent for fieldwork, and this was carried out between 9 October and 15 October 2014.

5.3.1 History and archaeology of Hatchet Gate Farm

Hatchet Gate Farm pit was brought into use in the 1990s for private purposes. No Palaeolithic artefacts have been recovered from this pit. Some artefacts may have been found in deposits of the same terrace but their nature and contextual information is unclear (Prestwich 1872, p. 39-40; Westlake 1900).

5.3.2 Geology and topography at Hatchet Gate Farm

The bedrock geology at Hatchet Gate Farm comprises sand, silt and clay of the Poole Formation (see Figure A5.1 in Appendix 5). North and south of the site the landscape is incised by tributaries of the Avon, exposing deposits of the London Clay Formation. To the east the Marsh Farm Formation and Wittering Formation are found (BGS 2004). Hatchet Gate Farm pit lies on terrace 10 of the Avon at a height of *c*. 105 m OD and *c*. 72m above the modern floodplain (BGS 2004). BGS mapping shows a strip of terrace deposit extending 1000m southwest of the pit, gently sloping towards the valley. The Hatchet Gate Farm site is located near the northern edge of terrace 10. To the east of the gravel pit the terrace is better preserved and covers the area from Morgan's Vale to Little Orchard. On the valley side the terrace is bordered by head deposits.

5.3.3 Excavation at Hatchet Gate Farm

A mechanical excavator was used to clean the three faces of the gravel pit. After cleaning the pit the fine sediment deposit within the gravels, as identified by Mr Pasmore, was observed in the north and south sections of the pit. Below these exposures a trench was dug by hand to investigate the underlying sediments and the relation of the silt deposit to the bedrock. The bedrock surface dips west to east from 103.16m OD to 102m OD and is overlain by crudely bedded gravel with interbedded fine sediment deposits. The river gravel is matrix supported, poorly sorted and compact, in a clayey matrix (see Figure A5.1-A5.8 in Appendix 5).

5.4 Woodriding Pit (Terrace 10)

The disused gravel pit (E 418634 N 117807, SU 18634 17807; 101m OD) is located north of Woodriding House, west of the water reservoir at Stricklands Plantation (see Figure A7.1 in Appendix 7) An area of 2173m^2 has been extracted. It is situated about 6km northeast of Fordingbridge, Hampshire, between Woodgreen and Hale. The gravel pit is located on the land belonging to Woodriding house, property of Mr and Mrs Gillmon who gave consent for the fieldwork. Work was carried out between 11 October and 22 October 2014.

5.4.1 History and archaeology of Woodriding

The gravel pit lies in an area known as Stricklands Plantation. This was originally part of the Hale House Estate. In 1928 the Hale House Estate was broken up and Stricklands Plantation was sold to a timber company, Mitchell & Co, in Downton who harvested oak from the plantation. For about 50 years the area was left alone and became infested with rhododendron, leaving the land inaccessible. In 2007 the land was offered for sale by Mitchell & Co. and purchased by Mr and Mrs Gillmon, owners of the adjacent Woodriding House. In 2008 a government grant was given to Mr and Mrs Gillmon for clearance of the rhododendron, the gravel pit was revealed (pers. comm. Mrs Gillmon 2014). When the pit was first dug and active is unknown and no indications are given on historic maps. No Palaeolithic artefacts are known to be recovered from this pit (HER). Although a few archaeological finds have been recorded from terrace 10, the HERs and grey literature provide minimal contextual information.

5.4.2 Geology and topography at Woodriding

The bedrock geology at Woodriding comprises sand, silt and clay of the Poole Formation (see Figure A7.1 in Appendix 7). In the tributary valleys northwest and southeast of the pit the bedrock is formed by the London Clay formation (BGS 2013; BGS 2004). Woodriding Pit lies on terrace 10 of the Avon at a height of *c*. 101m OD *c*. 70m above the modern floodplain (BGS 2004). BGS mapping shows the terrace extending northeast-southwest for about 2800m. To the northwest and southeast of the pit the landscape is incised by tributary streams of the Avon which eroded away most of the river terrace deposit. In the northeast T10 is more widely preserved. The Woodriding gravel pit is located near the western edge of T10.

5.4.3 Excavation at Woodriding

A section of approximately 4x4.5m was cleaned below the sand layer highest in the section, using a mechanical excavator. A high water table and the risk of slope collapse prohibited excavation to bedrock. The sediments consisted of 4m of moderately to poorly sorted, clayey, matrix supported gravel. Three gravel units could be discerned of which the boundary between the lower two (HB1.2 and HB1.9) is diffuse. These deposits show limited bedding and consist of medium-fine gravel. Before the water table rose following rain, a small sand lens was observed towards the bottom of the section. A grey clay vein crosses through the section diagonally. The top unit (HB1.1) is well defined from the underlying units and is interspersed with horizontally bedded, crudely graded silty, clayey sand layers (see Figure A7.2-A7.7).

5.5 Woodgreen (Terrace 7)

Woodgreen gravel pit (E 417200 N 117025, SU 17200 17025; 62m OD) is situated south of the village of Woodgreen, 3km northeast of Fordingbridge (see Figure A9.1 in Appendix 9). The quarried area comprises 20377m^2, dissected by the Woodgreen to Godshill road. The area northeast of the road is the largest and part of it is now used as a cemetery that first appeared on the 1943 National Survey. The east side of the pit is bordered by forest; the west and north by houses and their land. These plots first appeared on the Drivers' Map, 1814 (Richardson et al. 1814).

Woodgreen gravel pit is one of seven sites of special geological or physiographic interest within the New Forest that, as a whole, is designated as a Site of Special Scientific Interest (SSSI) (Wildlife and Countryside Act 1981, last revision: 28 February 1996). Woodgreen gravel pit specifically is designated as SSSI because of the preservation of Pleistocene fluvial deposits and the discovery of one of the most prolific Palaeolithic sites in Solent catchment at this location (ibid.).

In 1986 Bridgland and Harding (1987) investigated Woodgreen pit as part of the Nature Conservancy Council's Geological Conservation Review. They opened a new section in order to improve the stratigraphy and sedimentology of the location and the context of the Palaeolithic artefacts. They exposed a 4m section of horizontally bedded coarse-medium gravel overlying Bagshot Beds sand (bedrock). A small biface was found in situ within cross-stratified, reddish, clast supported and framework supported gravel. The excavation revealed an orange sand layer towards the bottom of the section (Bridgland and Harding 1987). Fieldwork was carried out between 15 September and 23 September 2014, with the aim to re-expose this sand deposit for OSL dating. Consent was obtained from the Forestry Commission, Natural England, the New Forest National Park Authority and the Verderers' Court (permit number 015596/2014).

5.5.1 History and archaeology of Woodgreen

Woodgreen is first mentioned in 1889 by Westlake who recorded the collection of 24 bifaces and 4 flakes between the 1870's and 1880's. these were found between 0.3 and 3 metres (1and 9 feet) from the top of the gravel (Westlake 1889). The first artefact was found *in situ* on 28 April 1876, 1.5m deep (Westlake 1902). Reid (1902, p.37), who geologically surveyed the area between 1896 and 1900, describes the site as the source of 'numerous implements'. In his notebooks Westlake recorded 926 artefacts collected from Woodgreen. A large number of those are described as 'eolithic' and are now regarded natural. This could be the explanation for the number of artefacts estimated by Roe to be much lower (1968). Roe lists 409 bifaces, 7 rough-outs, 11 retouched flakes, 143 unretouched flakes, 1 core and 9 miscellaneous pieces (Roe 1968). The author of this thesis analysed 635 pieces from Woodgreen, of which 104 are miscellaneous and include some likely ‘eolith’ pieces. This number of artefacts from Woodgeen makes it the richest Palaeolithic site in the Avon valley and one of only 19 ‘super sites’ in the United Kingdom (Brown et al. 2013).

5.5.2 Geology and topography at Woodgreen

The bedrock geology comprises sand, silt and clay of the Bagshot Formation (see Figure A9.1 in Appendix 9). The excavation carried out in 1986 by Bridgland and Harding revealed small-scale relief, possibly reflecting scour features (Bridgland and Harding 1987). Woodgreen gravel pit lies on terrace 7 of the Avon, at a height up to 63m OD and *c*. 33m above the modern floodplain (BGS 2004). A small stretch can of terrace be traced to the southwest along the summit of Godshill Enclosure. Further remnants of the terrace are found north and south of the site that have become isolated patches through erosional processes.

5.5.3 Excavation at Woodgreen

The Bridgland and Harding section was located using photographs of the 1986 excavation. To the southwest of the old trench a new section (section 1) of 2.5x3m was cleaned. To provide a better understanding of the sedimentological structure of the terrace a second section (section 2) of 2.7x3m was excavated to the southwest. A mechanical excavator was used for the initial cleaning and excavation, the final cleaning of the section was done by hand using a hand pick and trowel. The sediments in section 1 consist of 3m of cross-bedded, poorly sorted, coarse to medium, matrix supported flint gravel, interspersed with a thin, horizontally-bedded silty deposit and horizontally-bedded sand layer. The terrace erosionally overlies fine sand and clay of the Bagshot Formation that is exposed at 58.7m OD and drops *c*. 40cm in height in the north corner of section 1. Sediments exposed in section 2 consist of 2.5m of cross-bedded, moderately to poorly sorted, coarse to medium, matrix supported flint gravel. The bedrock, exposed at *c*. 58.30m OD, gently slopes to the southwest (see Figure A9.2-A9.6).

5.6 Somerley Pit (Terrace 6)

The gravel pit (E 412845 N 107825, SU 12845 07825; 45m OD) is located on Somerley Estate, about 570 metres to the west of the Estate House, 3km northwest of Ringwood, Hampshire (see Figure A11.1 in Appendix 11). Consent was given by the Estate for a targeted cleaning and sampling of the face of the pit. Fieldwork was carried out between 14 and 22 September 2015.

5.6.1 History and archaeology of Somerley pit

The gravel pit at Somerley became active prior to 1868, as indicated on the County Series 1:2500 published in 1868. Today the gravel pit at Somerley Estate is occasionally worked for private use and the extracted area currently comprises about 1000m^2. No Palaeolithic artefacts have been recovered from the site. One Palaeolithic artefact has been recorded from Hamer Warren, 2.4km north of Somerley, where P. Harding found a biface from a load of hoggin derived from a gravel pit in terrace 6 at Hamer Warren (reported to the HER by P. Harding in 2007). Additionally, on the other side of the valley from Somerley Estate two Palaeolithic artefacts were found near Poulner, possibly related to a gravel pit in terrace 6 (Proceedings of the Hampshire Field Club, 1923).

5.6.2 Geology and topography at Somerley

Somerley pit lies on terrace 6 of the Avon, at a height of *c*. 45m OD and *c*. 26m above the modern floodplain (BGS 2005). Terrace 6 is relatively well-preserved and is found for about 10km along the Avon valley and for a large part of that it is 2.5km wide (see Figure A11.1 in Appendix 11). This spread of terrace is dissected by tributary valleys where the superficial geology has been eroded away. To the east of the site there is an abrupt fall in altitude down to the level of the modern flood plain where terraces 4-1 are found. The BGS mapping and field observations suggest a significant break of slope between terraces 6 and 5 and the lower lying terraces. There is no superficial geology preserved on the break of slope (BGS 2004). The underlying geology at the Somerley Pit comprises fine sand, silt and clay of the Parkstone Sand Member of the Poole Formation. North and south of the site the landscape is incised by old tributary streams to the Avon which eroded away the superficial geology of river terrace 6 and 5. These areas now form small valleys. The pit is situated close to the southern edge of such an interfluve.

5.6.3 Excavation at Somerley pit

The sediments exposed in the Somerley gravel pit consist of 5.6m of moderately sorted, horizontally-bedded, sandy gravel interspersed with cross-bedded sandy layers at *c*. 2 m below the top of the terrace (45m OD). Repeated sequences of matrix supported, to clast supported layers are identified below the sand layers. The upper 1.5m of terrace deposit exposed shows evidence of cryoturbation and the inclusion of clasts of frozen fine sediment in the river gravel. The terrace is capped by 10-20cm of topsoil. Two locations were identified where bedded sand deposits were particularly clear, one in the northwest and one in the southeast side of the pit, and were selected for OSL sampling and sedimentlogical logging (section 1 and 3). In addition, a trench was dug in the south of the pit (section 2) (see figure A11.1 and A11.2). Below section 1 a 1.5m deep trench was dug to establish the basal contact of the terrace gravel with the bedrock. This was not reached and further excavation of the trench was ceased for health and safety reasons. The sediments visible in the trench were recorded before backfilling. During further gravel extraction by the estate in March 2016 bedrock was reached approximately 2.4m below the original section at *c*. 39.3m OD (pers. comm. Darren Sharp 2016).

To establish the height of the bedrock a trench of 3.5m long and 2.5m wide was dug in the south corner of the gravel pit where the estate keeper had found a thick sand deposit that was interpreted as bedrock. Section 2 comprised 140cm of finely horizontally-bedded sand and gravelly sand situated below 3.2m of horizontally-bedded gravel. The sand deposit was underlain by 80cm horizontally-bedded, alternatingly matrix and clast supported, sandy gravel, sitting on fine grey sand and light grey stiff clay bedrock of the Parkstone Sand Member (bedrock) exposed at 39.6m OD. After recording bedrock height and the lowest part of the section, the trench was partly backfilled for health and safety reasons. A similar deposit was encountered by the estate keepers in the east corner of the gravel pit, during gravel extraction prior to the fieldwork.

Section 3 was 4m wide and 2.5m high. Here 3.2m of cross-bedded coarse-medium, alternating clast supported and matrix supported gravel was exposed. The gravel was interspersed with cross-bedded, graded sand, horizontally-bedded and cryoturbated sand and horizontally-bedded inversely graded sand.

5.7 Ashley Pit (Terrace 5)

Ashley pit is a disused gravel pit (E 413293 N106143, SU 13293 06143; 36m OD) located 1.5km northwest of Ringwood, Dorset, on land leased to the Forestry Commission by Somerley Estate (see figure A13.1 in Appendix 13). Consent for the fieldwork was received from the Forestry Commission (permit number: 016765/2015) and Somerley Estate and carried out between 14 and 22 September 2015.

5.7.1 History and archaeology of the site

Based on the County Series 1:2500 map published in 1871 and the County Series 1:2500 map published in 1897, it appears that Ashley pit was active before 1871 and became disused before 1897. Today the gravel pit is not in use. An area of 6060m^2 has been extracted. No Palaeolithic artefacts are known to have been found at the location but at least three Palaeolithic artefacts have been found in association with terrace 5 elsewhere in the valley. From Ashford station, 8km north of Ashley Pit, 10 Palaeolithic bifaces, 1 core and 3 flakes have been recorded (Roe 1968). The exact find location of other finds associated with terrace 5 deposits is less certain.

5.7.2 Geology and topography at Ashley

The bedrock at Ashley pit is fine sand, silt and clay of the Parkstone Sand Member of the Poole Formation (see figure A13.1 in Appendix 13). Ashley pit lies in terrace 5 of the Avon valley terrace sequence, at a height of *c*. 34m OD and *c*. 18m above the modern floodplain (BGS 2005). Terrace 5 can be traced for about 2km north of the site along the valley edge. A narrower stretch of T5 about 7km long lies north of Fordingbridge. Around Ashley pit T5 is bordered by T6 deposits to the west. To the east of the site there is an abrupt fall in altitude down to the level of the modern flood plain where T4-1 are found. The stretches of terrace 5 and 6 deposits are dissected by valleys which incision has led to the erosion of the Pleistocene terraces and exposure of the underlying Tertiary bedrock.

5.7.3 Excavation at Ashley pit

A section of Ashley gravel pit was cleaned with a mechanical excavator. The 5 by 3.5m section exposed 3.3m of horizontally bedded, cryoturbated, medium, sandy gravel, interspersed by thin sand and clay deposits. The gravel deposit is overlain by 1.9-2.2m of fine fluvial deposits and topsoil. Bedrock, comprising of fine sands and clay of the Parkstone Sand Member is exposed at *c*. 30.1m OD and dips 20cm in the south corner of the section.

5.8 Bickton Pit (Terrace 4)

Bickton gravel pit (E 414981 N 112409, SU149124; 28m OD) is located southeast of Bickton Manor House, in Bickton, 2km south of Fordingbridge (see Figure A15.1 in Appendix 15). The gravel pit is small; worked occasionally and covers 83m^2. A thin layer of sand was observed within the horizontally bedded gravel deposit exposed in the pit. The land is owned by Mr and Mrs Sykes who gave their consent for the fieldwork which was carried out on 15 October 2015.

5.8.1 History and archaeology of Bickton

Bickton gravel pit does not appear on any of the historic survey maps but the manor house does, and was built in the 15th century. No Palaeolithic artefacts have been recorded from the Bickton gravel pit or immediate surrounding areas. 16 Palaeolithic artefacts, including 12 bifaces and three unretouched flakes and a miscellaneous piece, have been found in the general area of Fordingbridge. Palaeolithic finds with a more secure association with T4 deposits are found further away from Bickton on the floodplains around Christchurch at Latch Farm. However, in this area the number of terraces does not compare with higher up in the valley, hampering further correlations.

5.8.2 Geology and topography at Bickton

Bickton gravel pit lies on terrace 4 of the Avon valley terrace sequence, at a height of *c*. 28 m OD and *c*. 6m above the modern floodplain (BGS 2005) (see Figure A15.1 in Appendix 15). Extensive remnants of T4 are preserved in the middle section of the Avon valley up to Salisbury. T4 has been widely extracted by large scale commercial activity during the second half of the 20th century in the area between Ringwood and Fordingbridge. The bedrock geology at the Bickton location comprises sand, silt and clay of the Poole Formation.

5.8.3 Excavation at Bickton

Due to limited access to the site the fieldwork at the Bickton gravel pit has been restricted to cleaning the section by hand where the sand layer was regarded suitable for OSL dating. After cleaning the section was rapidly logged and drawn and 4 OSL samples were taken from 4 different locations within the pit. All sample locations have been recorded using dGPS and photographed. Bickton gravel pit exposures comprised horizontally-bedded, moderately sorted, silty gravel. Approximately 1 to 1.5m below the top of the terrace, the gravel is interspersed with cross-bedded, silty sand deposits. The sand deposits are overlain by cross-stratified framework gravel alternating with matrix supported gravel.

Chapter 6 Sedimentology of the Avon Pleistocene river terraces

6.1 Introduction

This chapter presents the sedimentology data obtained from the field sites introduced in chapter 5. Sedimentology data, including grain size distribution, clast lithology and angularity-roundness classifications were obtained from selected deposits at the sites based on sampling the sediments, wet-sieving the >45mm-63μm fraction and applying laser diffraction to the >63μm fraction. The sieved sediments were then analysed for lithology and angularity-roundness. Sedimentology data are discussed per sampled stratigraphic layer and a comparison is made between deposits from the same site to evaluate how the depositional environment changed over time, and to support their identification as separate sedimentary units. The fieldwork provided the opportunity to evaluate different sediment-recording techniques. Image-based automated grainsizing and laser scanning were used and the results from these methods are compared with the sieving data. The image-based automated grain size data is presented per photographed frame and compared to evaluate the distinctiveness of the different deposits. Where sieving data and image-based data were available for the same deposits the results were directly compared. The same frames were scanned to directly compare roughness, ruggedness and focal statistics indices based on the scan data with the image-based automated grainsizing and sieving results.

6.2 Bemerton

6.2.1 Particle size distribution

Four gravel samples were retrieved from three different sediment layers in undifferentiated terrace deposits exposed at Bemerton (Figure 6.1). Particle size distributions were obtained using the methods outlined in section 4.3. The width of the section did not allow the use of image-based automated grainsizing as the frame could not be placed correctly onto the section. The section was scanned to allow comparison between sieving data, and roughness and ruggedness indices. This section discusses the particle size distribution of each sample based on the sieving and laser diffraction results, followed by a comparison between the samples. Section 6.10.2 presents the scan data in comparison to the sieving results. Figure 6.2 and Figure 6.3 summarise the data of all samples of the site. The grain size distributions of the individual samples are presented in Appendix 16.

Figure 6.1 Section in the undifferentiated terrace deposit at Bemerton showing gravel sample locations and the main stratigraphic units. 1= BEM2.2; 2=BEM2.3; 3=BEM2.4a; 4=BEM2.4b.

Sample BEM2.2 shows a bimodal grain size distribution. The medium gravel is very poorly sorted. The dominant grain size is 11.2-16mm (-3.5φ) and D_{50} is 10.6mm. 9.2% of the sample falls in the <63μm fraction, which composition was analysed by laser diffraction. The laser diffraction data shows three peaks in volume density around the size fractions 5, 8, 10.5φ, respectively reflecting a medium coarse silt, very fine silt and clay component, with coarse silt being most dominant.

Sample BEM2.3 shows a unimodal grain size distribution. The gravel is coarse to very coarse and poorly sorted. The dominant grain size is >45mm (-5.5φ). As this is the maximum mesh size used for sieving, this fraction may include larger clasts. D_{50} is 41.1mm. The <63μm fraction is just under 3.2% of the total sample weight. This size fraction shows a poorly sorted particle size distribution. It is mainly composed of very fine silt, medium fine silt and clay as can be seen from the peaks in volume density around the size fractions around 6, 8, 10.5φ in the laser diffraction data.

Sample BEM2.4a shows a bimodal grain size distribution. The very coarse gravel is very poorly sorted. The dominant grain sizes are >45mm (-5.5φ) and 16-22.4mm (-4φ). D_{50} is 19.7mm. Again, the 45mm size class may include larger clasts as this is the maximum mesh size used for sieving. The <63µm fraction is about 5.2% of the total sample weight. Laser diffraction analysis shows three peaks in the volume density distribution around the size fractions 6, 8, 10.5φ, representing the medium fine silt, very fine silt and clay components. Most pronounced is the presence of very fine silt.

Sample BEM2.4b shows a bimodal grain size distribution. The very coarse gravel is very poorly sorted. The dominant grain sizes are >45mm (-5.5φ) and 16-22.4mm (-4φ). D_{50} is 19.7mm. As mentioned above, the 45mm size class may include larger clasts. 9.9% of the sample falls in the <63µm fraction. The laser diffraction data shows a poorly sorted particle size distribution with three peaks in volume density around the size fractions 6, 8, 10.5φ. The very fine silt component is most pronounced.

Sediment statistics were based on the combined sieving and laser diffraction data and are presented in Appendix 17. Percentage calculations of the particle size distribution data from laser diffraction relative to the sieving data provide integrated frequency and cumulative frequency distributions of each sample, which are compared in Figure 6.2. Figure 6.3 shows the laser diffraction particle size distribution of the <63µm fraction of the three samples.

The sediment statistics in Appendix 17 and frequency distribution curves in Figure 6.2 show that sample BEM2.2 consists of generally smaller clasts but the percentage gravel content relative to the other texture categories is similar to that of BEM 2.4a and BEM2.4b. BEM2.3 is best sorted in comparison with the other samples. It is sorted towards coarse and very coarse gravel and shows the highest percentage of gravel (90.2%) relative to the other textural groups. The grain size distribution of BEM2.4a and BEM2.4b follow a generally similar curve, although BEM2.4b shows a more pronounce bimodal curve.

The particle size distribution from the laser diffraction shows a strong similarity in the composition of <63µm fraction of BEM2.4a and BEM2.4b with very fine silt being most present (Figure 6.3). Medium to coarse silt become slightly more present in sample BEM2.3 but remains comparable to BEM2.4a and BEM2.4b. The composition of the <63µm fraction from BEM2.2 shows a clearly different frequency curve with coarse silt being most present.

The comparable particle size distribution of BEM2.4a and BEM2.4b confirm their designation to a similar sediment deposit. The results indicate a crude grading of the sediment within BEM2.4. The distinct particle size distribution of BEM2.3 and BEM2.2 confirms the identification of these deposits as different sediment layers. The laser diffraction data indicates a pronounced change in fine sediment source during the formation of BEM2.2.

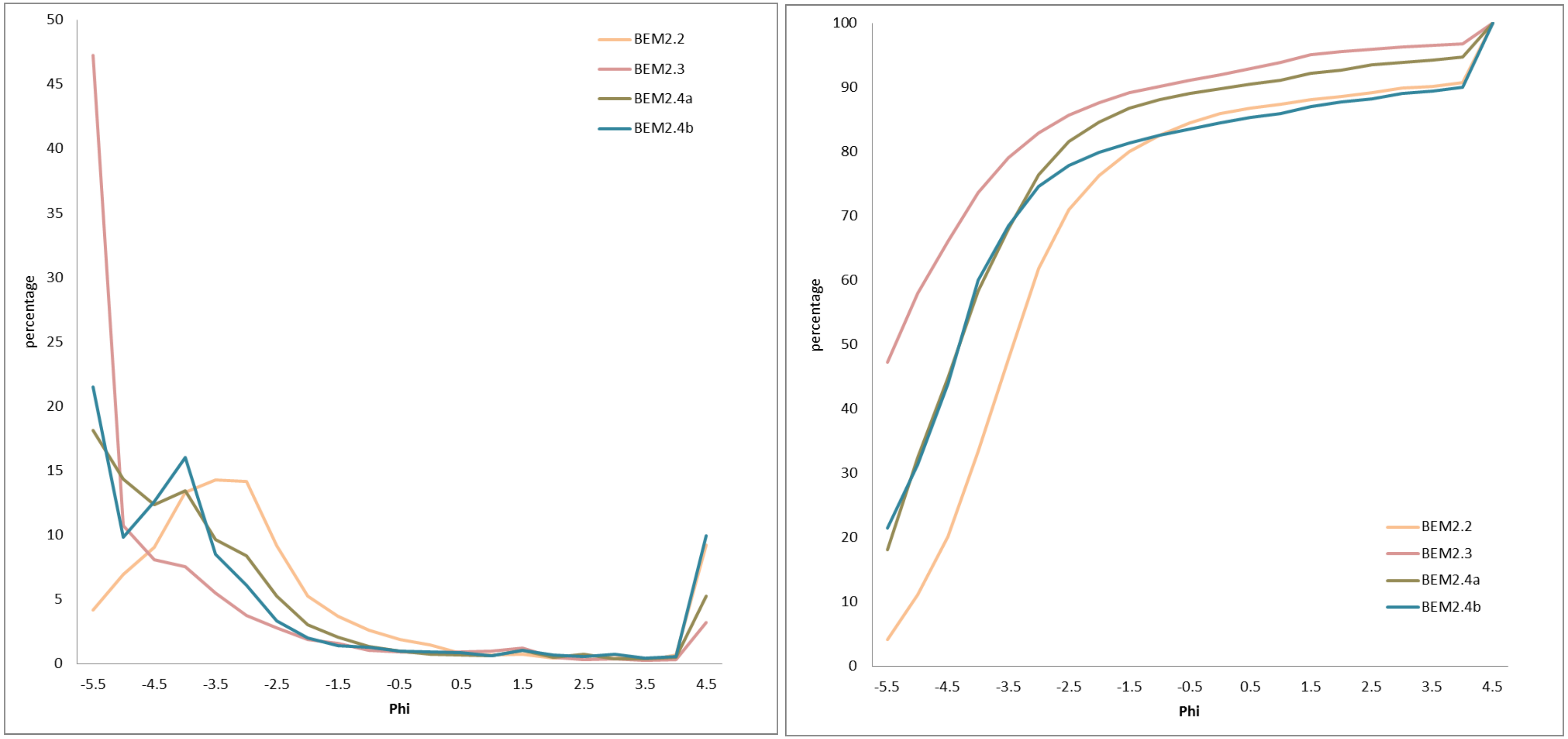

Figure 6.2 Particle size distribution of the four gravel samples from Bemerton showing weight in percentages of each size fraction (left) and the cumulative percentage of the weight in percentages (right).

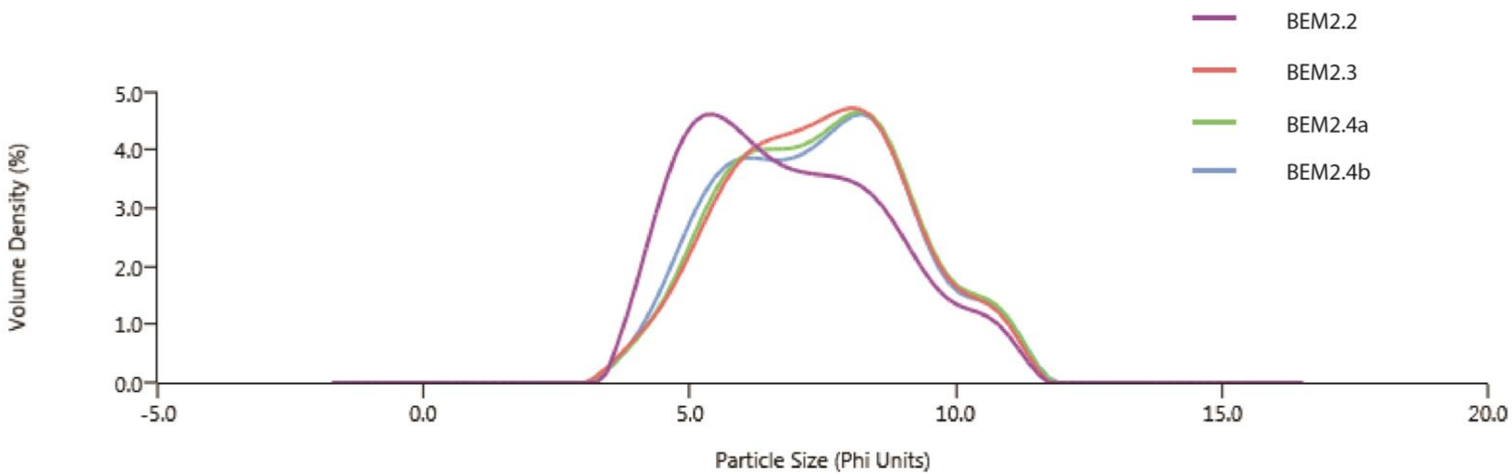

Figure 6.3 Comparison of particle size distributions of the <63µm fraction from BEM2.2, BEM2.3, BEM2.4a and BEM2.4b.

6.3 Hatchet Gate Farm

6.3.1 Particle size distribution

Two gravel samples were retrieved from two different sediment layers in terrace 10 deposits exposed at Hatchet Gate Farm (Figure 6.4). Particle size distributions were obtained using the methods outlined in section 4.3.2 and 4.3.3. Image-based automated grainsizing was applied to sediment units HA1.1, HA1.2 and HA1.3. The section was scanned to allow comparison between sieving data, image-based automated grain-sizing (IBAG) results and roughness and ruggedness indices. This section discusses the particle size distribution of each sample based on the sieving and laser diffraction results, followed by a comparison between the samples. Section 6.10.1 presents IBAG results. Section 6.10.2 presents the scan data in comparison to the sieving and IBAG results. Figure 6.5 and Figure 6.6 summarise the data of all samples of the site. The grain size distributions of the individual samples are presented Appendix 18.

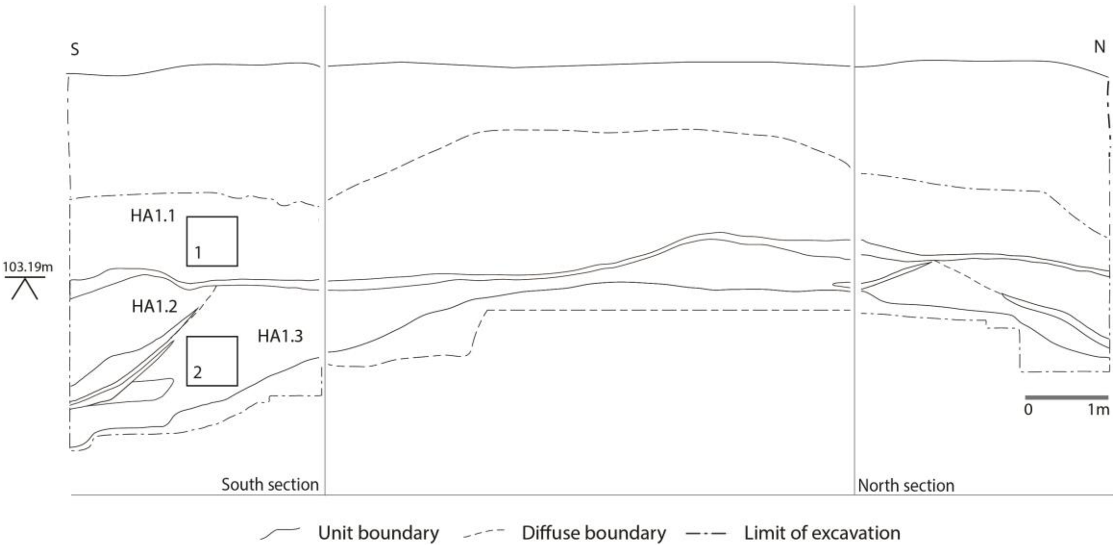

Figure 6.4 Section in terrace 10 at Hatchet Gate Farm showing gravel sample locations and the main stratigraphic units. 1= HA1.1; 2=HA1.3

Sample HA1.1 shows a polymodal grain size distribution. The coarse silty, sandy medium gravel is very poorly sorted. The dominant grain size is 16-22.4mm (-4φ) and D_{50} is 11.1mm. 10.7% of the sample falls in the <63µm fraction. The laser diffraction data shows a poorly sorted distribution with three peaks in volume density around the size fractions 6, 8, 11φ, respectively reflecting a medium fine silt, very fine silt and clay component. Medium fine silt and very fine silt are most dominant.

Sample HA1.3 shows a bimodal grain size distribution. The gravel is very coarse and very poorly sorted. The dominant grain size is >45mm (-5.5φ) and D_{50} is 11.1mm. Particles between 16-22.4mm form a second dominant group. The <63µm fraction is 8.9% of the total sample weight. The particle size distribution in this fraction is poorly sorted. It is mainly composed of medium coarse silt, very fine silt and clay as can be seen from the peaks in volume density around the size fractions 6, 8, 11φ in the laser diffraction data.

Sediment statistics are based on the combined sieving and laser diffraction data and are presented in Appendix 19. The particle size distributions obtained from sieving and laser diffraction provide a frequency distribution and cumulative frequency distribution of each sample, which are compared in Figure 6.5. Figure 6.6 shows the laser diffraction particle size distribution of the <63µm fraction of the two samples.

The sediment statistics and frequency distribution curves of sample HA1.1 and HA1.3 show a similar particle size distribution for the finer fraction of the samples up until very fine gravel. HA1.1 contains more very fine to coarse gravel. In HA1.3 the gravel importantly consists of very coarse gravel. HA1.1 contains more sand but the curves of both grain size distributions show a small peak around -1.5φ, indicating the presence of medium sand in both deposits.

The particle size distribution from the laser diffraction shows a fairly similar composition of the <63µm fraction from HA1.1 and HA1.3. Medium coarse silt and very fine silt are most present in both samples with the only difference that the very fine silt component becomes more dominant in HA1.1 compared to HA1.3. The particle size distribution of HA1.1 and HA1.3 is comparable with a minor decrease in gravel content and average gravel size from HA1.3 to HA1.1.

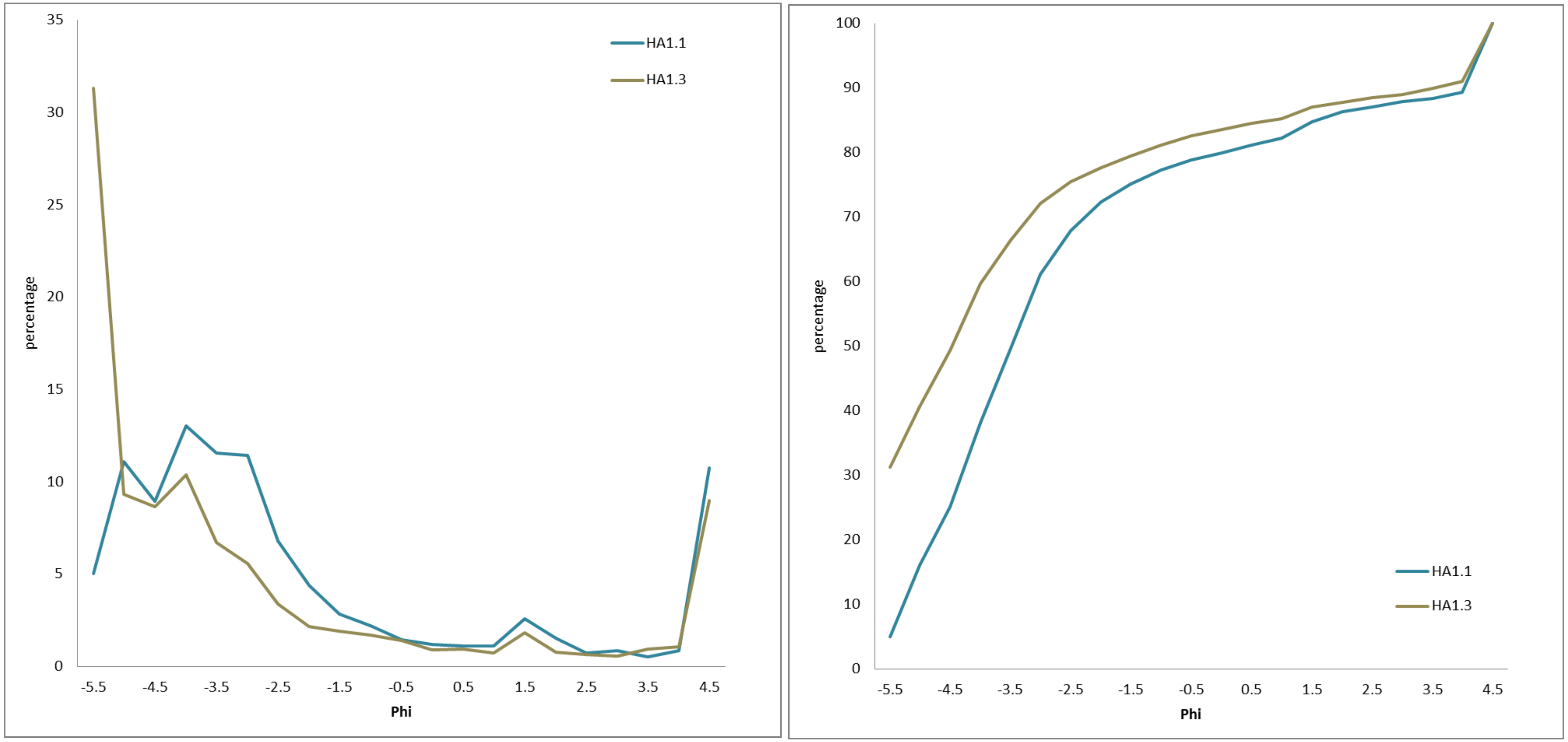

Figure 6.5 Particle size distribution of the two gravel samples from Hatchet Gate Farm showing weight in percentages of each size fraction (left) and the cumulative percentage of the weight in percentages (right).

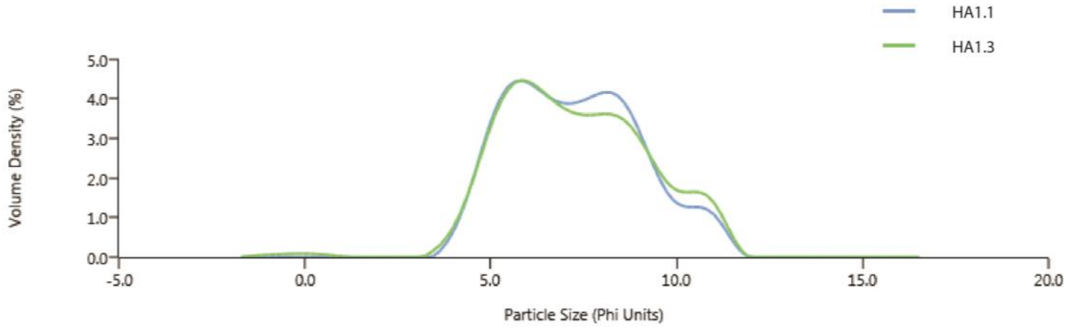

Figure 6.6 Comparison of particle size distributions of the <63µm fraction from HA1.1 and HA1.3.

6.4 Woodriding

6.4.1 Particle size distribution

Three gravel samples were retrieved from three different sediment layers in terrace 10 deposits exposed at Woodriding (Figure 6.7). The 45mm-63µm fraction of all samples was wet-sieved. The sediments retained per sieve were dried and weighed to obtain a weight percentage of each sediment fraction of the total sample. The <63µm sediment was analysed using laser diffraction. Multiple image-based automated grainsizing analyses were applied to sediment units HB1.1, HB1.2 and HB1.9 at various locations on the section. The terrace deposit was scanned to allow comparison between sieving data, IBAG results and roughness and ruggedness indices. This section discusses the particle size distribution of each sample based on the sieving and laser diffraction results, followed by a comparison between the samples. Section 6.10.1 presents IBAG results. Section 6.10.2 presents the scan data in comparison to the sieving and IBAG results. Figure 6.8 and Figure 6.9 summarise the data of all samples of the site. The grain size distributions of the individual samples are presented in Appendix 21.

Sample HB1.1 shows a bimodal grain size distribution. The medium gravel is very poorly sorted. The dominant grain size lies between 11.2-22.4mm (-3.5φ and -4φ) D_{50} is 13.4mm. 4.8% of the sample falls in the <63µm fraction. The laser diffraction data shows a poorly sorted particle size distribution with three peaks in volume density around the size fractions 5.5, 8, 11φ, respectively reflecting a medium silt, very fine silt and clay component. The medium silt fraction is most dominant.

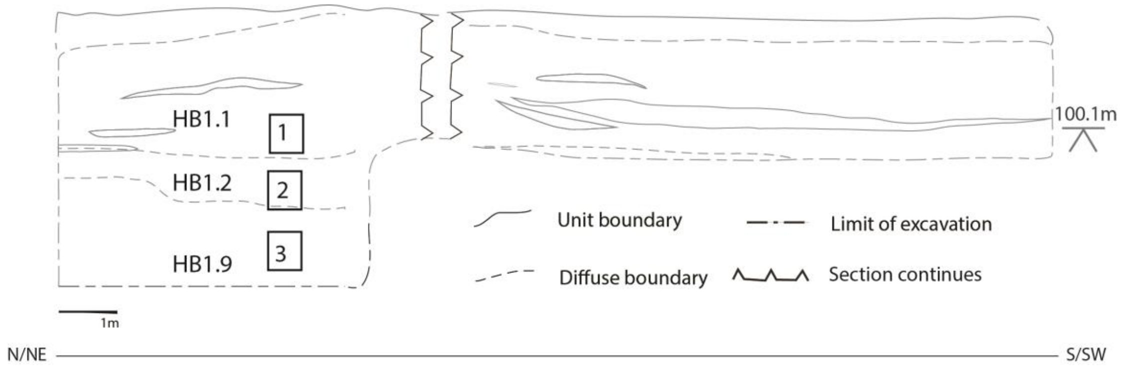

Figure 6.7 Section in terrace 10 at Woodriding showing gravel sample locations and the main stratigprahic units. 1= HB1.1; 2=HB1.2; 3=HB1.9.

The grain size distribution of sample HB1.2 is unimodal. The coarse silty, medium gravel is very poorly sorted. The dominant clast size is 11.2-16mm (-3.5φ) D_{50} is 9.6mm. A large percentage of the total sample weight, 14.4%, falls within the <63µm fraction. The particle size distribution in this fraction is poorly sorted. It is mainly composed of medium silt, very fine silt and clay as can be seen from the peaks in volume density around the size fractions 6, 8, 11φ in the laser diffraction data.

The grain size distribution of sample HB1.9 is trimodal. The coarse gravel is very poorly sorted. The dominant clast size is 22.4-31.5mm (-4.5φ) and D_{50} is 16.9mm. The <63µm fraction is 5.7% of the total sample weight. The particle size distribution in this fraction is poorly sorted. It is mainly composed of medium silt to very fine silt and some clay as can be seen from the plateau in volume density from fractions 6φ to 8φ and the small peak around11φ in the laser diffraction data.

Sediment statistics are based on the combined sieving and laser diffraction data and are presented in Appendix 22. The particle size distributions obtained from sieving and laser diffraction provide a frequency distribution and cumulative frequency distribution of each sample, which are compared in Figure 6.8. Figure 6.9 shows the laser diffraction particle size distribution of the <63µm fraction of the three samples.

The sediment statistics and frequency distribution curves of the samples show broadly similar grain size distributions for HB1.1 and HB1.9 but a different curve for HB1.2. The latter is muddy and contains less gravel. The gravel it contains is on average smaller as can be seen from the peak around -3.5 φ. It contains no clasts over 45mm. HB1.9 contains a higher proportion of coarse gravel and medium sand than HB1.1.

The particle size distribution from the laser diffraction shows a fairly similar compositions of the <63µm fraction for all three samples. HB1.2 is the coarsest sample. HB1.2 contains a larger amount of medium silt compared to the other samples. The particle size distribution of the three samples from Woodriding show changes in gravel composition between the three identified deposits confirming their identification as distinct sediment units.

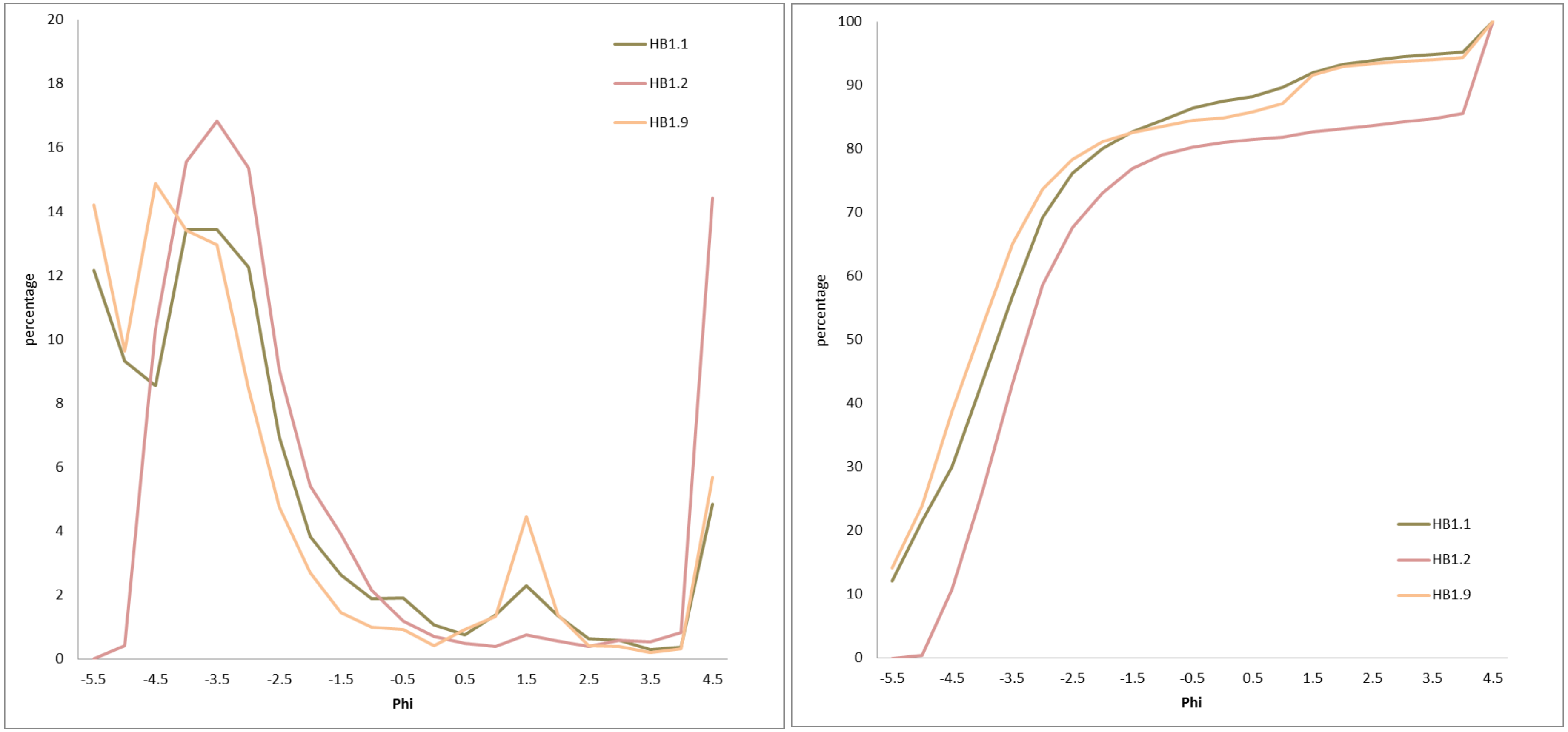

Figure 6.8 Particle size distribution of the three gravel samples from Woodriding showing weight in percentages of each size fraction (left) and the cumulative percentage of the weight in percentages (right).

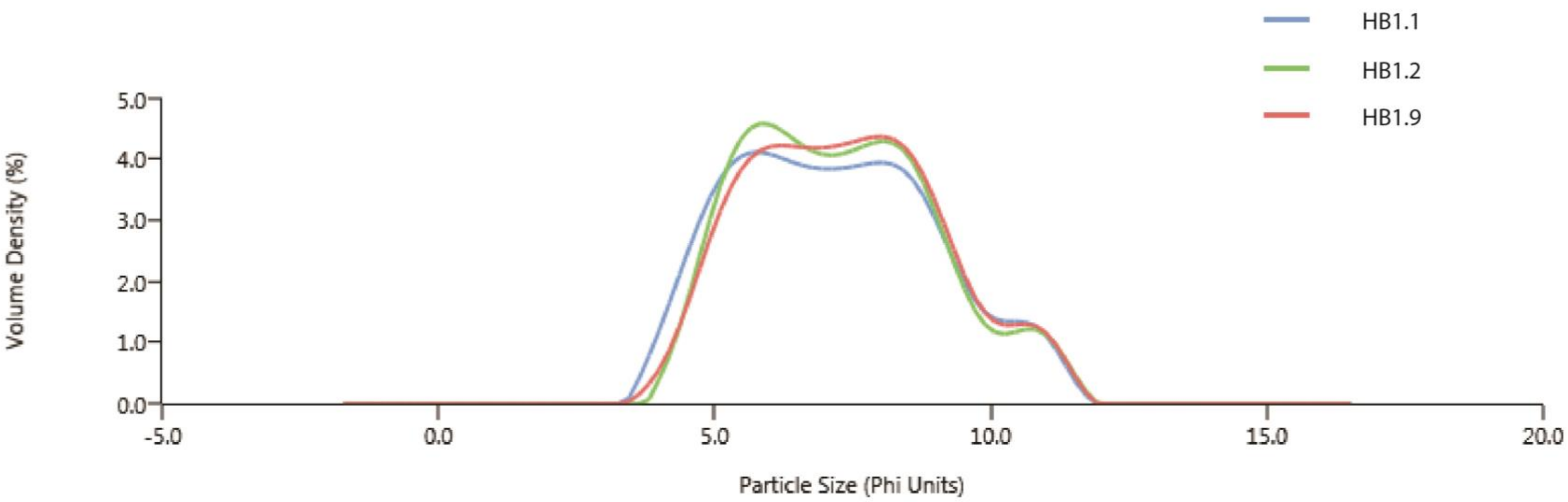

Figure 6.9 Comparison of particle size distributions of the <63μm fraction from HB1.1, HB1.2 and HB1.9.

6.5 Woodgreen

6.5.1 Particle size distribution

Four gravel samples were retrieved from four different sediment layers identified in two sections in terrace 7 at Woodgreen (Figure 6.10). Image-based automated grainsizing was applied to sediment units throughout the sections. The terrace deposit was scanned to allow comparison between sieving data, IBAG results and roughness and ruggedness indices. This section discusses the particle size distribution of each sample based on the sieving and laser diffraction results, followed by a comparison between the samples. Section 6.10.1 presents IBAG results. Section 6.10.2 presents the scan data in comparison to the sieving and IBAG results. Figure 6.11 and Figure 6.12 summarise the data of all samples of the site. The grain size distributions of the individual samples are presented in Appendix 23.

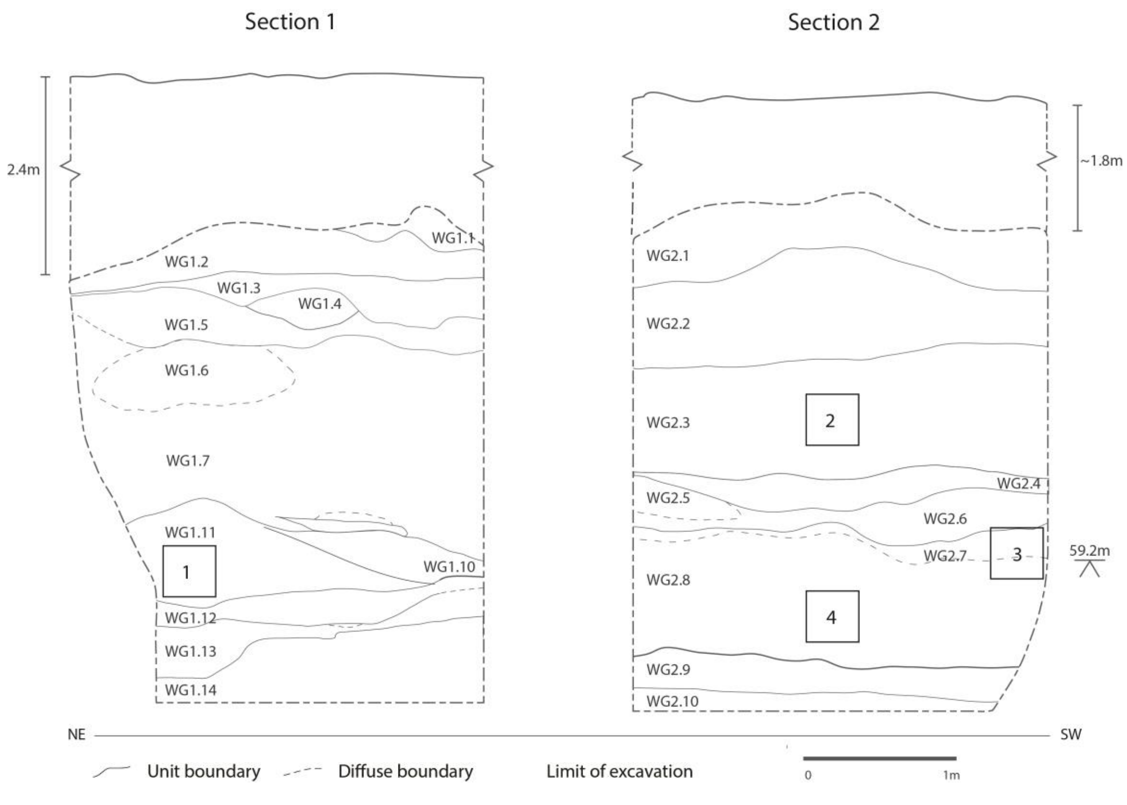

Figure 6.10 Two sections in terrace 7 at Woodgreen showing gravel sample locations and the main stratigraphic units. 1= WG1.11; 2=WG2.3; 3=WG2.7.4a; 4=WG2.8.

Sample WG1.11 shows a unimodal grain size distribution. The coarse gravel is poorly sorted. The dominant grain size is 16-22.4mm (-4φ) and D_{50} is 17.4mm. 3.5% of the sample falls in the <63μm fraction, which composition was analysed by laser diffraction. Particle size distribution in this fraction is poorly sorted. Peak concentrations occur at 5.5, 8 and 11φ. The medium silt component is most pronounced and grades into finer silt.

The grain size distribution of sample WG2.3 is biomodal. The very coarse gravel is very poorly sorted. The dominant grain size is 45mm (-5.5φ) and over. D_{50} is 21.0mm. The <63μm fraction is 5.6% of the total sample weight. This size fraction shows a poorly sorted particle size distribution. It is mainly composed of medium fine silt, very fine silt and clay as can be seen from the peaks in volume density around the size fractions around 6, 8, 11φ in the laser diffraction data.

The particle size distribution of WG2.7 shows a unimodal, poorly sorted coarse gravel. Clasts of 16-22.4mm (-4φ) are most dominant and D_{50} is 17.5mm. The <63μm fraction is 3.9% of the total sample weight and shows a poorly sorted particle size distribution. Peaks occur at 5.5, 8 and 11φ. The medium silt component is most dominant and grades into finer silt.

Sample WG2.8 shows a bimodal grain size distribution. The coarse gravel is very poorly sorted. The dominant grain size is 22.4-32mm (-4.5φ) and D_{50} is 18.0mm. The frequency distribution shows the presence of some medium sand. 5.8% of the sample falls in the <63μm fraction. The laser diffraction data shows a poorly sorted particle size distribution. Medium to very fine silt are present in almost equal percentages forming a plateau in the frequency distribution curve. A second peak in volume density occurs at 11 φ. This shows that the <63μm fraction mainly consists of silt with a small clay component.

Sediment statistics were based on the combined sieving and laser diffraction data and are presented in Appendix 24. The particle size distributions obtained from sieving and laser diffraction provide a frequency distribution and cumulative frequency distribution of each sample, which are compared in Figure 6.11. Figure 6.12 shows the laser diffraction particle size distribution of the <63μm fraction of the four samples.

The sediment statistics and frequency distribution curves show a striking resemblance between WG1.11 and WG2.7. Both mainly consist of very coarse, coarse and medium gravel and little sand or mud. WG2.3 differs in that it shows a high percentage of very coarse gravel (42.2%) and a larger sand component (11.1%). WG2.8 shows a more equal distribution of grains between 45-8mm and a more pronounced medium to fine sand component compared to the other samples.

The similarity between WG1.11 and WG2.7 is also reflected in the laser diffraction particle size distribution curves. WG2.8 shows a higher concentration of clay and a lower concentration of medium silt than the other samples. The particle size distribution of the four samples confirms the correlation between WG1.11 in section 1 and WG2.7 in section 2 and confirms the distinction of these deposits from WG2.3 and WG2.8.

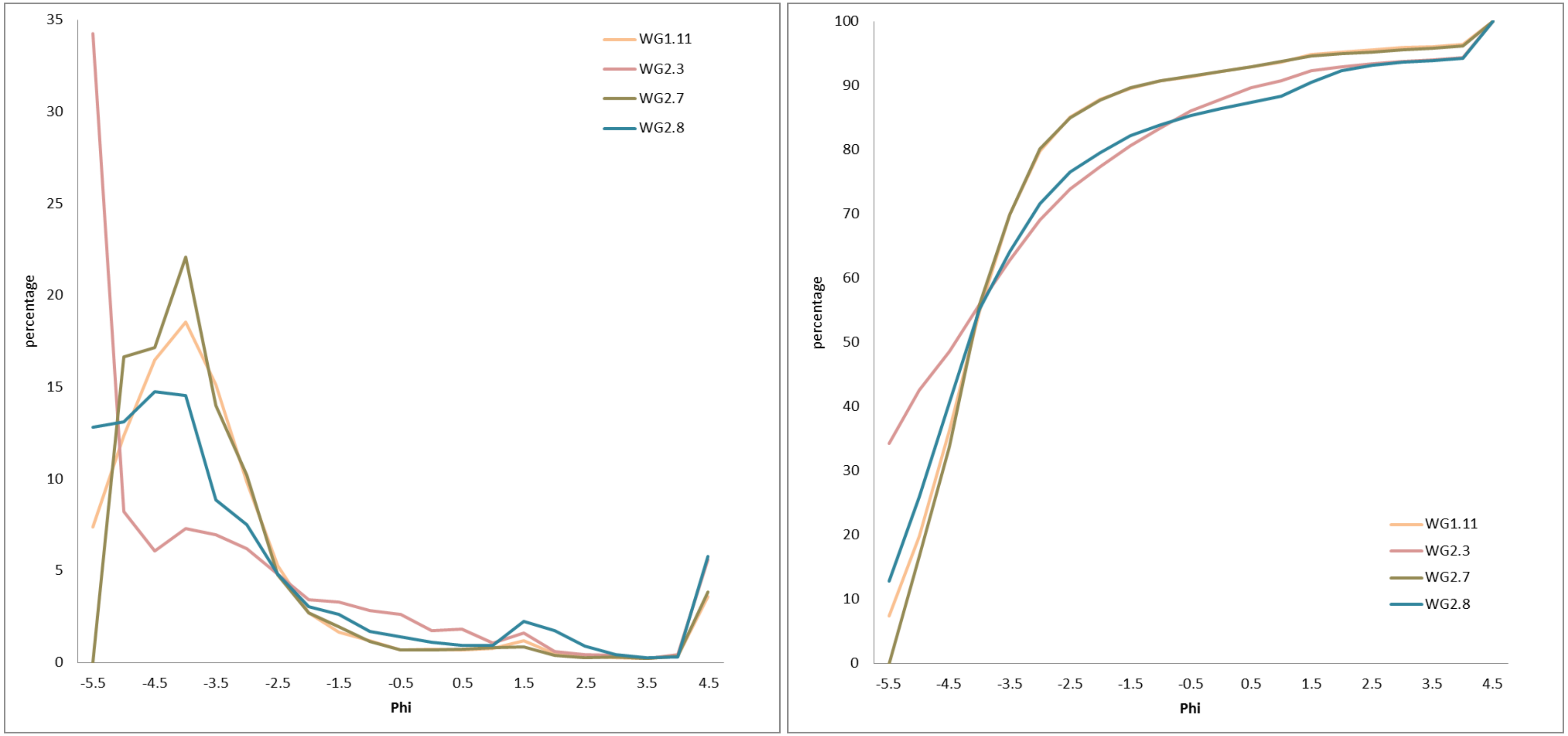

Figure 6.11 Particle size distribution of the four gravel samples from Woodgreen showing weight in percentages of each size fraction (left) and the cumulative percentage of the weight in percentages (right).

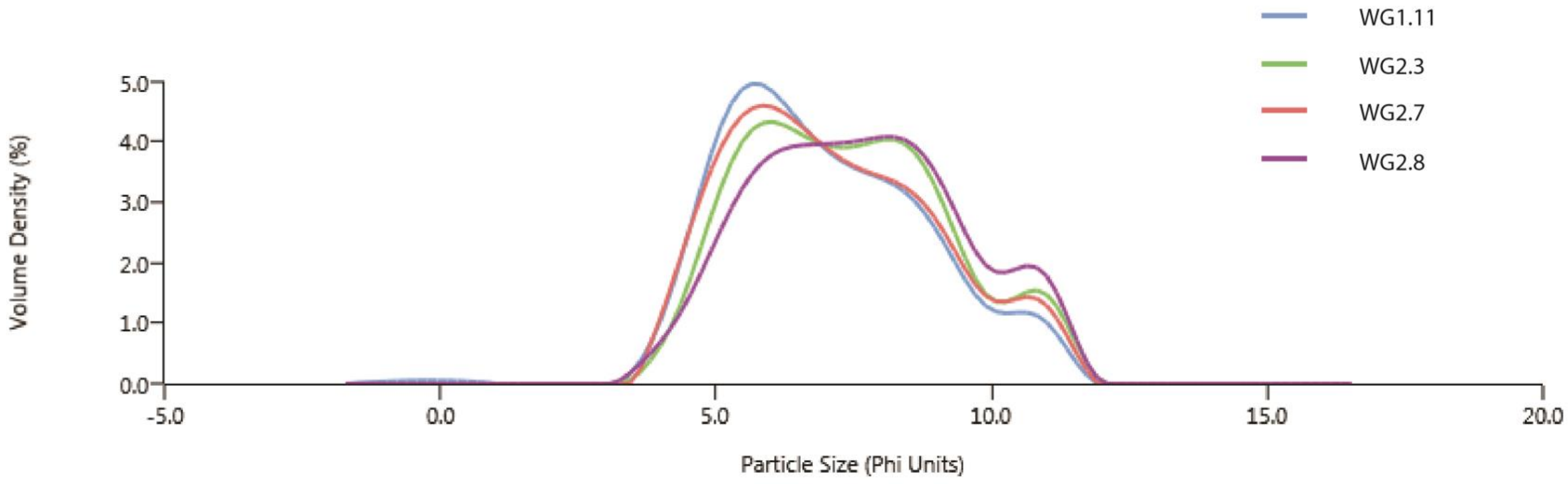

Figure 6.12 Comparison of particle size distributions of the <63µm fraction from WG1.11, WG2.3, WG2.7 and WG2.8.

6.6 Somerley Pit

6.6.1 Particle size distribution

Five gravel samples were retrieved from five sediment layers identified in two sections in terrace 6 exposed in Somerley Pit (Figure 6.13). The 45mm-63µm fraction of all samples was wet-sieved. The sediments retained per sieve were dried and weighed to obtain a weight percentage of each sediment fraction of the total sample. The <63µm sediment was analysed using laser diffraction. Image-based automated grainsizing was applied to sediment units throughout both sections. The sections were scanned to allow comparison between sieving data, IBAG results and roughness and ruggedness indices. This section discusses the particle size distribution of each sample based on the sieving and laser diffraction results, followed by a comparison between the samples. Section 6.10.1 presents IBAG results. Section 6.10.2 presents the scan data in comparison to the sieving and IBAG results. Figure 6.14 and Figure 6.15 summarise the data of all samples of the site. The grain size distributions of the individual samples are presented in Appendix 26.

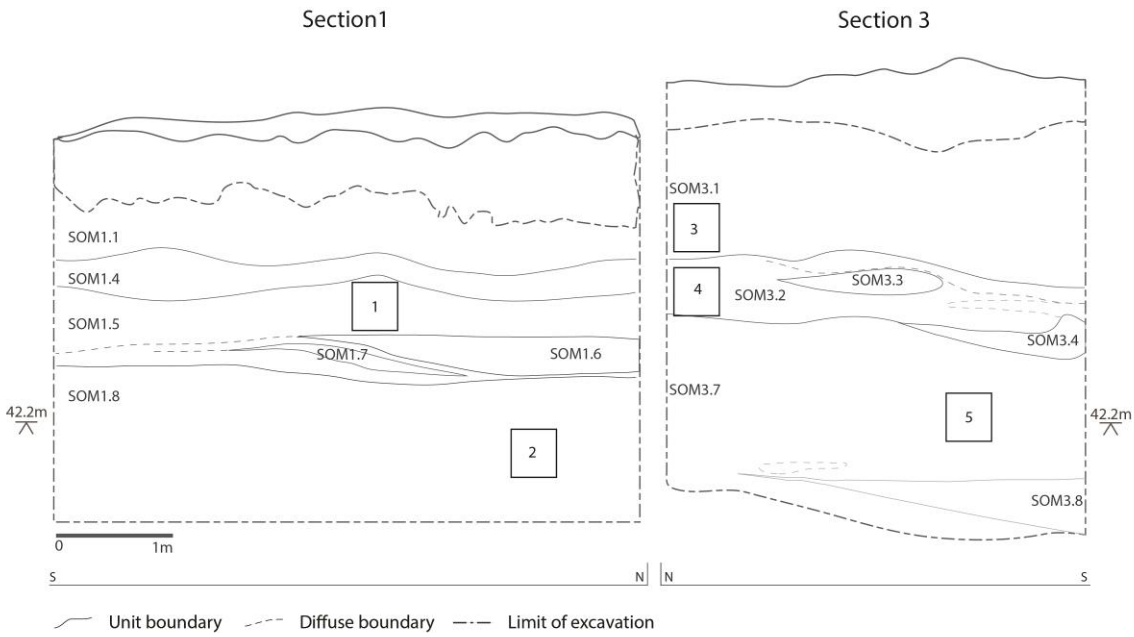

Figure 6.13 Two sections in terrace 6 in Somerley Pit showing gravel sample locations and the main stratigraphic units. 1= SOM1.5; 2=SOM1.8; 3=SOM3.1; 4=SOM3.2; 5=SOM3.7.

Sample SOM1.5 shows a trimodal grain size distribution. The sandy coarse gravel is very poorly sorted. The dominant grain size is 16-22.4mm (-4φ) and D_{50} is 12.5mm. The second peak lies around the coarse to medium sand fraction (1-1.5 φ). The <63μm fraction is 1.6% of the total sample weight. The particle size distribution in this fraction is polymodal. It is mainly composed of coarse silt, very fine silt and clay as can be seen from the peaks in volume density around the size fractions 5, 8, 11φ in the laser diffraction data.

Sample SOM1.8 shows a bimodal grain size distribution. The coarse gravel is poorly sorted. The dominant grain size is 16-22.4mm (-4φ) and D_{50} is 15.4mm. A minor peak in the frequency distribution lies around the medium sand fraction. 2.2% of the sample falls in the <63μm fraction. The laser diffraction data shows a poorly sorted distribution with three peaks around the size fractions 4.5, 8, 11φ, respectively reflecting coarse silt, very fine silt and clay components. Very fine silt is most dominant.

The particle size distribution of SOM3.1 shows a unimodal, very poorly sorted coarse gravel. Clasts of 31.5-45mm (-5φ) are most dominant and D_{50} is 19.3mm. The <63μm fraction is 7.4% of the total sample weight and shows a poorly sorted grain size distribution. Medium to very fine silt is present in almost equal percentages forming a plateau in the frequency distribution curve. A second peak occurs at 11φ. This shows that the <63μm fraction mainly consists of silt with a small clay component.

Sample SOM3.2 shows a trimodal grain size distribution. The sandy coarse gravel is very poorly sorted. The dominant grain size 16-22.4mm (-4φ) and D_{50} is 12.6mm. The second peak lies around the coarse to medium sand fraction (1-1.5φ). The <63μm fraction is just over 1% of the total sample weight. This size fraction mainly consists of very fine silt and a smaller contribution of coarse silt and clay as can be seen from the peaks in volume density around the size fractions 4.5, 8, 11φ in the laser diffraction data.

The grain size distribution of SOM3.7 is trimodal. The coarse gravel is very poorly sorted. Grains of 16-22.4mm (-4φ) make up the largest part of the sample. D_{50} is 13.8mm. A minor peak in the frequency distribution lies around the medium sand fraction. 2.4% of the sample falls in the <63μm fraction. The laser diffraction data shows a possible bimodal distribution, one representing the silt fraction and one around 11φ reflecting a clay component.

Sediment statistics were based on the combined sieving and laser diffraction data and are presented in Appendix 27. The particle size distributions obtained from sieving and laser diffraction provide a frequency distribution and cumulative frequency distribution of each sample, which are compared in Figure 6.14. Figure 6.15 shows the laser diffraction particle size distribution of the <63µm fraction of the four samples.

The sediment statistics and frequency distribution curves show a strong resemblance between SOM1.5 and SOM3.2 Both contain similar percentages of gravel and sand, most clearly demonstrated in the cumulative grain size distribution. SOM1.8 and SOM3.7 also show a very comparable grain size distribution. The grain size distribution of SOM3.1 differs from the two pairs with a coarser and more dominant gravel fraction and less sand but slightly more silt and clay.

The particle size distribution in the <63µm fraction shows more variance, especially in the silt component. SOM1.8 contains the highest percentage of coarse silt. SOM3.2 shows the highest percentage of very fine silt, followed by SOM1.5. The particle size distribution of the five samples confirms the correlation between SOM1.5 and SOM3.2 and SOM1.8 and SOM3.7 and the distinction between those and the difference of SOM3.1 from the other deposits.

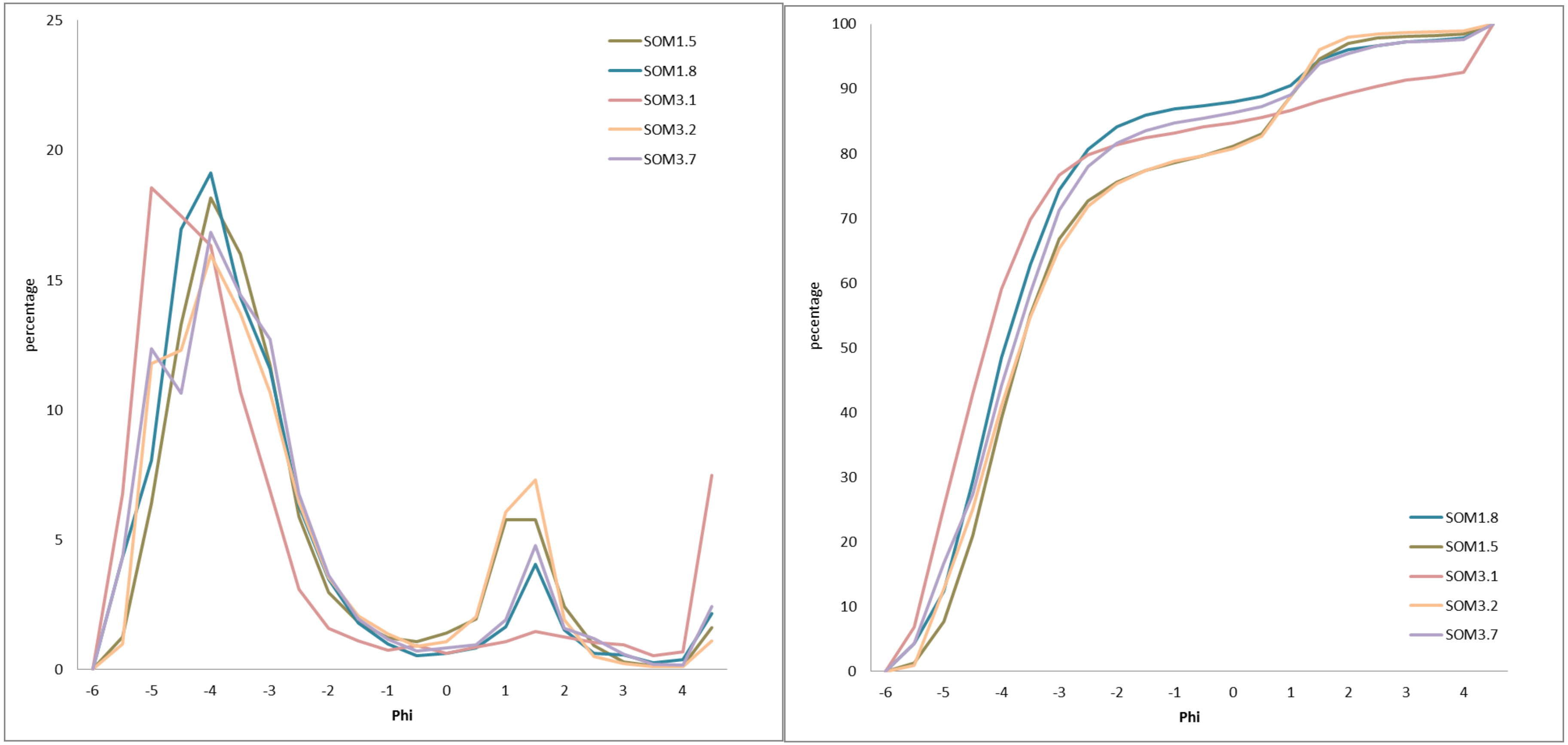

Figure 6.14 Particle size distribution of the five gravel samples from Somerley showing weight in percentages of each size fraction (left) and the cumulative percentage of the weight in percentages (right).

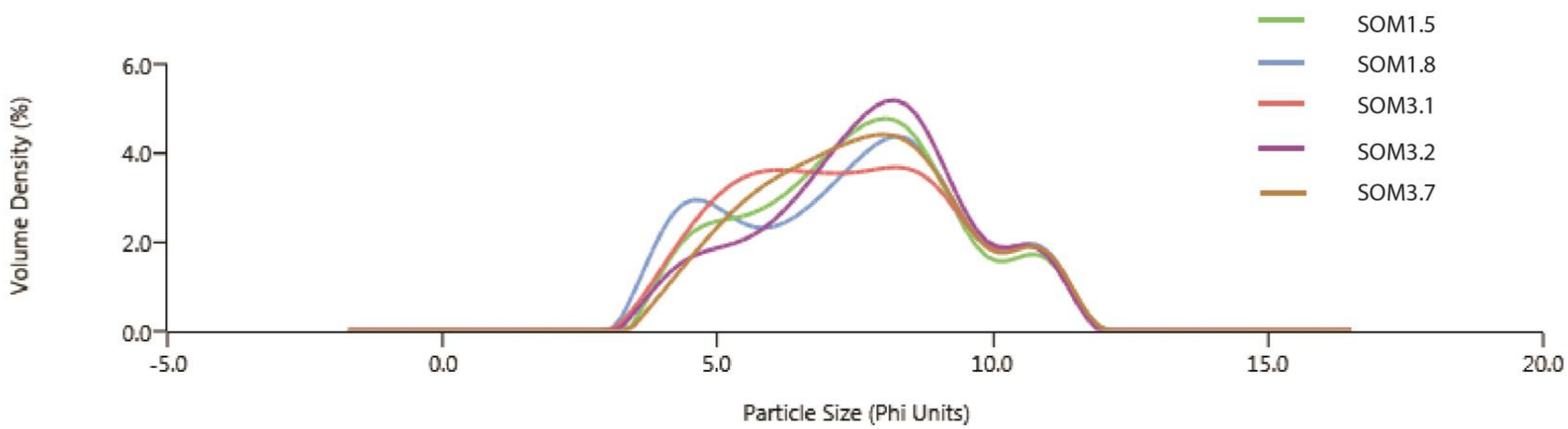

Figure 6.15 Comparison of particle size distributions of the <63µm fraction from SOM1.5, SOm18, SOM3.1, SOM3.2 and SOM3.7.

6.7 Ashley Pit

6.7.1 Particle size distribution

Three gravel samples were collected from three different sediment layers identified in a section in terrace 5 exposed at Ashley Pit (Figure 6.17). The 45mm-63μm fraction of all samples was wet-sieved. The sediments retained per sieve were dried and weighed to obtain a weight percentage of each sediment fraction of the total sample. The <63μm sediment was analysed using laser diffraction. Image-based automated grainsizing was applied to sediment units throughout both sections. The section was scanned to allow comparison between sieving data, IBAG results and roughness and ruggedness indices. This section discusses the particle size distribution of each sample based on the sieving and laser diffraction results, followed by a comparison between the samples. Section 6.10.1 presents IBAG results. 6.10.2 presents the scan data in comparison to the sieving and IBAG results. Figure 6.17 and Figure 6.18 summarise the data of all samples of the site. The grain size distributions of the individual samples are presented in Appendix 29.

Sample ASH1.6 shows a polymodal grain size distribution. The coarse gravel is very poorly sorted. Gravel of 45mm (-5.5φ) and over and 22.4-31.5mm is most abundant. D_{50} is 15.2mm. The <63μm fraction is 2.5% of the total sample weight. The particle size distribution in this fraction is poorly sorted. It is mainly composed of coarse silt, very fine silt and clay as can be seen from the peaks in volume density around the size fractions 5, 8, 10.5φ in the laser diffraction data.

The particle size distribution of ASH1.11 is poymodal. The sandy, very coarse gravel is very poorly sorted. The coarse gravel is poorly sorted. Clasts of 45mm (-5.5φ) and over and 16-22.4mm are most dominant (-4φ). The sand is mainly medium and coarse (1-1.5φ). D_{50} is 13.5mm. Only 0.76% of the sample falls in the <63μm fraction and contains mainly very fine silt and lesser percentages of coarse silt and clay.

The particle size distribution of ASH1.13 shows a bimodal, very poorly sorted medium gravel. Clasts of 16-22.4mm (-4φ) are most dominant and D_{50} is 10.8mm. The <63μm fraction is 1.2% of the total sample weight and mainly contains very fine silt and a smaller percentage of clay.

Sediment statistics were based on the combined sieving and laser diffraction data and are presented in Appendix 30. Percentage calculations of the particle size distribution data from laser diffraction relative to the sieving data provide integrated frequency and cumulative frequency distributions of each sample, which are compared in Figure 6.17. Figure 6.18 shows the laser diffraction particle size distribution of the <63μm fraction of the three samples.

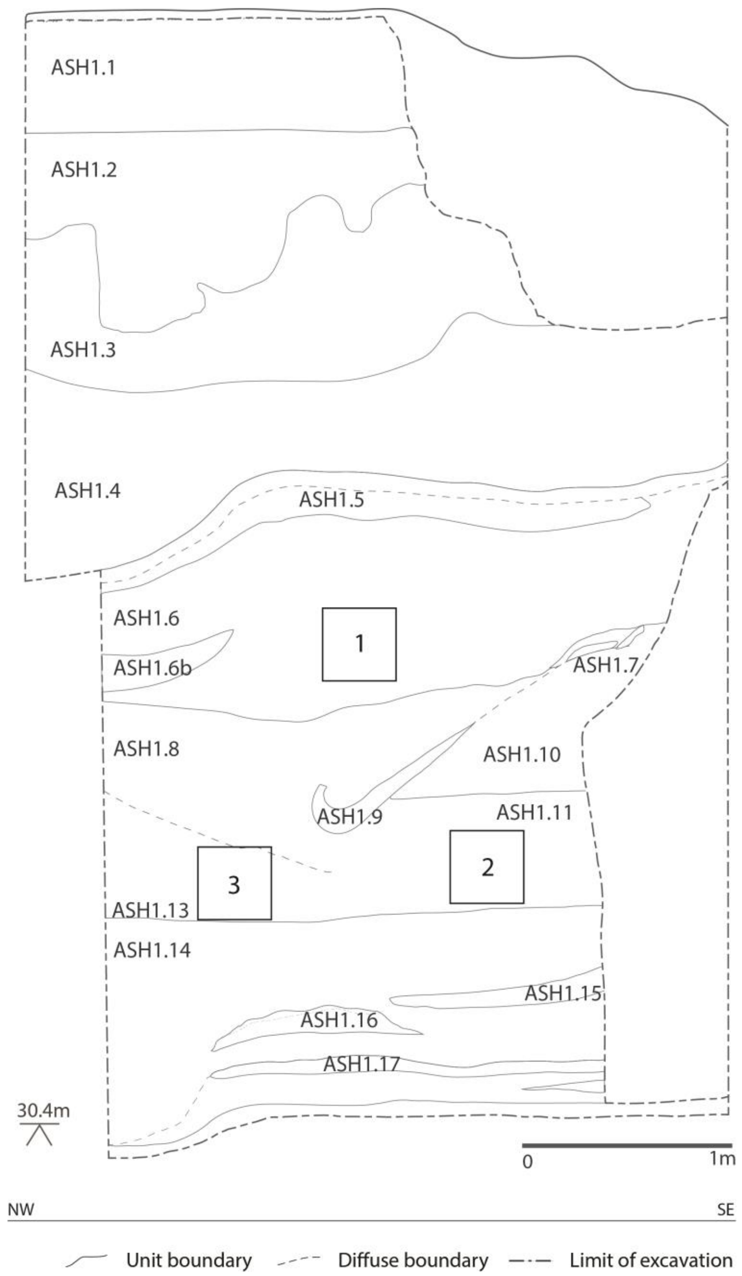

Figure 6.16 Section in terrace 5 at Ashley Pit showing gravel sample locations and the main stratigraphic units. 1= ASH1.6; 2=ASH1.11; 3=ASH1.13.

The sediment statistics and frequency distribution curves show no clear resemblance between the three samples. The composition of ASH1.6 and ASH1.13 is comparable; the difference between the two mainly consists of a different particle size distribution in the gravel fraction. ASH1.11 stands out for its higher sand content (22.9%) relative to the other samples. The particle size distribution in the <63µm fraction shows the strongest resemblance between ASH1.11 and ASH1.13, however the latter does not show the clear presence of coarse silt as is the case for ASH1.11. The particle size distribution of ASH1.6 in the <63µm fraction is coarser, mainly consisting of silt and containing a higher proportion of coarse silt than ASH1.11 and ASH1.13. The particle size distribution of the three samples confirms the identification of the sediments as separate deposits.

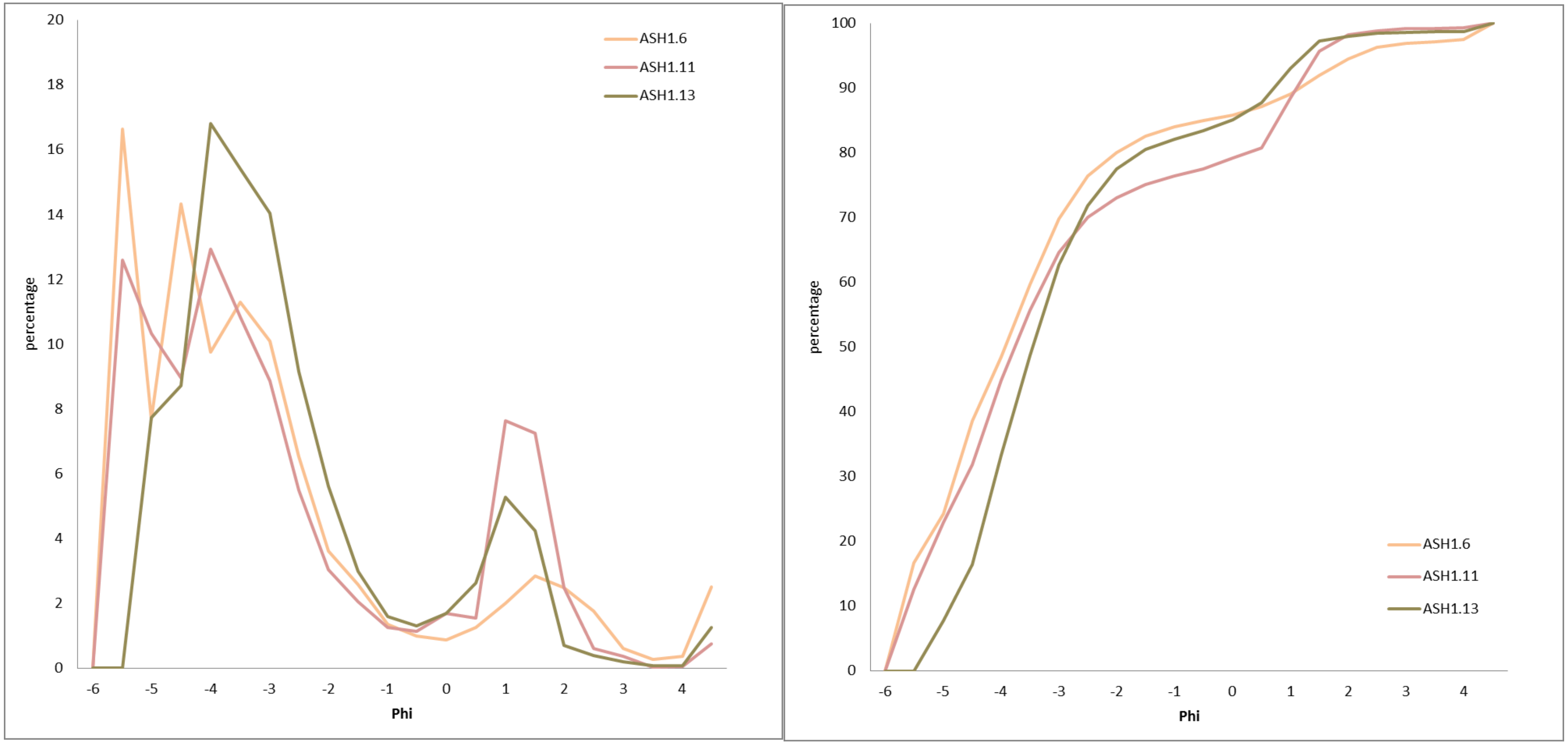

Figure 6.17 Particle size distribution of the three gravel samples from Ashley pit showing weight in percentages of each size fraction (left) and the cumulative percentage of the weight in percentages (right).

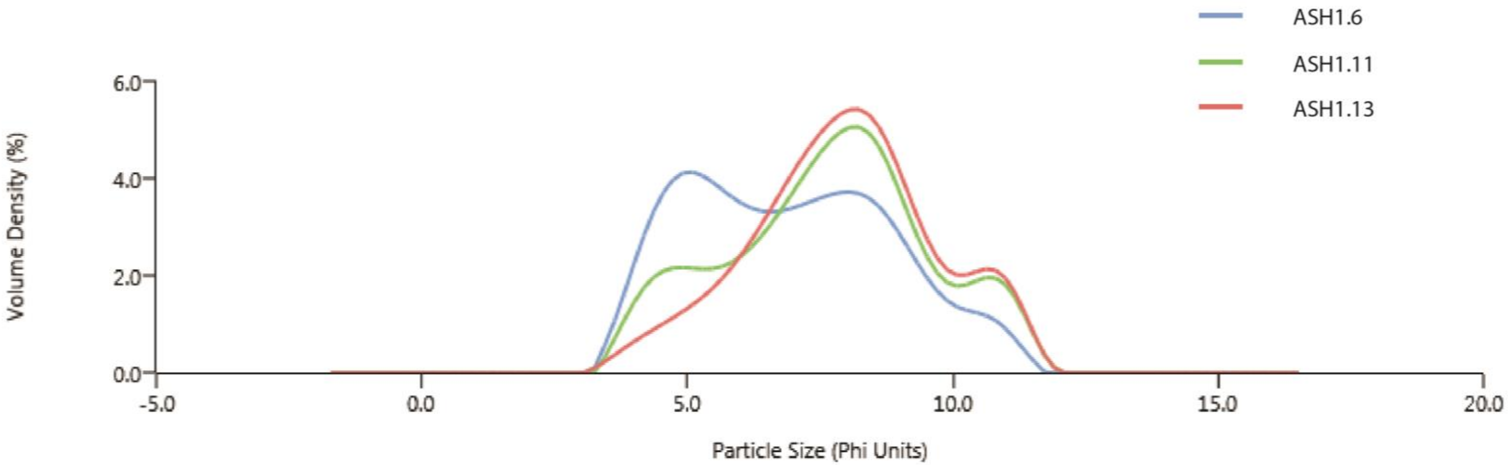

Figure 6.18 Comparison of particle size distributions of the <63μm fraction from ASH1.6, ASH1.11 and ASH1.13.

6.8 Clast lithology

From each site two sediment samples were analysed for clast lithology. Each sample was graded for grain size distribution analysis (4.3.2). The lithology was described for all size fractions >8mm and is summarised in Appendix 32. Counting the lithology of more than one size range can provide a characterisation of the sediment (Bridgland 1986). The lithological composition of the different grades presented in figures Appendix 32 and an assessment of used fractions in previous works led to the selection of the 11.2-16mm and 16-31.5mm grades for comparison of the lithological composition of the terraces (Allen and Gibbard 1993; Clarke 1981; Kubala 1980). The results are presented in Table 6.1 and Figure 6.19.

Lithologies encountered were:

- Flint. This was by far the most dominant lithology, derived from the Chalk, present in the north of the Avon valley.
- Tertiary flint. Rounded to well-rounded flint derived from gravel beds within Lower Tertiary deposits or from Clay-with-flints. The Tertiary bedrock is found in the Avon valley from Breamore southwards. Clay-with-flint is patchily distributed over the Chalk.
- Sandstone. Coarse to fine sandstone is mainly derived from Lower Cretaceous deposits in the northwest of the research area. Some ferruginous sandstone however may have been derived from iron-concreted Tertiary sand beds.
- Chert. The chert that was mainly encountered in the terrace deposits in the Avon valley was orange-brown, grainy chert derived from Greensand deposits that outcrops in the northwest of the research area.
- Limestone. Limestone is derived from Lower Cretaceous outcrops in the north of the research area.
- Quartz/quartzite. Quartz is a crystalline rock derived from hard rocks. Quartz often forms veins in igneous rocks. Quartzite is a metamorphic rock resulting from sedimentary rocks. Quartz and quartzite may have been derived from local and non-local sources.
- Ironstone. Iron concretion or nodules formed in ferruginous Tertiary sand deposits.

The terraces showed similar lithological compositions. Angular to subangular flint was with 80% or more the most dominant lithology in all samples. Generally, 1-5% of

Tertiary flint was present, but slightly more in the samples from Somerley and Ashley and in HB1.8 22.4-31.5mm. Tertiary flint was totally absent from Bemerton in the 11.2-16mm and 16-31.5mm fractions (but see a small trace in the smaller grades in Appendix 32). This pattern reflects the distribution of the Tertiary bedrock and clay-with-flint. At Bemerton, located on the Chalk, the clay-with-flint deposits are the only source for Tertiary pebbles. Lower down in the valley where the Avon incised in Tertiary bedrock, this deposit is the likely and much more widely available source. This pattern is also described by Kubala (1980) and Clarke (1981) who observed an increase in Tertiary pebbles to the southwest of the Avon valley where Tertiary gravels outcrop.

All samples contained around 1-5% sandstone except the gravel from Bemerton. Here both size fractions in both samples contained almost 10% sandstone. Sandstone is derived from Lower Cretaceous strata and is not very durable. This explains the decrease of sandstone down the valley away from the source and in the lower terraces, which are increasingly reworked. Bemerton is located close to the source.

The chert component was mainly made up of Greensand chert. Between 0.5-1% chert was found in the majority of the samples. The 22.4-31.5mm fractions from both the Bemerton samples had slightly higher chert contents around 1.8%. Sample SOM1.1 11.2-16mm contained the largest amount of chert at 3.37%. The slightly higher percentages observed at Bemerton can be explained by its position close to the Lower Cretaceous outcrops. The high percentage encountered in the SOM1.1 11.2-16mm sample can possibly be explained by the contribution of sediments transported to the site by the tributary just north of the Somerley (see Figure 5.1) which drains the Cretaceous bedrock to the northwest (see Figure 2.4).

Limestone was present in very low percentages (<1%) in a few samples (Bemerton, Somerley, Ashley). The presence of Chalk and limestone generally rapidly decreases away from the Chalk bedrock (Kubala 1980). It is usually absent from the 'Older river terraces' and T6-10 as these deposits are increasingly decalcified through percolating rainwater (ibid.). The presence of some limestone clasts at Bemerton is the result of the location of the site on Chalk bedrock and the trace of limestone encountered at Somerley and Ashley is likely the result of uncompleted decalcification of these terrace deposits as opposed to the higher terraces.

Traces of vein-quartz and ironstone were found in a few of the terraces. The latter was only encountered in the smaller size fractions (see Appendix 32). Quartz could have been derived from clay-with-flint and Tertirary deposits that include some far-travelled durable lithologies. The ironstone is most likely incorporated through erosion of ferruginous Tertiary sand beds.

The majority of the flint (between 60-90%) is subangular with often around 10% angular and subrounded clasts and a smaller percentage of very angular clasts. The broken surface of the broken Tertiary flints was most often angular to subangular. Sandstone was most often subangular to rounded and occasionally well-rounded. Chert was most often subangular to subrounded and limestone and chalk was most often subrounded. Vein-quartz was most often sub-rounded to rounded.

The generally more rounded shapes observed for the sandstone and limestone clasts is the result of these rocks being less durable. The general roundedness of the very durable quartz affirms the suggestion that these clasts were likely derived from Tertiary deposits during which formation they became rounded in a beach-environment (Edwards and Freshney 1987; Gibbard 1986). The presence of very angular and angular flint and broken Tertiary flint may indicate some *in situ* breakage possibly as a result of frost damage. The dominance of subangular flint in the river terraces indicates substantial reworking of the flint since its erosion out of the Chalk (see Appendix 33).

The most prominent pattern that is revealed from the clast lithology analysis of these sites is the distinctive composition found at Bemerton, and the general increase of Tertiary flint at Somerley and Ashley. Limestone clasts are only found at Bemerton and the lower terraces. Vein-quartz appears more randomly. The clast lithology described here is in good agreement with observations made by Kubala (1980) and Clarke (1981) who described the gravel from the Avon terraces as uniform, with fine to coarse, subangular to subrounded flint from the Upper Chalk forming 80% of the clasts. Rounded to well-rounded Tertiary pebbles were generally present. Pebbles of chalk, Purbeck limestone, Lower Cretaceous sandstone, and ferruginous Tertiary sandstone were encountered as were traces of vein-quartz, ironstone and jasperine flint (Clarke 1981, Kubala 1980).

The pattern observed from the here studied sites is mostly influenced the local geology of the sites. The non-durable clasts of sandstone and chalk are well represented at Bemerton, closest to its source. The increase of Tertiary pebbles at the sites away from the chalk is the result of the incorporation of clasts from the underlying Tertiary beds. The trace of chalk and limestone in the lower terraces indicates these deposits are lithologically less 'mature', meaning they probably underwent less reworking and decalcification (Bridgland 1986). Possibly the same can be said about the terrace deposit at Bemerton although the influence of the local geology on clast lithology composition obstructs direct comparison with the lower and more southern terrace deposits.

SAMPLE	Size fraction	Flint	Tertiary flint	Chert	Sandstone	Limestone	Quartz	**Count**
BEM2.4a	22.4-31.5mm	88.54	-	1.72	9.74	-	-	**349**
	11.2-16mm	89.19	-	0.77	9.65	-	0.39	**259**
BEM2.4b	22.4-31.5mm	88.45	-	1.82	9.73	-	-	**329**
	11.2-16mm	89.07	-	-	9.84	0.82	-	**366**
HA1.1	22.4-31.5mm	93.79	3.11	0.31	2.80	-	-	**322**
	11.2-16mm	94.08	3.27	0.61	2.04	-	-	**490**
HA1.3	22.4-31.5mm	90.35	2.89	0.96	5.79	-	-	**311**
	11.2-16mm	93.64	2.83	1.06	2.47	-	-	**283**
HB1.2	22.4-31.5mm	93.89	1.11	0.56	4.44	-	-	**360**
	11.2-16mm	95.91	0.88	0.29	2.92	-	-	**342**
HB1.8	22.4-31.5mm	87.39	7.16	0.57	4.87	-	-	**349**
	11.2-16mm	93.80	3.23	0.99	1.74	-	0.25	**403**
WG2.3b	22.4-31.5mm	95.89	2.28	0.46	1.37	-	-	**219**
	11.2-16mm	96.50	1.27	-	2.23	-	-	**314**
WG1.11	22.4-31.5mm	95.22	2.39	-	2.39	-	-	**544**
	11.2-16mm	92.71	2.43	0.40	4.45	-	-	**247**
SOM1.1	22.4-31.5mm	89.53	6.98	0.78	2.71	-	-	**258**
	11.2-16mm	92.86	1.98	3.37	1.39	-	0.40	**504**
SOM1.5	22.4-31.5mm	90.55	6.04	0.79	1.84	0.79	-	**381**
	11.2-16mm	92.58	4.15	-	2.37	0.89	-	**337**
ASH1.6	22.4-31.5mm	90.87	5.94	0.46	2.74	-	-	**219**
	11.2-16mm	94.74	3.29	0.44	1.10	0.22	0.22	**456**
ASH1.11	22.4-31.5mm	92.26	5.81	0.43	1.29	-	0.22	**465**
	11.2-16mm	94.41	3.50	-	2.10	-	-	**286**
ASH1.13	22.4-31.5mm	92.31	5.41	0.57	1.71	-	-	**351**
	11.2-16mm	92.75	5.10	0.27	1.88	-	-	**745**

Table 6.1 Clast lithology of the 22.4-3.15mm and 11.2-16mm size fractions of sediments from the terrace deposits studied in this research.

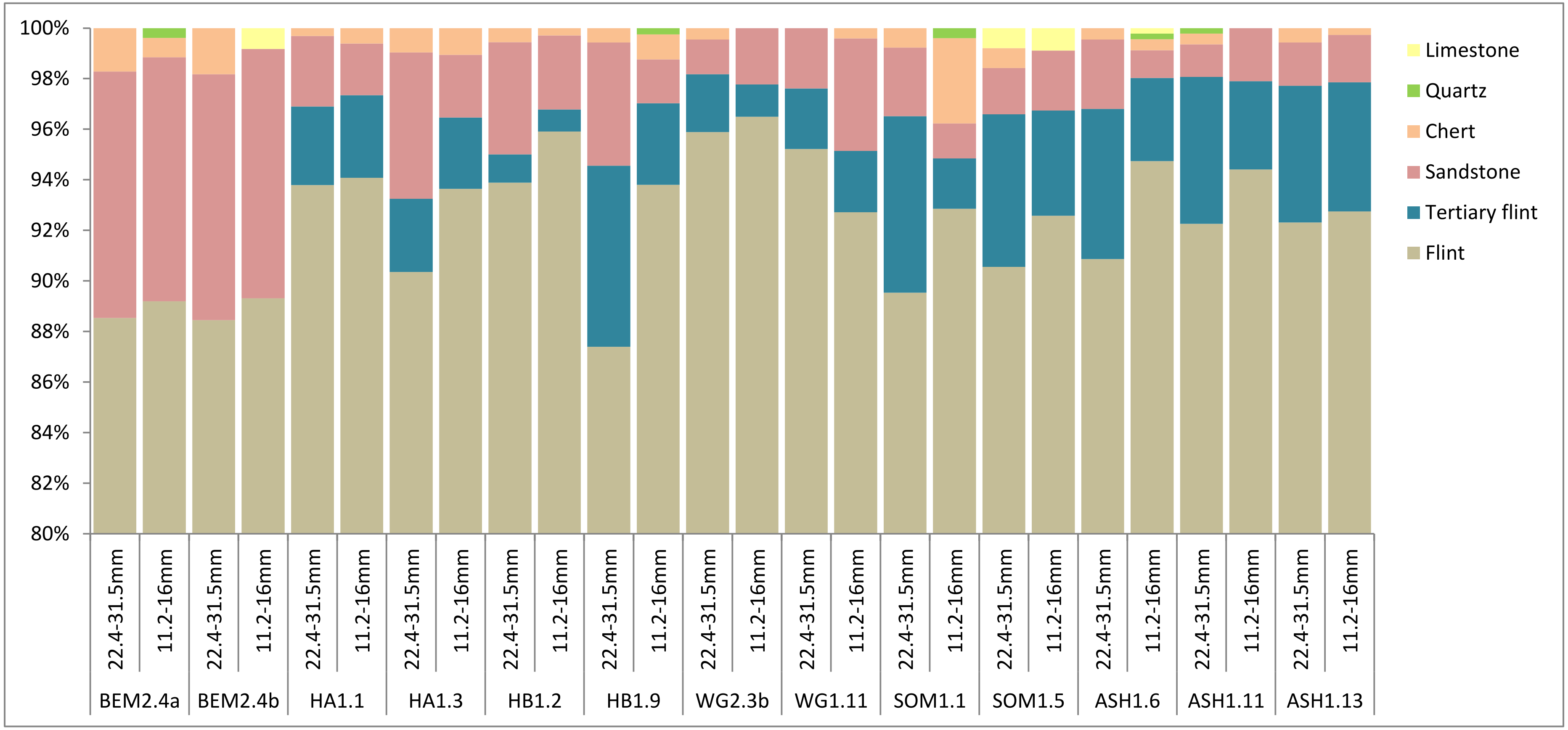

Figure 6.19. Graphic presentation the clast lithology composition of the analysed sediments (sediment samples are plotted on the x-axis). Lithologies are presented as percentages of the total stone count per sample and plotted of the y-axis.

6.9 Palynological analysis

Fine-grained sediments within the terrace deposits that were thought to have had the potential to preserve pollen were sampled for palyonological analysis (see Appendices 5, 7, 9, 11 and 13 for sample locations). Coarse river terrace deposits generally show poor pollen preservation (Cushing 1967; Cruse 1987; Pearsall 2015). The sampled sediments were expected to contain low densities of pollen grains. It was therefore decided that if conventional sediment volumes ($1cm^3$) yielded >10 pollen, a bulk sample would be processed and analysed. The concentration of pollen and other plant and insect material in the sediments was calculated using a marker grain (Lycopodium) (Moore et al. 1991). Eleven samples from six units were prepared to conduct the initial assessment of pollen content, which results are presented in Table 6.2.

The pollen counts were generally low, and in order to reach the minimum marker grain pollen count multiple glass slides needed to be prepared for several samples. All samples contained small quantities of non-pollen palynomorphs and plant cells, and all except sample EE7 contained insect exoskeleton fragments. Very little pollen was present in any of the samples except EE12 which contained 17 pollen grains. Between all slides, 8 pollen types were identified. *Betula* Birch was best represented and was found in all except the EE5 and EE10 samples. The remaining pollen types were only found once or twice in total over all the samples. Three pollen grains could only be identified as comparable to known pollen types (cf.). These included two cf. *Salix* Willow and one cf. *Sparganium* Bur-reed. Four pollen grains were too poorly preserved to be identified. Pollen preservation was best in ASH1.9, represented in samples EE11 and EE12, which pollen assemblage is briefly further discussed. A bulk sample of EE12 was prepared in the hope to obtain a larger pollen assemblage. Unfortunately, this did not result in sufficient numbers of pollen for conventional pollen analysis.

The presence of *Betula* Birch and *Pinus* Pine might reflect a regional vegetation of woodland on well-drained, nutrient poor grounds. *Ulmus* Elm could have grown on more basic grounds and represents a more thermophilous species than *Betula* and *Pinus*. Cf. *Salix* and Poaceae possibly represent the vegetation in the more open and light areas in the landscape, for example on the floodplains. *Sparganium* Bur-reed is usually found along the waterside or on damp grounds. The presence of this type of habitat may be indicated by cf. *Sparganium*. These types of pollen are not uncommon for cool temperate climates, which is in agreement with the type of environment suggested by the sediment deposits (Ellenberg 1979, Schaminée et al. 2010, Tamis et al. 2004, Weeda et al. 2005).

This tentative reconstruction may reflect some aspects of the environment in the Avon valley during the deposition of ASH1.9. However, this should be approached cautiously. Such low pollen concentrations do not provide a statistically reliable ground for environmental reconstruction and may represent a reworked assemblage (Birks and Birks 1980; Fægri and Iversen 1989; Lowe and Walker 1997). The presence of pollen and other plant and insect remains has shown that fine sediments from the Avon river terrace deposits do contain climate proxies albeit in small quantities. In terrace deposits with limited organic deposits to aid chronological and environmental reconstructions, fine grained sediments should be sampled as they do provide valuable additional information, although often with low pollen densities.

SITE		Woodriding	Hatchet Gate Farm				Somerley		Ashley			
Unit		HB1.8	HA1.4				SOM3.4		ASH1.9a	ASH1.9b	ASH1.16	ASH1.17
Sample		EE1	EE2	EE3	EE4	EE5	EE6	EE7	EE11	EE12	EE9	EE10
No. of slides		1	2	1	1	2	1	2	2	2	2	1
No. Lycopodium		500	201	410	367	421	503	392	500	500	391	327
NPP		41	4	7	22	74	10	71	6	21	10	4
Plant material		170	19	57	61	83	133	632	79	183	64	47
Poss. Hyphal elements		3	11	4	1	4	2	7	3	32	8	11
Insect?		11	1	6	3	23	6	0	2	13	4	7
Microscopic charcoal		63	60	44	22	113	56	103	258	378	54	96
Pollen		**0**	**0**	**1**	**2**	**3**	**0**	**2**	**4**	**17**	**2**	**1**
Of which:	Betula	-	1?	1	2	-	1?	1	2	9	2	-
	Pinus	-	-	-	-	-	-	-	-	1	-	-
	Quercus	-	-	-	-	1	-	-	-	-	-	-
	Ulmus	-	-	-	-	-	-	-	-	1	-	1
	cf. Salix	-	-	-	-	-	-	-	1	1	-	-
	Ericaceae	-	-	-	-	-	-	1	-	-	-	-
	Poaceae	-	-	-	-	-	-	-	1	2	-	-
	cf. Sparganium	-	-	-	-	-	-	-	-	1	-	-
	NID	-	-	-	-	2	-	-	-	2	-	-

Table 6.2 Results of palynological analysis of fine-grained sediments from Woodriding, Hatchet Gate Farm, Somerley and Ashley.

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6.10 Methodological developments

6.10.1 Image-based automated grainsizing

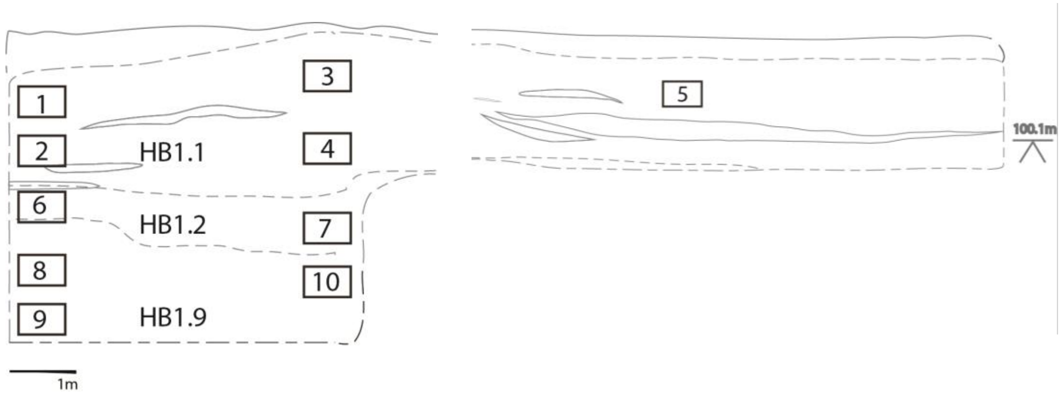


Figure 6.20 Section in terrace 10 at Woodriding showing photograph locations for image-based automated grainsizing and the main stratigraphic units.

For each sedimentary layer identified at every site, several representative locations were selected for image collection for image-based automated grainsizing (Appendices 20, 25, 28, and 31). The method is discussed based on the results from Woodriding where 10 photographs were taken related to the three main sedimentary units identified in the field (Figure 6.20). The photographs used for the IBAG analysis and the resulting grain size distributions are presented in Figure 6.21-6.27. The IBAG results of the seven photographs show similar poorly sorted, bimodal grain size distributions with the majority of the grains falling between 8-0.5mm (-3 and 0.5φ) and below 0.35mm resulting from the detection limit. In contrast, the data obtained from frame 3 (HB1.1) does not record a 1.5φ and smaller fraction but a high percentage of medium sand (1φ). The clear differences in texture visible in the photographs cannot readily be recognised in the IBAG grain size distributions. A comparison of the results from each photograph is presented in Figure 6.25. This again shows the similarity between the obtained grain size distributions with the exception of frame 3 that shows a large percentage of very coarse sand. The IBAG results are compared with the sieving data in Figure 6.26 and Figure 6.27. The IBAG data shows an offset compared to the sieving results, underrepresenting the larger size fractions (medium to coarse gravel) and over representing the fine gravel to coarse sand fraction and the >0.35mm sediment. The class weight histograms of HB1.2 compared with frame 7 show the best resemblance.

Although the method has been applied successfully in other research (Basell in prep. (Graham, Reid, et al. 2005; Graham, Rice, et al. 2005) its contribution to the understanding of grain size distribution in the terrace deposits studied for this research seems limited. Sediment deposits showing variations in grain size distribution in the field, and in grain size distribution based on sieving data (e.g. HB1.1 and HB1.9), are not reflected in the results obtained from image-based automated grainsizing. A possible explanation is the obscuration of individual clasts by a sheet of finer sediment resulting in poor performance of the watershed segmentation algorithm. Image-based automated grainsizing appears to work best on relatively large, clean clasts. The representation of sand and finer sediments in image-based grainsizing is limited by pixel size and when widely present, the watershed algorithm does detect a homogeneous surface. Therefore, this method is most applicable when the grain size distribution of coarse, clast supported sediments is of interest. However, as it is especially problematic to obtain representative sample sizes for coarse grained sediments, this method can still offer a quick way of recording large clast size distributions.

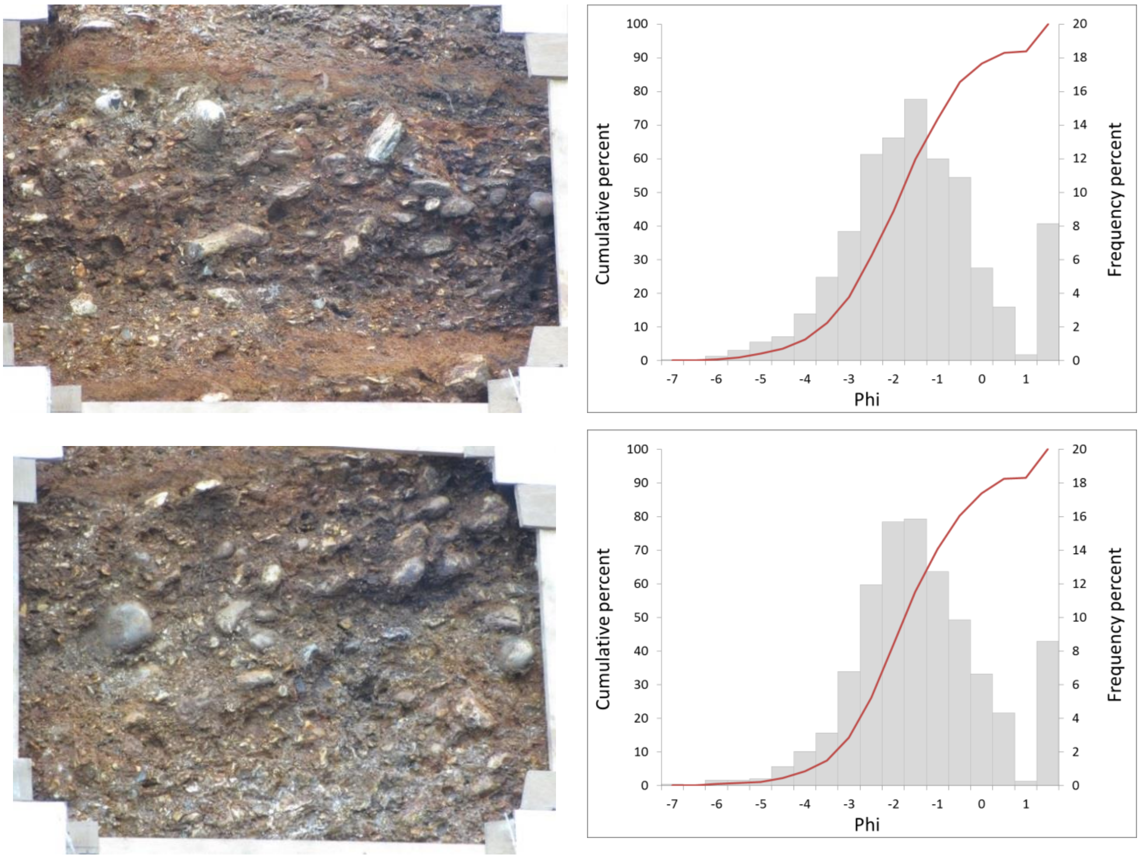


Figure 6.21 Photographs and the resulting grainsize distributions of frame 1 and 2 at Woodring.

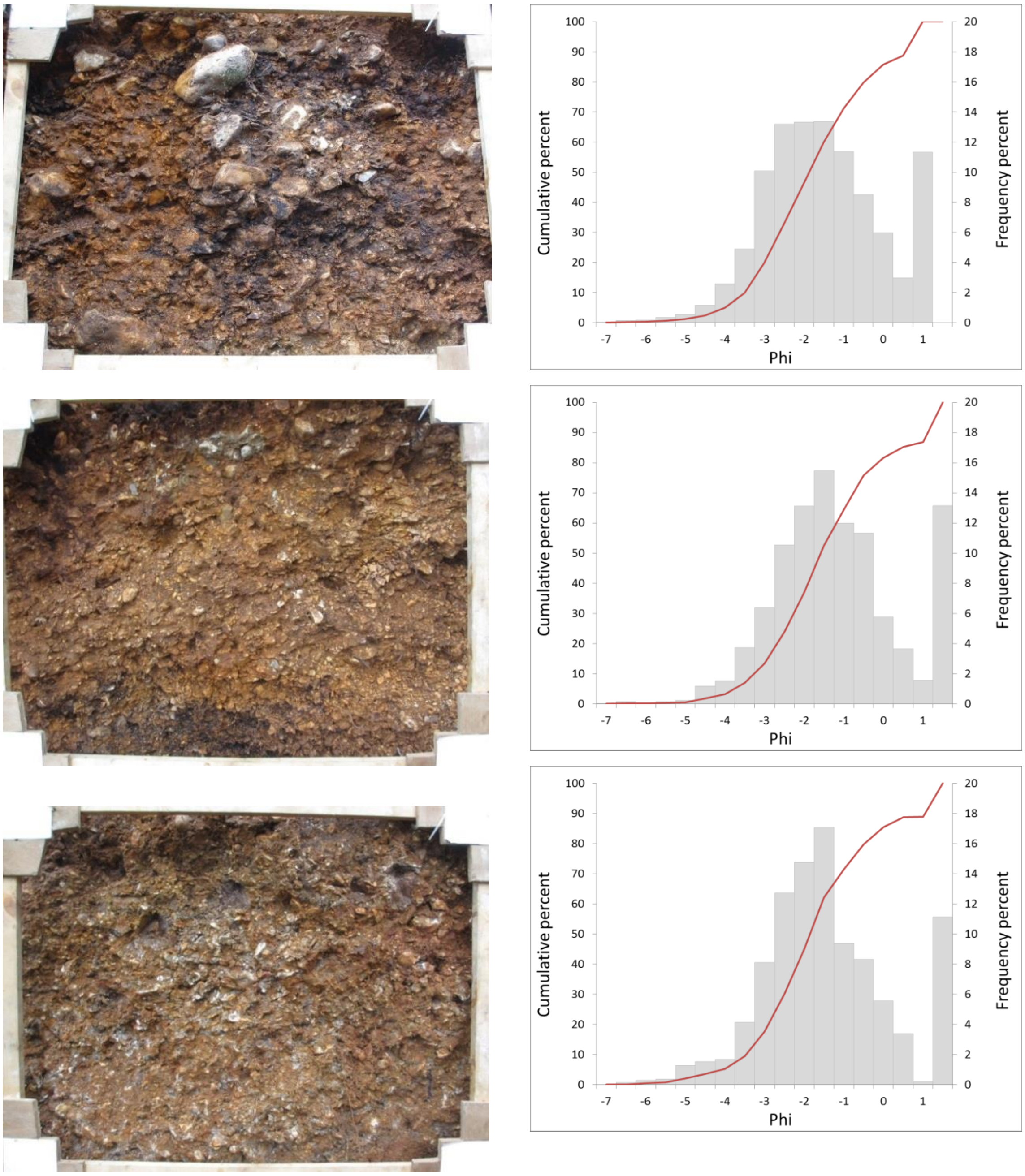


Figure 6.22 Photographs and the resulting grainsize distributions of frame 3-5 at Woodriding.

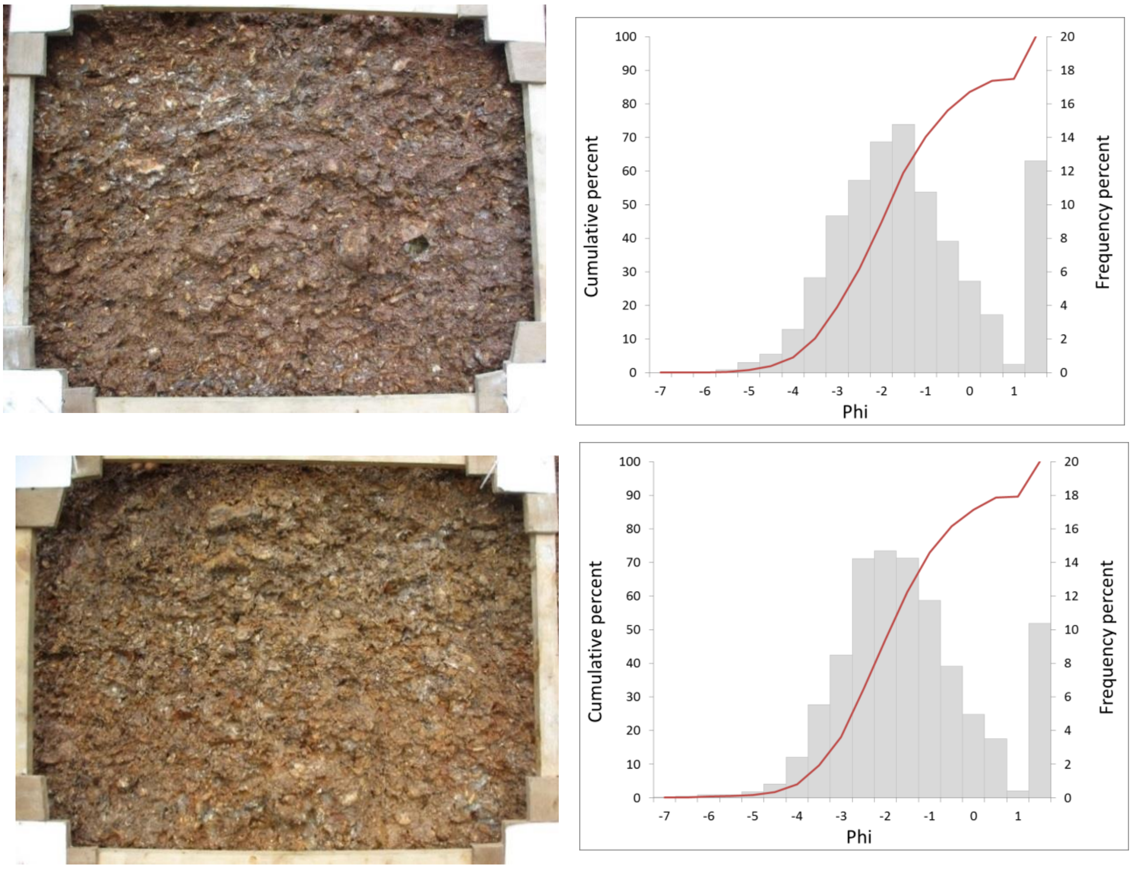


Figure 6.23 Photographs and the resulting grain size distributions of frame 6 and 7 at Woodriding.

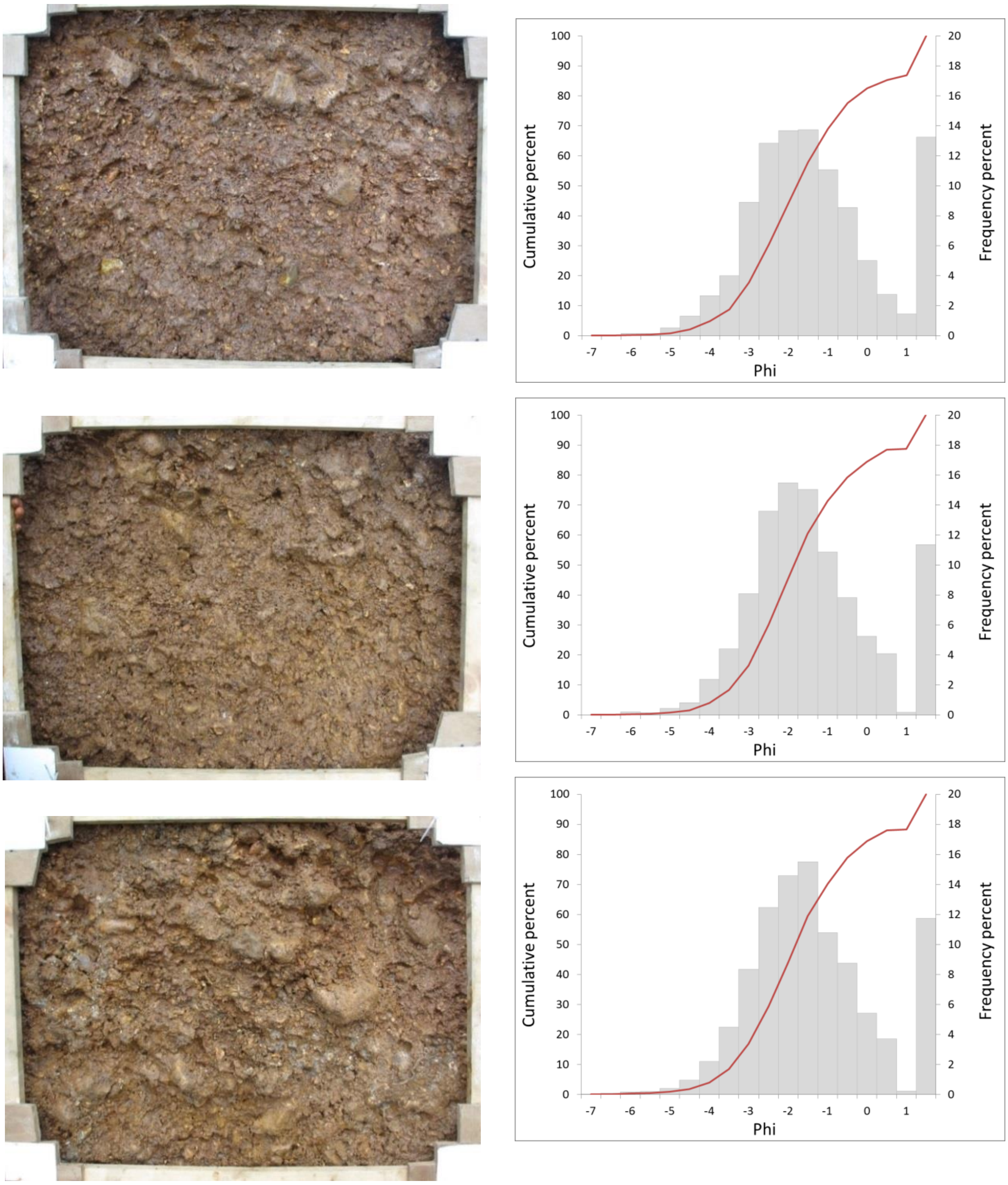


Figure 6.24 Photographs and the resulting grainsize distributions of frame 8-10 at Woodring.

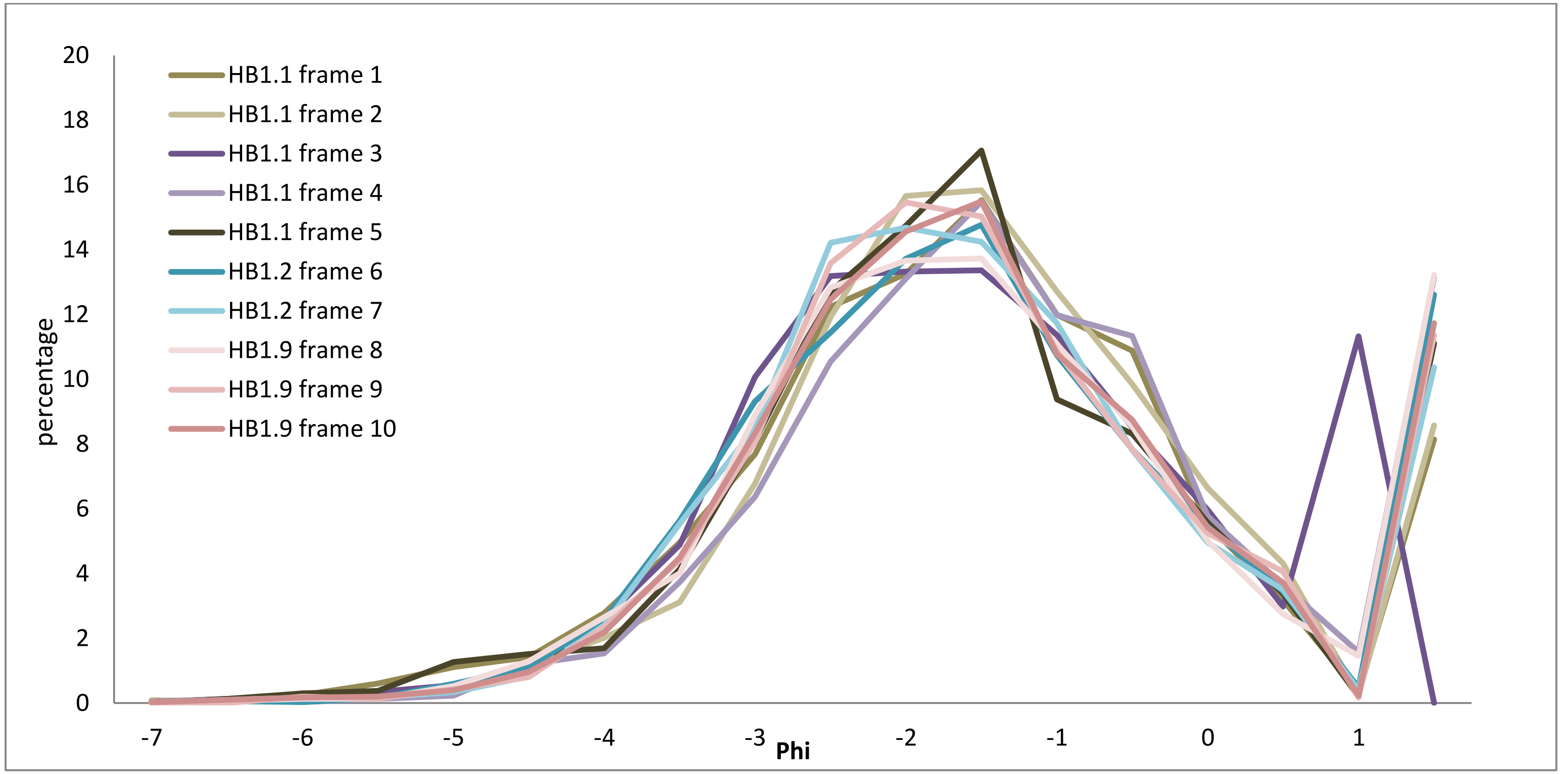
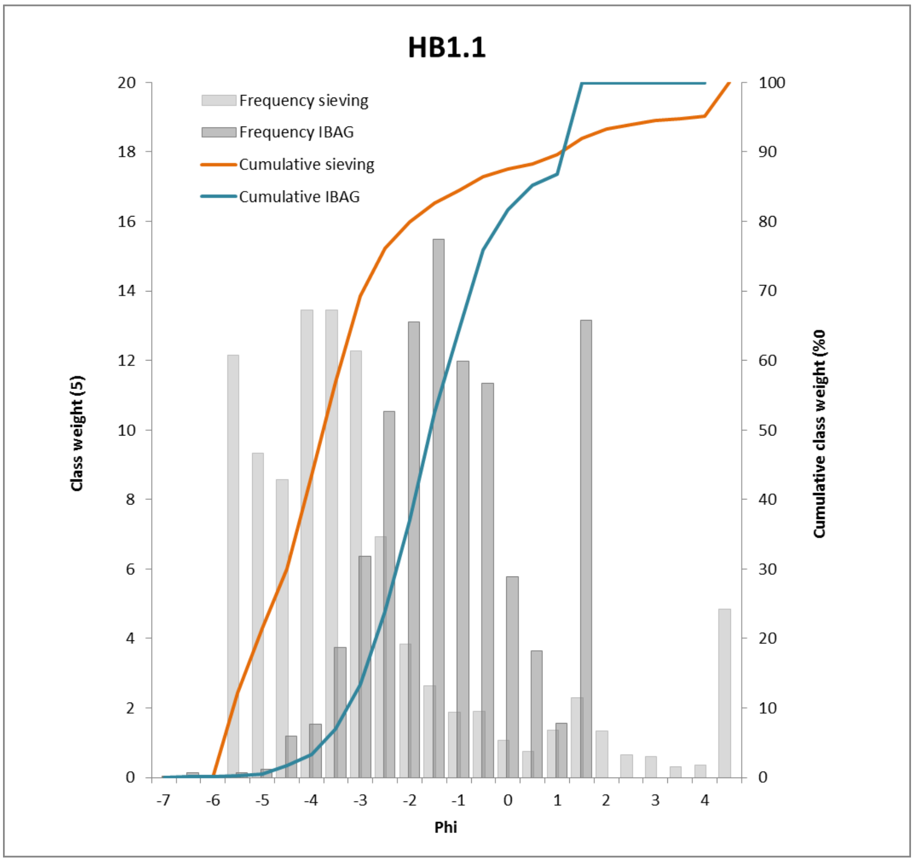


Figure 6.25 Comparison of percentage frequency of the grain size distributions of HB1.1, HB1.2 and HB1.9 obtained from image-based automated grainsizing.



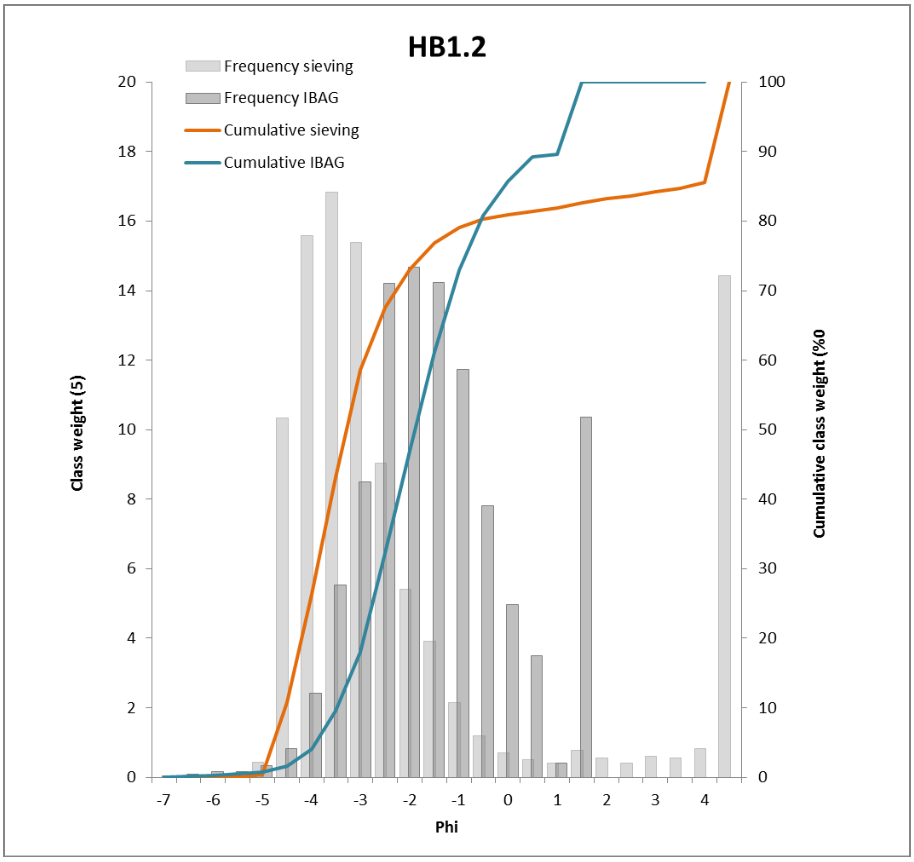


Figure 6.26 Comparison of sieving and IBAG results. HB1.1 was compared with frame 4 and HB1.2 was compared with frame 7.

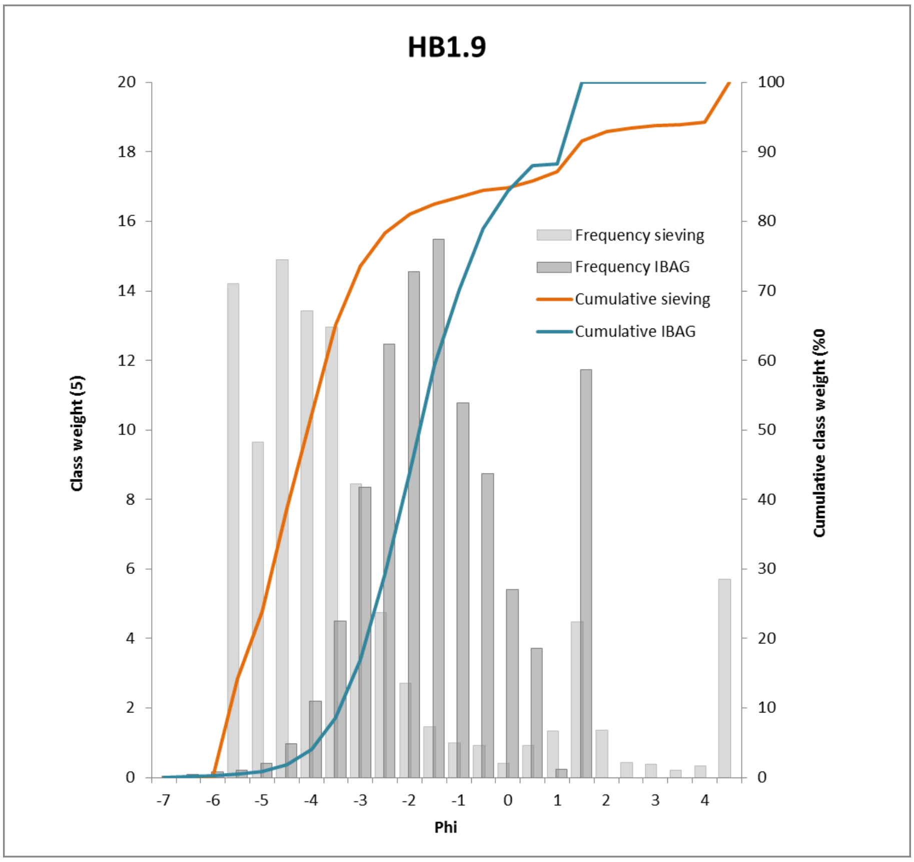


Figure 6.27 Comparison of sieving and IBAG results. HB1.9 was compared with frame 10.

6.10.2 3D Laser Scanning

3D Laser Scanning was used for the recording of all the field sites except Bickton and provided very high-resolution point-cloud data of sediment structures preserved within the terrace deposits. These data revealed differences in the surfaces of various sediment structures and offered the possibility of experimenting with various methods of topographic surface analyses to test their applicability for the recording of sedimentological and stratigraphic structures.

All laser scans were geo-referenced using a dGPS, and therefore every data point was given an X, Y, and Z value referring to the British National Grid. Z therefore refers to metres above Ordnance Datum. However, to analyse the surface of the scanned section in analogue to LiDAR data or digital terrain model, a raster must be created in which the pixel value corresponds to height above the surface of interest. In other words, Z should correspond to distance from an idealised plane through the sediment section. This meant that the coordinate system of the scan data had to be redefined to tilt the approximately vertical sediment section to a horizontal plane (Figure 6.28). The drawback of this was that the real-world data were lost. However, these data remain preserved in the general scan worlds from which the analysed scan data were 'sampled' (selected and copied to a new model space). The redefined X, Y and Z values of the point cloud could be exported as a text file, and imported in ArcGIS. The point cloud was converted to a raster file that could then be analysed using geomorphometry tools in GIS software (Blaszczynski 1997; Pike et al. 2009).

An area from the general 'scan world' of the Hatchet Gate Farm pit was sampled to apply different geomorphometric analyses to the raster file and test its ability to represent different sedimentological surfaces. Figure 6.29 presents the results of the different analysis. An area was chosen in which different sediment units were identified in the field and are visible on the photo drape and the scan. The raster file shows the general surface trend of the sediment section which in not perfectly straight as can also be seen in the horizontal view of the section with the idealised plane and re-orientated X, Y and Z. This problem can be expected to be more prominent when a larger part of the section is analysed. However, geomorphometry and focal statistics analyse the surface within a specified window and therefore look at small scale differences (e.g. a 'rough surface' between two clasts) rather than the overall trend. All applied analyses demonstrate a difference between deposits of different dominant grain sizes, such as sand lenses versus gravel deposits. These analyses produce surface ratios that, with further work relating these ratios to different clast size distributions based on the sieving data, could be used to quantify sediment surface textures and allow the identification of sedimentary units based on scan data. The recognition of more subtle differences between gravel deposits is less clear from the analyses of the laser scan data. However, these structures appear visible in the raw scan data and can potentially be used to visualise and measure larger sediment structures (detailed scans of all scanned sections are presented in Appendices 3, 5, 7, 9, 11, and 13). The combination of the raw scan data and analysed selected sections together can provide additional information to field observations. Scan data combines all information obtained by traditional recording methods such as measurements and photographs. Systematic laser scanning of excavations provides an extremely rapid means of capturing large quantities of data and facilitates the 3D digital conservation of sites.

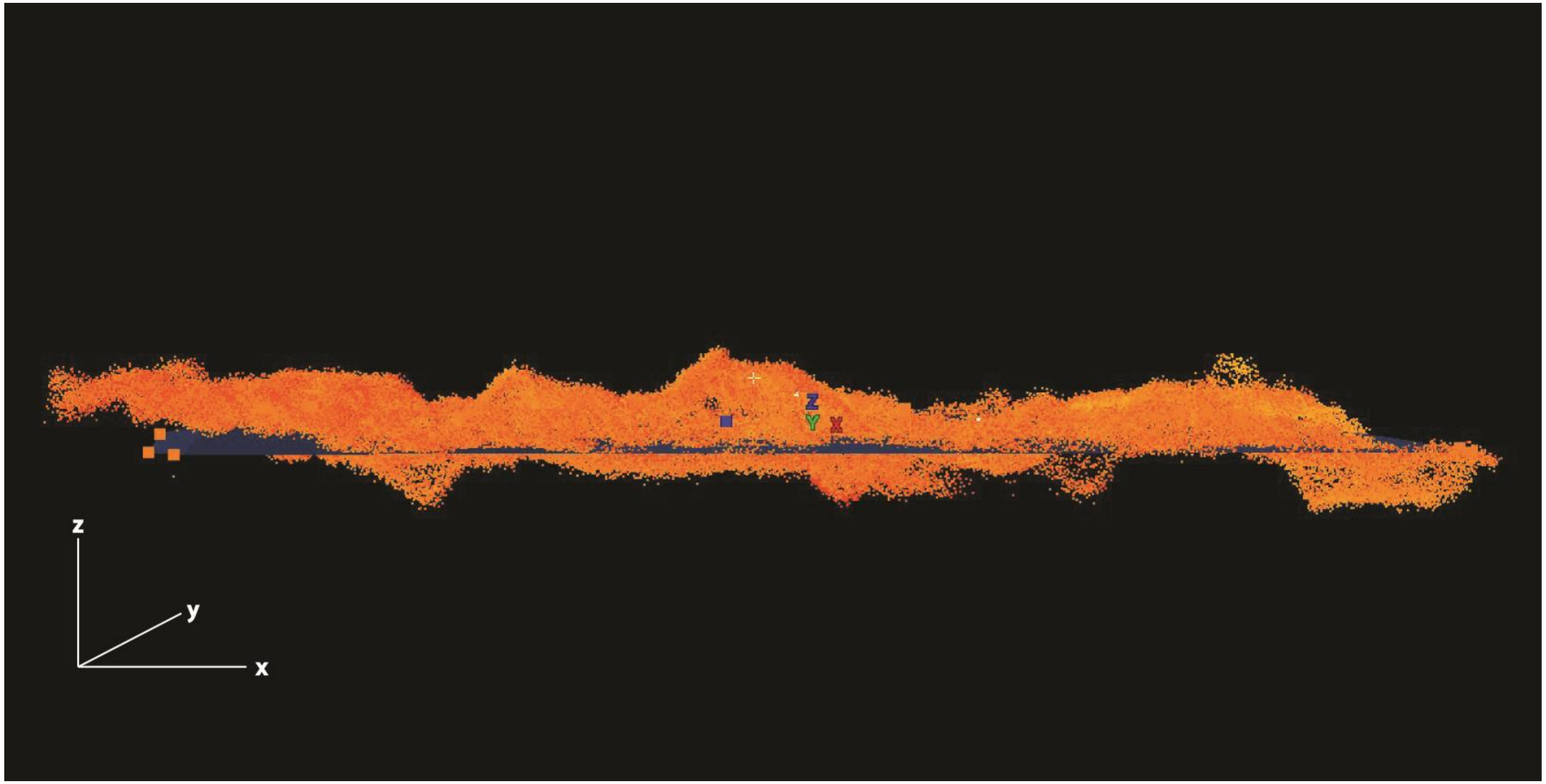


Figure 6.28 Reorientation of the scan data relative to an idealised plane through the scanned section.

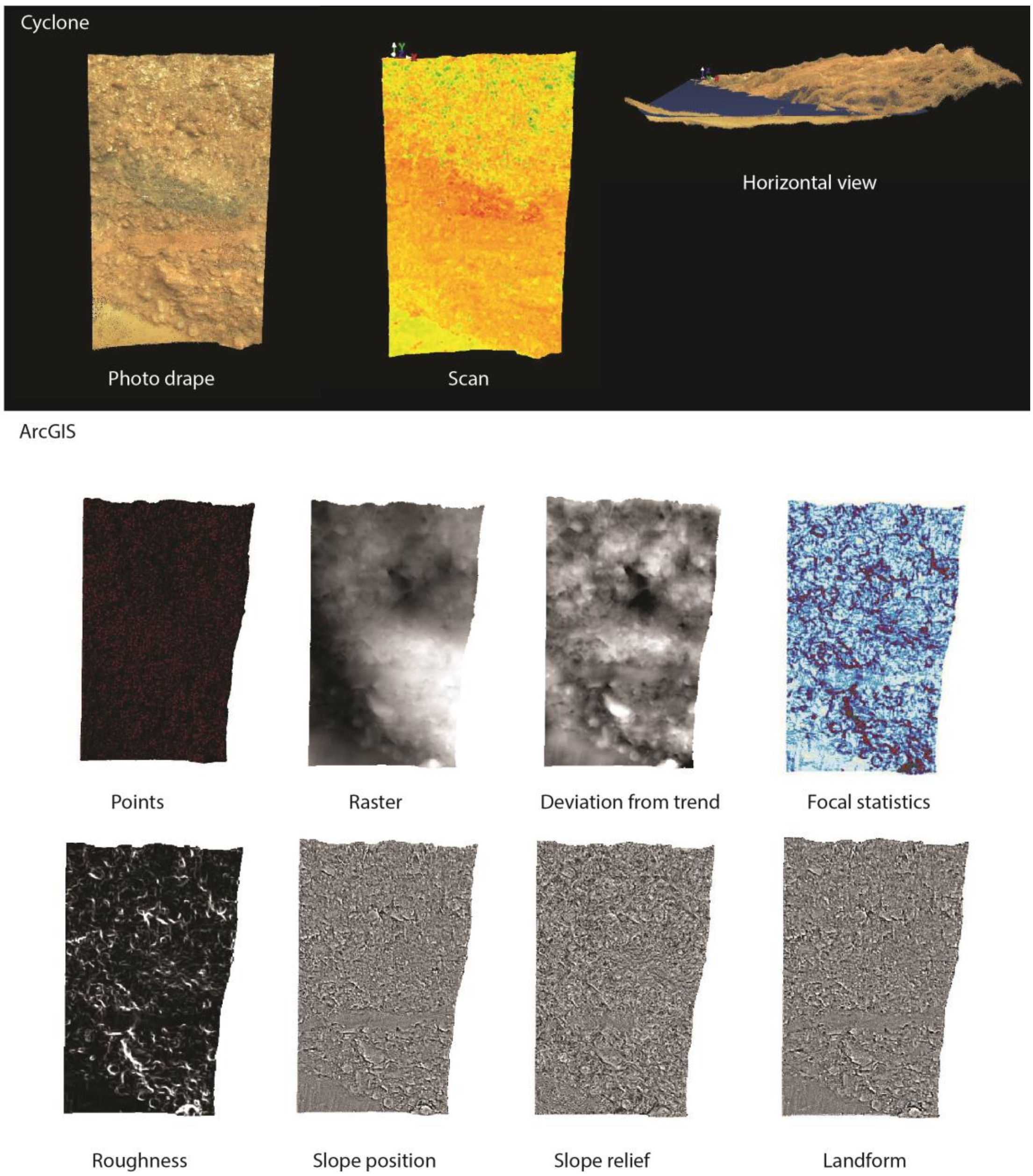


Figure 6.29 Overview of different presentations of the scan data in Cyclone and ArcGIS.

6.10.3 Modelling terrace deposition and erosion

The volume of the terrace deposits has been calculated to assess deposition and erosion processes over time in the Avon valley. These calculations were based on two types of data. Firstly, information from borehole records was digitised to generate terrace thickness data by recording the height of the top and bottom of the terrace deposits. In combination with the mapped extent of the terraces, this could be modelled into two polygons. One representing the top of the terrace, the other representing the base of the terrace. The volume between the two polygons equates the volume of the terrace deposit. Secondly, the terrace volumes were calculated based on the superficial geology thickness models (STM) available through Edina Digimap.

The results of the terrace volume calculations of both methods are presented in Figure 6.30 together with the average thickness of the terraces. The methods show comparable results. A remarkable pattern apparent in both methods is the decrease in terrace volume from T10 to T7 and an increase in volume from T6 to T4. The volume calculated for T3 and T2 is very comparable. T7 and T1 have least volume. All terraces have comparable average thicknesses. The variation in volume per terrace therefore reflects their geographic extent.

With both methods the volume of the preserved terrace fragments and the volume of the reconstructed palaeo-floodplains were modelled. The applicability of the latter was limited by the preferential preservation of the terraces on either the east or west side of the valley. The more widely preserved T10 allowed the volume of this palaeo-floodplain to be calculated. This was then used to estimate the volume of the eroded sediments through subtracting the volume of the preserved terrace fragments from that estimated for the palaeo-floodplain. The volume of eroded sediments could then be compared to that of the preserved lower terrace deposits. The volume of eroded sediment could therefore be calculated for each period of valley incision (Figure 6.31). A comparison of the estimated volume of the eroded sediment with the volume of the preserved terrace fragments of the next lower terraces indicates whether net aggradation or erosion occurred (Brown et al. 2009a). Figure 6.32 shows that the volume of T4 exceeds the expected volume based on estimated volume of eroded sediments from T5. This indicates that net aggradation took place during the deposition of T4. The increased sediment could have been supplied from upstream bedrock erosion, or through the introduction of sediments though the erosion of older terrace deposits and introduction of material by tributaries. T2 exceeds the expected volume based on estimated volume of eroded sediments from T3, suggesting that T2 also includes eroded sediments of multiple preceding terraces, as part of the cut-and-fill processes of terrace formation that characterises the formation of the lowest terraces.

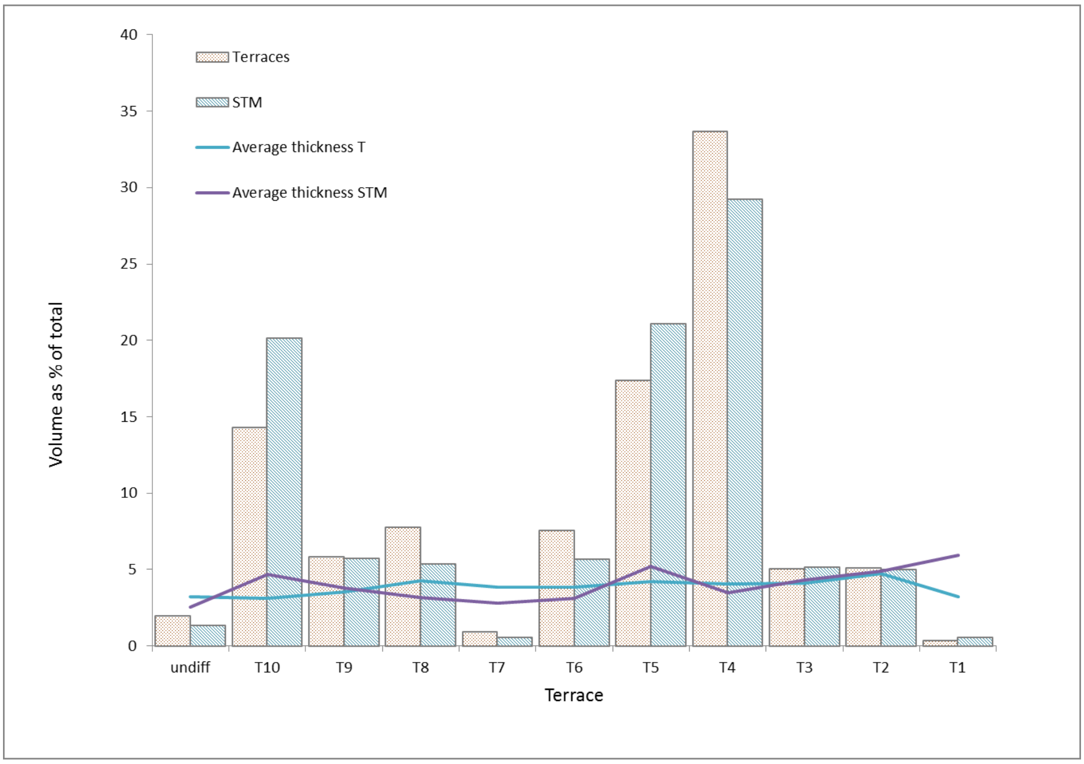


Figure 6.30 terrace volume calculations based on the reconstructed terrace thicknesses from borehole records (Terraces) and based on superficial geology thickness models (STM). The terraces are plotted on the x-axis, the volume of each terrace is presented as percentage of the total volume of terrace deposits.

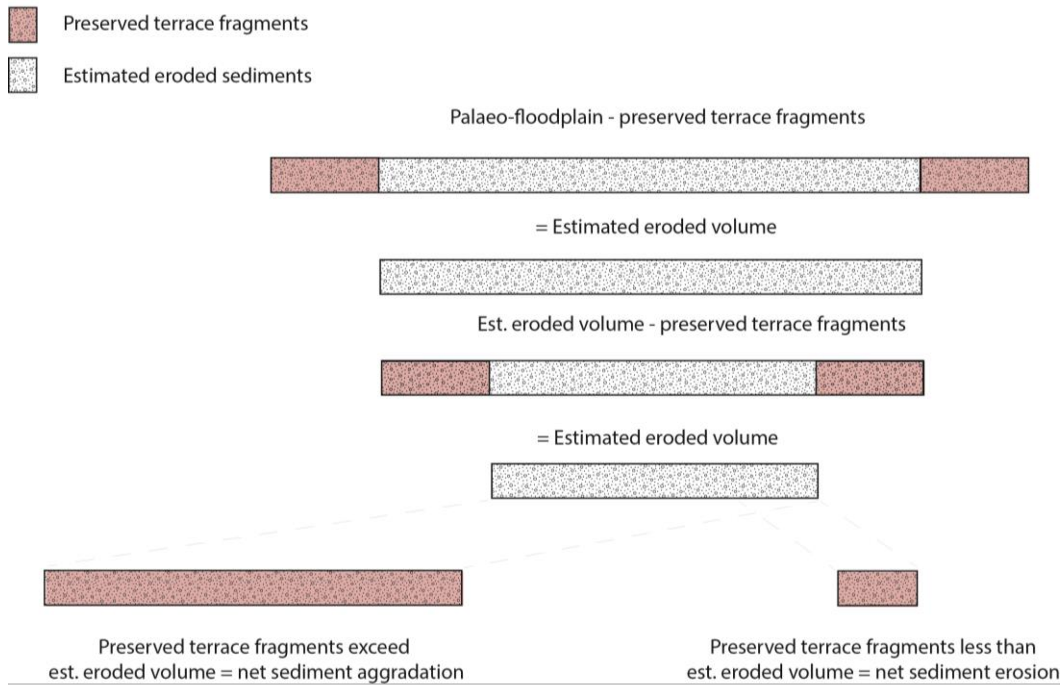


Figure 6.31 Schematic representation of terrace volumes and the calculation of net aggradation and erosion.

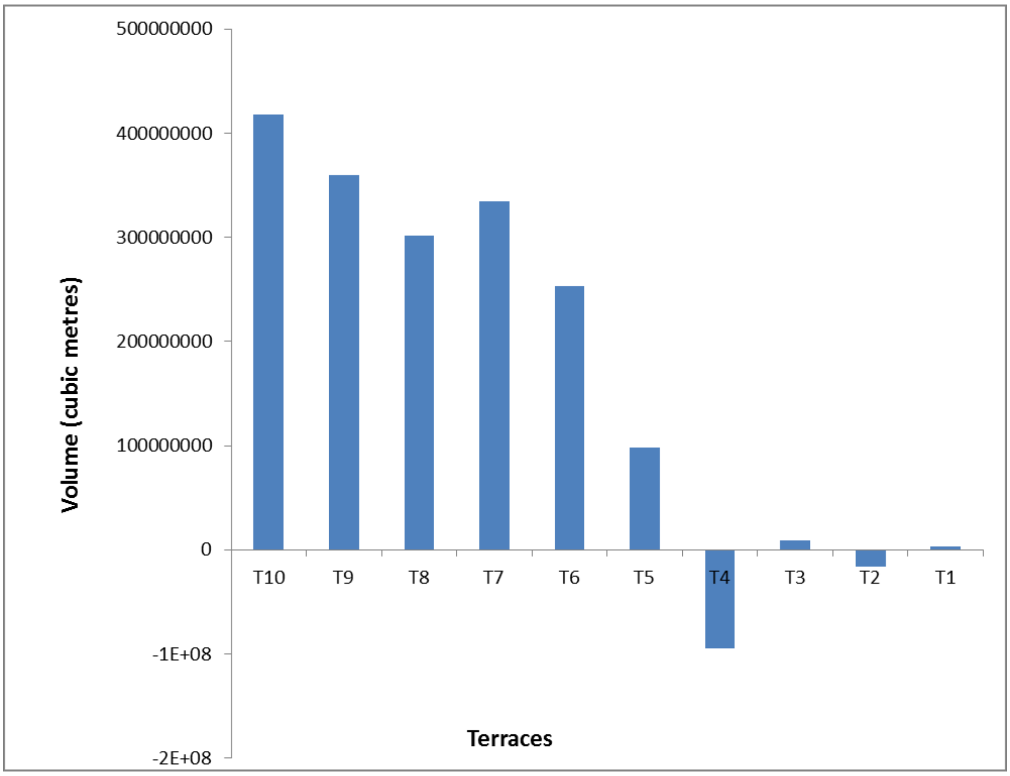


Figure 6.32 Histogram illustrating the difference between the estimated volume of eroded sediments and the volume of the preserved terrace fragments. The volume of the preserved fragments of T4 exceed the estimated volume of eroded sediments based on the erosion of T5.

6.11 Reconstruction of the depositional environment

Sediment logs based on field observations are presented in Appendices 4, 6, 8, 10, 12 and 14. This information was combined with the results presented in this chapter to reconstruct the depositional environment at each site.

6.11.1 Bemerton (Undifferentiated terrace)

At Bemerton 4 sediment units were identified unconformably overlying weathered chalk bedrock. The chalk consists of weathered autochthonous chalk and chalk rubble and shows a very variable elevation between 76 and 73m OD. This weathering interface possibly indicates the occurrence of solution processes during the Quaternary (Chartres and Whalley 1975). A thin layer of very dark, stiff clay was observed between the fluvial gravel and chalk surface. The sediment units directly overlying the chalk consisted of very poorly sorted gravel, including large flint nodules (up to 20cm) which showed limited abrasion or weathering. The overlying sediment unit also included large flint nodules that formed a crude band, possibly indicating a reactivation event. The inclusion of large flint nodules in this unit (BEM2.3) and underlying unit (BEM2.4) is possibly the result of locally eroding chalk. The fluvial deposit in general fines upwards and the top sediment unit (BEM2.2) includes clast supported medium gravel that is crudely bedded with bands of framework gravel. This is likely deposited as migrating gravel bars in a braided river system. In section 2 the terrace deposit is capped by about 70cm of gravelly topsoil that gradually grades into the terrace deposit. Elsewhere, as is indicated in pit 1, the gravel is capped by 190cm massive silt: brickearth. Brickearths are periglacial loess deposits occurring across southern England in discontinuous spreads (Antoine et al. 2003).

The particle size analysis of the <63μm fraction shows a generally similar size distribution for the samples from BEM2.4 and BEM2.3 with a dominance of very fine silt and clay. That of BEM2.2 however, includes a larger percentage of coarse silt. Coarse silt is transported as dust clouds under cold conditions and derived from bare landscapes. The presence of clay and some fine sand however, points to fluvial transport and therefore landscape erosion (Kovacs 2008; Vandenberghe 2013). Its inclusion in BEM2.2 possibly indicates the erosion of a dust covered landscape or the infiltration of this from the overlying brickearth (Sun et al. 2002; Vandenberghe 2013).

The presence of Tertiary flint, sandstone and chalk indicates erosion and incorporation of clasts from the bedrock (Hopson et al. 2007). The presence of non-durable clasts could indicate that this terrace is immature (Bridgland 1986). The relative high percentages of sandstone in the gravel is likely derived from the Upper Greensand Formation outcropping west to north of the site and suggests that the terrace was deposited by a river flowing northwest-southeast (Wylye River).

6.11.2 Hatchet Gate Farm (T10)

At Hatchet Gate Farm 2.75m of fluvial sediments were found unconformably overlying fine sandy bedrock of the Poole Formation. The bedrock surface dips west to east from 103.16 m O.D. to 102 m O.D. The presence of lag-cobbles deposited directly at the erosional boundary with the bedrock indicates a phase of bedrock erosion including bedload transport of gravel and subsequent decrease of water velocity causing the largest clasts to settle and imbricate (Bridge 2005). This is followed by further sediment deposition. The deposition of unit HA1.5 indicates the infilling of a depression or channel in the gravelly floodplain of the braided river. This deposit is overlain by another gravel unit. A period of erosion occurred between the deposit of HA1.2 and HA1.3. This suggests at least two, possibly three periods of gravel deposition and two phases of erosion. A first erosional event cut the bedrock, the second period of erosion removed part of the gravel deposited during the formation of HA1.2 and HA1.3. The gravel deposition of HA1.1, and HA.1.2 and HA1.3 can represent different stages of terrace formation, e.g. during the transition from a cold to warmer climate and *vice versa* (whether during a glacial-interglacial or stadial-interstadial) (Bridgland and Westaway 2008a). Erosion would have been significant as no fine-grained sediments are preserved between the gravel units. Alternatively, the gravel bodies represent intra-cyclic sediment deposition forming compound terraces (Brown et al. 2015; Lewin and Gibbard 2010). The presence of Tertiary flint indicates the erosion and incorporation of bedrock sediments. Palynological analysis of 4 samples from HA1.5 showed very low pollen concentrations.

6.11.3 Woodriding (T10)

At Woodriding three main gravel units were identified. HB1.9 is a coarse, very poorly sorted gravel deposit that contains relatively high percentage of medium sand. This could point to the inclusion of eroded sand from the Tertiary bedrock. HB1.9 is overlain by silty, very poorly sorted, medium gravel (HB1.2). This unit contains a relatively high percentage of mud. This may indicate a period of landscape erosion and inclusion of fines in the gravel body. The particle size analysis of the <63μm fraction shows that it includes coarse to fine silt and clay. This poorly sorted particle size distribution is characteristic for fluvially transported fines (Kovacs 2008; Vandenberghe 2013). A seam of large cobbles at the boundary between HB1.1 and HB1.2 indicates a reactivation surface overlain with bedded, coarser, sandier gravel (HB1.1), interspersed with horizontally bedded, crudely graded silty, clayey sand layers. The presence of multiple and large sand layers in HB1.1 suggests that during the time of deposition of these sediments this area lay in the active region of the main channel of the braided river. The presence of Tertiary flint indicates the erosion and incorporation of bedrock sediments.

6.11.4 Woodgreen

At Woodgreen *ca*. 4.5m of fluvial sediments were found unconformably overlying the Tertiary sands. The bedrock showed small scale scour features indicating bedrock erosion prior to gravel deposition. Sediments exposed in the section 2 consisted of 2.5m of cross-bedded, moderately to poorly sorted, coarse to medium, matrix supported flint gravel. The presence of lag cobbles in WG2.3 is suggestive of a reactivation phase between the deposition of this layer and WG2.4. Unit WG1.12 is a channel infill, covered by framework gravel from which the majority of fine sediments have been removed. WG1.9 is a small drape of silt and clay, interbedded in the gravel and possibly represents the deposits from a standing pool of water during lowered water stands (Miall 1996). This deposit has been checked for pollen preservation. It included only two *Artemisia* pollen and some insect remains. An ESEM of the sediment shows a uniform grain size, an open structure with relatively uniform pores and the presence of heavy minerals, together indicating its loessic origin (Figure 6.33a and b) (A. Brown pers. comm. 2014). This deposit therefore indicates the presence of loess in the landscape and its incorporation in fluvial deposits through landscape erosion. This is interesting because most of the loess deposits in southern England which have been dated, suggest attributions to the late Devensian cold stage (MIS 2); MIS 6 and MIS 12 (Antoine et al. 2003). This loessic element is also recognised in the <63μm fraction of WG2.7, WG2.3 and WG1.11 but less so in WG2.8. This indicates an increased influx of loess through landscape erosion possibly in combination with increased Aeolian influx prior to fluvial erosion and incorporation in the terrace deposit. The presence of Tertiary flint indicates the erosion and incorporation of bedrock sediments.

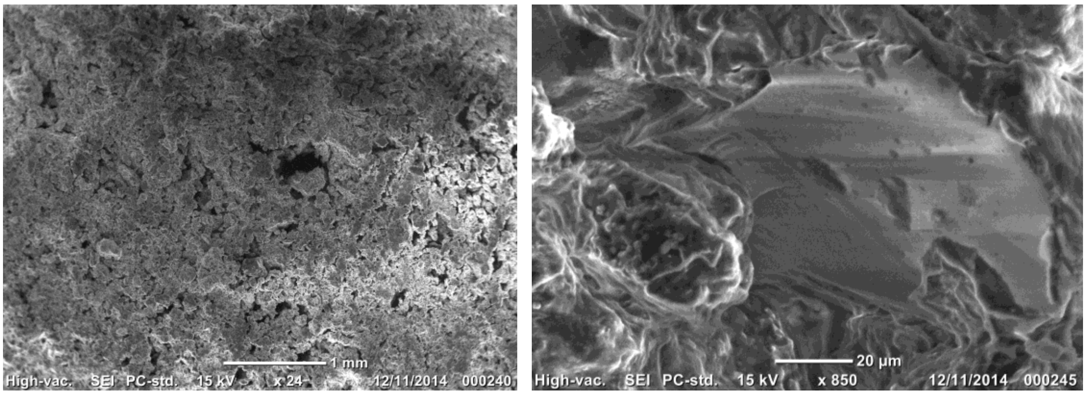


Figure 6.33 a) Environmental scanning electron microscope (ESEM) of sediment from WG1.9 showing a uniform grain size, open structure with relatively uniform pores, and b) heavy mineral grains (possibly Zircon) (images courtesy of A. Brown).

6.11.5 Somerley

At Somerley pit 5.6m of fluvial deposits were found overlying Tertiary sand. In section 2, 80cm of gravel, deposited on the bedrock, was overlain by a 140cm of cross-bedded sand and gravelly sand. These sediments probably represent the deposits of a main channel in the braided river system. This was overlain by horizontally bedded gravel interbedded with cross-bedded sand layers. The gravel shows a set of graded layers that alternate between matrix supported and clast supported gravel. These cross-strata represent the migration of channel bars and sediment deposition under cyclically changing fluvial regimes (Bridge 2005; Miall 1996). Throughout the gravel pit at *ca*. 150cm below the top of the gravel a unit can be identified that consists of gravel interbedded with cross-bedded and horizontally-bedded sand layers. The cross-bedded sand layers represent deposition on the lee-side of gravel bars. Horizontally bedded sand presents the deposition in channels. This unit indicates the presence of multiple active channels at this location during the time of deposition. The top of the fluvial deposits at Somerley show cryoturbation features indicating periglacial conditions subsequent to terrace formation. The inclusion of massive sand blocks in the top demonstrates the erosion and incorporation of frozen sediments in the floodplain. Especially the gravel from units SOM1.5 and SOM3.2 contains relatively large percentages of sand. These units are interbedded with sand layers. This indicates the contribution of sand to the system, through the erosion of bedrock or sand deposits elsewhere in the floodplain. The relatively high percentage of Tertiary flint in the gravel also indicates to bedrock erosion and incorporation in the fluvial deposits. The presence of un-durable clasts such as sandstone and especially limestone indicates this terrace deposit in not very mature (Bridgland 1986). The particle size distribution of the <63µm fraction of the samples shows quite some variation. Two pollen samples were prepared from SOM3.4. Both were virtually vacant of any pollen.

6.11.6 Ashley

At Ashley pit 3.3m of horizontally bedded fluvial gravels interbedded with fines were found unconformably overlying sand and clayey bedrock. The gravel includes alternating matrix supported and clast supported gravel indicative of migrating channel bars and cyclically changing fluvial regimes (Bridge 2005; Miall 1996). The fine sediment deposits are horizontally-bedded and represent the deposition in channels. The clay in ASH1.9 is deposited in standing water conditions in a pool on the braided floodplain during low water stands. Cryoturbation processes have subsequently deformed this deposit. ASH1.9 contained 21 pollen which were all indicative of cold and locally wet conditions. This phase was followed by the deposition of horizontally-bedded gravel, a thick deposit of fluvial fines and is capped by topsoil. The presence of 'drop stones' in ASH1.4 is indicative of periglacial conditions during sediment deposition (Leeder 1982). This deposit also shows indications of cryoturbation. Together this section therefore presents evidence of up to three periods of periglacial conditions occurring after the deposition of ASH1.9, ASH1.4 was deposited under periglacial conditions and the subsequent cryoturbation of this layer indicates another cold period. The sediments at Ashley contain relatively high percentages of sand and Tertiary pebbles indicating the erosion of bedrock and incorporation of clasts in the floodplain. The particle size distribution of the <63μm fraction of ASH1.6 shows a relatively large component of coarse and fine silt. This again indicates the presence of loess in the landscape and its erosion and inclusion in the fluvial sediments.

6.12 Summary

The composition of all analysed samples is summarised and compared in Figure 6.34. All samples consist of sand and gravel. The sediments from Bemerton and Woodgreen are both most clast supported with some more matrix supported gravel. At Hatchet Gate Farm and Woodriding there is a sediment deposit that shows relatively high fine sediment contents (HA1.1 and HB1.2). This could be the result of local or temporal signal of landscape erosion and incorporation of clays from bedrock deposits. The deposits at Somerley and Ashley are clearly sandier and include higher percentages of Tertiary flint, both indicative of the incorporation of bedrock sediments. A loessic component has been found in the <63μm of at least one of the samples at each site.

The observed sediment structures of the studied terrace sequence shows: generally massive fluvial deposits at Bemerton (undiff.); a possible compound terrace at Hatchet Gate Farm and Woodriding (T10); a crudely cross-bedded, compact gravel at Woodgreen (T7); and horizontally-bedded, sandy gravels resulting from migrating gravel bars, possibly formed in a cyclically changing fluvial regime at Somerley and Ashley (T6 and T5). Evidence of periglacial conditions is only recognised through cryoturbation features in T6 and T5 and Somerley and Ashley. At the latter evidence of three subsequent cold periods is preserved. The stratigraphic divisions identified in the field were verified through clast lithological analysis and could also be observed in the scan data. The recording of the sections using traditional methods has provided detailed information on various sedimentary structures. Image-based automated grain-sizing may offer a method for rapid and larger scale sediment recordings. The calculation of terrace volumes and the application of a sediment budget approach have shown that the volumes of T9 to T5 do not exceed the mass predicted by the estimated erosion of the previous terrace (cf. Brown et al. 2009a, b). However, there is more mass in T4 than predicted by the erosion of T5 alone. After the deposition of T4 terrace volumes have remained relatively constant.

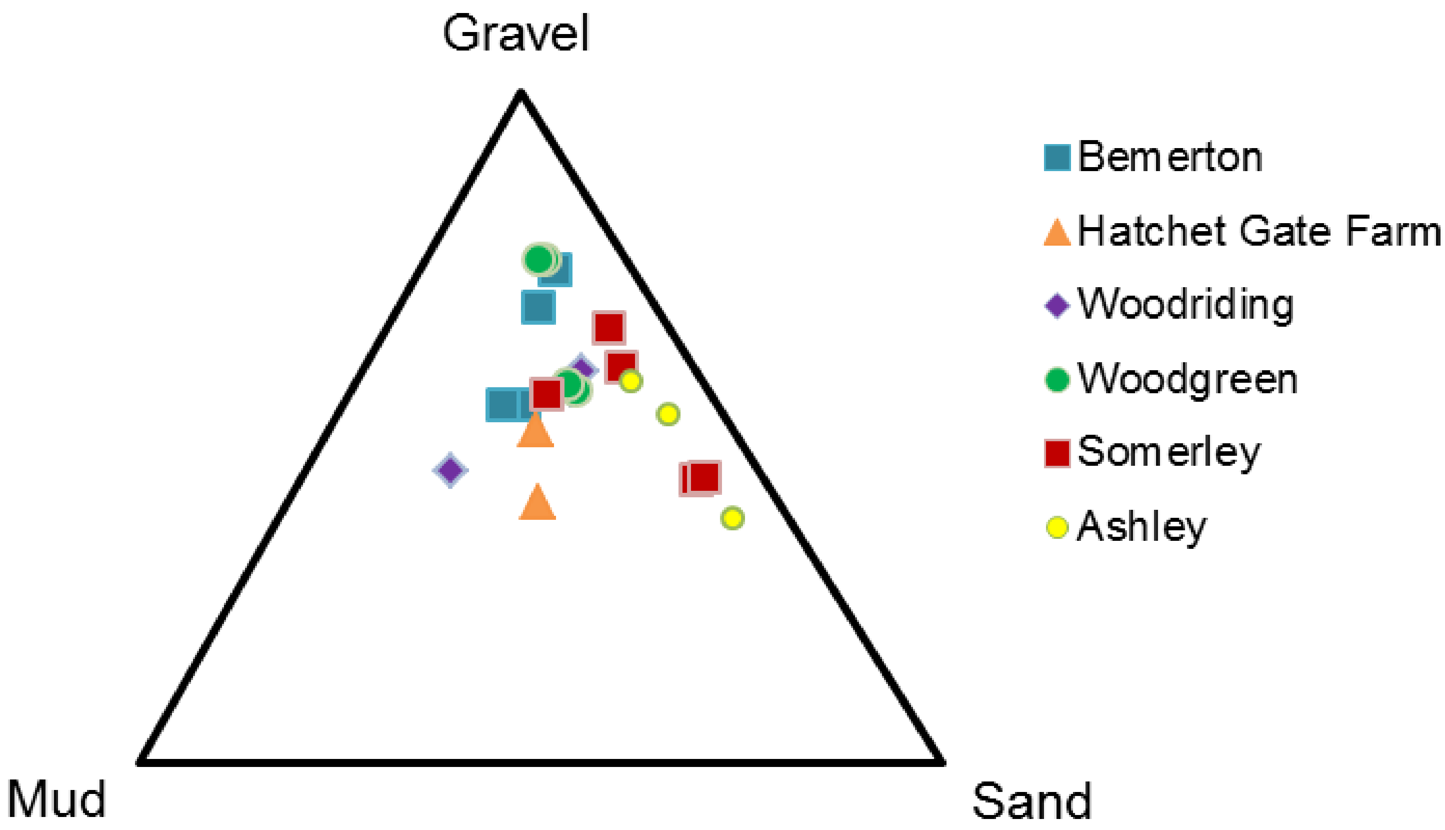


Figure 6.34 Comparison of the sediment composition of the different terrace deposits.

Chapter 7 Optically stimulated luminescence dating of the Avon terraces

7.1 Introduction

The primary aim of the OSL dating conducted for this thesis was to establish the age of the river terraces in the Avon valley. As these are the major source of evidence of Lower and Middle Palaeolithic hominin presence in the area, dating the deposits delimits periods of hominin occupation. This facilitates the comparison of the Avon valley Palaeolithic record with that of other river systems and the general understanding of hominin occupation of Britain (see Chapter 2 and Chapter 3). Secondly, by dating a range of terraces the temporal dimensions of the geomorphological history of the Avon valley can be assessed. The stratigraphy of the terraces can be used as an intrinsic control to the obtained OSL results. Thirdly, the chronology of terrace formation in the Avon valley allows this to be related to the geomorphological history of the wider Solent River System and determine the relationship of the Avon terraces with those formed by the Solent and its other tributaries. Ultimately this contributes to the development of a 4D-model of the Pleistocene landscape of the Avon valley and associated hominin occupation in the area (Chapter 10). In the following chapter the OSL dating results are presented and evaluated. The field sites were selected according to the criteria and aims outlined in Chapter 5. The location and context of the samples is summarised in Table 7.1. The OSL samples and signals were obtained and analysed following the methods outlined in Chapter 4.

7.2 Analytical assessment of acceptability of the results

All samples were subjected to a set of diagnostics to estimate the influence of laboratory and environmental factors on the acquired D_e values, to critically assess and optimise them. The principles and methods of the analytical tests are described in Appendices 34 and 35. The acceptability of age estimates is drawn from diagnostics illustrated in Figures 2-8 in Appendix 35, provided for each sample. The results of the analytical tests are summarised in table A35 together with the applied laboratory procedures, and (values used for) D_r calculations. Table 7.2 presents the total mean D_r and D_e and the calculated age of all the analysed samples.

The natural OSL signal is calibrated against known laboratory doses to yield equivalent dose values (Figure 1 Appendix 35). The signal analyses of all samples generally produced ‘flat’ or declining curves with increased optical stimulation time indicative of a limited influence of partial bleaching (Figure 7 Appendix 35). The relatively high inter-aliquot variability of 19 of the 25 samples may indicate heterogeneous dose absorption and/or inaccuracies in calibration (Figure 4 Appendix 35). Over dispersion of the natural signal in multi-grain aliquots does not necessarily imply inaccuracy. However, when this is also detected in the repeated regenerative-dose signals (Figure 5 in Appendix 35) the sensitivity correction may be problematic (Murray and Wintle 2003).

Except the four samples from Bickton (GL15075-78), all had poor repeat regenerative-dose ratios. These samples showed over dispersed (>5% of the measured D_e values lie beyond ±2σ of the standardising value) D_e values indicative of a significant impact of uncorrected sensitisation upon dose response and D_e interpolation. This effect on the reliability of the OSL age estimates was quantified by the ratio of interpolated to applied regenerative-dose values (Table A35.1 in Appendix 35 and Figure 5 of the sample diagnostics). The sensitivity-correction was considered effective when both the repeat dose ratios and the interpolated to applied regenerative-dose ratios ranged across 0.9-1.1.

Seven samples (GL14042, GL15038, GL15039, GL15041, GL15033, GL15035, and GL15037) showed in addition to the poor repeat regenerative-dose ratios (potentially) significant U-disequilibria estimated by laboratory-based Ge γ spectrometry (Figure 8 Appendix 35). All the samples from Bickton had good repeat regenerative dose ratios but three hade potentially significant U-disequilibria (GL15075, GL15077, GL15078). Age estimates are based on D_r that is assumed not to have changed over the period of burial. This implies that U and Th decay series are in secular equilibrium. However, dis-equilibria in these decay chains can be caused by geochemical sorting that moves parent or daughter nuclides into or out of a system at a rate significant relative to the half-life of the daughter nuclides (Olley et al. 1996). This can be caused by weathering processes, solution and precipitation reactions, gaseous diffusion of radioisotopes, and/or alpha particle withdraw (ibid.). This means that over the time of burial U and Th emissions may have been temporarily instable and therefore emitted a variable D_r. The obtained D_r used for age estimation may not be the dominant D_r over burial time and can lead to age under or over estimation. The duration of dis-equilibrium is a function of the initial dis-equilibrium and the half-lives of the nuclides involved and in an open system can persist and equilibrium may never be re-attained (Olley et al. 1996). Although the impact of this phenomenon on age estimates is usually insignificant, the age estimates of samples where this effect is pronounced (>50% U-disequilibrium between ^{238}U and ^{226}Ra) should be accepted tentatively (ibid.). This is the case for three samples (GL15038, GL15041, and GL15033). All except the Bickton samples had D_e values of >100Gy and signal saturation and effects of laboratory irradiation must be taken into account. The saturation exponential shape of the dose response curve possibly limits the precision of D_e values from samples with high doses. However, there are precedents in the literature (e.g. Pawley et al. 2008) where large D_e values have generated age estimates that are consistent with independent chronological control. These cases however are few, hampered by the lack of independent age controls of ‘old’ OSL dates. The analytical assessment of the acceptability of the results urges all but one sample (GL15076) to be accepted tentatively.

SITE	Terrace	CONTEXT	Field Code	Lab Code	Easting	Northing	Latitude	Longitude	Elevation
BEMERTON	undiff.T	Loess overlying undifferentiated terrace deposit	BP02	GL14038	412,872.43	131,240.93	51.08035	-1.81762	78
			BP04	GL14039	412,872.43	131,240.93	51.08035	-1.81762	78
			BP01	GL14040	412,872.43	131,240.93	51.08035	-1.81762	78
			BP03	GL14041	412,872.43	131,240.93	51.08035	-1.81762	78
HGF	10	Fine sediment within T10	HALE02	GL14045	419,298.40	119,113.04	50.97111	-1.72653	105
			HALE01	GL14046	419,298.40	119,113.04	50.97111	-1.72653	105.5
WOODRIDING	10	Two fine sediment deposits within T10	HALE03	GL14047	418,634.96	117,751.94	50.9589	-1.73604	102
			HALE04	GL14048	418,634.96	117,751.94	50.9589	-1.73604	102
WOODGREEN	7	Fine sediment deposit within T7	WGRE01	GL14042	417,198.39	117,004.06	50.95222	-1.75653	63.3
			WGRE02	GL14043	417,198.39	117,004.06	50.95222	-1.75653	63.3
			WGRE03	GL14044	417,198.39	117,004.06	50.95222	-1.75653	63.3
SOMERLEY	6	3 fine sediment deposits within T6	SOM01	GL15038	412,836.55	107,841.91	50.86994	-1.81895	42
			SOM02	GL15039	412,836.55	107,841.91	50.86994	-1.81895	44
			SOM03	GL15040	412,836.55	107,841.91	50.86994	-1.81895	44
			SOM04	GL15041	412,836.55	107,841.91	50.86994	-1.81895	44
			SOM05	GL15042	412,836.55	107,841.91	50.86994	-1.81895	45
ASHLEY	5	Fine sediment deposit overlying T5; 3 fine sediment deposits within T5	ASH01	GL15033	413,315.34	106,149.27	50.85471	-1.81221	36
			ASH02	GL15034	413,315.34	106,149.27	50.85471	-1.81221	36
			ASH03	GL15035	413,315.34	106,149.27	50.85471	-1.81221	36
			ASH05	GL15036	413,315.34	106,149.27	50.85471	-1.81221	36
			ASH04	GL15037	413,315.34	106,149.27	50.85471	-1.81221	36
BICKTON	4	4 fine sediment deposits within T4	BICK01	GL15075	414,982.43	112,414.54	50.91101	-1.78827	28
			BICK02	GL15076	414,982.43	112,414.54	50.91101	-1.78827	28.5
			BICK03	GL15077	414,982.43	112,414.54	50.91101	-1.78827	28.5
			BICK04	GL15078	414,982.43	112,414.54	50.91101	-1.78827	28.5

Table 7.1. Summary of OSL sample locations. Terrace attributions are based on Kubala (1980) and Clarke (1981). Easting and Northing are based on BNG OSGB 1936. Latitude and Longitude are based on WGS 84 (SRID4326) and elevation is in metres above ordnance datum.

TERRACE/SITE	Field Code	Lab Code	Total Dr (Gy.ka^{-1})	De (Gy)	Age (ka)
Undiff.T BEMERTON	BP02	GL14038	1.76 ± 0.08	150.8 ± 7.1	86 ± 6 (4)
	BP04	GL14039	2.01 ± 0.14	141.0 ± 12.8	70 ± 8 (7)
	BP01	GL14040	2.15 ± 0.10	150.8 ± 5.6	70 ± 4 (3)
	BP03	GL14041	2.36 ± 0.12	138.0 ± 6.4	58 ± 4 (2)
T10 HGF	HALE02	GL14045	2.75 ± 0.14	613.5 ± 42.2	223 ± 19 (17)
	HALE01	GL14046	1.82 ± 0.09	481.0 ± 35.7	264 ± 23 (21)
T10 WOODRIDING	HALE03	GL14047	1.10 ± 0.07	287.2 ± 19.8	262 ± 25 (22)
	HALE04	GL14048	0.91 ± 0.06	340.4 ± 24.8	375 ± 38 (34)
T7 WOODGREEN	WGRE01	GL14042	0.65 ± 0.05	173.7 ± 11.7	269 ± 26 (23)
	WGRE02	GL14043	0.61 ± 0.04	214.6 ± 14.1	354 ± 35 (31)
	WGRE03	GL14044	0.66 ± 0.05	207.0 ± 14.8	312 ± 31 (28)
T6 SOMERLEY	SOM01	GL15038	0.78 ± 0.07	193.5 ± 12.1	247 ± 27 (24)
	SOM02	GL15039	0.71 ± 0.06	238.6 ± 15.5	336 ± 34 (30)
	SOM03	GL15040	0.89 ± 0.07	195.1 ± 14.3	219 ± 23 (20)
	SOM04	GL15041	0.76 ± 0.06	218.0 ± 28.8	285 ± 44 (41)
	SOM05	GL15042	0.67 ± 0.05	207.5 ± 11.5	310 ± 30 (26)
T5 ASHLEY	ASH01	GL15033	1.89 ± 0.09	269.8 ± 19.3	143 ± 12 (11)
	ASH02	GL15034	0.34 ± 0.04	66.8 ± 3.3	198 ± 23 (22)
	ASH03	GL15035	0.60 ± 0.06	163.8 ± 7.6	271 ± 28 (25)
	ASH05	GL15036	0.69 ± 0.05	77.8 ± 6.6	114 ± 12 (11)
	ASH04	GL15037	0.35 ± 0.04	112.6 ± 4.2	323 ± 37 (34)
T4 BICKTON	BICK01	GL15075	0.66 ± 0.06	16.6 ± 0.9	25± 3 (2)
	BICK02	GL15076	0.16 ± 0.02	19.2 ± 0.8	14 ± 1 (1)
	BICK03	GL15077	0.69 ± 0.05	13.6 ± 0.6	20 ± 2 (1)
	BICK04	GL15078	0.91 ± 0.07	17.2 ± 0.7	19 ± 2 (1)

Table 7.2 D_r, D_e and age data of the OSL samples. Ages are expressed relative to the year of sampling. Uncertainties in age are quoted at 1σ confidence, are based on analytical errors and reflect systematic and experimental variability and experimental variability alone.

7.3 Intrinsic assessment of reliability of the results

The intrinsic assessment of the reliability of the results is based on the repeatability of age estimates from the same deposits, the stratigraphic position of samples within a section and their stratigraphic relationship to other dated deposits in the region. For this reason the intrinsic assessment of the results is discussed by site and according to increasing age.

7.3.1 OSL results Bickton (T4)

At Bickton four OSL samples were taken from four fine sediment deposits within terrace 4 (see Figure 7.1 and Table 7.3). The analytical assessment of the reliability of the dates from Bickton indicates that the age estimate of one sample (GL15076) can be conventionally accepted. The other samples (GL15074, GL15077, GL15078) show potentially significant U-disequilibria resulting in a potentially erroneous dose rate calculation and an increased chance of age over- or under representation (Olley et al. 1996). However, the estimated OSL age of these samples show a good replication of ages from stratigraphically comparable deposits and are in relative good agreement with the age estimate of the accepted sample. Further support for the acceptability of the Bickton OSL age estimates comes from a dated deposit at Ibsley, 2.5km down the valley. Here peat was found underlying terrace 3. Based on the distinct pollen assemblage it is assigned to the Ipswichian Ip IIb pollen zone, related to MIS 5e (123ka). The peat rests unconformably on Bagshot Beds, probably in a hollow formed by fluvial erosion (Barber and Brown 1987). The suggested age for the Ibsley peat is in agreement with the proposed Devensian age for the overlying 4 terraces which cover the modern valley (Clarke and Green 1987). The results from Bickton are in agreement with this proposed chronology. However, the relative young age for terrace 4 around 15-20ka either suggests a relative contemporaneity of T4-1 and the occurrence of some sufficient cold periods before the start of the Holocene. Or, the young age of the dated deposit may highlight complications in the current terrace mapping. High resolution LiDAR data provide geomorphological evidence that suggests complex reworking of the valley terraces (Figure 7.2).

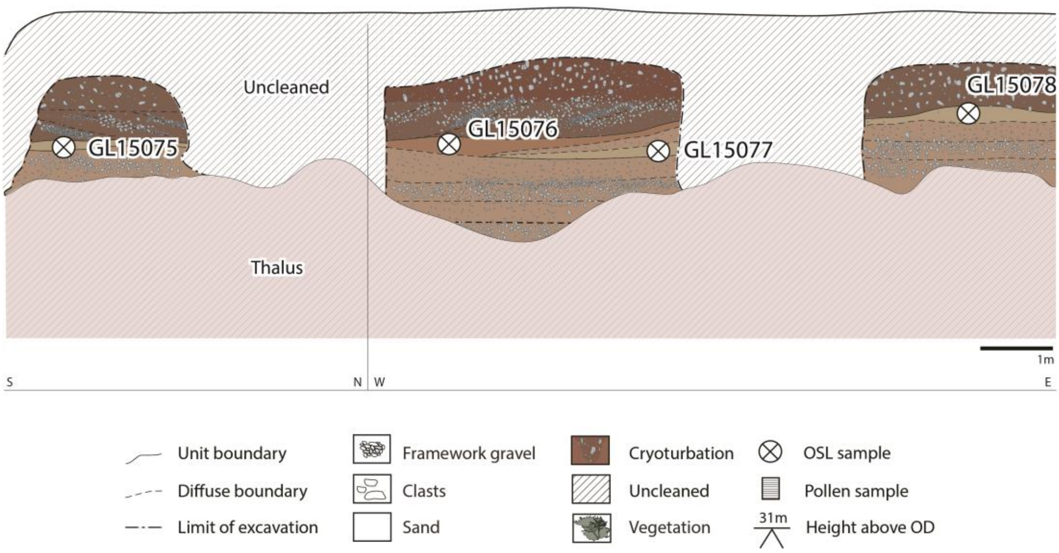


Figure 7.1 OSL sample locations at Bickton.

Field Code	**Lab Code**	**Total Dr (Gy.ka -1)**	**De (Gy)**	**Age (ka)**
BICK01	GL15075	0.66 ± 0.06	16.6 ± 0.9	25± 3 (2)
BICK02	GL15076	0.16 ± 0.02	19.2 ± 0.8	14 ± 1 (1)
BICK03	GL15077	0.69 ± 0.05	13.6 ± 0.6	20 ± 2 (1)
BICK04	GL15078	0.91 ± 0.07	17.2 ± 0.7	19 ± 2 (1)

Table 7.3 OSL dating results of the samples from Bickton.

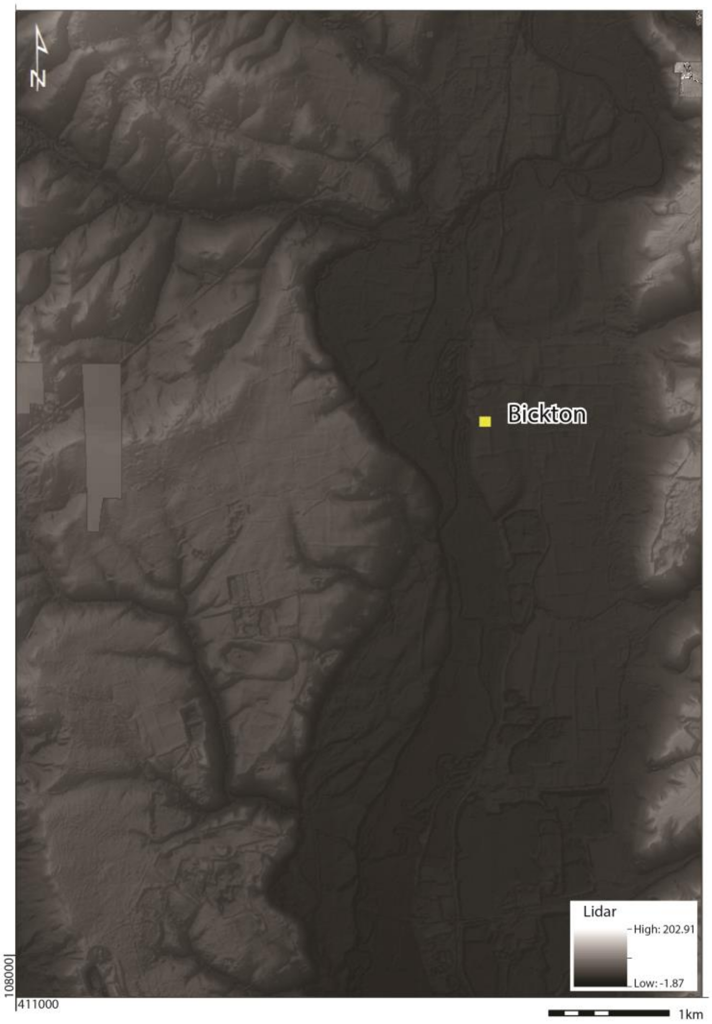


Figure 7.2 Geomorphology of the river terraces in the modern floodplain of the Avon valley visible on high resolution Lidar imaging (50cm, hillshade Z:1) of the area around Bickton (based on Lidar data available from the Geomatics Group of the Environment Agency).

The sequence of terrace formation and valley incision proposed in Figure 7.3 suggests that valley incision formed a scour in the Tertiary bedrock during a cold period prior to MIS 5e. The hollow filled-in with interglacial deposits during MIS 5e forming the Iblsey peat. Subsequent erosion and sedimentation possibly removed the majority of the interglacial deposits contemporary to the Iblsey peat before covering the latter with gravel and sand. Subsequent erosion and deposition was not as pronounced as the proceeding periods, only forming poorly distinguishable terraces. Rather than deep incision and terrace formation, considerable reworking of the terrace deposits occurred within the confined area of the valley.

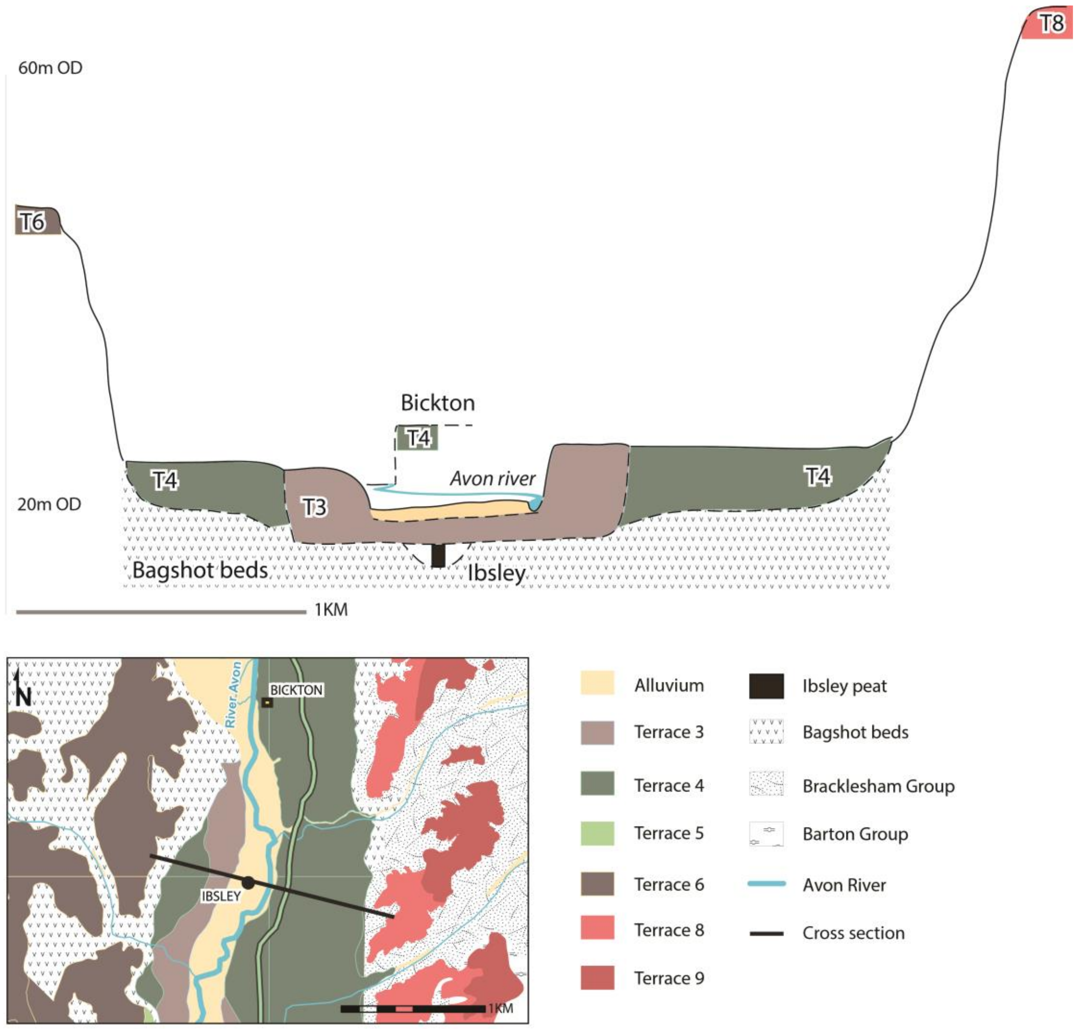


Figure 7.3 Valley cross-section at Ibsley showing the stratigraphic position of T4 and the peat at Ibsley (geology based on 1:10000 scale geology data, with permission of the British Geological Survey and 1:10000 scale OS VectorMap Local [shape file], Digimap Licence).

7.3.2 OSL results Bemerton (undifferentiated terrace)

At Bemerton four OSL samples were taken from brickearth overlying an undifferentiated terrace deposit (see Figure 7.4 and Table 7.4). The analytical assessment of the reliability of the dates from Bemerton indicates that they all show poor repeat regenerative-dose ratios but generally narrow mean age ranges. The estimated ages are intrinsically consistent, demonstrating repeatability, stratigraphic consistency within the section and they are in accordance with the age of brickearth deposits elsewhere in Britain. Brickearth is an aeolian dust deposit. It is transported under periglacial conditions and deposited in cold steppe environments near margins of main Quaternary ice-sheets, in Europe principally around 50°N (Antoine et al. 2003). Brickearth has been identified in the New Forest area to overly most of the river terrace deposits and can be subdivided in an Upper (younger) brickearth and a more extensive Lower Brickearth (Reynolds et al. 1996). The majority of the dated brickearth deposits in the region are of Late Devensian age (Parks and Rendell 1992). Reynolds et al. (1996) suggested the Lower brickearth to be of pre-Devensian age and the Upper brickearth of MIS 2 age (ibid.).

Closer to Bemerton brickearth deposits in include the famous fossiliferous Fisherton brickearth, found downhill from the site in the Nadder valley (Delair and Shackley 1978; Lyell 1827). Based on the faunal assemblage a final Ipswichian (80ka – MIS 5a) or early middle Devensian age (70ka – MIS 4) has been proposed for the deposition of the Fisherton brickearth (Delair and Shackley 1978, Green et al. 1983). The OSL age estimates calculated here are in good agreement with those proposed for Fisherton and brickearth deposits elsewhere in Britain (Bates et al. 2014; Rose et al. 2000; Wenban-Smith et al. 2010), and are therefore tentatively accepted and provide a minimum age of terrace deposition at Bemerton, being pre- MIS 4.

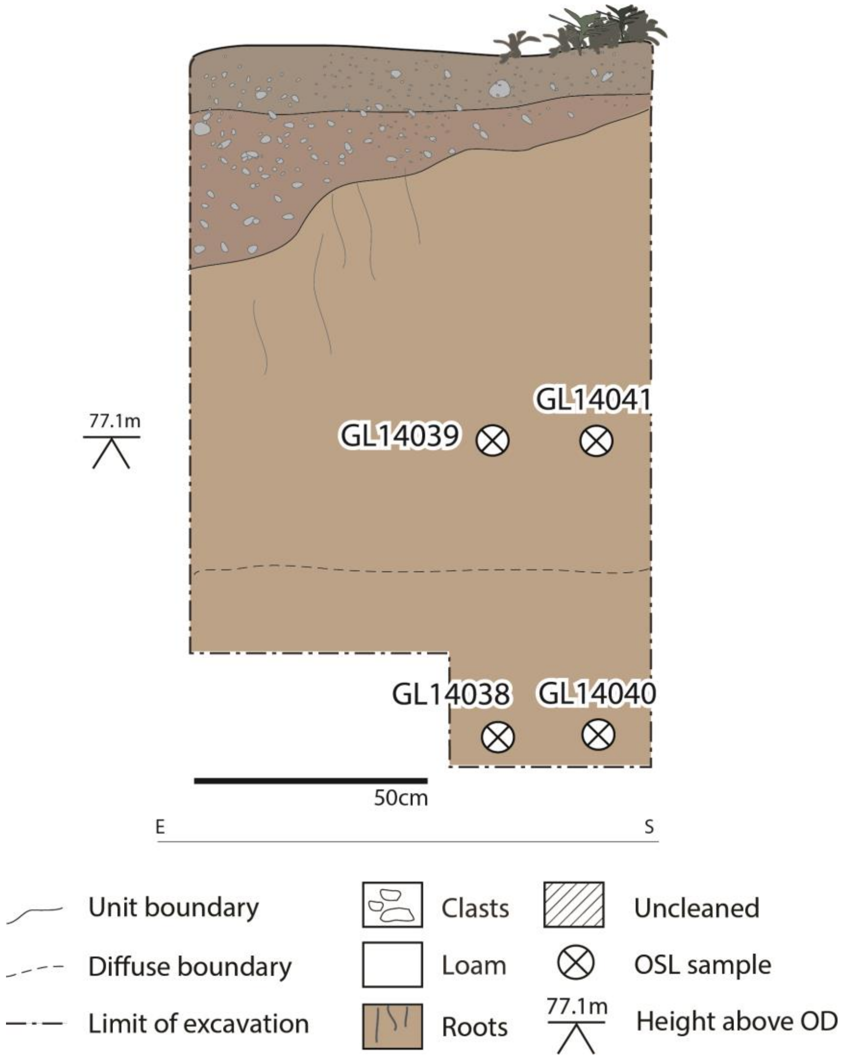


Figure 7.4 OSL sample locations at Bemerton.

Field Code	Lab Code	Total Dr (Gy.ka -1)	De (Gy)	Age (ka)
BP03	GL14041	2.36 ± 0.12	138.0 ± 6.4	58 ± 4 (2)
BP04	GL14039	2.01 ± 0.14	141.0 ± 12.8	70 ± 8 (7)
BP02	GL14038	1.76 ± 0.08	150.8 ± 7.1	86 ± 6 (4)
BP01	GL14040	2.15 ± 0.10	150.8 ± 5.6	70 ± 4 (3)

Table 7.4 OSL dating results of the samples from Bemerton.

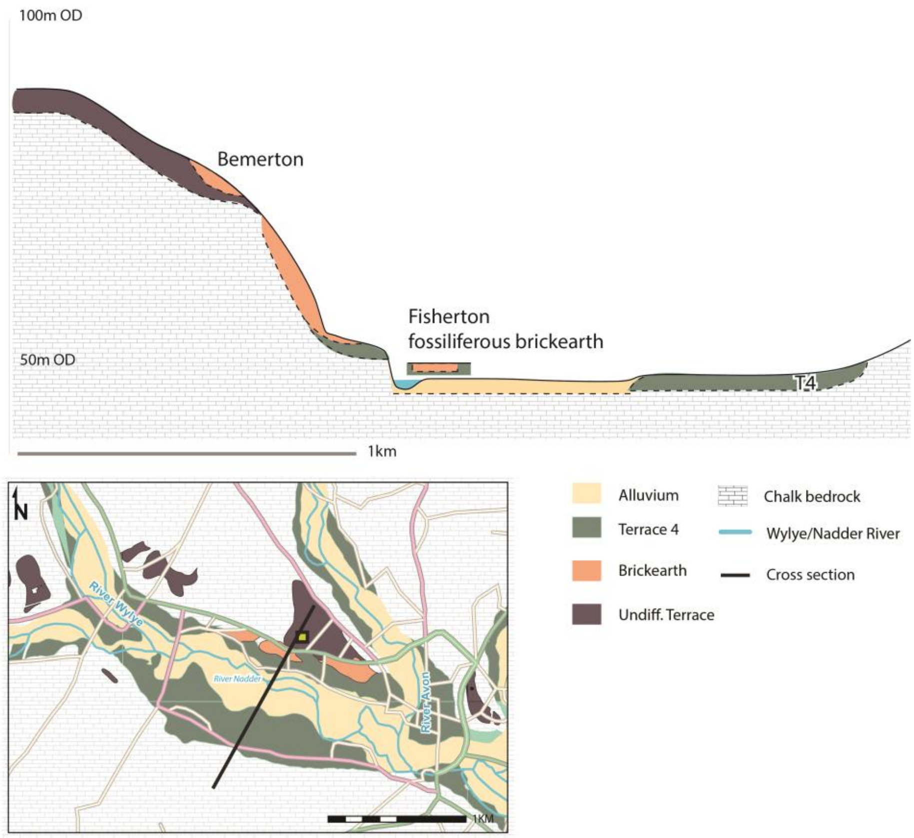


Figure 7.5 Valley cross-section at Bemerton showing the stratigraphic position of undifferentiated terrace deposits, T4 and the brickearth at Fisherton (geology based on 1:10000 scale geology data, with permission of the British Geological Survey and 1:10000 scale OS VectorMap Local [shape file], Digimap Licence).

7.3.3 OSL results Ashley (T5)

At Ashley five OSL samples were taken from five different fine sediment deposits (see Figure 7.6 and Table 7.5). Three of the samples were taken from fine sediments interbedded in the terrace 5; two were taken from overlying fluvial sand and silt. The OSL age estimates from Ashley show considerable variation.

The analytical assessment of the reliability of the dates from Ashley indicates that they all show poor repeat regenerative-dose ratios. Two samples have potential (GL15035 and GL15037) and one (GL15033) significant U-disequilibria. This indicates that D_r values may have fluctuated during burial time and that the estimated D_r is an over or underestimation of the dominant dose rate during the period of burial (Olley et al. 1996). The impact of this becomes especially significant when dose rates are very low as is the case for the GL15035 and GL15037. In such cases small variations in D_r can have a significant impact on age estimations. The low D_r for GL15035 and GL15037 may indicate an age over estimation for these samples. This could possibly explain the poor agreement of GL15033 and GL15037 taken from the same deposit (ASH1.3). The age estimation of the former, 143±12, although having a significant U-disequilibrium, is more in agreement with the two remaining samples (GL15034 and GL15036) that did not show U-activity anomalies.

The remarkably old age estimate of GL15035 and GL15037 for this river terrace, the first above the modern floodplain, does not fit with the dating of the interglacial and overlying cold-climate deposits lower in the valley that are assigned to MIS5e and 15-20ka respectively (see above). The possibly more reliable age estimates of the two samples that did not show potentially significant U-disequilibria (GL15034, GL15036) are on stratigraphic and geomorphological grounds more acceptable. However, these are in relatively poor agreement. GL15034 is estimated to date to 198±23ka and GL15036 is dated to 114±12ka. The ages of the two samples are in disagreement with their stratigraphic position in the section. Moreover, the younger age of GL15036 would suggest a deposition of the dated sediments during the transition from MIS 5e to MIS 5d. Although the sediments indicate cold climate conditions that could relate to MIS 5d the absence of any indications of a major interglacial prior to the deposition of ASH1.16 makes this scenario highly unlikely. Deposits dated to MIS5e and subsequent cold stages are found down in the valley from Ashley at Ibsley and Bickton and further upstream at Fisherton (see above). The terrace deposit exposed at Ashley is the first in the sequence of Avon terraces that lies above the current floodplain. Its stratigraphic position and the geomorphology of the valley suggest that between the deposition of the fifth terrace (as seen at Ashley) and the deposition in of the terraces in the valley below a period of considerable incision occurred thus that Ashley must be older than the valley deposits.

For the remaining sample (GL15034) unfortunately no U-decay could be detected. However, Figures 3 to 5 in Appendix 35 of this sample show comparatively good test results with a normally distributed inter-aliquot variation around 200ka. Although tentatively, it is suggested that GL15034 provides thus far the most reliable age estimate for terrace deposition at Ashley, dated to around 200ka (MIS 6).

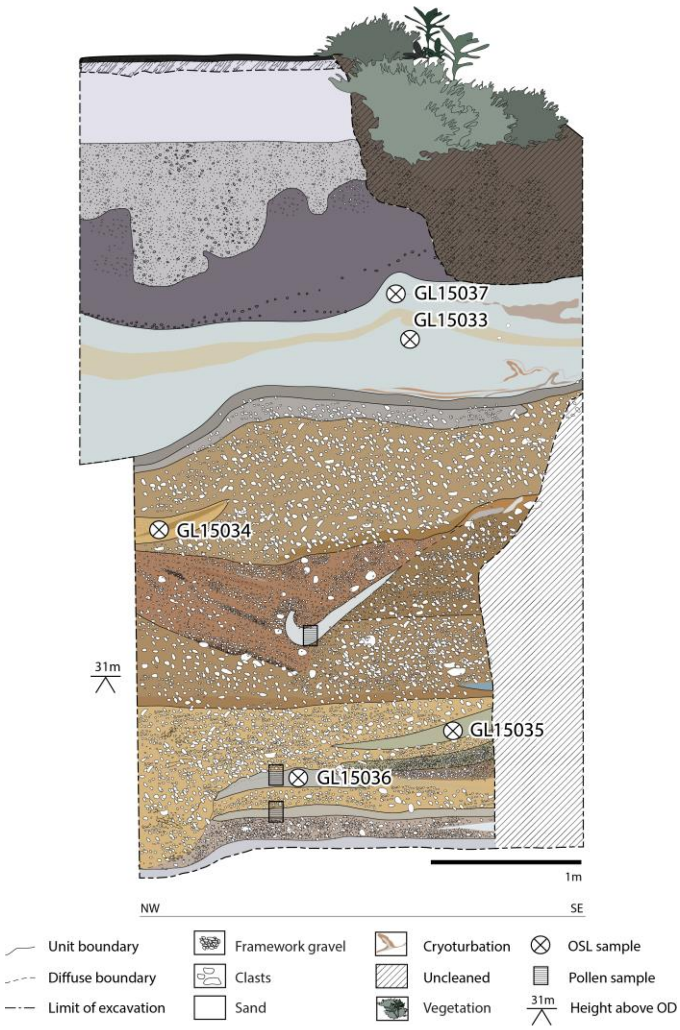


Figure 7.6 OSL sample locations at Ashley.

Field Code	Lab Code	Total Dr (Gy.ka -1)	De (Gy)	Age (ka)
ASH04	GL15037	0.35 ± 0.04	112.6 ± 4.2	323 ± 37 (34)
ASH01	GL15033	1.89 ± 0.09	269.8 ± 19.3	143 ± 12 (11)
ASH02	GL15034	0.34 ± 0.04	66.8 ± 3.3	198 ± 23 (22)
ASH03	GL15035	0.60 ± 0.06	163.8 ± 7.6	271 ± 28 (25)
ASH05	GL15036	0.69 ± 0.05	77.8 ± 6.6	114 ± 12 (11)

Table 7.5 OSL dating results of samples from Ashley.

7.3.4 OSL results Somerley (T6)

At Somerley five OSL samples were taken from three different fine-grained sediment deposits within terrace 6 (see Figure 7.7 and Table 7.6). The OSL age estimates for sediment deposition at Somerley ranges between 219±23 and 336±34 (MIS 7-9). This variability in results from sediments in close stratigraphic position indicates the generally poor repeatability of the OSL age estimates from this gravel body. Two samples show significant U-disequilibria (GL15038 and GL15041) and one a potentially significant U-disequilibrium (GL15039). The possibly more reliable samples, GL15040 and GL1542, have estimated OSL ages of 219±23 and 310±30 respectively. Both show relatively good dose recovery and signal analysis results but poor inter-aliquot D_e distributions and especially GL15042 has poor low and high repeat regenerative dose ratios (Figures 3-7 of the named samples in Appendix 35). The difference in age is in disagreement with the stratigraphically comparable position of the samples. The stratigraphic positon of the sediments in relationship to other dated deposits is discussed together with the results from Woodgreen, Woodriding and Hatchet Gate Farm (see below).

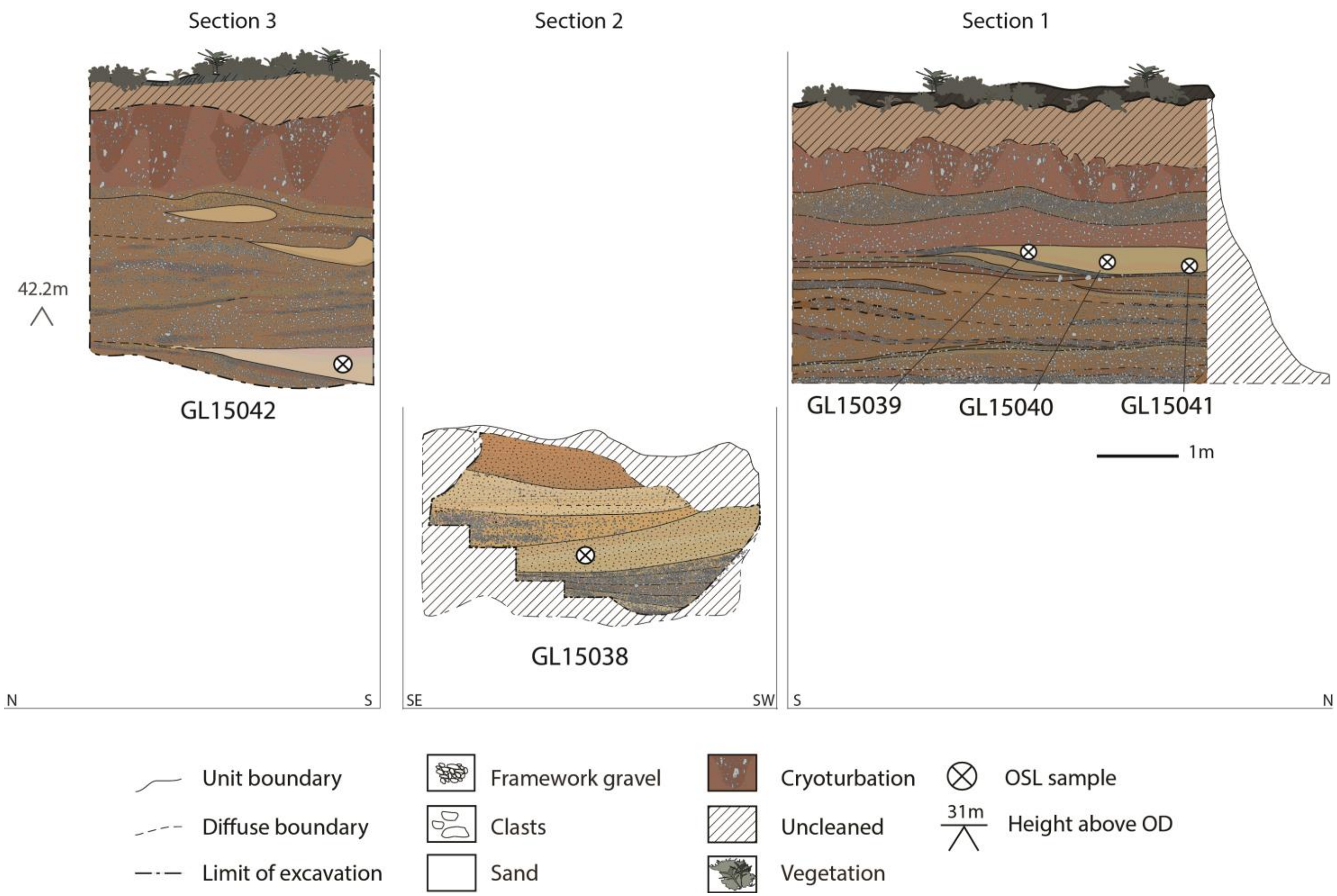


Figure 7.7 OSL sample locations at Somerley.

Field Code	Lab Code	Total Dr (Gy.ka -1)	De (Gy)	Age (ka)
SOM02	GL15039	0.71 ± 0.06	238.6 ± 15.5	336 ± 34 (30)
SOM03	GL15040	0.89 ± 0.07	195.1 ± 14.3	219 ± 23 (20)
SOM04	GL15041	0.76 ± 0.06	218.0 ± 28.8	285 ± 44 (41)
SOM05	GL15042	0.67 ± 0.05	207.5 ± 11.5	310 ± 30 (26)
SOM01	GL15038	0.78 ± 0.07	193.5 ± 12.1	247 ± 27 (24)

Table 7.6 OSL dating results of samples from Somerley.

7.3.5 OSL results Woodgreen (T7)

At Woodgreen three samples were taken from a fine sediment deposit within terrace 7 exposed in section 1 (see Figure 7.8 and Table 7.7). All samples showed poor repeat regenerative-dose ratios. Except for GL14042 the age estimates from Woodgreen are in relatively good agreement. Only for GL14042 a potentially significant U-disequilibrium was recorded which may indicate an age underestimation for this sample. If this is the case and the other two samples are assumed to be reliable based on the comparability of the results demonstrating repeatability of the measurement at the site, an age around 312-354ka (MIS9-10) can be proposed for sediment deposition at Woodgreen. Although this age is in broad agreement with intrinsically expected ages based on the archaeological evidence from the site (large artefact concentrations in Britain are dated between 400ka and 200ka (Stringer 2006)), the comparability of the age estimates from Woodgreen with those from terrace 10 and 6 urges caution (see below).

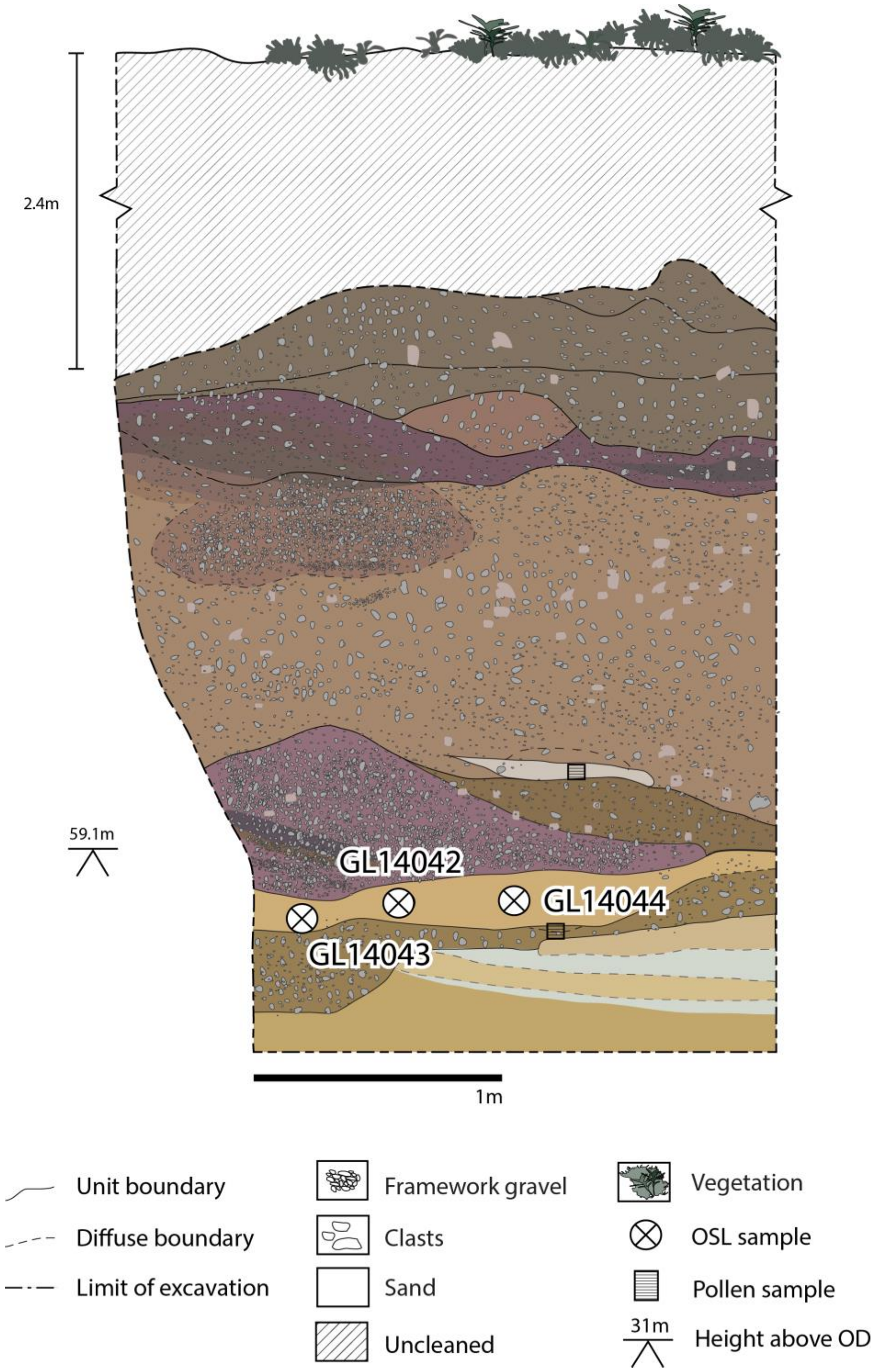


Figure 7.8 OSL sample locations at Woodgreen.

Field Code	Lab Code	Total Dr (Gy.ka -1)	De (Gy)	Age (ka)
WGRE01	GL14042	0.65 ± 0.05	173.7 ± 11.7	269 ± 26 (23)
WGRE02	GL14043	0.61 ± 0.04	214.6 ± 14.1	354 ± 35 (31)
WGRE03	GL14044	0.66 ± 0.05	207.0 ± 14.8	312 ± 31 (28)

Table 7.7 OSL dating results of samples from Woodgreen.

7.3.6 OSL results Woodriding and Hatchet Gate Farm (T10)

At Woodriding two OSL samples were taken from two fine sediment deposits in the upper part of a terrace 10 exposure (see Figure 7.9 and Table 7.8). Both samples, GL14047 and GL14048, have poor repeat regenerative-dose ratios, high inter-aliquot variability and vary considerably in estimated OSL age, with 262±25 and 375±38 respectively. These results can be compared with those from Hatchet Gate Farm where two samples were taken from a fine sediment deposit also within terrace 10 (Figure 7.10 and Table 7.8). The samples from Hatchet Gate Farm, GL14045 and GL14046, have age estimates of 223±19 and 264±23 respectively but also show poor repeat regenerative dose ratios. The results from Hatchet Gate Farm are comparable to the younger of the two samples from Woodriding. If GL14048 would be regarded as an outlier, the results from Woodriding and Hatchet Gate Farm would suggest terrace deposition around 260ka (MIS 8).

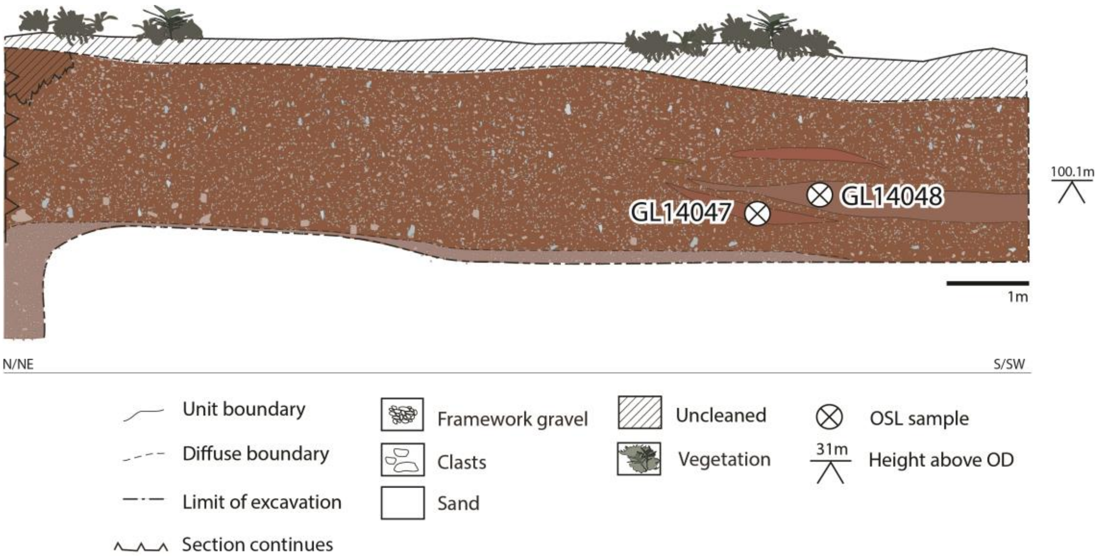


Figure 7.9 OSL sample locations at Woodriding.

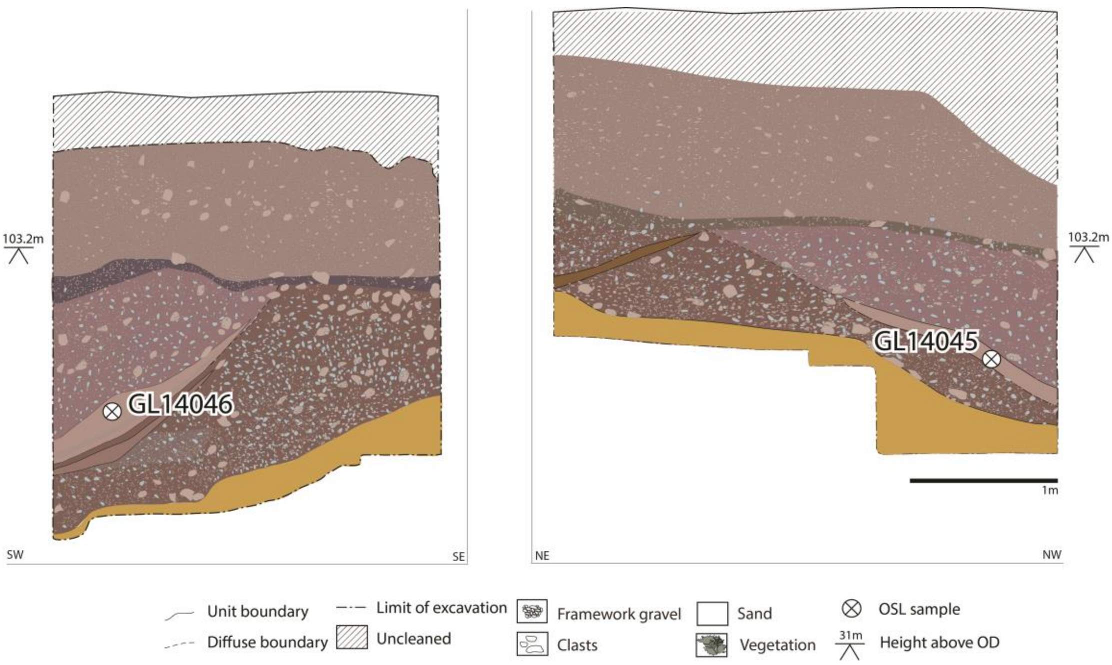


Figure 7.10 OSL sample locations at Hatchet Gate Farm.

Field Code	Lab Code	Total Dr (Gy.ka -1)	De (Gy)	Age (ka)
HALE03	GL14047	1.10 ± 0.07	287.2 ± 19.8	262 ± 25 (22)
HALE04	GL14048	0.91 ± 0.06	340.4 ± 24.8	375 ± 38 (34)
HALE02	GL14045	2.75 ± 0.14	613.5 ± 42.2	223 ± 19 (17)
HALE01	GL14046	1.82 ± 0.09	481.0 ± 35.7	264 ± 23 (21)

Table 7.8 OSL dating results of samples from Woodriding and Hatchet Gate Farm.

For an intrinsic assessment of the reliability of the results from these sites the data is best compared to the age estimates from Woodgreen and Somerley. The sediments dated at these four sites are assigned to three, altitudinally separated and stratigraphically clearly distinct terraces. However, the age estimates from the three terraces are statistically indiscriminant and all lie around 250ka and 300ka. The stratigraphic position of the dated sediments and their association to three different river terrace deposits indicates these results are unreliable. A geomorphological explanation for a supposed contemporaneity would require the unlikely occurrence of at least four subsequent phases of massive sediment deposition and extreme downcutting around 250-300ka. Rapid and extreme climate fluctuations would be needed to facilitate such processes, at a scale that would transcend the Avon valley and should be recognised in geomorphological and proxy records in the region and far beyond.

A much more plausible explanation is that the results from the four sites reflect the upper limit of quartz OSL dating in the area. It is assumed that the OSL growth usually follows one or two exponential saturation coefficients (Aitken 1998, Lowick et al. 2010). The upper limit of a stable OSL signal is defined by the saturation level of the luminescence dose-response curve (Aitken 1998, Wintle 2008). For quartz the upper limit lies typically below 200Gy. With quartz dose rates in sandy sediments varying between 1 and 1.5 Gy ka^{-1} this would give an upper age limit of around 100-200ka (Wintle and Murray 2006), although older age estimates are obtained from deposits in Britain (e.g. Pawley et al. 2008). The samples from Somerley, Woodgreen, Woodriding and Hatchet Gate Farm all have D_e values >170Gy, possibly reaching signal saturation. The age estimates from these sites suggest the age upper limit for quartz dating in the Avon valley could lie around 260-300ka. This slightly higher limit than typically suggested for quartz is possibly facilitated by the relatively low D_r in the Avon valley. Signal saturation at these sites would also explain the variation in age estimates per site as when the natural OSL signal reaches saturation the accuracy and precision of D_e diminishes (Wintle and Murray 2006). The generally low dose rates at Somerley and Woodgreen between 0.61 and 0.89 Gy ka^{-1} and D_e values around 200Gy may suggest that the age of these sediments approach that of the dating limit.

In addition to the general analytical tests and intrinsic assessment of reliability, a D_e/D_r plot allows the relationship between dose rate and equivalent dose to be further examined to discuss the consistency and reliability of several samples from the same stratigraphic body. This facilitates the assessment of the intrinsic reliability of the results. Toms et al. (2005) argue that if OSL results are reliable, age estimates should be similar regardless variations in dose rate or equivalent dose. This is illustrated in D_e/D_r plots in which the D_r and D_e values of reliable results from the same deposit should lie on a straight line from the origin (Figure 7.11). A line is drawn from the origin through the data points of each gravel body. The gradient of the line represents sample age and decreases with increased sample age. The plot illustrates results from Bickton and Bemerton show generally good within-site reproducibility. The data from Ashley are rather dispersed and two trend lines can be drawn. The steeper gradient is proposed here based on the assessment of reliability of the samples from Ashley. The results from Somerley, Woodgreen, Woodriding and Hatchet Gate Farm fall along a general shallow gradient. This likely reflects the upper limit of quartz OSL dating in the Avon valley.

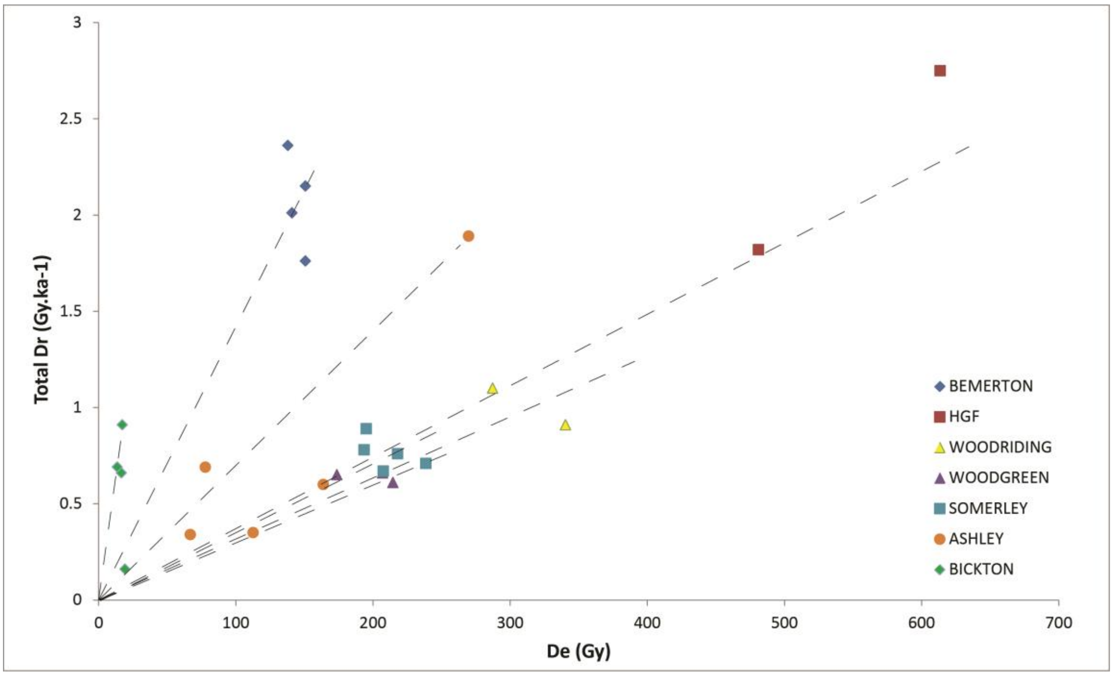


Figure 7.11 Bivariation of D_e and D_r for all samples from the Avon valley.

The samples from the Avon valley would benefit from a multi-mineral approach in which feldspar from the same deposits is used for OSL dating (Kars et al. 2008; Kars and Wallinga 2009). Feldspar has a higher upper limit (Buylaert et al. 2012; Thiel et al. 2011) and is therefore able to detect whether the age plateau met in the samples from the higher terraces in the Avon valley is the result of signal saturation in quartz or generally poor OSL behaviour. If the results indeed represent the upper quartz OSL dating limit, feldspar OSL dating could resolve the chronology of the higher terraces and confirm the age of the Palaeolithic record in the Avon valley. It has been agreed to use four samples, two from T6 and two from T10, for feldspar OSL dating. This will provide information on the upper limit of quartz OSL in the area relevant to OSL dating results elsewhere in the Solent area (Briant et al. 2012; Briant and Schwenninger 2009; Briant et al. 2009; Briant et al. 2006; Hatch 2014; Schwenninger et al. 2007) and further establish the use of feldspar OSL dating in Britain.

Chapter 8 Artefact analysis

8.1 Introduction

The artefact assemblages from Bemerton, Milford Hill and Woodgreen were analysed for this research to study the depositional context and taphonomic processes at these locations and address questions regarding their integrity and significance for the understanding of hominin behaviour in the Avon valley. Over the past 150 years numerous Palaeolithic artefacts have been collected from the three sites (Blackmore 'Locked notebook', Salisbury Museum; Westlake 1900). The artefacts from these sites have been studied before but only in general terms of number and types of tools present and broad descriptions of biface shapes (Roe 1968, 1969a; Wessex Archaeology 1993). This research was aimed at conducting the first detailed analysis of the assemblages recording artefact condition, tool types, and biface variability (for a discussion of the methods applied see section 4.6). This information was combined with information about the sedimentological context of the artefacts obtained during fieldwork (Chapter 5) and sediment analysis (Chapter 6). The following chapter deals with the depositional context and taphonomic processes, assemblage composition, raw material use and biface variability of each site in turn. This is followed by a broader discussion of the similarities and differences between the sites to answer questions regarding hominin behaviour in the Avon valley.

8.2 The Palaeolithic record from Bemerton

8.2.1 The artefact assemblage from Bemerton

The artefact assemblage from Bemerton comprises 151 artefacts. The current location of the artefacts is summarised in Appendix 37. The artefacts have been recovered from several terrace exposures around Bemerton during the second half of the 19th century and the beginning of the 20th century (Blackmore 'Locked notebook', Salisbury Museum; Read 1885). In 1968 Roe (1968) recorded 102 artefacts from Bemerton 'General', 1 from Cherry Orchard Lane, 1 from New Road, and 1 from Roman Road. The pit at Roman Road seems to have been the most prolific findspot (Read 1885) and is the most probable source of finds from Bemerton designated as 'General'. There is no specific information about the stratigraphic location of the artefacts within the gravel deposit.

The artefact assemblage from Bemerton includes 100 bifaces (65%), 39 flakes (25%), 12 miscellaneous pieces (7%), and 2 possible Levallois flakes (see Appendix 38). No cores were found (Table 8.1). At Bemerton all artefacts are made on flint with the exception of one refined biface which is made on chert. Cortex retention on artefacts from Bemerton is limited (Table 8.2). The majority of flakes exhibit less than 50% cortex. The bifaces from Bemerton are relatively intensely knapped with 25% of all the bifaces being fully worked and 62% of the bifaces being almost entirely worked with only a small (0-25%) piece of cortex remaining. On 11% or of the bifaces 25-50% of the cortex remains. The cortex is most commonly left on the body of the biface (40%) or on multiple sides around the butt (26%). For 37 (37%) of the bifaces a blank type could be identified; 35% are made on nodular flint and 2% on flakes. The remaining 33% are either fully worked or the blank type could not be ascertained.

The bifaces range in size from 60mm, to 169mm, and the average size is 103mm. The smallest flake is 25mm, the largest is 143mm and the average size is 80mm. The frequency of flakes per size category (Figure 8.1) shows three peaks and indicates that the majority of flakes in the assemblage are *c*. 80mm or smaller with a decreasing number of flakes with decreasing size.

ARTEFACTS

	Bemerton		Milford Hill		Woodgreen	
	N	%	N	%	N	%
Bifaces	100	64.9	346	72.8	389	60.6
Flakes	39	28.5	92	22.1	137	24.6
Cores	0	0.0	5	0.2	5	0.8
Miscellaneous	12	6.6	24	4.9	104	14
Total	151	100	467	100	635	100

Table 8.1 Assemblage composition of Bemerton, Milford Hill and Woodgreen.

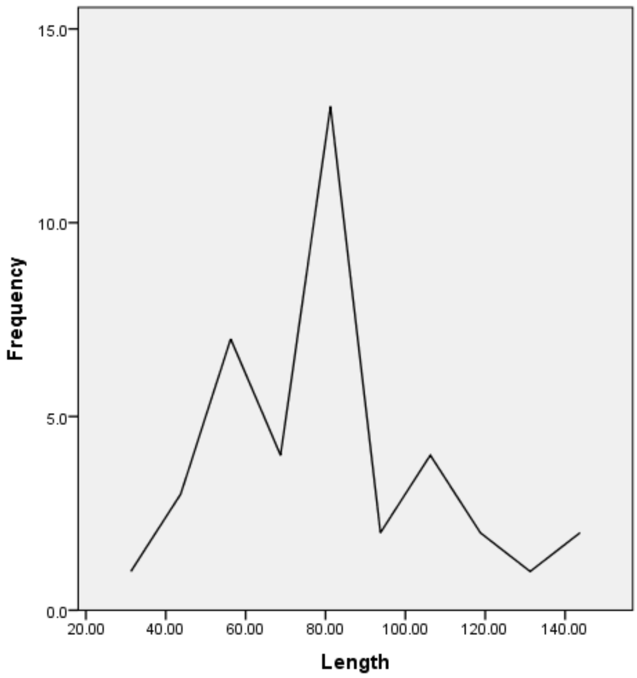


Figure 8.1 Frequency distribution of flakes from Bemerton. Size categories of flakes in mm are plotted on the x-axis. The frequency of flakes in each size category is expressed as percentage of the total number of flakes and plotted on the y-axis.

CORTEX RETENTION

	Total		Bifaces		Flakes	
	N	%	N	%	N	%
0%	35	23.2	25	25	8	20.5
0-25%	83	55.0	62	62	16	41.0
25-50%	23	15.2	11	11	9	23.1
50-75%	4	2.6	1	1	2	5.1
>75%	3	2.0	0	0	2	5.1
NID	3	2.0	1	1	2	5.1
Total	151	100	100	100	39	100

Table 8.2 Cortex retention on artefacts from Bemerton.

8.2.2 Depositional context at Bemerton

The sediment structures and grain size distributions observed at Bemerton indicate the bedload transport of sediments including the incorporation of clasts of up to 200mm deposited in a braided river (BEM2.4 and BEM2.3) followed by a depositional environment of migrating gravel bars, indicated by the presence of crudely bedded coarse to medium gravel (BEM2.2). The occurrence of solution processes at the site is indicated by the irregular boundary of the gravel with the underlying chalk bedrock. The solution of the latter has likely also disturbed the overlying fluvial sediments. Limited movement of artefacts in this context is therefore probable and intergranular collision resulting in artefact damage is likely. No indications have been found in the literature regarding the precise findspot locations of artefacts within the gravel body at Bemerton.

The grain size distribution of the artefacts was compared to that of the sampled sediments from Bemerton (Figure 8.2). This indicates that almost all artefacts generally exceed the size of natural clasts but measurement and weighing of the nodules over 45mm from BEM2.3 show that natural clasts approach artefact sizes. The high proportion of large clasts in the artefact sample might be suggestive of a different depositional agency, e.g. introduction of artefacts to the site by hominins. However, the collection history of the artefacts probably influenced this 'particle size distribution' to be skewed to larger artefacts through selective sampling of the latter from the quarried sediments. The large clasts present in the sediment are likely derived from the local chalk bedrock and incorporated in the sediment with limited transport through solution and erosion of chalk. Although artefact sizes exceed dominant clast size in the sampled section, they are comparable to that of locally derived large nodules. The latter are likely to have become incorporated within the gravel through the solution of the chalk bedrock and are therefore not an indication of fluvial transport capacities. The artefacts from Bemerton, exceeding general sediment clast size, will thus have been discarded in proximity to the site.

The degree of patination and staining of artefacts at Bemerton is variable (Table 8.3 and Table 8.4, and Figure 8.3 and Figure 8.4). The majority of tools are heavily patinated (45.7%) and moderately stained (50.3%). Iron and manganese concretion is almost entirely absent from the Bemerton artefacts (Table 8.5 and Figure 8.5). 13 (8.6%) of the patinated tools show one side to be totally and the other side partly patinated. 18 (11.9%) artefacts have one side totally and one side partly stained. The majority of the artefacts from Bemerton are 'rolled' or 'very rolled' (54.3% and 33.8% respectively) and 11.9% is in 'fresh' or 'slightly rolled' condition (Table 8.6and Figure 8.6). 76.8% of all artefacts from

Bemerton are unbroken and 78.4% of all 'very rolled' artefacts are unbroken (Table 8.7 and Figure 8.7). The majority of the broken artefacts show damage to the tip (41.6%), sides (36.1%) or the body (11.1%). 6 (4%) artefacts show a fresh fraction, and 8 (5.3%) have a broken surface that is patinated, stained and abraded to a similar degree as the total artefact.

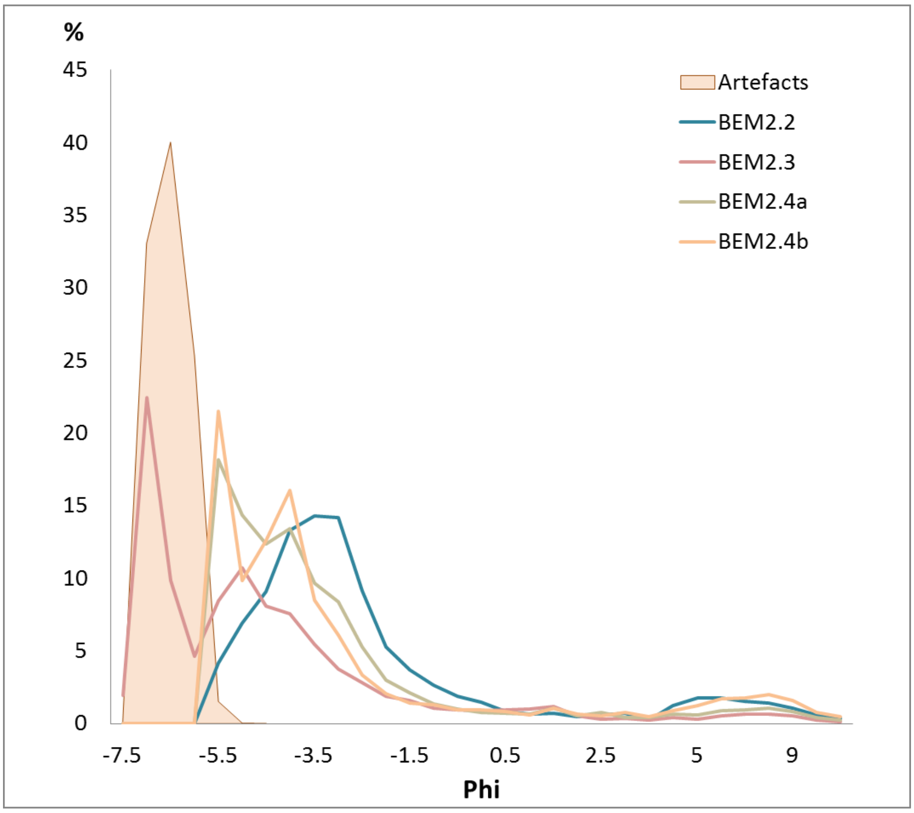


Figure 8.2 Clast size distribution of the artefact assemblage from Bemerton compared to that of the sediment deposits from the site. The x-axis shows clast size categories in phi, the y-axis plots the weight of the clasts per size category as percentage of the total weight of the sediment samples and for the artefacts of the total weight of all the artefacts.

PATINATION

	Bemerton		Milford Hill		Woodgreen	
	N	%	N	%	N	%
None	0	0.0	7	1.5	11	1.7
Some	8	5.3	83	17.8	109	17.2
Moderate	60	39.7	217	46.5	369	58.1
Heavy	69	45.7	134	28.7	125	19.7
Very heavy	14	9.3	26	5.6	21	3.3

LOCATION OF PATINATION

	Bemerton		Milford Hill		Woodgreen	
	N	%	N	%	N	%
N/A	0	0.0	7	1.5	11	1.7
One side partly	1	0.7	15	3.2	17	2.7
One side totally	0	0.0	0	0.0	1	0.2
Two sides partly	90	59.6	368	78.8	551	86.8
One side totally, one side partly	13	8.6	31	6.6	26	4.1
Entirely	47	31.1	46	9.9	29	4.6

Table 8.3 Degree and location of patination on artefacts from Bemerton, Milford Hill and Woodgreen

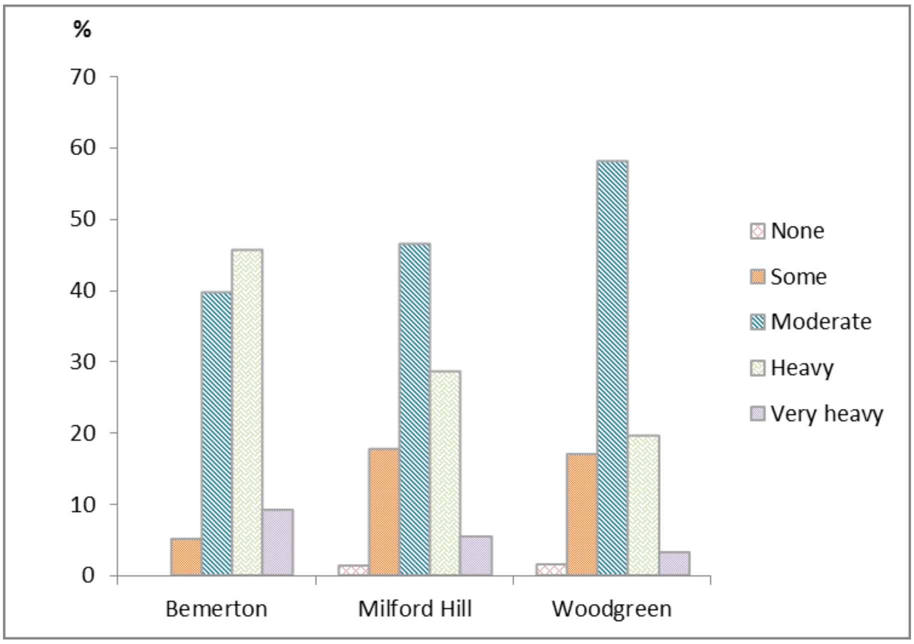


Figure 8.3 Histogram presenting the degree of patination on artefacts from Bemerton, Milford Hill and Woodgreen. The sites are plotted on the x-axis, the frequency with which the categories of patination occur in each assemblage is expressed as percentage of the total number of artefacts per site.

STAINING

	Bemerton		Milford Hill		Woodgreen	
	N	%	N	%	N	%
None	0	0.0	6	1.3	6	0.9
Some	48	31.8	174	37.3	105	16.5
Moderate	76	50.3	230	49.3	254	40.0
Heavy	21	13.9	45	9.6	181	28.5
Very heavy	6	4.0	12	2.6	89	14.0

LOCATION OF STAINING

	Bemerton		Milford Hill		Woodgreen	
	N	%	N	%	N	%
N/A	0	0.0	6	1.3	6	0.9
One side partly	4	2.6	7	1.5	11	1.7
One side totally	0	0.0	3	0.6	3	0.5
Two sides partly	62	41.1	225	48.2	120	18.9
One side totally, one side partly	18	11.9	39	8.4	161	25.4
Entirely	67	44.4	187	40.0	334	52.6

Table 8.4 Degree and location of staining on artefacts from Bemerton, Milford Hill and Woodgreen.

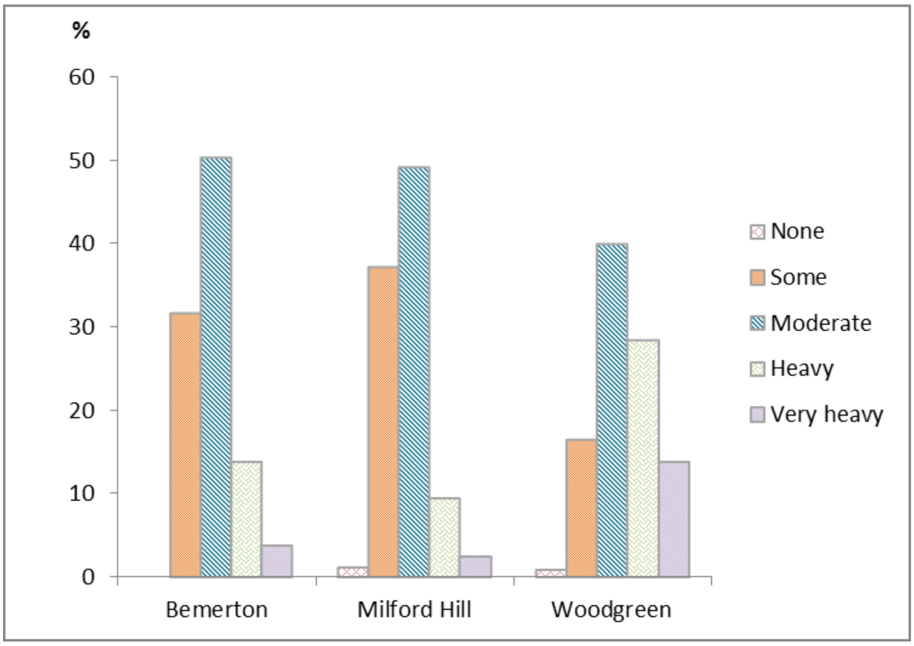


Figure 8.4 Histogram presenting the degree of staining on artefacts from Bemerton, Milford Hill and Woodgreen. The sites are plotted on the x-axis, the frequency with which the categories of staining occur in each assemblage is expressed as percentage of the total number of artefacts per site.

IRON-MANGANESE CONCRETION	Bemerton		Milford Hill		Woodgreen	
	N	%	N	%	N	%
N/A	147	97.4	448	95.9	257	40.5
One side partly	1	0.7	14	3.0	128	20.2
One side totally	0	0.0	0	0.0	28	4.4
Two sides partly	3	2.0	5	1.1	130	20.5
One side totally, one partly	0	0.0	0	0.0	86	13.5
Entirely	0	0.0	0	0.0	6	0.9

Table 8.5 Location of iron-manganese concretion on artefacts from Bemerton, Milford Hill and Woodgreen.

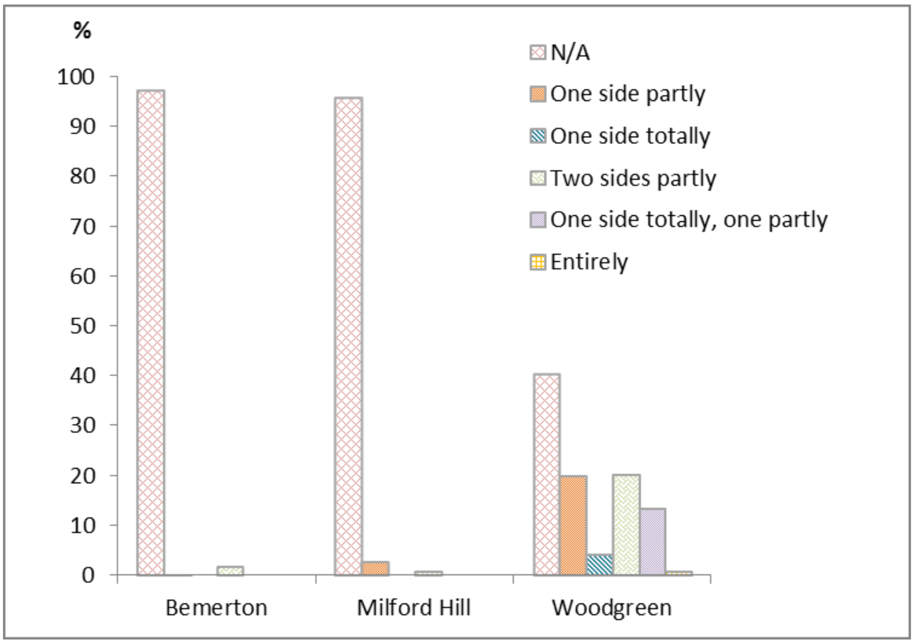


Figure 8.5 Histogram presenting the location of iron-manganese concretion on artefacts from Bemerton, Milford Hill and Woodgreen. The sites are plotted on the x-axis, the frequency with which iron-manganese concretion is found on a certain part of an artefact is expressed as percentage of the total number of artefacts per site.

ABRASION

	Bemerton		Milford Hill		Woodgreen	
	N	%	N	%	N	%
Fresh	3.0	2.0	6.0	1.3	25.0	3.9
Slightly rolled	15.0	9.9	119.0	25.5	151.0	23.8
Rolled	82.0	54.3	258.0	55.2	349.0	55.0
Very rolled	51.0	33.8	84.0	18.0	109.0	17.2

Table 8.6 Number and percentages of abraded artefacts from Bemerton, Milford Hill and Woodgreen.

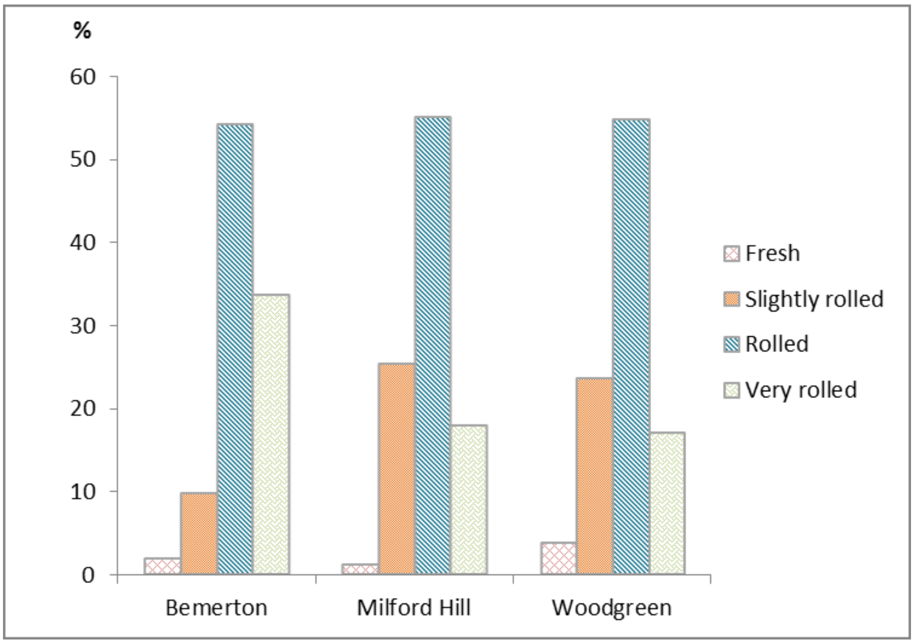


Figure 8.6 Histogram presenting the degree of abrasion on artefacts from Bemerton, Milford Hill and Woodgreen. The sites are plotted on the x-axis, the frequency with which the categories of abrasion occur in each assemblage is expressed as percentage of the total number of artefacts per site.

BREAKAGE

	Bemerton		Milford Hill		Woodgreen	
	N	%	N	%	N	%
Unbroken	116	76.8	323	69.2	462	72.8
Broken	27	17.9	102	21.8	112	17.6
NID	8	5.3	42	9.0	61	9.6

Table 8.7 Number and percentages of broken artefacts from Bemerton, Milford Hill and Woodgreen.

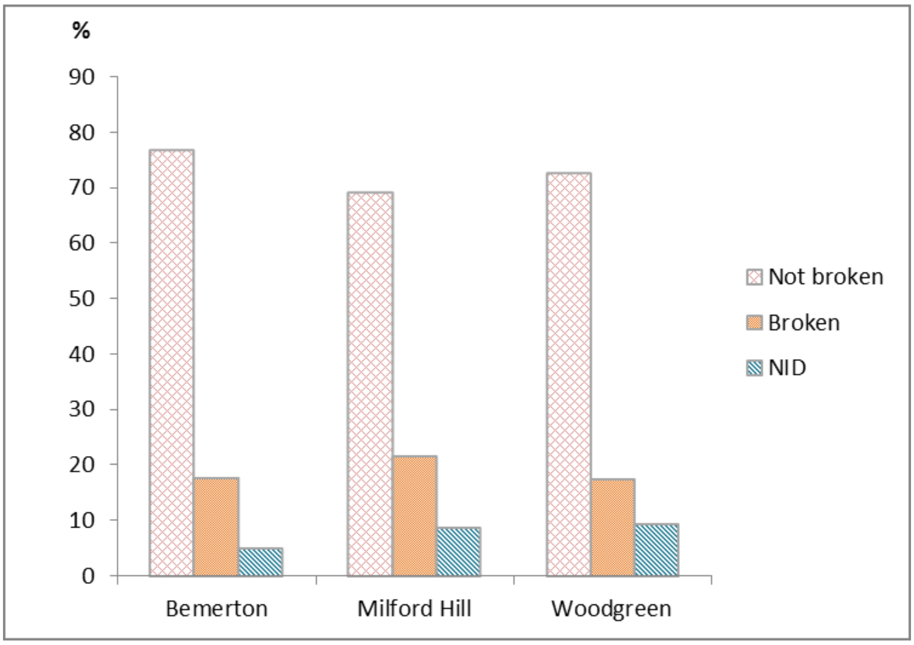


Figure 8.7 Histogram presenting the percentages of broken artefacts from Bemerton, Milford Hill and Woodgreen. The sites are plotted on the x-axis, the percentage of broken and not broken artefacts per site are plotted on the y-axis.

8.2.3 Biface variability at Bemerton

The biface sample contains 41.7% pointed bifaces, 47.9% ovate bifaces and 9.6% cleavers as defined by the shape ratios developed by Roe (1969b) (Figure 8.8). This is in agreement with the brief description of the assemblage provided by Roe (1969, 1981) who observed that ovate bifaces are dominant but pointed types do occur. Within the basic division of pointed, ovate and cleaver bifaces, a variety of shapes exist, especially in the pointed and cleaver types (Figure 8.8). Bifaces from Bemerton are generally refined or thin in relation to their width. The artefacts are not significantly elongated as is indicated by the high mean elongation ratios. High edge shape and profile shape ratios shows a tendency towards equal tip and butt thickness and breadth. Overall these metric measurements reflect the tendency to ovate-shaped bifaces with uniform cross-sections and outline at Bemerton (Table 8.8).

Statistical tests could not reliably be carried out to investigate the relationship between artefact shape and indications of the depositional context or technical aspects such as cortex retention and blank type. The significance of the differences could not be reliably tested because the minimum expected frequency in the cross tabulation for the Chi-square test was less than one and over 20% of the cells had expected frequencies less than five (Dytham 2011).

Data on artefact shape and indications of the depositional context, cortex retention and blank type use are visualised in Appendix 41 to aid comparison and indicate that pointed artefacts are more often 'heavily' or 'very heavily' abraded. Ovates and cleavers are more 'moderately to 'heavily' stained and more 'rolled' and 'very rolled'. All biface types from Bemerton show limited iron-manganese concretion. Figure 8.9 shows the relationship between cortex location and biface shape. Ovate bifaces are most often fully worked or show cortex retention on the sides or body. Pointed bifaces most often have cortex retained on the butt or multiple locations around the butt. A comparison of blank types per biface type is presented in Figure 8.10. Ovates are most often fully worked and pointed types are most often made on nodular flint.

	Mean		
Length	102.95	±	24.43
Breadth	70.70	±	13.71
Thickness	31.89	±	8.41
Refinement	0.45	±	0.09
Tip refinement	0.19	±	0.05
Elongation	0.70	±	0.12
Edge Shape	0.77	±	0.20
Profile shape	0.75	±	0.20
Pointedness	0.38	±	0.10

Table 8.8 Mean size and shape ratios of unbroken bifaces from Bemerton.

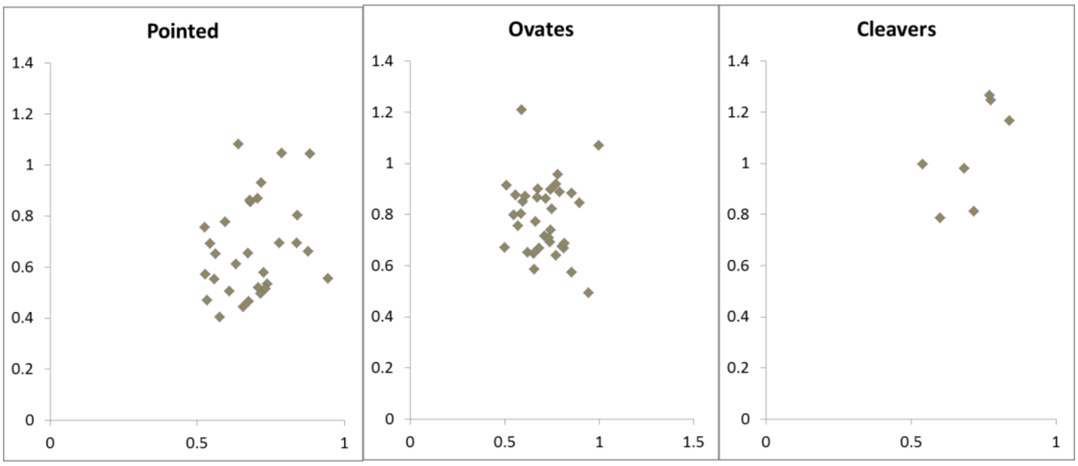


Figure 8.8 Tripartite diagram of unbroken bifaces from Bemerton, including 41.7% pointed, 47.9% ovate, 9.6% cleaver types. The elongation ratio (B/L) of each biface is plotted on the x-axis and the edge shape ratio (B1/B2) is plotted on the y-axis.

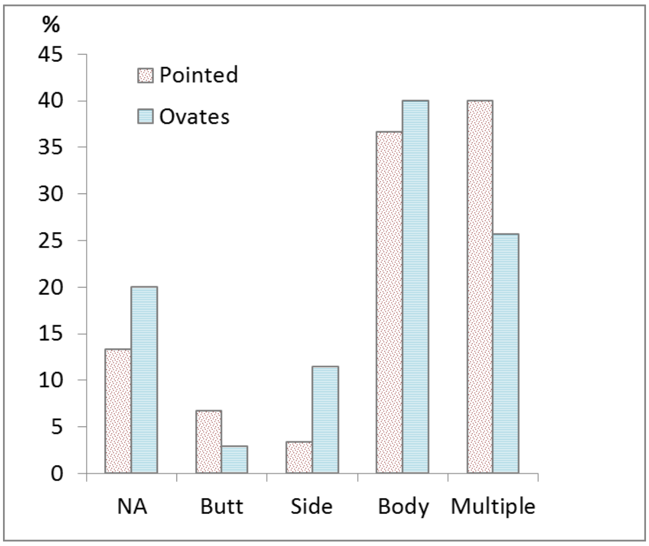


Figure 8.9 Illustration of the relationship between the location of cortex and biface shape at Bemerton. The location of cortex is plotted on the x-axis, the frequency with which cortex was found on the butt, side, body or on multiple locations is expressed as percentage of the total pointed and ovate bifaces and plotted on the y-axis.

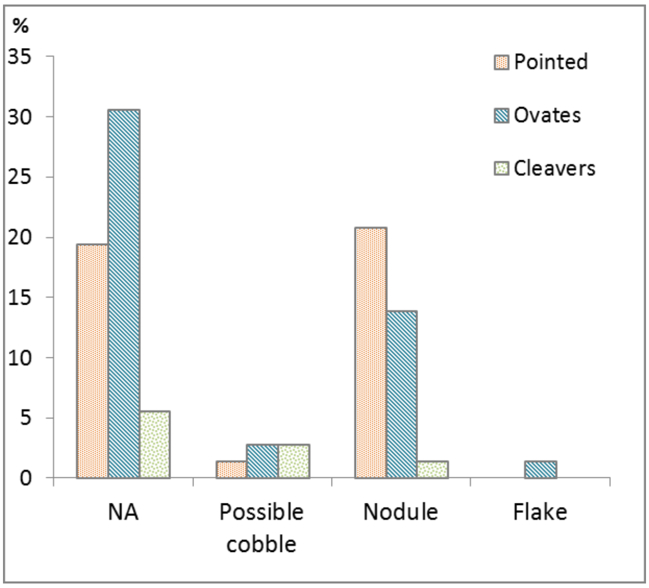


Figure 8.10 Biface shape in relation to blank types. The blank types identified at Bemerton are shown on the x-axis. The frequency of their occurrence in the assemblage is expressed as percentage of the total number of unbroken bifaces.

8.3 The Palaeolithic record from Milford Hill

8.3.1 The artefact assemblage from Milford Hill

The present artefact assemblage from Milford Hill comprises 467 artefacts. The current location of the artefacts is summarised in Appendix 37. The artefacts were recovered from the excavation of cellars, gravel pits, and road cuttings during the second half of the 19th century and the beginning of the 20th century (Blackmore 'Locked notebook', Salisbury Museum; Blackmore 1864, 1865, 1867; Read 1885).

The artefact assemblage from Milford Hill comprises 346 bifaces (73%), 91 flakes (22%), 6 cores (<1%), 24 miscellaneous pieces (5%) (Table 8.1), and 2 possible Levallois flakes (see Appendix 39). The majority of artefacts are made on flint and 9 (2%) on chert. Of all the bifaces 8 (2 %) are made on chert and are intensely worked with on average 25% cortex present. Of the entire sample 13% of bifaces are fully worked. On 57.8% of the bifaces <25% of cortex is retained and on 24% of the bifaces 25-50% cortex was found. On 4.9% >50% of the clast is unworked (Table 8.9). The cortex is most often left unworked on multiple locations (around the butt) on the biface (46%) or on the body (32%). The blank type of 66% of all the artefacts could be identified. 220 (64%) bifaces are made on nodular flint and 8 (2%) are made on flake blanks. For 34% of the bifaces a blank type could not be identified.

The bifaces range in size from 58mm, to 260mm, and the average size is 123mm. The average size of the bifaces is 123mm. The smallest flake is 44mm, the largest is 145mm and the average size is 84mm. Figure 8.11 shows the frequency of flakes per size category. The majority of flakes is between 100-50mm.

CORTEX RETENTION

	Total		Bifaces		Flakes	
	N	%	N	%	N	%
0%	66	14.1	45	13.0	17	18.7
0-25%	234	50.1	200	57.8	26	28.6
25-50%	117	25.1	83	24.0	25	27.5
50-75%	36	7.7	17	4.9	13	14.3
>75%	14	3.0	1	0.3	10	11.0
NID	0	0.0	0	0.0	0	0.0
Total	467	100	346	100	91	100

Table 8.9 Cortex retention on artefacts from Milford Hill.

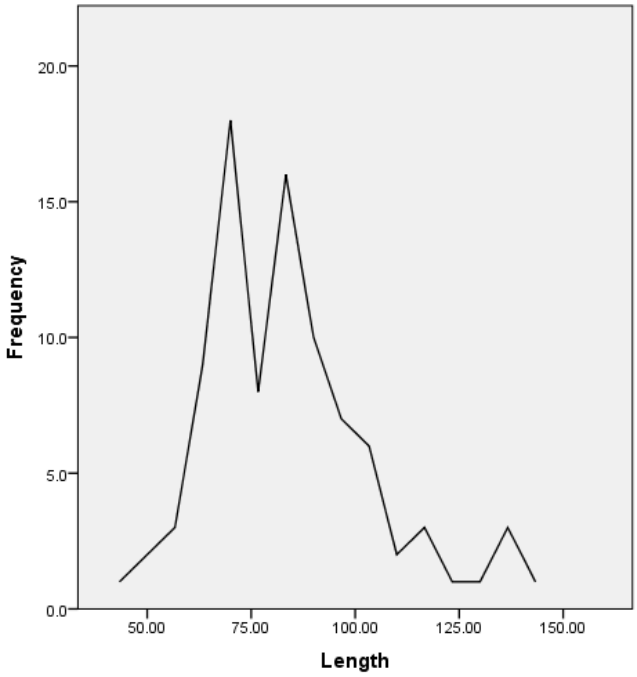


Figure 8.11 Frequency distribution of flakes from Milford Hill. Size categories of flakes in mm are plotted on the x-axis. The frequency of flakes in each size category is expressed as percentage of the total number of flakes and plotted on the y-axis.

8.3.2 Depositional context at Milford Hill

Unfortunately, no sediment exposure was accessible at Milford Hill. However, the detailed description provided by Blackmore of the terrace deposits he observed whenever exposed during building or road works, offers valuable insights in the depositional context of the Palaeolithic artefacts at the site. More recently, an archaeological and geological watching brief at Milford Hill offered the opportunity to reinvestigate its Pleistocene sediments, contributing to the understanding of the depositional context at this location (Harding and Bridgland 1998).

The flint gravel deposits at Milford Hill are described as containing a '*larger portion of sub-angular greensand chert than at Bemerton*', and some rolled Tertiary pebbles and sandstone (Blackmore 'Locked notebook', Salisbury Museum, p.29). The gravel includes some very large chalk flint nodules (ibid.), probably comparable to the situation at Bemerton. These nodules appeared little rolled or water worn (Blackmore 1864). Blackmore ('Locked notebook', Salisbury Museum) further described the gravel at Milford Hill as very closely resembling that seen at Bemerton. The deposit shows limited stratification and rests unconformably on the chalk. The chalk surface at Milford Hill is very irregular due to the presence of ‘potholes’ (ibid.). The gravel was observed to vary much in different spots with some patches containing a large amount of stiff clay whilst others are quite sandy and loose. A bed of loose white gravel and sand was found extending irregularly from northeast to southwest across the top of Milford Hill. Blackmore recorded the discovery of a ‘large quantity’ of land snails in a loose sand band, the upper molar of a species of horse, a small mammoth tusk and the lower tusk of a boar, all in association with the loose white sand and gravel deposit (‘Locked notebook’, Salisbury Museum). The latter is overlain by dark red, clay and gravel. The artefacts have been found in various levels of the gravel, some immediately at the boundary with the chalk bedrock, but the majority in the dark red clay and gravel, towards the base (Blackmore 1867).

Harding and Bridgland (1998) also observed an irregular boundary between the chalk bedrock and the distrubed gravel. They argue that not only the former has been subject to solution processes but that also chalk present in the gravel has been soluted from the sediments explaining the disturbance of the gravel and its clayey texture (ibid.). The presence of lenses and blocks of ‘coombe rock’ (chalky debris) implies the deposition of the sediments close to the contemporary valley sides and they suggested that the sediments at Milford Hill represent a fast flowing river that incorporated soliflucted chalk from the valley sides, contributing Palaeolithic artefacts to the fluvial sediments (Harding and Bridgland 1998).

The close resemblance between the deposit at Bemerton and Milford Hill permits the clast size distribution of the Milford Hill artefacts to be compared to that of the sediments from Bemerton (Figure 8.12). Almost all artefacts from Milford Hill exceed the clast size distribution of the sediments from Bemerton. The large flint nodules found in the gravel at Bemerton (see section 8.2.2) and described by Blackmore to be also present at Milford Hill (Blackmore 1864) approach the size of the largest bifaces. These flint nodules could have become incorporated in the gravel through chalk bedrock erosion without considerable down-stream transport. This is supported by the description of the nodules as little rolled or water worn (ibid.). As at Bemerton, the artefacts from Milford Hill exceed the general size of natural clasts from Bemerton and could have been minimally moved from the local discard location.

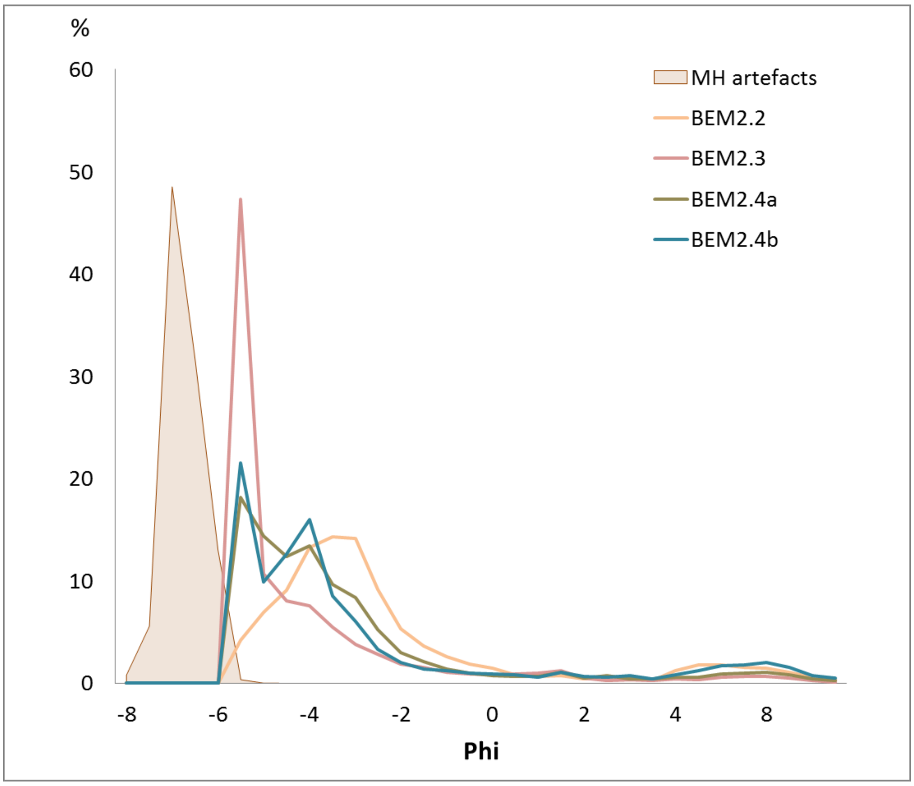


Figure 8.12 Clast size distribution of the artefact assemblage from Milford Hill compared to the sediment deposits from the Bemerton. The x-axis shows clast size categories in phi, the y-axis plots the weight of the clasts per size category as percentage of the total weight of the sediment samples and for the artefacts of the total weight of all the artefacts.

The degree of patination and staining of artefacts at Milford Hill is variable (Table 8.3 and Table 8.4, and Figure 8.3 and Figure 8.4). The majority of tools are moderately patinated (46.5%) and moderately stained (49.3%) with a relatively low proportion of heavy and very heavily stained artefacts (9.6% and 2.6% respectively). Iron and manganese concretion is almost entirely absent from the artefacts from Milford Hill (Table 8.5 and Figure 8.5). 31 (6.6%) of the patinated tools show one side to be totally and the other side to be partly patinated. 39 (8.4%) artefacts have one side totally and one side partly stained. Patination or staining is rarely found to be totally restricted to one side and artefacts are most often partly patinated and/or stained on two sides of the artefact (78.8% and 48.2%).

The majority of the artefacts from Milford Hill are 'slightly rolled' or 'rolled' (25.5% and 55.2% respectively) (Table 8.6 and Figure 8.6). 69.2% of all artefacts from Milford Hill are unbroken (Table 8.7 and Figure 8.7) and 65.5% of all 'very rolled' artefacts are unbroken. The majority of the broken artefacts show damage to the tip (44.5%), sides (16.4%) or the butt (16.4%). Blackmore records at least five occasions on which the point of bifaces was broken during gravel extraction and three occasions when damage was caused to the side of artefacts by the workmen. 24 (5.1%) artefacts show a fresh fraction, and 39

(8.4%) of the artefacts have a broken surface that is patinated, stained and abraded to a similar degree as the total artefact.

8.3.3 Biface variability at Milford Hill

The biface sample contains 58.1% pointed bifaces, 36.7% ovate bifaces and 5.1% cleavers as defined by the shape ratios developed by Roe (1969b) (Figure 8.13). Roe attributed the site to the 'Pointed Tradition' and notes that triangular and pear-shaped bifaces with rough butts are commonest and that 'ovate types are present but rare' (1969, p). This is also emphasised by earlier workers. Read (1885 p.122) states '*The scarcity of the oval pattern should be remarked*' Blackmore (1865, p 250-252) describes the assemblage as '*...with two or three exceptions, all of the long pointed type…*'. The data presented here indicate the dominance of pointed types has been over-emphasised with 79 (36.7%) bifaces being metrically defined ovates. Within the categories of 'pointed', 'ovates' and 'cleaver' ovate and cleaver types exhibit considerable shape variability. The pointed bifaces exhibit less shape variability (Figure 8.13). The bifaces are generally large, heavy and thick but elongated with refined tips (indicated by the low mean refinement ratio of 0.16) resulting in pointed artefacts with wedge shaped cross-sections (Table 8.10).

Statistical tests could not be carried out to investigate the relationship between artefact shape and indications of the depositional context or technical aspects such as cortex retention and blank type. This was because the significance of the differences could not be reliably tested due to the minimum expected frequency, (in the cross tabulation for the Chi-square test) being less than one; and over 20% of the cells having expected frequencies less than 5 (Dytham 2011).

Data on artefact shape and indications of the depositional context, cortex retention and blank type use are visualised in Appendix 41 to aid comparison and indicate that pointed artefacts are more often 'heavily' patinated but ovates and cleavers are more often 'very heavily' patinated. Pointed bifaces are least stained and less often 'rolled' or 'very rolled' than ovates. All biface types from Milford Hill show limited iron-manganese concretion. Figure 8.14 shows the relationship between cortex location and biface shape. Ovate bifaces are most often fully worked or show cortex retention on the sides or body. Pointed bifaces most often have cortex retained on the butt or multiple locations around the butt. A comparison of blank types per biface type is presented in Figure 8.15. Ovates are most often fully worked and pointed types are most often made on nodular flint.

	Mean		
Length	122.95	±	31.43
Breadth	73.53	±	14.30
Thickness	37.47	±	9.42
Refinement	0.51	±	0.11
Tip refinement	0.16	±	0.05
Elongation	0.61	±	0.11
Edge Shape	0.68	±	0.18
Profile shape	0.63	±	0.19
Pointedness	0.34	±	0.11

Table 8.10 Mean size and shape ratios of unbroken bifaces from Milford Hill.

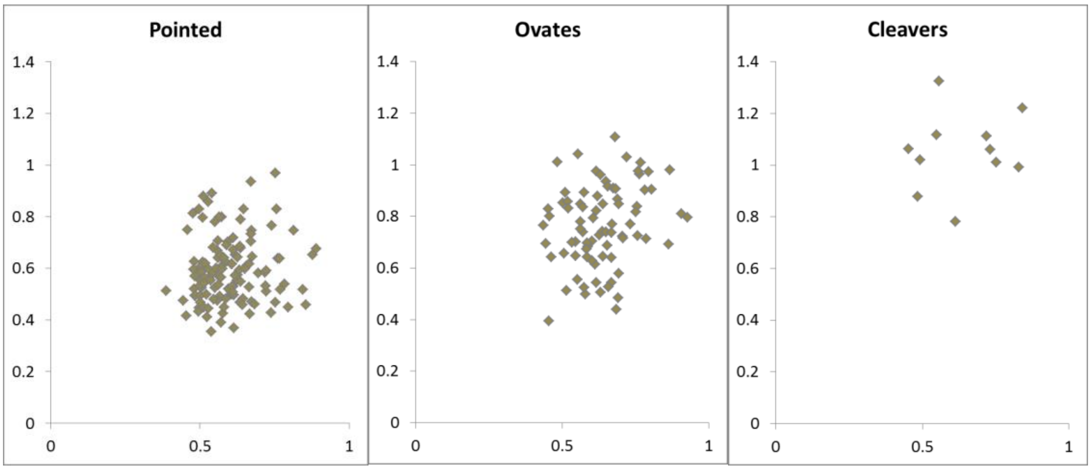


Figure 8.13 Tripartite diagram of unbroken bifaces from Milford Hill, including 58.1% pointed, 36.7% ovate, 5.1% cleaver types. The elongation ratio (B/L) of each biface is plotted on the x-axis and the edge shape ratio (B1/B2) is plotted on the y-axis.

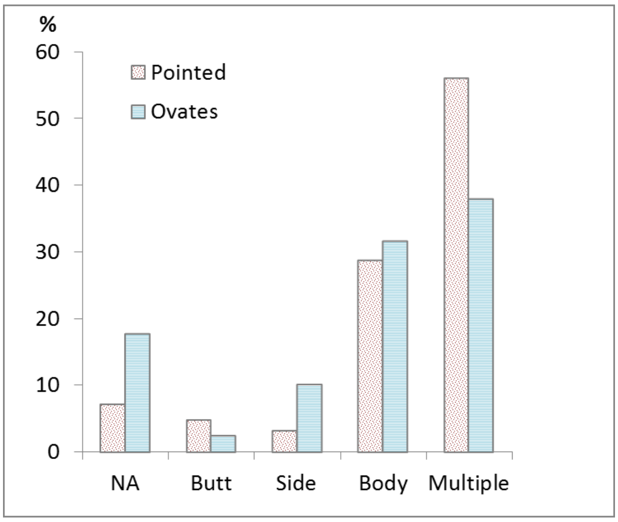


Figure 8.14 Illustration of the relationship between the location of cortex and biface shape at Milford Hill. The location of cortex is plotted on the x-axis, the frequency with which cortex was found on the butt, side, body or on multiple locations is expressed as percentage of the total pointed and ovate bifaces and plotted on the y-axis.

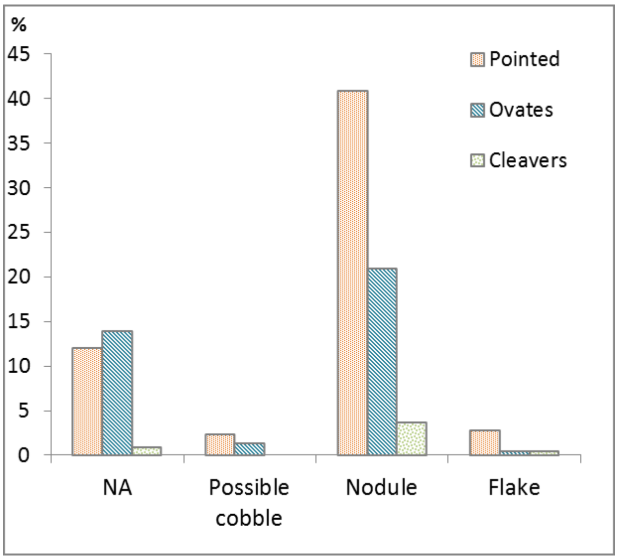


Figure 8.15 Biface shape in relation to blank types. The blank types identified at Milford Hill are shown on the x-axis. The frequency of their occurrence in the assemblage is expressed as percentage of the total number of unbroken bifaces.

8.4 The Palaeolithic record from Woodgreen

8.4.1 The artefact assemblage from Woodgreen

The Woodgreen assemblage studied here comprises 635 artefacts. The current location of the artefacts is summarised in Appendix 37. All artefacts were recovered from the gravel pit at Woodgreen during the end of the 19th and begin of the 20th century (Blackmore 'Locked notebook', Salisbury Museum; Westlake 1900). Roe (1968) recorded 573 artefacts from Woodgreen including 409 bifaces.

The assemblage studied for this research included 389 (60%) bifaces, 137 (25%) flakes, 5 (1%) cores, 104 (14%) miscellaneous artefacts (Table 8.1), and 5 possible Levallois flakes (see Appendix 40). With the exception of 10 chert artefacts all tools analysed from Woodgreen are made on flint. 9 of the chert artefacts are bifaces (2% of the total number of bifaces). The latter are intensively knapped with on average <25% cortex retained on the artefact. In general flint bifaces from Woodgreen are also intensively knapped with over 1/3 being fully worked and 45% retaining less than 25% cortex. On 17% of the bifaces 25-50% cortex was found and on only 2% of the bifaces 50% or more cortex was left (Table 8.11). The worked character of the bifaces from Woodgreen result in a high percentage of artefacts for which cortex location (36%) or blank type (52%) could not be identified. Where cortex was present it was most often found on multiple locations (around the butt) or on the body of the biface. The blank type of 37% of all the artefacts could be identified. 125 (32%) bifaces are made on nodular flint and 18 (5%) are made on flake blanks. For 63% of the bifaces a blank type could not be identified.

The bifaces range in size from 49mm, to 200mm, and the average size is 98mm. The smallest flake is 35mm, the largest is 147mm and the average size is 81mm. Figure 8.16 shows the frequency of flakes per size category. The frequency distribution of flakes per size category shows a normal distribution. The number of flakes increases with decreasing size down to ca. 80mm after which the frequency again decreases.

CORTEX RETENTION						
	Total		Bifaces		Flakes	
	N	%	N	%	N	%
0%	195	30.7	140	36.0	44	32.1
0-25%	260	40.9	174	44.7	51	37.2
25-50%	134	21.1	67	17.2	28	20.4
50-75%	28	4.4	6	1.5	8	5.8
>75%	18	2.8	2	0.5	6	4.4
NID	0	0	0	0.0	0	0.0
Total	635	100	389	100	137	100

Table 8.11 Cortex retention on artefacts from Woodgreen.

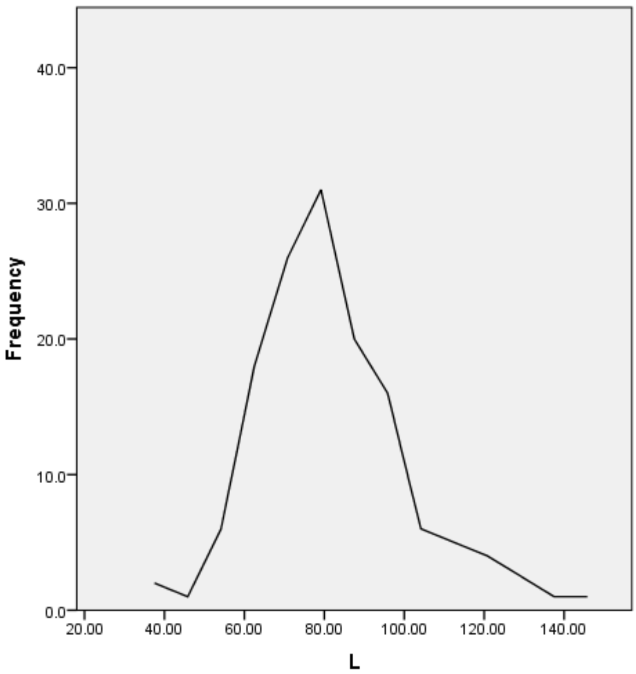


Figure 8.16 Frequency distribution of flakes from Woodgreen. Size categories of flakes in mm are plotted on the x-axis. The frequency of flakes in each size category is expressed as percentage of the total number of flakes and plotted on the y-axis.

8.4.2 Depositional context at Woodgreen

Sediment structures of the deposits at Woodgreen show crudely bedded gravel with bands of medium framework gravel. The latter forming under relatively low sediment transport rate with limited supply of transportable finer grains causing segregation of sand and gravel (Bridge 2005). The overlying matrix supported gravel indicates a depositional environment of migrating gravel bars (WG1.7-WG1.13 and WG2.4-WG2.8). This is followed by a period of reactivated water current velocities and sediment load indicated by a band of large clasts (Chapter 6 and 7) and poorly sorted gravel (WG1.1-WG1.5 and WG2.1-WG2.3). Towards the top of the deposit (uncleaned in this research) Bridgland and Harding (1987) described a 'finer and paler matrix supported gravel'. During their fieldwork a biface was recovered from the clast supported medium gravel of unit WG1.11. Blackmore notes that artefacts have been found throughout the entire sequence ('Locked notebook', Salisbury Museum).

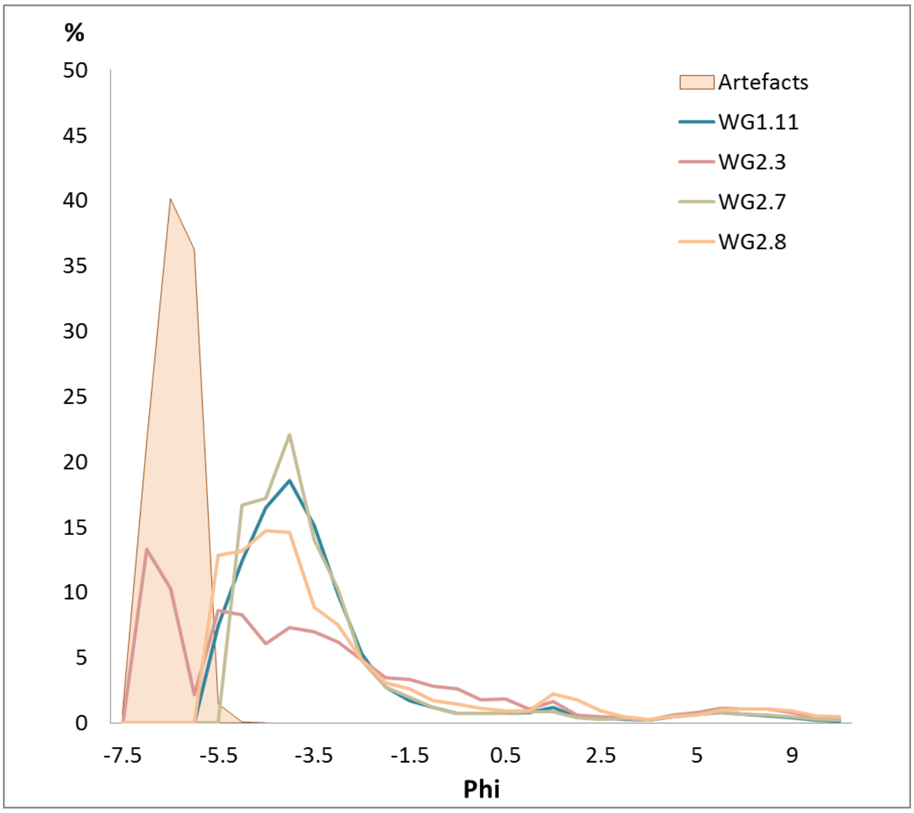


Figure 8.17 Particle size distribution of artefacts from Woodgreen compared to sediments from the site. The x-axis shows clast size categories in phi, the y-axis plots the weight of the clasts per size category as percentage of the total weight of the sediment samples and for the artefacts of the total weight of all the artefacts.

The size distribution of artefacts from Woodgreen was compared to that obtained from the sediments (Chapter 7). (Figure 8.17). The size of almost all artefacts exceeds that of natural clasts although some large clasts from WG2.3 fall within the same size category as some artefacts. Large clasts found at Woodgreen include rolled nodules and large cobbles possibly derived from the Tertiary bedrock. The degree of patination and staining of artefacts at Woodgreen is variable (Table 8.3 and Table 8.4, and Figure 8.3 and Figure 8.4). The majority of artefacts are moderately patinated (58.1%) and moderately stained (40.0%) with a significant proportion of 'heavily' and 'very heavily' stained artefacts (28.5% and 14.0% respectively). Iron and manganese concretion occurs often on artefacts from

Woodgreen (Table 8.5 and Figure 8.5). 26 (4.1%) of the patinated tools show one side to be totally and the other side partly patinated. The majority (86.8%) is partly patinated on two sides. 334 (52.6%) artefacts are entirely stained, 161 (25.4%) are stained on one side totally and one side partly and 120 (18.9%) are partly stained on two sides.

The majority of the artefacts from Woodgreen are 'rolled' or 'slightly rolled' (55.0% and 23.8% respectively) (Table 8.6 and Figure 8.6). 72.8% of all artefacts from Woodgreen are unbroken and 63.3% of all 'very rolled' artefacts are unbroken and 75.1% of all rolled artefacts are unbroken (Table 8.7). The majority of the broken artefacts show damage to the side (33.5%), tip (32.9%) or the butt or body (both 14.4%). 31 (4.9%) artefacts show a fresh fracture, and 66 (10.4%) artefacts have a broken surface that is patinated, stained and abraded to a similar degree as the total artefact.

8.4.3 Biface variability at Woodgreen

The biface sample from Woodgreen contains 49.6% pointed bifaces, 46.3% ovate bifaces and 4.1% cleavers as defined by the shape ratios developed by Roe (1969b) (Figure 8.18). Although the site has often been discussed in the light of hominin presence and occupation patterns in Britain the artefact assemblage has received less attention (Westaway et al. 2006; Ashton and Hosfield 2010; Brown et al. 2013). Apart from notes by Westlake, the primary collector at the site, and Blackmore, director of the Blackmore Museum in Salisbury and main collector of the Bemerton and Milford Hill assemblages, of recent workers only Roe (1968, 1981) makes a note of the biface types in the assemblage: '*Many ovates in a large (hundreds) mixed series*' (1981, p. 210). This differs from the results presented here that suggest almost equal proportions of ovate and pointed bifaces. This can be explained by the occasional typological anomalies that can occur when applying Roe's method for identifying biface types, inter-analyst variation and especially the likely different samples employed for analysis.

Within the categories of 'pointed', 'ovates' and 'cleaver' types a variety of shapes exist in the cleaver category but shapes in the pointed and ovate biface groups are more consistent (Figure 8.18). The bifaces from Woodgreen are generally small, shortened with a tendency to uniform edge and profile shape. These metric measurements reflect the tendency to ovate-shaped bifaces which is also indicated in the mean pointedness ratio that falls just within the ovate category as defined by Roe (Table 8.12).

Statistical tests could not reliably be carried out to investigate the relationship between artefact shape and indications of the depositional context or technical aspects such as cortex retention and blank type. The significance of the differences could not be reliably tested because the minimum expected frequency in the cross tabulation for the Chi-square test was less than one and over 20% of the cells had expected frequencies less than five (Dytham 2011). The data is visualised in Appendix 41 to aid comparison. This indicates that pointed artefacts are slightly more often ‘heavily’ and ‘very heavily’ patinated than ovates, the latter are more often ‘heavily’ and ‘very heavily’ stained. Ovate bifaces are slightly more often ‘very rolled’ than pointed types. Iron and manganese concretion is present on all types. Figure 8.19 shows the relationship between cortex location and biface shape. Ovate bifaces are most often fully worked or show cortex retention on the sides or body. Pointed bifaces most often have cortex retained on the butt or multiple locations around the butt. A comparison of blank types per biface type is presented in Figure 8.20. Ovates are most often fully worked and pointed types are most often made on nodular flint.

	Mean		
Length	97.65	±	24.39
Breadth	67.01	±	12.58
Thickness	31.76	±	9.20
Refinement	0.48	±	0.12
Tip refinement	0.18	±	0.04
Elongation	0.70	±	0.12
Edge Shape	0.71	±	0.19
Profile shape	0.70	±	0.18
Pointedness	0.36	±	0.10

Table 8.12 Mean size and shape ratios of unbroken bifaces from Woodgreen

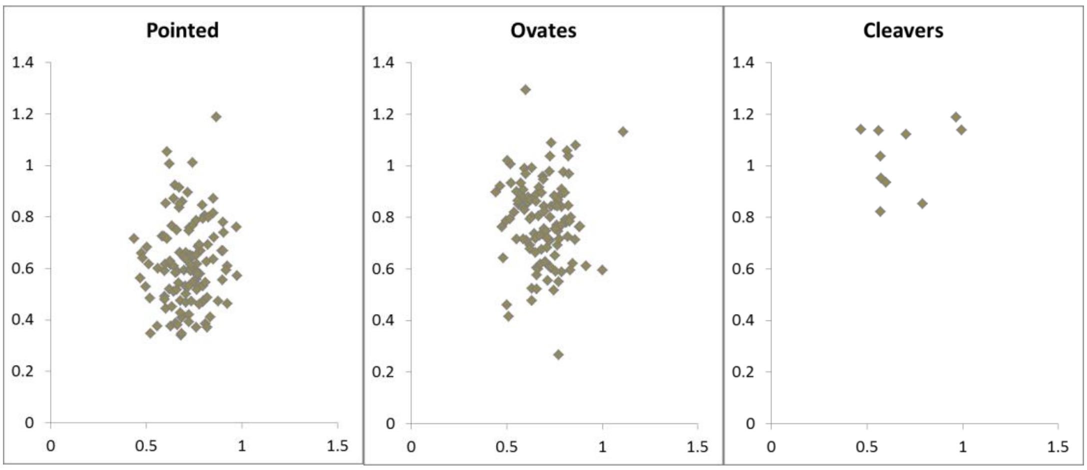


Figure 8.18 Tripartite diagram of unbroken bifaces from Woodgreen, including 49.6% pointed, 46.3% ovate, 4.1% cleaver types. The elongation ratio (B/L) of each biface is plotted on the x-axis and the edge shape ratio (B1/B2) is plotted on the y-axis.

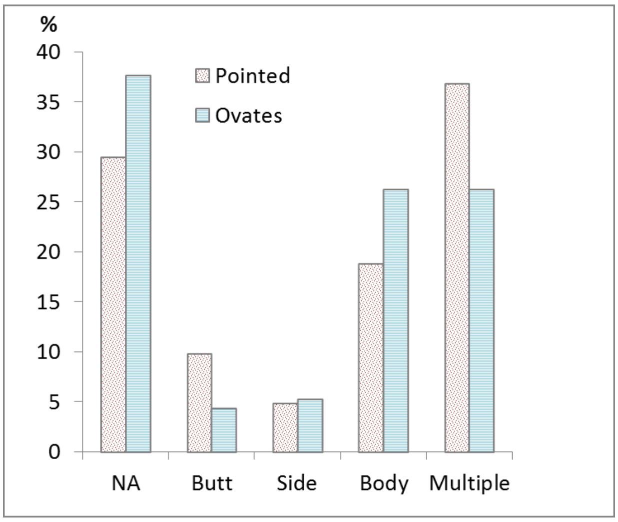


Figure 8.19 Illustration of the relationship between the location of cortex and biface shape at Woodgreen. The location of cortex is plotted on the x-axis, the frequency with which cortex was found on the butt, side, body or on multiple locations is expressed as percentage of the total pointed and ovate bifaces and plotted on the y-axis.

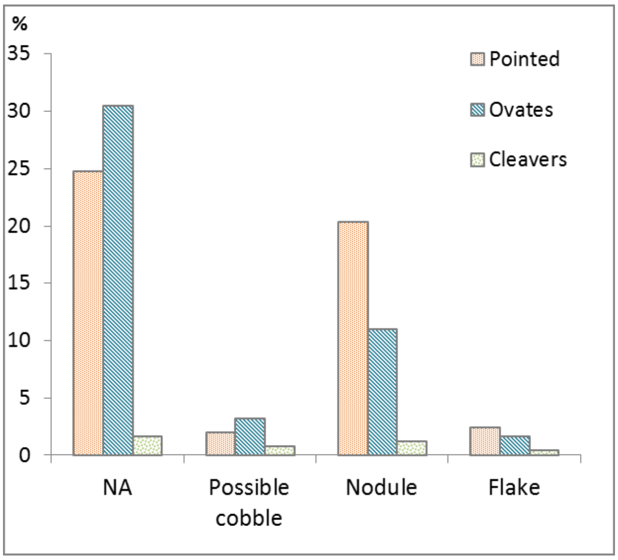


Figure 8.20 Biface shape in relation to blank types. The blank types identified at Woodgreen are shown on the x-axis. The frequency of their occurrence in the assemblage is expressed as percentage of the total number of unbroken bifaces.

8.5 Site formation and integrity in the Avon valley

The following discussion of site formation processes, site integrity and hominin landscape use draws on information from the condition of the artefacts, sedimentological context and artefact assemblage data of which the details are presented above. Here the information from the individual sites is compared and combined with information about Palaeolithic site distribution in the Avon valley discussed in Chapter 3 and terrace formation modelling presented in Chapter 6. In combination this provides information about site formation and integrity that facilitates the further discussion of observed differences and similarities between the sites in the light of hominin landscape use and behaviour.

8.5.1 Collection history

The assessment of the Palaeolithic site distribution presented in Chapter 3 highlights a few important points that contribute to the discussion of site formation in the Avon valley. Firstly, although quarries extracting river gravels were present throughout the valley, distributed over all terraces and known to local antiquarians, only Bemerton, Milford Hill and Woodgreen were noted as remarkably large sources of Palaeolithic flint implements. This suggests that the discovery of artefacts at these locations is not just the result of building or quarry activities. Secondly, antiquarians in the region were interested in all geological exposures and did not focus attention only on sites yielding large quantities of artefacts, which indicates that these concentrations are not the result of biased interest.

The collection history of assemblages such as those found at Bemerton, Milford Hill and Woodgreen, likely influenced the composition of the assemblages available for study today. It is to be expected that knapping sites contain large numbers of flakes relative to the number of bifaces (unless additional bifaces preliminarily worked or finished elsewhere have been brought in). For example, in an experimental production of a flint biface of 230 grams Newcomer (1971) produced 51 flakes. A knapping scatter at Boxgrove (Q1/A) consisted of 1.13% bifaces and 97.88% flakes (roughing-out, thinning-, finishing- and broken flakes) (Roberts and Parfitt 1999). If hominins were producing bifaces at the studied sites, a larger number of flakes than bifaces can be expected. The results from this research show that all assemblages studied comprised low numbers of flakes and that the sample from Woodgreen included significantly more miscellaneous artefacts and flakes and fewer bifaces than were present in the assemblage from Milford Hill. No significant difference was found between Woodgreen and Bemerton or between Bemerton and Milford Hill (Table 8.1 and Appendix 42).

The detailed notes from Blackmore on the discovery of the Palaeolithic artefacts at Milford Hill offer valuable insights into the collection history of the sites and an explanation for the low number of flakes in the assemblages: '*…there exists, scattered through the gravel, a large number of flint flakes or chippings, which were cast aside as apparently of no use…*' (Blackmore 1864, p.244). This indicates flakes were present at the site. In the following quote Blackmore ('Locked notebook', Salisbury Museum, p. 114) discusses the problem of collection bias: *'Besides those two implements one found about half a dozen rough flint flakes which were apparently considered of no use, indeed such rough waste flakings must necessarily have been struck off in the manufacture of the more finished tools. I could match them all, from the similar specimens of the later stone period. I attribute considerable importance to the finding of these rough waste flakings with the implements as supplying an important link in the process of manufacture of all such remains of the handicraft of man; they are easily overlooked and do not appeal much to the uneducated eye.'*

The significantly higher number of miscellaneous flakes from Woodgreen seems to indicate personal interests or preferences of the collectors. At Woodgreen Westlake collected plenty of 'eolith' artefacts, now regarded as natural (Westlake 1900). The presence of plenty of miscellaneous flakes could be the result of his interest in all types of artefacts. The assemblages of all three sites contain similarly low numbers of flakes in relation to bifaces. It is important to note that flakes *were* collected at all three sites, indicating that Blackmore and Westlake were aware of the potential importance of flakes as well as bifaces and that their collecting were not entirely focused on the latter. The size distributions of the flakes show that very small flakes were collected, though not as many and as small as would be expected from a complete knapping sequence (e.g. Newcomer 1971). This is likely the result of artefact collection but could also relate to hominin behaviour at the sites or depositional processes (Isaac 1989; Roth and Dibble 1998). The latter is further discussed below.

8.5.2 Fluvial processes and depositional contexts

It is clear that collection history influenced the composition of the assemblages from the studied sites. However, flake-biface ratios have also been put forward as an indication of fluvial processes (Isaac 1989). This is based on the concept that smaller particles are preferentially removed from a site under fluvial processes (ibid.). Sedimentological research shows that there is no clear relationship between clast size and transport distance, because processes such as entrapment and burial of smaller clasts can hamper further transport (Hassan et al. 1992). 'Winnowing' of flakes from the assemblage is therefore unlikely unless the shape of flakes influences their preferential transport. This has been proposed recently by

Byers et al. (2015) who observed a relationship between size and weight, in combination with the shape of flakes and their settling time in a flowing water body. The flat shape of a flake can delay its settling velocity and therefore increase its transport distance (ibid.). This process is not directly transferable to flakes discarded on the dry floodplain where settling velocity is no factor. Once deposited onto the ground surface of river bank, or bar, the shape of a flake could have an anchoring effect as flat shapes are more prone to 'sliding' than 'rolling' and therefore to entrapment between larger clasts (Chambers 2004). A comparison of the size distribution of flakes and that of the sediments negates the influence of winnowing on the artefact assemblages because the sediments include clasts in the size range missing from the flake sizes. The presence of flakes at the sites, especially well recorded for Milford Hill, shows that bifaces were knapped locally. The composition of the studied assemblages and size distribution of flakes indicate that artefact collection skewed towards a higher number of bifaces and preferential collection of larger flakes. Assemblage composition, flake size distribution, and technological aspects of flakes can provide information about hominin behaviour at the site (Roth and Dibble 1998; Stahle and Dunn 1982). Unfortunately the collection bias limits its analytical value and the flakes were therefore not further investigated for this research.

The depositional context of the sites was further analysed through comparison of the size distribution of the respective fluvial sediments with that of each artefact assemblage. At all three sites the size distribution of the artefacts exceeds that of the general clast size of the sediments. This could not be directly observed from Milford Hill but is based on a comparison of the size of the artefacts from this site with the sediments from Bemerton. At Bemerton and Milford Hill large, unrolled flint nodules have been observed of a size that lies within the range of the largest artefacts present at these sites. This is to be expected if the artefacts are made on raw material that is sourced from the local bedrock or gravel. By definition the artefacts must be smaller than the largest nodules in the local environment. These nodules are likely derived locally from the chalk bedrock through solution processes. The largest clasts present in the sediments from Woodgreen are rolled flint nodules and large cobbles, the latter likely derived from the Tertiary bedrock. The rolled flint nodules are probably transported down-stream from the chalk. The presence of artefacts exceeding the sediment's clast size distribution suggests that the artefacts are in proximal context. The depositional context at Bemerton and Milford Hill, with the incorporation of locally eroded large flint nodules in the gravels, and poor distinction of higher-level terrace deposits in this area, (because of the limited accommodation space in the confined chalk valley) suggest vertical incorporation of sediments. Around Woodgreen, the valley widens and terraces are well-developed through incision of the erodible Tertiary bedrock, redeposition of fluvial sediments from valley sides, and terrace preservation through lateral channel migration (cf. Brown et al. 2015; Brown et al. 2013). This is also shown in the assessment of terrace formation processes and terrace volume calculations in the Avon valley which suggest that sediment reworking, lateral erosion and down-cutting were important geomorphological processes in the formation of the valley terraces (Chapter 6 section 6.10.3). This is associated with limited down-stream transport of bedload and the incorporation and planation of fluvial sediments from previous terraces (Brown et al. 2009a; Brown et al. 2010).

These observations are important in relation to the discussion of Palaeolithic site distribution and site formation in fluvial contexts as has been touched upon in Chapter 3. Previously it has been suggested that a change in fluvial processes at confluence zones and at the boundary of the Chalk-Tertiary bedrock can result in the aggradation of artefacts and the formation of 'super sites' with little significance for hominin behaviour (Ashton and Hosfield 2010; Hosfield 1999). The clast size distribution of the sediments from Bemerton and Woodgreen do not show a high proportion of large clasts in the same size range as Palaeolithic artefacts (this could not be directly observed for Milford Hill). If fluvial processes led to the aggradation of bifaces, this would equally have led to the aggradation of large clasts. The size of the Palaeolithic artefacts generally exceeds that of the clasts found in the sediments.

Moreover, distribution of Palaeolithic find-spots and their relationship to terrace deposits shows that there is no increased concentration of artefacts down the transition from Chalk to Tertiary bedrock. The only large artefact concentration down-stream of the Chalk-Tertiary boundary is Woodgreen. The theorised break in slope from the Chalk to Tertiary bedrock causing the above mentioned change in fluvial processes and artefact deposition as proposed by Hosfield (1999) was not observed on high-resolution elevation models. In addition, Woodgreen is situated *ca*. 1km down-stream of the Chalk-Tertiary boundary which suggests this geological boundary had no direct influence on site formation at Woodgreen. The change in bedrock could have provided a source of raw material through the erosion of the chalk bedrock and the incorporation of flint nodules in the river gravels which may have attracted hominins to this location (Ashton and Hosfield 2010). However, the site is not directly located at the boundary of the different bedrock types indicating that other factors may have contributed to hominin site selection.

8.5.3 The *état physique* of artefacts as indication of taphonomic processes

It has been suggested that the condition of artefacts can provide information about their depositional context and that groups of artefacts showing different degrees of surface alteration may reflect exposure to different depositional processes and could represent groups with different spatio-temporal resolutions (Ashton 1998; Ashton and Hosfield 2010; Chambers 2004; Glauberman and Thorson 2012; Harding et al. 1987; Hosfield 1999; Isaac 1989; Shackley 1974). However, the exact conditions under which these characteristics occur are still poorly understood (Andrefsky 2005; Chambers 2004; Glauberman and Thorson 2012; Purdy and Clark 1987; Thiry et al. 2014) which limits its contribution to the understanding of hominin behaviour during the Palaeolithic. The following section discusses the results of the description of the appearance of the artefacts from Bemerton, Milford Hill and Woodgreen and its possible contribution to the understanding of these assemblages.

8.5.4 Patination, staining and iron-manganese concretion on artefacts

The link between the context and condition of artefacts from Milford Hill and Woodgreen is discussed by Blackmore who notes that '*Some are stained a bright ochreous color, whilst others still preserve the original tints of the flints; this is entirely owing to the unequal composition of the beds of gravel from which the implements have been derived, and in no way affects the comparative age of the specimens*.' (1864, p. 244). At Milford Hill he observed: '*it is remarkable that this staining does not appear to be due to their present position in the gravel, some of the darkest specimens have been dug out of the pale chalk rubble, side by side with fragments of flint retaining its original hue: and on the other hand, perfectly unstained examples have been obtained from the dark ochreous gravel*.' (Blackmore 1867, p. 229). About the condition of the artefacts in relation to the deposits at Woodgreen he noted: '*there is very little staining in the upper part of No.1. Implements easily identified from this bed. The staining of the flints from beds No.2 and No.4 is very much alike. The black band or vein No.3 is very easily traced and leaves its mark on all flints and implements in its vicinity most useful for identifying the exact position of many of the implements*.' (28 September 1909, 'Locked notebook', Salisbury Museum).

Artefacts from Bemerton and Milford Hill are significantly (χ^2 =69.583, df = 8, p <0.001) more often "heavily" and "very heavily" patinated than those from Woodgreen (Table 8.3 and Figure 8.3 and Appendix 42). Artefacts from Woodgreen are most often "heavily" and "very heavily" stained (χ^2 =150.865, df = 8, p <0.001) (Table 8.4 and Figure 8.4 and Appendix 42). Iron and manganese concretion is limited at Bemerton and Milford Hill but occurs commonly in varying degrees on artefacts from Woodgreen (Table 8.5 and Figure 8.5). The data did not permit this to be statistically verified as the significance of the differences could not be reliably tested because the minimum expected frequency in the cross tabulation for the Chi-square test was less than 1 and over 20% of the cells had expected frequencies less than 5 (Dytham 2011).

The results presented here show that within sites no significant groups could be identified when looking at the relationship of artefact shapes and artefact condition. However, the comparison of patination, staining, abrasion and iron-manganese data of the three sites demonstrate that significant differences exist in the condition of artefacts between sites. Using visual inspection of the assemblages and combining the condition categories, (i.e. patination, staining, iron-manganese concretion and abrasion), permitted the comparison of artefacts and the identification of groups *within* assemblages. Appendix 44 provides an impression of groups of artefacts with similar surface conditions that could be recognised within the assemblages.

The groups at Woodgreen could be linked to the division made by Blackmore who mentions little staining of artefacts from the upper part of the terrace deposit, moderate staining of flints from his bed 2 and 4, and dark marking on artefacts from the 'black band' (manganese) (Blackmore 'Locked notebook', Salisbury Museum). At Milford Hill he noted that artefact condition did not correspond to the sedimentological context from which it was derived, with unstained or white patinated artefacts found in ochreous gravel. Harding and Bridgland (1998) emphasised the significant influence of chalk dissolution at Milford Hill not only of the bedrock, resulting in the irregular solution features (also observed at Bemerton), but also of chalk that must have been present in the gravel. They argue that this must have resulted in localised post-depositional disturbances of the gravel (ibid.). A number of bifaces were found with calcium concretion indicating their incorporation within chalk rich deposits at some point during their depositional history. Harding and Bridgland (1998) observed the presence of lenses and blocks of 'coombe rock' which they linked to the erosion of, and therefore proximity of the site to the contemporary valley side. The observation made by Blackmore that the condition of artefacts did not always correspond to their present sedimentological context can possibly be explained by the fact that artefacts were incorporated in the gravel as part of the erosion of the contemporary chalk valley sides and therefore in a chalk rich sedimentary context. The chalk would have influenced the appearance of the artefacts in the earlier stages of their taphonomic history; and the chalk's subsequent solution from the surrounding sediments has resulted in a mismatch between the artefacts' appearance and the sedimentary context from which they were recovered. The variety in the appearance of the artefacts from Milford Hill can therefore be related to the different sedimetological contexts of the tools prior to extensive dissolution.

To conclude, within sites, groups of artefacts with characteristic conditions could only be identified based on visual inspection, and not be statistically verified. This demonstrates the difficulties of statistically comparing subjective descriptions of artefact conditions. It also shows that it is especially the combination of patination/staining/abrasion/iron-manganese concretion, which is characteristic. The groups identified in this research could be related to historic descriptions. At Woodgreen this has offered a broad indication of the original stratigraphic opposition of some of the artefacts within the section. This is not the case at Milford Hill and Bemerton where the appearance of artefacts was found not to match their direct sedimentary surroundings (Blackmore 'Locked notebook', Salisbury Museum). This difference between Woodgreen and Milford Hill and Bemerton can probably be contributed to the influence of chalk dissolution at the latter two sites, which has distorted the initial sediment context of the artefacts. At Woodgreen, located on the Tertiary bedrock, inclusion of chalk to the river gravels was likely limited. The different appearance of artefacts from the sites therefore seem to reflect valley wide differences in depositional contexts influenced by e.g. chemical and hydrological characteristics of the bedrock. This shows that the *état physique* of artefacts does not offer universal indications of their post-depositional history but that with a detailed understanding of the geological context and post-depositional processes it can contribute to the reconstruction of site formation processes and integrity.

Related to this discussion is the description of Read 1885 of a biface that shows different stages of patination in different flake scars suggesting the reuse of an old artefact. The tool made many years previously could have been encountered at the location by a hominin who reused the tool. The period between use and reuse is unclear as the development of patation may occur on short time scales and varies according to local conditions. The reuse of old artefacts has also been described at La Noira in France (Moncel et al. 2013). This highlights the significance of these locations in the landscape as places to return to. When this occurs within the span of a few generations this could be a learnt pattern. When exceeding multiple generations or groups this could indicate the value of these locations in another sense e.g. niche construction (Brown et al. 2013). Pope et al. (2006) suggested that a hominin encounter with an old artefact could also instigate the subsequent use of such a location. This of course depends on how long artefacts remain exposed. The reused tool suggests that artefacts were still present at the surface, but had developed patina, when subsequent groups of hominins discarded newly made (and possibly reused old) bifaces. This is also suggested by the presence of artefacts with differential weathering on both sides of the artefact.

8.5.5 Abrasion and breakage of artefacts

Apart from patination and staining, the degree of abrasion of artefacts as an indication of artefact transport and site integrity has received substantial attention (Chambers 2004; Harding et al. 1987; Hosfield 1999; Isaac 1989; Shackley 1974). The processes influencing artefact abrasion however, are complex and quantification or experimental replication of abrasion observed in the archaeological record has proven to be difficult (Hosfield 1999; Lewin and Brewer 2002). Nonetheless a tendency remained to draw a linear correlation between the degree of abrasion and artefact transport distance (Ashton and Hosfield 2010; Hosfield 1999). Other recent experiments have demonstrated that abrasion of artefacts can occur under highly localised conditions, and may be sporadic and non-linear (Chambers 2004). Artefact transport in a river system is often episodic and for the majority of time the artefact is stable and bombarded with more mobile clasts resulting in abrasion without substantial transport (Chambers 2004; Hassan and Church 2001). These observations demonstrate how localised processes differentially influence the abrasion of artefacts and that its correlation to a degree of reworking is difficult to establish. Moreover, the concern has been raised that clast size and shape may influence initial entrainment and clast transport (Chambers 2004), further complicating the processes that mechanically alternate individual artefacts. Although no clear relationship between clast size and transport distance has been established (Hassan et al. 1992), clast morphology seems to influence the duration and initial entrainment of clasts (Schmidt and Ergenzinger 1992). Chambers (2004) has demonstrated a similar effect for fluvial transport of bifaces and observed that 'lenticuliar convex' (rod shaped) bifaces are more prone to rolling and 'plano-convex' (plate shaped) more prone to sliding. Breakage of artefacts may provide an additional indication of their depositional history. It is likely related to abrasion as the degree of rounding of clasts is proportional to shape (Lewin and Brewer 2002), suggesting that abraded artefacts should be more frequently broken and that especially biface tips will show increased damage with an increased degree of abrasion. For this research the degree of artefact abrasion and breakage was recorded to explore differences between and within sites and investigate how this can provide information about site formation processes in these particular cases.

Table 8.6 and Figure 8.6 illustrate that artefacts from Milford Hill and Woodgreen show similar degrees of abrasion and that artefacts from Bemerton are more heavily abraded (33.8%). Woodgreen shows the highest percentage (3.9%, N=25) of fresh artefacts (χ^2 =38.188, df = 6, p <0.001). Table 8.7 and Figure 8.7 show the number of broken artefacts per site. Milford Hill has the highest percentage of broken artefacts (21.8%) (χ^2 =6.266, df = 4, p 0.180). At Bemerton and Woodgreen the percentage of broken artefacts in the 'very rolled' abrasion category is higher than that of the total assemblage This was not the case for the artefacts from Milford Hill. Damage occurred most often on the tips or sides of the artefacts.

The relationship between artefact size and abrasion is explored by looking at the mean size of artefacts in each abrasion category (Appendix 43). This shows that the 'fresh' artefacts are largest and heaviest. The mean size and weight data of 'slightly rolled', 'rolled', and 'very rolled' artefacts show that size does not further decrease with increased abrasion, and that 'very rolled' artefacts are significantly larger than 'rolled' artefacts. These data show that smaller artefacts are not significantly more abraded and that most abraded artefacts are in fact on average larger than 'slightly rolled' and 'rolled' artefacts. This demonstrates that smaller artefacts are not more prone to abrasion through preferential transport of smaller clasts. Heavy abrasion of large artefacts may be the of result them being bombarded by more mobile clasts.

The relationship between artefact shape and abrasion studied for this research focused on unbroken bifaces. An objective description of the shape of artefacts per abrasion category was based on the shape ratios developed by Roe (1968) (see Appendix 43). Broken bifaces were excluded from this particular analysis as these would distort the average shape ratios of the unbroken bifaces. Of all unbroken bifaces the 'rolled' and 'very rolled' artefacts were more often ovate shaped and have least refined tips. This may be related to the influence of biface shape on artefact transport (cf. Chambers 2004). It is possible that ovate shaped artefacts are more easily reworked and therefore appear more abraded.

All assemblages included both 'fresh' and 'very rolled' artefacts. This shows that not all artefacts were affected by the same abrasion processes, likely highlighting the different localised conditions as identified by Chambers (2004).

The evaluation of site collection history, site distribution, fluvial processes and the depositional contexts of Bemerton, Milford Hill and Woodgreen show that these sites reflect hominin presence in proximity to these locations. Hominins were coming down to the floodplain, and probably knapping on the floodplain. The debitage and artefacts they produced subsequently became incorporated into the gravel bed. Fluvial processes such as lateral reworking may have resulted in the incorporation of artefact groups with different depositional histories. The different condition of groups of artefacts may represent such subsequent periods of artefact contribution to the site. The evidence of artefact reuse indicates that some were (again) visible on the floodplain. Assessment of terrace formation processes, the distribution of artefacts within the valley, and the reconstructed position of artefacts within the gravel body suggest that these subsequent periods of occupation occurred within a single cycle of terrace formation. This has implications for the period represented by the assemblages and significant consequences for the understanding of landscape use as these records suggest the repeated revisiting of these locations by hominins.

8.6 Hominin landscape use and behaviour in the Avon valley

The assessment of site formation and integrity discussed above suggests that the locations at which these large concentrations of artefacts were found were revisited by hominins over a longer period of time which suggests a preference for or an attractiveness of these locations (cf. Brown et al. 2013). The following section discusses what indications this research has identified for hominin activities at these sites and how they were using the landscape. The presence of large quantities of flakes, although collected selectively and underrepresented in the studied assemblages, and rough-outs indicates that hominins were making tools locally. Other aspects of the assemblages, such as artefact size, raw material and blank type use and biface variability can offer further insights in the activities of hominins in the Avon valley.

8.6.1 Biface variability in the Avon valley

A considerable debate regarding the significance and meaning of biface variability exists. The main hypotheses developed to explain British biface variability focus on the influence of raw material, re-sharpening, chronological change and cultural design on biface shape (Ashton and McNabb 1994; Bridgland and White 2015; McPherron 1999; Wenban-Smith 2004). However, the role of many other factors such as cognitive capacities, individuals, different members of the society, artefact use, on biface shape have also been explored (e.g. Gamble et al. 2011; Gero 1991; Hiscock 2014; Kohn and Mithen 1999; Machin 2009). The Palaeolithic record presented here provides a unique case in which three large sites from a well-defined area could be studied in their geological, depositional, and spatio-temporal context.

Firstly, the maximum size of bifaces is limited by the size of the available raw material (Ashton and McNabb 1994). Large flint nodules can be derived from chalk bedrock or from superficial deposits into which nodules are incorporated through fluvial processes. The latter might influence their quality by external damage, size reduction and internal fracturing, and nodules from chalk outcrops are often regarded as larger, of better quality and the preferred blank type (White 1998). If raw material predicts artefact size and if sites located at or near the chalk bedrock are assumed all to have equal access to good quality flint, artefacts can be expected to be larger in these areas (ibid.). This can be tested by looking at the average size of bifaces from sites in different geological regions. This hypothesis is complicated by the observation that size variation of artefacts is also correlated to knapping and reduction intensity of artefacts (McPherron 2006). This would mean that a direct correlation between artefact size and raw material size is difficult to make, as small artefacts may simply reflect more intensely reduced/re-knapped tools. Reasons for hominins to do this could however relate to raw material availability as such that when raw material is less widely available, artefacts may be more intensely re-used/re-sharpened (McPherron 2006). Such behaviour could be reflected in the reduced presence of cortex on smaller artefacts (ibid.) although this could also indicate a difference in knapping skills, artefact curation and tool function (Ashton and McNabb 1994; Machin 2009; McPherron 1999; Roe 1968; White 1998). The recoding of cortex retention and artefact size can be used to explore this resharpening.

McPherron (2006) has also related reduction intensity to biface shape because artefact re-sharpening will lead to a decreased pointedness in order to maintain stable width-length ratios. This suggests that ovate shapes are more intensely reduced and will therefore show lower percentages of cortex and will be generally smaller. If shape is the result of reduction intensity and reduction intensity is related to raw material availability, then it can be expected that in areas of widely available raw material artefacts are larger, more pointed and retain more cortex than in areas where raw material is scarcer and bifaces are repeatedly re-sharpened. White (1998) however, has suggests the contrary. He theorised that when good quality flint is available, ovate bifaces are produced as 'preferred shapes' (ibid.) and when raw material is of less good quality, pointed bifaces are made. Thus near the chalk, where raw material is assumed to be widely available, White (1998) expects ovate bifaces; in areas where raw material is of lesser quality or there is a reduced availability, such as from river gravels, pointed bifaces would be expected (ibid.). White (1998; Ashton and White 2003) has argued that the different shapes do not reflect alternative use but that they do have different functional capacities with the ovate shape being most efficient and therefore the 'preferred' shape. The different shapes could also relate to different functions or just to different functionality (reflecting not necessarily different *actions* but a different way of *using* the tool) (Mitchell 1995; White 1998).

Biface variability in Britain has also been interpreted as reflecting cultural groups or chronological change (e.g. Bridgland and White 2015; Roe 1969b; Wenban-Smith 2004). Roe (1969b) has applied the dominance of ovate or pointed bifaces in assemblages from the British Isles to assign these to different groups or 'traditions'. The variation between biface assemblages has also been explained from a chronological perspective (Bridgland and White 2014, 2015; Pettitt and White 2012; Wenban-smith 2004). These interpretations suggest that earlier sites (MIS 13) are dominated by ovate bifaces, followed by mixed ovate and pointed assemblages during MIS 11 and a further increase in biface diversification in time with the occurrence of ficrons, cleavers and Levallois technique around MIS 9/8 (Bridgland and White 2014, 2015; Pettitt and White 2012; Wenban-Smith 2004). The following section will summarise and compare the results of the artefact analysis from the Avon sites. This data is then used to address the significance and possible meaning of biface variation in Britain.

8.6.2 Comparison of the assemblages from the Avon valley

The assemblages from all three sites consist of a small number of chert artefacts, mostly bifaces. Milford Hill contains the highest number of chert artefacts although the data does not allow this to be statistically verified because the minimum expected frequency in the cross tabulation for the Chi-square test was <1 and over 20% of the cells had expected frequencies <5 (Dytham 2011).

A comparison of the artefact size distribution of all artefacts from Bemerton, Milford Hill and Woodgreen is presented in Figure 8.21. This shows that the assemblage from Milford Hill contains the largest artefacts, the artefacts from Woodgreen are in general smaller and the size distribution of the Bemerton assemblage falls in between the other two. Table 8.13 shows the significant difference in size and weight of the artefacts from the three sites.

A comparison of cortex retention and cortex location on artefacts per site and on all bifaces per site is presented in Appendix 42. The significance of the differences could not be reliably tested because the minimum expected frequency in the cross tabulation for the Chi-square test was <1 and over 20% of the cells had expected frequencies <5 (Dytham 2011). A comparison of the data however, suggests that 25% or more cortex was most often retained on artefacts from Milford Hill and occurred most often on multiple locations on the artefacts.

A significant difference (χ^2 =106.417, df = 6, p <0.001) was observed in the blank types identified at each site. The samples from Bemerton and Woodgreen contain more artefacts for which blank types could not be identified. At Milford Hill nodules were significantly more often recognised as blank types. This difference is maintained when looking at the blank types of bifaces only per site (χ^2 =65.877, df = 6, p <0.001). Bifaces from Bemerton and Woodgreen are more often fully worked or left with limited cortex inhibiting blank type recognition. Nodules are most often used at Milford Hill and flakes are most often used at Woodgreen for biface production.

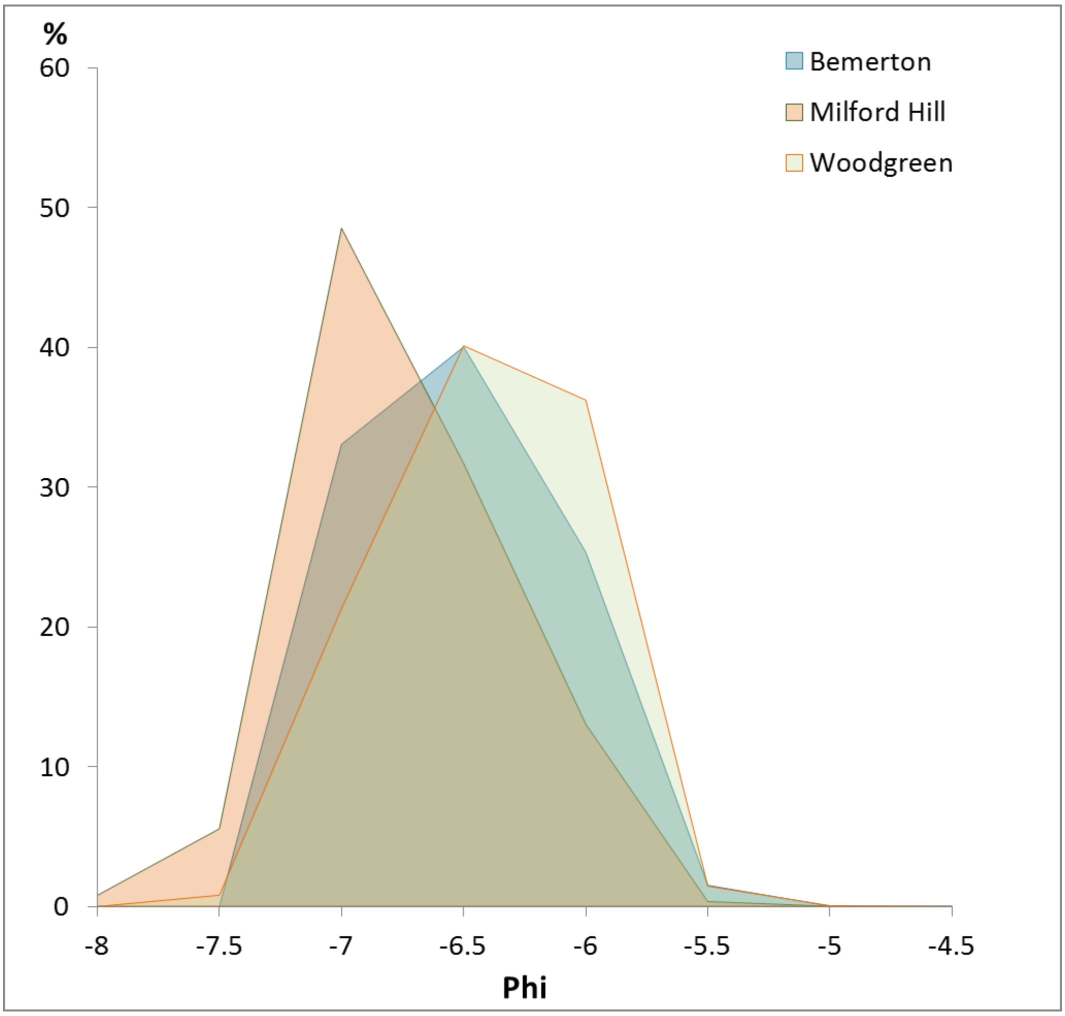


Figure 8.21 Particle size distribution of the artefact assemblages from Bemerton, Milford Hill and Woodgreen. The weight per size category in phi is expressed as percentage of the total weight of the artefact assemblage from each site.

MEAN SIZE AND WEIGHT PER SITE

	Bemerton (N=151)			Milford Hill (N=467)			Woodgreen (N=635)			
	Mean			Mean			Mean			Significance
Length	97.53	±	26.19	114.73	±	34.12	93.22	±	23.50	<0.001*
Breadth	68.69	±	17.23	71.38	±	16.86	65.33	±	14.88	<0.001*
Thickness	29.65	±	10.15	33.85	±	11.30	28.06	±	10.22	<0.001*
Weight	235.52	±	165.46	306.33	±	221.14	195.14	±	143.38	<0.001*

Table 8.13 Mean length, breadth, thickness (mm) and weight (g) of all artefacts per site. *Levels of significance are calculated using the Kruskal Wallis test (see Appendix 42).

Based on the shape ratio developed by Roe (1969b), bifaces were divided in pointed, ovate and cleaver types. Metrically defined ovate bifaces were most dominant in the assemblage from Bemerton, Milford Hill was characterised by mainly pointed types and Woodgreen contained both in roughly equal proportions. Metrically defined cleaver types were scarce at all three sites. This is in agreement with the low number of cleavers recognised in a large data set of British bifaces analysed by Roe (1969b), which only included 2% cleavers. The difference in the number of ovates, pointed and cleaver bifaces between the Avon sites however, is not statistically significant (χ^2 =4.905, df = 4, p 0.297). The shape ratios and tripartite diagrams of the three sites are compared in Table 8.14 and Figure 8.22, and Figure 8.23. The average size and shape ratios presented in Table 8.14 show significant differences in biface shapes between the sites. Appendix 42 presents the results of the post-hoc analysis (Fisher's Least Statistical Differences for the normally distributed data and the Mann-Whitney test on pairs of sites for data that failed the test of homogeneity of variances). Bifaces from Milford Hill are significantly longer, thicker and more elongated with more refined tips than the bifaces from Bemerton and Woodgreen. They are also thicker in relation to the maximum width of artefacts compared to those from the other sites. The artefacts from Woodgreen are significantly narrower than those from the other two sites. Apart from this there are no significant differences in shape and size ratios between Bemerton and Woodgreen. Bifaces from Milford Hill are more pointed than those from Bemerton but not significantly more than those from Woodgreen. The edge shape of bifaces from Milford Hill is significantly more triangular than those from Bemerton. Again this is not the case for Woodgreen. Overall, the biface assemblage from Milford Hill is most significantly different from the other two sites and most different from Bemerton in particular.

	BEMERTON (N=72)			MILFORD HILL (N=215)			WOODGREEN (N=246)			
	Mean			Mean			Mean			Significance
Length	102.95	±	24.43	122.95	±	31.43	97.65	±	24.39	<0.001*
Breadth	70.70	±	13.71	73.53	±	14.30	67.01	±	12.58	<0.001
Thickness	31.89	±	8.41	37.47	±	9.42	31.76	±	9.20	<0.001
Refinement	0.45	±	0.09	0.51	±	0.11	0.48	±	0.12	<0.001*
Tip refinement	0.19	±	0.05	0.16	±	0.05	0.18	±	0.04	<0.001
Elongation	0.70	±	0.12	0.61	±	0.11	0.70	±	0.12	<0.001
Edge Shape	0.77	±	0.20	0.68	±	0.18	0.71	±	0.19	0.002
Profile shape	0.75	±	0.20	0.63	±	0.19	0.70	±	0.18	<0.001
Pointedness	0.38	±	0.10	0.34	±	0.11	0.36	±	0.10	0.010

Table 8.14 Size and shape ratios of all unbroken bifaces from Bemerton, Milford Hill and Woodgreen. *Levels of significance are calculated using the Kruskal Wallis test (see Appendix 42).

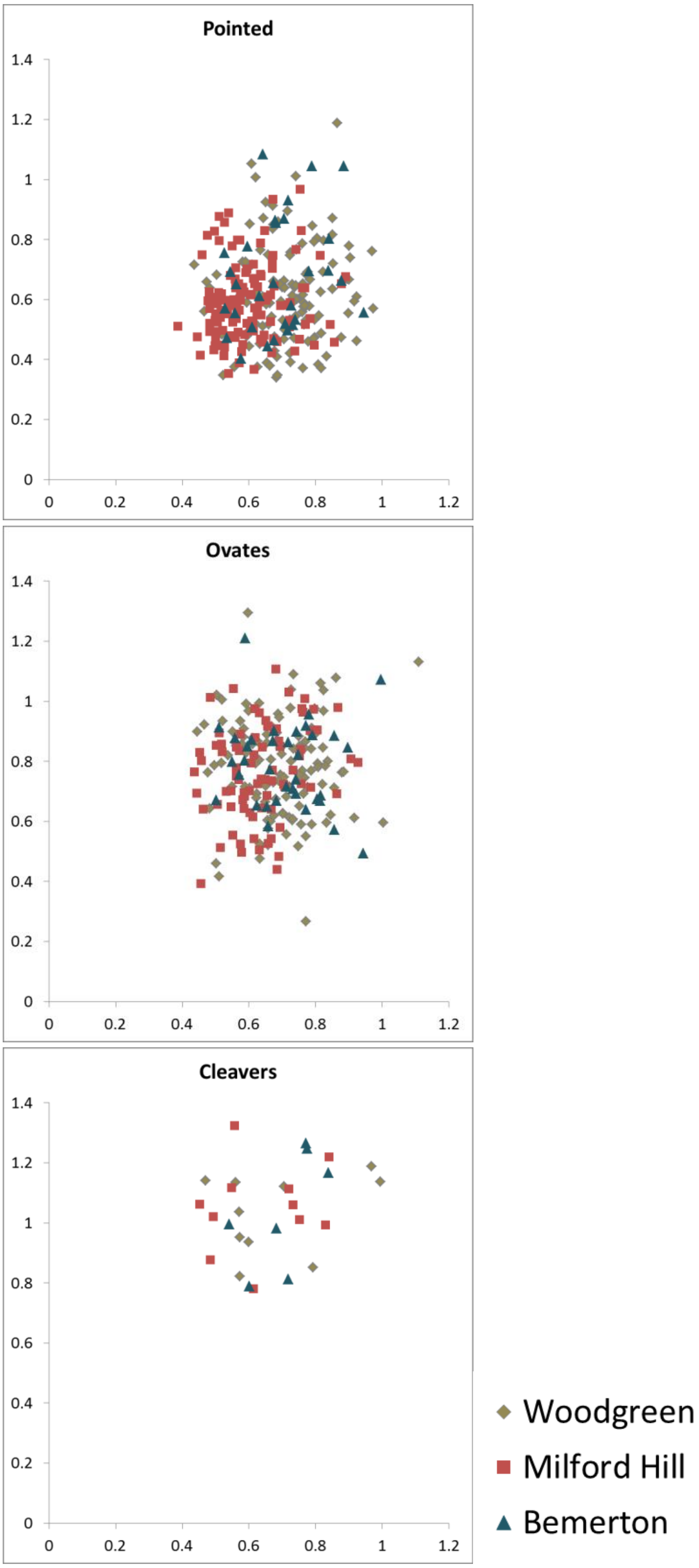


Figure 8.22 Comparison of the typological composition of Bemerton, Milford Hill and Woodgreen. The elongation ratio (B/L) of each biface is plotted on the x-axis and the edge shape ratio (B1/B2) is plotted on the y-axis.

Interestingly, the relationship recognised in the individual assemblages between artefact shape and blank type could be statistically verified for the entire unbroken biface assemblage (χ^2 =28.102, df = 6, p <0.001). Pointed bifaces are significantly more often to be produced on nodules; fully worked bifaces are most often ovate shaped.

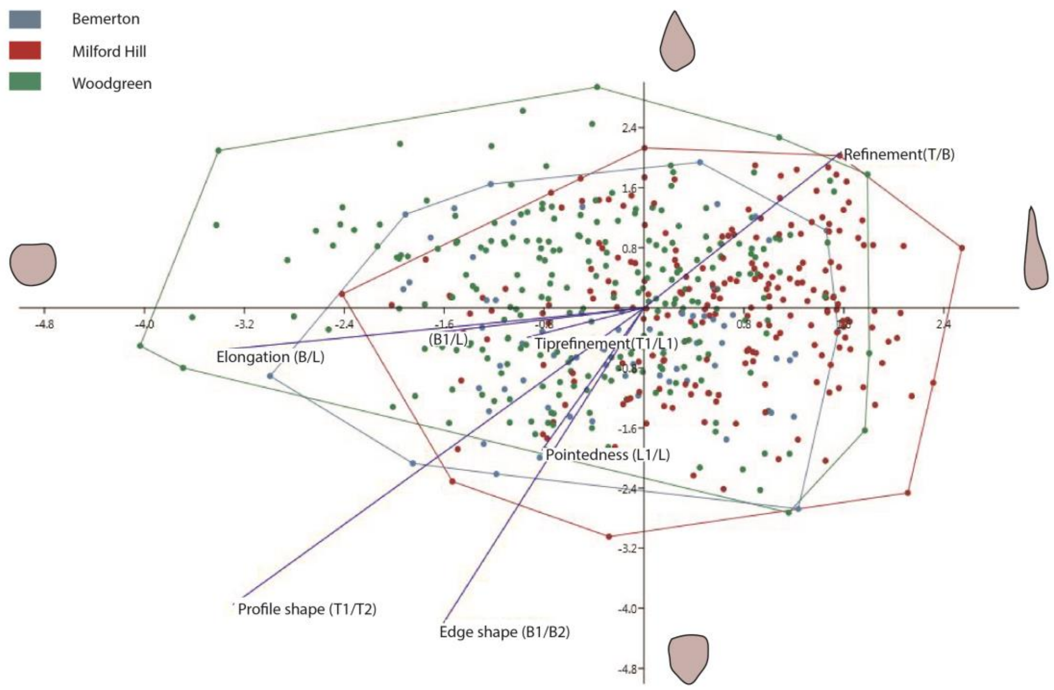


Figure 8.23 Linear discriminant analysis of the shape ratios of all unbroken bifaces from Bemerton, Milford Hill and Woodgreen.

8.6.3 Raw material and reduction

At all three sites the majority of artefacts was made on flint and only a few on chert. At Milford Hill chert was used more often than at Bemerton and Woodgreen. The percentages of chert are comparable to those obtained from the lithology analyses of the sediments at Bemerton and Woodgreen (Chapter 6) (Allen and Gibbard 1993). The higher portion of chert at Milford Hill may reflect the higher portion of chert in the river gravels at this location as noted by Blackmore ('Locked notebook', Salisbury Museum, p.29) and more recently confirmed by Harding and Bridgland (1998). These data indicate that raw material for artefact production was likely sourced from locally present gravel beds. The similarity in lithological composition between the artefact assemblages and that of the gravel suggests that hominins did not preferentially selected one over the other. However, the significant difference in average artefact size between the sites points out that the average size of the raw material available to hominins was different at the three sites. Apart from size a significant difference was seen in blank type use per site. At Milford Hill nodules were more often used for the production of bifaces than could be identified at Bemerton or Woodgreen. At the latter flakes were most often used as blanks for biface production. This can be regarded as an efficient way of raw material use or a means of transporting raw material blanks. The large artefacts at Milford Hill are predominantly made on nodules (as opposed to eroded river gravels) resulting in high percentages of cortex being left on the tools. This may indicate the wider availability of nodules to hominins at Milford Hill than to those at Bemerton and Woodgreen.

Milford Hill and Bemerton are both located on the chalk bedrock, Woodgreen is situated on Tertiary bedrock, just down-stream of the southern extent of the chalk in the Avon valley. Sites located at or near chalk outcrops are usually assumed to have offered hominins good access to flint nodules (White 1998). It has been proposed that at sites away from fresh flint resources (such as found in cretaceous chalk deposits), rolled nodules and river bed gravels would be sourced by hominins for stone tool production (White 1998). The significantly smaller artefacts from Woodgreen could therefore result from the reduced size of raw material available locally to hominins and a generally limited availability of large flint nodules. This would imply that hominins at Woodgreen did not source flint from the nearby (*ca*. 1km north of the site) chalk and rather used locally available flint from the river. However, the artefacts found at Bemerton are also significantly smaller than those from Milford Hill but unlike Woodgreen, Bemerton is found on the chalk where hominins are assumed to have had access to good quality flint (cf. White 1998). The difference between Bemerton and Milford Hill could therefore indicate a difference in local conditions that influenced the accessibility of large flint nodules. For example through chalk outcrops, bedrock erosion and/or vegetation cover.

However, hominins at Bemerton were very close to Milford Hill. This would suggest that hominins also here sourced their raw material very locally, even if better quality flint was available nearby (at Milford Hill). It is possible that direct availability of flint at the site was more important than its quality. This may imply that hominin activities in the landscape were not as strongly influenced by stone raw material sources as has been proposed before (Ashton and Hosfield 2010), and that these sites were of significance for other reasons, e.g. the presence of plant and animal resources, and that the activities they were carrying out there other than stone tool manufacture needed to be completed quickly. The pattern of raw material selection and acquisition suggests expediency was important.

This discussion also highlights the over-emphasis of many interpretations for the Palaeolithic on lithics. Other material categories under-represented in the Palaeolithic record may have co-influenced site selection, such as proximity to wood, bones, and plant materials, not preserved at the sites here in dealt with.

Another scenario is that hominins did not know about better sources elsewhere in the landscape. This is unlikely as knowledge of the landscape and mobility defines the existence of hunter gatherers (Lee and Daly 1999) although could have been the case when they were moving into new territory. The differential availability of flint resources is therefore a plausible explanation for the variations observed in the Avon valley. This however, if it is accepted that hominins knew about the available resources within the Avon valley, still implies that hominins were sourcing raw material very locally or could indicate that there is a temporal difference in the availability of raw material and therefore in the use of the three sites.

Alternatively, biface size has been related to knapping and reduction intensity (McPherron 2006). This may also be related to raw material availability. Where raw material is scarcer artefacts would be more intensely re-used and re-sharpened, resulting in a reduction in size and cortex (ibid.). Increased reduction of artefacts can lead to a more ovate biface shape (McPherron 2006). This suggestion is confirmed by the higher percentage of ovates in the assemblage from Bemerton and possibly also by the larger proportion of ovates in the sample from Woodgreen compared to that of Milford Hill. Thus ovate shapes possibly occur when raw material is scarcer and large pointed artefacts are made when large, good quality flint nodules are available such as at Milford Hill.

This is in disagreement with the model proposed by White (1998) who suggests that ovate shapes are the preferred form and when good quality flint is available this shape will be produced. The ovate dominated assemblage from Bemerton also supports this suggestion but the good quality flint and large pointed bifaces from Milford Hill do not. The wide availability of flint at Milford Hill possibly led to limited reduction and reuse of the artefacts and maintenance of pointed shapes (cf. McPherron 2006). Woodgreen could represent an intermediate situation where both ovate and pointed bifaces are made in response to the availability of both river gravels and flint nodules from nearby.

The assemblages from Milford Hill and Woodgreen contain very small, but pointed bifaces. When comparing the three assemblages the generally smaller assemblage from Bemerton is characterised by more ovate forms but also includes remarkably small pointed types. The bifaces from the Avon valley therefore do not show a clear tendency of smaller artefacts to be more ovate shaped (McPherron 2006). These data could be interpreted as showing that biface reduction need not necessarily lead to shape change, or that certain shapes were preferred. Small pointed bifaces often show some cortex retention as seen on larger tools, further contradicting the relationship between size, shape and knapping intensity. This could have functional reasons, further discussed below. These small tools are potentially significant for understanding the hominin groups that were present at the sites in the Avon valley. Gowlett (2006) has emphasised the importance of such size transformations as indication of the ability of hominins to project the same design at different scales and relates this to cognitive and processing abilities. The variation of size in bifaces at each site could simply be the result of raw material availability but may also reflect the different members of the community such as women or children, cultural, or chronological patterns.

The relationship between raw material characteristics and biface shape has been demonstrated in Figure 8.9, Figure 8.14 and Figure 8.19 and in the significant relationship between blank type and biface type (Appendix 42). Cortex location on bifaces was compared to that found on rough-outs showing that in the production of - especially pointed - bifaces a part of the nodule was often left unworked (Figure 8.24). Blank type influenced artefact size and shape through the initial volume of material but the shape of the nodule also seems to have instigated a particular sequence of technical approaches. The different degree of cortex retention and location on pointed and ovate shaped bifaces also could be related to a functional difference of the shapes (Mitchell 1995; White 1998). A remarkable difference between ovate and pointed shaped bifaces is the location of the maximum weight. Pointed bifaces are butt-heavy, in ovate bifaces the maximum weight usually lies in the middle. If this is inherent/essential to different functionality, this could offer a possible explanation for the higher degree of cortex around the butt on pointed shapes. To keep the maximum mass available in a blank, the butts are not knapped, leaving a high percentage of cortex. This relationship could further be investigated through experimental research that not only focusses on the function of the shape of bifaces but also includes the element of cortex retention in the set of variables.

The discussion above suggests that the variation in biface shapes between the sites may have an origin in raw material availability, onto which aspects of reduction and functionality are superimposed. The following section discusses the possibly chronological, social and cultural differences between the sites.

Figure 8.24 Examples of rough-out and bifaces from Milfrod Hill revealing original nodule shapes.

8.6.4 Chronology, culture and sociality

Variation in biface shape could also represent the transmission of skills, knapping techniques, preferences of a group or individuals and with the absence of/or imposed on other mechanisms this could be regarded as 'cultural' differences between the sites. Based on the metric differences between the sites this scenario would suggest a significant cultural/social difference between Bemerton and Milford Hill and less so between Bemerton and Woodgreen. Culture here is used in the sense as proposed by Wenban-Smith (2001, p.59) as '*a repertoire of common cultural practices socially acquired and transmitted within the context of a Palaeolithic population network*.' The significant differences in shapes at the three sites may therefore reflect mechanisms of how the skill of biface manufacture was learnt and transmitted. A detailed analysis of the technological repertoire applied to the bifaces from the sites could further inform on such processes.

The variation between biface assemblages has also been explained from a chronological perspective (Bridgland and White 2014, 2015; Pettitt and White 2012; Wenban-smith 2004). Applying the proposed chronology of biface types in Britain to the Avon Palaeolithic record would suggest that the ovate dominated assemblage from Bemerton is the oldest site of the three, followed by Woodgreen with both ovate and pointed bifaces, and the assemblage from Milford Hill representing the youngest of the three. This does not entirely contradict the relative stratigraphy of the sites as defined by their respective heights above the modern floodplain but it does contradict the correlation of the Bemerton and Milford Hill terrace proposed by Blackmore. However, Milford Hill is around 6m lower than Bemerton and could indeed be younger. The former has previously been correlated with Woodgreen based on the concentration of artefacts and stylistic considerations and has been related to MIS10-8 (Wymer 1999).The chronology of the sites has important bearings on the understanding of the British Palaeolithic. This is fully addressed in the following chapter.

Chapter 9 Discussion

9.1 Introduction

In the preceding chapters the depositional context of fluvial sediments associated with the main river terraces in the Avon valley has been reconstructed. The OSL dating of the terraces has provided a chronological framework for the Pleistocene landscape and the associated Palaeolithic record (see Chapter 7). Lithic analysis of the Palaeolithic assemblages from Bemerton, Milford Hill and Woodgreen has resulted in new information on site formation and hominin activities at these locations (see Chapter 8). This chapter integrates these themes to provide new insights in landscape evolution and hominin presence and behaviour in the Avon valley. The results are then considered within the broader context of the British Palaeolithic.

9.2 Pleistocene landscape evolution in the Avon valley

9.2.1 The Pleistocene river terraces in the Avon valley

The highest terrace deposits in the Avon valley are found at *ca*. 125m OD and *ca*. 100m above the valley floor. On BGS mapping (2004) these deposits are denoted as T10 and undifferentiated terrace. T10 deposits are mainly preserved on the east side of the valley in the New Forest area. Here, in the far east of the valley, undifferentiated terrace deposits are also found. This term has also been applied to Pleistocene fluvial sediments preserved on the interfluves of the Nadder, Avon and Bourne rivers and to the deposits at Bemerton and Milford Hill (see Figure 2.6). The latter are not correlated to those deposits found in the far east of the New Forest area. The T10 and undifferentiated terrace deposits east of the valley have a substantial height range and Kubala (1980) considered it to represent up to five separate depositional events (Barton et al. 2003). These deposits are 'draped' over the landscape and show limited altitudinal separation.

A staircase of five terraces flanks the sides of the Avon valley. The terraces are situated in height and geographic extent between the extensive T10 deposits and the spatially confined T4-T1 deposits close to and on the valley floor. T9 and T8 are separated from T10 by a break of slope. Fragments of these terraces are almost exclusively preserved on the east side of the valley. A break of slope separates T7 from the higher terraces. T7 is the least well-preserved terrace in the Avon sequence. Only small fragments remain in the area around Woodgreen east of the valley, near Ringwood Forest and south of Ringwood to the west of the valley (see Figure 2.6). T6 and T5 are exclusively preserved on the west side of the valley where large stretches are preserved. A significant break of slope separates this staircase of terraces from T4-T1 found in the geographically confined, modern valley. T4 and T3 are widely identified throughout the valley from Salisbury to Christchurch and are separated by a limited altitudinal difference. T2 and T1 are found along and mainly below the modern river (Barton et al. 2003; Bristow et al. 1991; British Geological Survey 1991, 2004, 2005; Hopson et al. 2007).

9.2.2 Sedimentology and depositional context of the Avon river terraces

The fieldwork and sedimentological analyses (Chapter 5 and 6) have provided new insights into the sedimentological structures of the Avon valley terraces and therefore contribute to the understanding of their formation. This research has focused primarily on T10 and T7-T4 deposits. After the following summary of the results its broader implications are discussed.

At Bemerton undifferentiated terrace deposits were found unconformably overlying a weathered chalk surface. The very irregular boundary with the chalk suggests the occurrence of solution processes during the Quaternary (Chartres and Whalley 1975; Harding and Bridgland 1998). The gravel deposits showed limited bedding but some fining upwards. The gravel was found to be overlain by 190cm brickearth indicating that cold and arid conditions succeeded, not necessarily directly, the deposition of this terrace (Antoine et al. 2003).

T10 deposits were investigated at Hatchet Gate Farm and Woodriding. At Hatchet Gate Farm the river terrace deposit was found to unconformably overly the sandy bedrock. The coarse gravel is crudely bedded, indicative of deposition in a cold climate braided river system. The presence of fine sediments interbedded between HA1.3 and HA1.2 suggests a period of low water stands and the deposition of fines in small pools or channel infilling on the floodplain. At Hatchet Gate Farm at least two depositional events are represented by HA1.3 and HA1.1 separated by a period of erosion. This is indicative of compound terrace formation. At Woodriding a large section shows three sediment units that represent different depositional environments but no clear erosional boundaries. Both Hatchet Gate Farm and Woodriding are located on T10 on current BGS maps. The former however, is located on O3 and the latter on O2 (Kubala 1980) and therefore may represent two separate depositional events as proposed by Kubala (1980). A comparison of the grain size distribution of the gravel and sand and the fine fraction shows that only the size distribution of HA1.3 is markedly different, but that HA1.1 is comparable to that of the deposits found at Woodriding. This suggests that the sediments at Hatchet Gate Farm and Woodriding are the result of two terrace formation events. At Hatchet Gate Farm a compound terrace is formed through the draped deposition of sediments also deposited at the location of Woodriding. Closer to the middle of the floodplain these deposits formed the terrace as observed at Woodriding.

T7 at Woodgreen rests unconformably on the sandy Tertiary bedrock. The observed scour features are the result of bedrock erosion through bedload transport prior to sediment deposition. The gravel is crudely bedded indicating a cool climate braided river environment. The presence of fine sediments interbedded in the gravel suggests periods of low water stands and the deposition of fines in small pools. The fine sediment sampled from WG1.9 included a loessic component, suggesting the presence of loess in the region and landscape erosion.

At Somerley 140cm thick sand layer was found interbedded in horizontally bedded T6 gravel deposits and 80cm above the sandy Tertiary bedrock. The gravel shows a set of graded layers that alternate between matrix supported and clast supported gravel. These cross-strata represent the migration of channel bars and sediment deposition under cyclically changing fluvial regimes (Bridge 2005; Miall 1996). About 150cm below the top of the terrace the gravel is interbedded with cross-bedded sand deposits. The sedimentology observed at Somerley suggests that at several times during the deposition of the fluvial sediments, main active channels of a braided stream were flowing at this location. The sedimentology in the top of the terrace includes blocks of frozen sediments, indicating thermal erosion under cold climate conditions probably resulting in the undercutting and erosion of the valley sides and incorporation of sediments from fringing (older) fluvial deposits. The sediments in the top of the terrace at Somerley also show cryoturbation features representative of cold climate conditions after terrace deposition. The sediment structures preserved at Plumley Farm (48m OD and 18m above the modern floodplain, T6 (BGS mapping) and T7 in Kubula's scheme (1980)) were described by Kubala (1980, p.6) as showing '*planar and cross-bedding with impersistent lenses of sand and open-work gravel… Similar features have been observed in pits in Ringwood Forest, but there, they are disrupted into pingo-like structures – evidence that the gravels were subjected to permafrost conditions after their deposition*.' This is in agreement with the cryoturbation features described in the top of T6 at Somerley.

T5 deposits observed at Ashley pit show similar bedding as described for Somerley. Here the sediments have been affected by repeated episodes of periglacial/cold conditions as is evidenced by cryoturbation structures at different heights within the section. ASH1.9

incorporates deposits indicative of a pool on the floodplain during low water stands. The very fine sediment preserved a low pollen count, all indicate cold climate conditions. This deposit has subsequently been deformed through cryoturbation. Periglacial/cold conditions also occurred during the deposition of ASH1.4 as is indicated by the presence of 'drop stones'. These larger clasts were incorporated in the fine sediments through the ice-rafting of stones indicating cold climate conditions and thermal erosion of sediments. ASH1.4 also shows cryoturbation features demonstrating cold climate conditions occurred again after sediment deposition.

The sediments at Bickton (T4) show planar and cross-bedding of relatively fine gravel and sand. Reid (1902) who discusses the T4-T1 together as 'valley gravel' notes the presence of Palaeolithic implements, mammoth teeth and fresh water shells in the valley gravels. Near Bickton, '*a quarter of a mile north of the Mill'*, the terrace was exposed in a gravel pit up to a depth of 3m (Reid 1902, p.47). Westlake found a layer of marl with land-shells (*Pupa*) between Bickton and Weir and noted *ca*. 4.8m of exposed terrace (Reid 1902, p.47).

T10 is most widely preserved after which the terraces notably decrease in width. Because all terraces show comparable average thicknesses (Chapter 6), the calculated terrace volumes of the preserved terrace deposits mirror their geographical extent. An attempt was made to reconstruct floodplain width during each depositional event as represented by the subsequent terraces. Its success was limited by the fact that terraces were preferentially preserved on one side of the valley (T9-T7 to the east and T6-T5 tot the west), hampering the estimation of the floodplain width across the valley. T10 formed the exception, with terrace fragments preserved on both sides of the valley. This offered the possibility to estimate the volume of this palaeo-floodplain. This is relevant to the reconstruction of landscape evolution because, in order for valley incision and terrace formation to occur, the river must have eroded this palaeo-floodplain before eroding the bedrock (see Chapter 6).

The sediment volume of each Avon valley terrace was calculated based on borehole data and superficial geology thickness models. This allowed a comparison of the preservation of each terrace which could be used to calculate net sediment erosion or aggradation during each subsequent terrace formation event (cf. Brown et al. 2009a, b). The preservation of T10 to both sides of the Avon valley allowed a palaeo-floodplain to be reconstructed for which the sediment volume could be estimated based on the average thickness and extent of this terrace. The difference between the estimated volume of the palaeo-floodplain and the volume of the preserved terrace fragments provided an indication of the volume of sediment that must have been reworked from the palaeo-floodplain onto the next younger floodplain in order for valley incision to occur. The estimation of sediment volume of the next younger floodplain could be compared with the expected reworked volume. When the former exceeded the latter, net aggradation occurred. When vice versa, net sediment erosion would have taken place (see section 6.10.3). The calculation of terrace volumes and the application of this sediment budget approach (cf. Brown et al. 2009a, b) have shown that the volumes of T9 to T5 do not exceed the mass predicted by the estimated erosion of the immediately preceding terrace. This indicates that these terraces were formed through the formation of a bedrock strath onto which the reworked fluvial sediments from the preceding floodplain were redeposited, resulting in a cascade response model of terrace formation and vertical sediment reworking down the terraces. This is confirmed by the presence of scour features in the bedrock as observed at Woodgreen and Ashley, and thermal erosion of the floodplain and valley sides as evidenced by the inclusion of 'blocks of fines' in the sediments at Somerley. In this cascade response model net loss of coarse-grained sediments is thus limited, being predominantly transported as bedload and vertically reworked down the terraces. Bedrock incision and the removal of fines from the erodible Tertiary substrate out of the system is therefore the principle mechanism behind terrace formation for T9-T5.

The sediment budget calculations also showed that the sediment volume of T4 exceeds the volume predicted by the estimated erosion of T5 alone and indicates net sediment aggradation during the deposition of T4. The increased sediment incorporated in T4 can have been generated through lateral erosion that caused also material from pre-T5 terraces to be incorporated in T4. Alternatively, the net sediment aggradation could be the result of increase in net sediment input from upstream bedrock erosion. The fragmented preservation of T7-T5 on the east side of the valley and the significant valley incision between these terraces and T4, suggest that the increased volume of T4 can be explained by the lateral erosion and incorporation of sediments from previous terraces. Subsequent removal of sediments has been limited, as can be seen by the maintenance of volume in T4-T1. This is typical for cut-and-fill terraces (Pazzaglia 2013). The net sediment aggradation during T4 is indicative of a significant fluvial activity, likely related to environmental and climatic change.

In sum, three different terrace formation processes shaped the Avon valley terrace sequence: T10 and the 'Older terraces' are formed through subsequent depositional events separated by limited valley incision resulting in 'draped' and minimally separated terraces and the formation of compound terraces. T9-T5 formed through bedrock erosion which created strath and accommodation space for the redeposition of coarse fluvial sediments from the preceding aggradation period. These processes resulted in the formation of terraces that are separated in height and by a bedrock strath. T4-T1 are minimally separated in height and formed through the filling of the spatially confined valley with eroded fluvial sediments from the higher terraces. Subsequent erosion and reworking of these sediments led to the formation of cut-and-fill terraces.

9.2.3 Age of the Avon river terraces

The OSL dating results have been fully discussed in Chapter 8. Table 9.1 presents a summary of the estimated ages and Figure 9.1 shows the stratigraphic position of all dated sediments in the valley. The intrinsic assessment of the reliability of the results suggests results of the younger deposits are plausible although some analytical problems exist. The age estimates obtained from T6, T7 and T10 however, are likely approaching saturation. Therefore in the following discussion the OSL results are cautiously used as guidance and in combination with other available data to consider the implications of the revised chronology.

Deposit	Site	Age (BP)	Marine Oxygen Isotope Stage	Chronostratigraphy
T4	Bickton	15-20ka	MIS2	Late Devensian
Brickearth	Bemerton	70ka	MIS4	Early Devensian
T5	Ashley	200ka	MIS6	Wolstonian
T6	Somerley	220-330ka	MIS7-9	Ilfordian/Hoxnian
T7	Woodgreen	310-350ka	MIS9-10	Hoxnian
T10	HGF/Woodriding	260-370ka	MIS8-11	Hoxnian

Table 9.1 Summary of OSL results from the Avon valley.

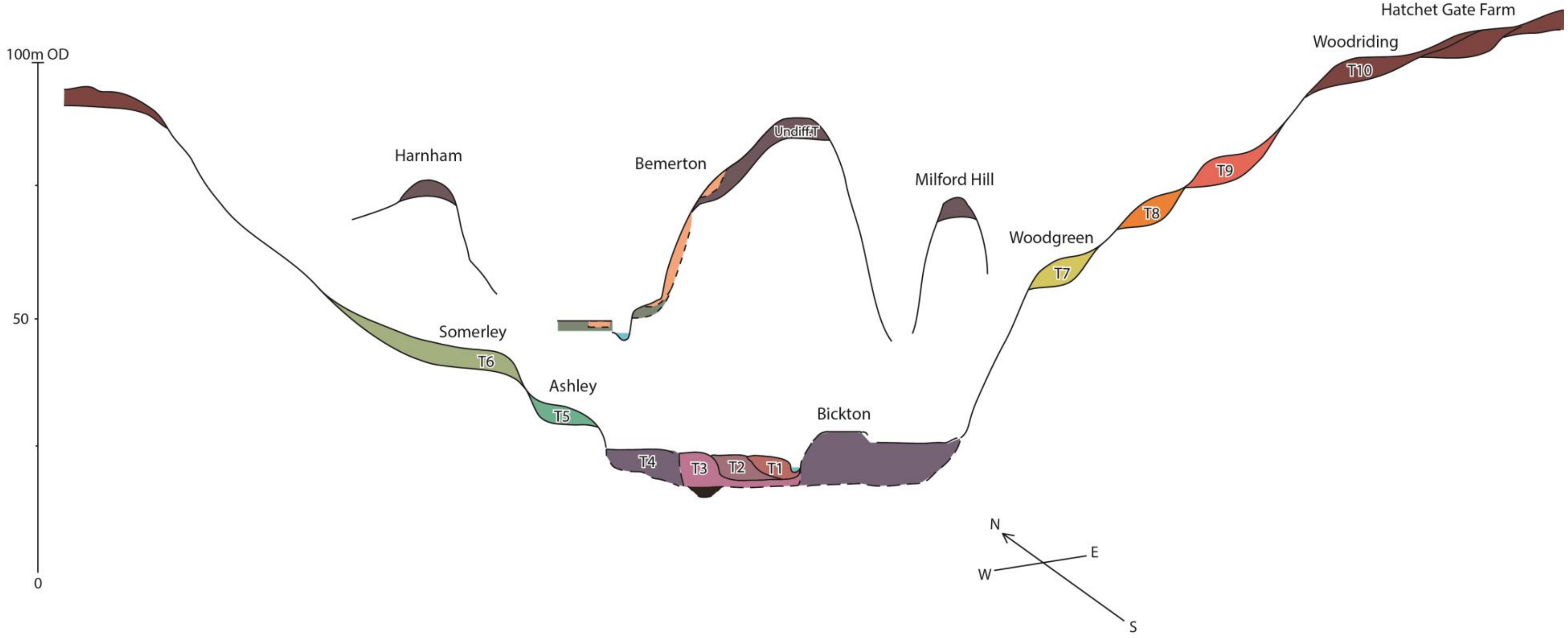


Figure 9.1 Idealised cross-section of the Avon valley looking in northeastern direction, showing the height of the river terraces and sites discussed in the text (height above OD of the sites is based on fieldwork data, the hieght of the other terraces is based on Lidar data available through the Geomatics Group of the Environment Agency).

T10 and 'Older river gravels': OSL dating suggests an MIS 8-11 age for the deposition of T10. This age estimate should be considered as a minimum as the analytical assessment of the OSL results has indicated a saturation of the OSL signal of the samples from Hatchet Gate Farm and Woodriding. Nonetheless, these dates may well be feasible for Palaeolithic archaeology has been found in association with T10 deposits. It should be noted that the sedimentology and geomorphology of these terrace deposits indicate that they could represent a significant period of time and multiple glacial-interglacial cycles The age proposed here only applies to the lower deposits O1 and O2 (Kubala 1980).

The age of the 'older river gravels' has been considered in previous work but was speculative without the availability of chronometric dates. Allen and Gibbard (1993) have emphasised the considerable age of the higher 'Older river gravels' and suggested an early Pleistocene age for their formation based on its height above floodplain and the degraded character (Allen and Gibbard 1993). Based on a time-averaged incision rate of ca. 0.007 m ka^{-1} and the use of the Avon Palaeolithic record as age tie-point, Maddy (1997; Maddy et al. 2000) has suggested the O5-O1 deposits to date between 0.95 and 1.4Ma. In this model T7 deposits, based on the artefact assemblage from Woodgreen, are assumed to date to MIS 12 (Maddy et al. 2000). Instead of a uniform uplift rate as proposed by Maddy et al. (2000), Westaway et al. (2006) suggested uplift rates in the Avon valley increased since 0.9Ma as a result of lower-crustal flow forcing that is a consequence of cyclic surface unloading caused by intensified climatic change following the onset of the 100ka cyclicity.

The suggestion for a change in regional uplift however, is based on the relative altitudes of terrace deposits and the use of the Palaeolithic record as chronological marker (Westaway et al. 2006). The relative altitude of the top of terraces can have been altered through erosional processes and should therefore be used with caution in the calculation of rates of tectonic uplift. The use of the Palaeolithic record as age-tie point is problematic as this is based on the current understanding of the archaeological record and could change with newly available chronometric dating. The proposed different incision rates by Maddy et al. (2000) and Westaway et al. (2006) mainly affect the estimated age of the lower terraces but both models agree in the age proposed for the 'Older river gravels' (0.9 Ma) and for T7 (~0.45 Ma (MIS 12)). Following the BGS memoirs, Maddy et al. (2000) and Westaway et al. (2006) argued that there was a change in terrace formation processes between T10 and T9-T5. They proposed this reflects a change in fluvial processes, instigated by the transition from 41ka to 100ka cyclicity of Milankovitch forcing on global climate in the late Early Pleistocene (the Mid Pleistocene Transition (MPT)) (Maddy et al. 2000; Westaway et al. 2006). This fundamental change in the earth's climate is widely identified in marine and terrestrial deposits (Head et al. 2008). A transition from broad low-relief fluvial landscapes in the Early Pleistocene to the development of narrow deeply incised valleys in the Middle Pleistocene has been widely recognised in fluvial systems and related to the MPT (Bridgland and Westaway 2008a, b). This change in climate instigated increased valley incision and has also been coupled to positive feedback effect of globally accelerated uplift caused by crustal unloading and lower crustal forcing (Bridgland and Westaway 2008a). The onset of the MPT is dated to 0.9Ma but the transition may span a considerable time (Head et al. 2008). The field research presented in this thesis supports the change in terrace formation but the new chronology does not fit well with this being linked to 0.9Ma or indicates that a significant period of time commenced between the deposition of T10 and T7. Both interpretations have different implications for the understanding of the formation of terraces in the Avon valley which are further discussed below in conjunction with the new dating results of T7.

T7: Many researchers have discussed the possible age of T7 in the Avon valley. They have been concerned with establishing the age for several reasons, but primarily to establish the timing of hominin presence and to calculate rates of landscape change (Maddy et al. 2000; Reid 1902; Westaway et al. 2006). This research has resulted in the first chronometric dates for T7. The direct OSL dating of sediments from Woodgreen suggest and age between 310-350ka (MIS 9-10). Although the analytical tests of the results urge some caution, these data are in agreement with the site's archaeological record. This estimated age for deposition of T7 is younger than previously proposed by both Maddy et al. (2000) and Westaway et al. (2006). Maddy et al. (2000) suggested an MIS 12 age based on the correlation of T7 with archaeologically rich terrace deposits in the Thames catchment. The same age was (MIS 12) proposed by Westaway et al. (2006) based on the correlation of T6 of the Avon sequence with Levallois-bearing deposits in the Stour valley and the dating of the presence of Levallois in Britain to MIS 9/8. Both previous age estimations for Woodgreen are problematic, as archaeologically rich sites need not necessarily be temporally equivalent and the appearance of Levallois in the Solent region is poorly dated. Nonetheless their MIS 12 age for T7 in the Avon valley has been used to calculate rates of landscape change and crustal uplift (Maddy et al. 2000; Westaway et al. 2006) and the interpretation of the archaeological record (e.g. Hosfield 2011).

The OSL results presented here indicate a younger age for the deposition of T7 and therefore the models of incision and uplift as proposed by Maddy et al. (2000) and Westaway et al. (2006) should be adjusted accordingly. If T7 is indeed deposited during MIS 10/9, and the transition in fluvial regime between the deposition of T10 and the lower terraces are related to 0.9Ma and the MPT, valley incision in the Avon valley happened at a faster rate than 0.007m ka^{-1} (Maddy et al. 2000). This would also mean that five instead of four glacial-interglacial cycles separates the deposition of T10 and T7. Alternatively, the correlation of T10 to 0.9Ma and/or the MPT needs revision. A younger age for T10 is not unlikely when it is taken into account that Acheulean bifaces have been found within this terrace. These different interpretations also impact the understanding of the age and formation processes of T9 and T8. In the first scenario, if T10 is dated to 0.9Ma and T7 to 0.3Ma, T9 and T8 were formed over an extended period that saw multiple glacial-interglacial transitions. This implies that there is not a direct relationship between each climate cycle and the formation of a terrace. T9 and T8 may then represent only the most severe glacial-interglacial cycles, or are compound terraces formed by multiple depositional events. In the second scenario, if T10 post-dates 0.9Ma, T9 and T8 could also relate each to a glacial-interglacial or stadial-interstadial cycle.

T6: The OSL age estimates from Somerley suggest T6 was deposited between MIS 9 and 7. Analytical limitations hinder a further refinement of this age but the results can be related to the dating of the preceding (T7) and following terraces (T5) to MIS 10-9 and MIS 6 respectively. This indicates that the formation of T6 is situated between MIS 9 and MIS 6, which is in good agreement with the OSL age estimates from Somerley. There is no evidence for this deposit to form a compound terrace, thus the formation of T6 could be related to a glacial-interglacial/stadial-interstadial within this time frame. The application of OSL feldspar dating will refine the chronological understanding of the deposition of T6.

T5: The OSL age estimates from Ashley pit suggest T5 was deposited during MIS 6. This can be compared to the dating results from T4 at Bickton and the reconstructed age of peat found at Ibsley (Barber and Brown 1987). The OSL results from Bickton suggest a MIS 2 age for the deposition of T4. This is in agreement with the Devensian age suggested for T4-T1 of the Avon terraces (Clarke and Green 1987). The peat found at Ibsley, underlying T3, has been related to MIS 5 based on the pollen assemblage recovered from it (Barber and Brown 1987). The stratigraphic position and age estimate of the dated sediments from Ashley (T5) are in agreement with those proposed for the peat from Ibsley and sediments from T4. T5 on the valley side, T4 and the Ibsley peat in the modern floodplain are separated by a bedrock bluff of *ca*.14m indicating a significant erosional event occurred between the deposition of T5 and the formation of the Ibsley peat and subsequent deposition of T4-3 covering the peat. The significant valley incision could have been instigated by the substantial increase in water supply from the melting of the permafrost and glaciation related to climatic warming towards the end of MIS 6. This has been widely observed in other fluvial systems and is also found reflected in the significant increase in discharge recorded for the Channel River at this time (Brown et al. 2010; Toucanne et al. 2009). The deeply incised valley formed a vegetated floodplain in the subsequent warm stage and old bedrock scours were infilled with interglacial sediments such as found at Ibsley (Barber and Brown 1987). Climatic deterioration following the deposition of the peat resulted in an increase of water supply and erosion of the majority of the interglacial sediments (ibid.). An MIS 6 age for the deposition of T5 could be in agreement with the age proposed for T6 if terrace formation in the Avon valley occurred once per climatic cycle.

T4-T1: The deposition of T4-T1 has been assigned to the Devensian (Clarke and Green 1987), which is in agreement with the age estimation for T4. However, the young age of T4 would put the deposition of all subsequent terraces after 20ka. This scenario is unlikely when the formation of T4-T1 is argued to be the result of climatic changes because significant climatic fluctuations after 20ka became increasingly limited (this is more widely observed, for example in the Exe valley (Brown et al. 2010). However, these floodplain terraces are formed by cut and fill processes for which it has been argued that these form primarily under complex autogenic responses (Schumm et al. 1987). This suggests a substantial time gap between the formation of the Ibsley peat and the deposition of the terraces. Cut and fill terraces are by definition formed through the reworking older sediment gravels and it is possible that the young age of the sediments from Bickton can be related to this mechanism.

Undifferentiated terrace deposits: Undifferentiated terrace deposits are found throughout the valley at different heights above the floodplain and therefore cannot all be related to the same depositional event (Hopson et al. 2006). Of special interest are those fragments of undifferentiated terrace deposits preserved in the area around Salisbury. Here these sediments have been the source of the large quantity of artefacts from Bemerton and Milford Hill, analysed for this research. The absence of sand beds within the gravel prohibited direct dating of the terrace deposit itself. The discovery and OSL dating of brickearth covering the undifferentiated terrace deposit in pit 1 at Bemerton provides a minimum age for these sediments of MIS 4 (70ka), but is also interesting in a number of other ways. Brickearth deposits are related to at least three depositional phases during the Late Pleistocene, between 10-25ka, 50-125ka and >170ka, with the majority dated to the Late Devensian (Parks and Rendell 1992). Its discovery at this location is significant as it lies in an area mapped as undifferentiated river terrace on the BGS mapping (BGS 2005) and it is not noted in detailed geological research of the area (Delair and Shackley, 1978, p.6 figure 3).

Brickearth identified elsewhere in the New Forest generally overlies river terrace deposits and can be subdivided in an Upper (younger) brickearth and a more extensive Lower Brickearth (Reynolds et al. 1996). Close to Bemerton brickearth deposits include the fossiliferous Fisherton brickearth, found just downhill from Bemerton in the Nadder valley (Delair and Shackley 1978; Lyell 1827). The Fisherton brickearths are underlain by chalk and vary in thickness between 3-6m and show laminae that are divided by layers of fine sand or small flints (Lyell 1827). In 1976 a small section was exposed during building excavations towards the west of Fisherton (SU 126306) (Delair and Shackley 1978). Here 34cm of brickearth was described to be overlying ochreous river gravel found at 53m OD. According to Delair and Shackley '*the acute thinning out of the brickearth at this point is very evident*.' (Delair and Shackley 1978, p.8). Particle size and shape analysis of the Fisherton brickearth from this location showed a mixed sand population of a fine and a coarser sand fraction, representing a redeposited and newly eroded element (Delair and Shackley 1978). Delair and Shackley (1978) suggest that the Fisherton brickearth cannot be regarded as loess, as the deposit has quite a low silt content (12%) and the laminae indicate a fluviatile origin (including fluvially redeposited aeolian sediments). This is confirmed by the shape and surface textures of the grains that don't show signs of wind action (Delair and Shackley 1978). Based on the faunal assemblage a final Ipswichian (Delair and Shackley 1978) or early middle Devensian age (Green et al. 1983) has been proposed for the deposition of the Fisherton brickearth. Westaway et al. (2006) tentatively suggested the Fisherton deposits to date tot MIS 3 and the underlying gravels of T4 to MIS 4.

The brickearth observed during the excavation at Bemerton does not match the description of that from Fisherton, suggesting different depositional conditions. The brickearth at Bemerton shows no bedding indicative of an aeolian origin. The OSL results suggest a MIS 4 (70ka) age for the deposition of the Bemerton brickearth. The chronological relationship between the sites depends on which interpretation for the age of the Fisherton sediments is followed (Delair and Shackley 1978; Green et al. 1983; Westaway et al. 2006). Bemerton and Fisherton are closely related in age and possibly contemporary. The Fisherton brickearth is derived from the erosion and redeposition of aeolian sediments present elsewhere in the landscape as is indicated by the observations from Bemerton. Particle size analysis of the brickearth from Fisherton and Bemerton would facilitate further comparison of the deposits and contribute to the understanding of the depositional history of these sediments in this region.

The age of the Bemerton brickearth and its chronological relationship to the Fisherton deposits is also of relevance to the question of the alleged hominin absence from Britain during MIS 6-4 (Pettit and White 2012). This idea has been based on the scarcity of finds confidently attributed to this period (Lewis et al. 2011), but can also be related to lack of deposits dated to MIS 6-4 that preserve hominin evidence (Wenban-Smith et al. 2010). Loessic deposits, especially in southern Britain, have been little studied. The dating of the Bemerton brickearth demonstrates that early Devensian deposits are preserved in the area and may be associated with hominin presence as is evidenced by the 2 *bout coupé* bifaces found in sediments of comparable age, at Fisherton. Further study of brickearth at Bemerton for Palaeolithic remains can contribute to the reassessment and refinement of wider patterns of hominin presence and absence in Britain during MIS 6-4, and together with information from Fisherton, inform on local hominin landscape use.

The age of the Fisherton brickearth also has bearings on the understanding of the age of T4. The latter, based on its stratigraphic position below the Fisherton brickearth, must at least pre-date MIS 3 (cf. Westaway et al. 2006) or MIS 4 (cf. Delair and Shackley 1978; Green et al. 1983). Such an age for T4 is not supported by the OSL results from Bickton, which date the deposition of T4 to MIS 2 (~20ka). This could indicate that problems exist with the Bickton age estimate. However, assessment of the analytical reliability of these results suggest that the young age of the Bickton sediments is most likely representative of the age of these deposits. The most plausible explanation for this discrepancy between the age estimate of T4 at Fisherton and that at Bickton is that the T4 at Bickton includes sediments reworked during more recent fluvial processes.

Despite the limitations of the dates on the upper terraces, the possibility of refining these remains through the application of feldspar OSL dating remains. Feldspar has a higher signal saturation than quartz and therefore has a higher age limit. It has successfully been used to date Pleistocene deposits in Europe (Buyaert et al. 2009; Thiel et al. 2011) and has the potential to refine the chronological understanding of landscape change in the Avon valley. The application of this technique to sediments from T10 could resolve several issues.

Firstly, feldspar OSL analysis of T10 deposits can date the onset of increased valley incision in the Avon valley. The age for this will provide information on the relationship between this landscape change and the MPT. Not only will this contribute to the understanding of formation of the Avon valley, it can also add to the knowledge of how and at what time scales the MPT influenced fluvial systems and contribute to the understanding of this globally observed phenomenon. Feldspar OSL dating of T10 can be combined with an investigation of peat deposits identified by Blackmore at Stoney Cross (T10, *ca*.10.8km east of, and *ca*. 93m above, the modern floodplain), which can provide environmental and biostratigraphic information on the deposition of the 'older river gravels'. Secondly, because samples were obtained from two separate depositional events within T10 (Woodriding pit is in O1 and Hatchet Gate Farm in O2 (Kubala 1980), feldspar dating of these deposits will provide a chronology for the 'draped' terraces in the Avon valley and therefore inform on the timing and, through correlation with glacial/interglacial or stadial/interstadial cycles, formation processes of these deposits. Thirdly, refining the age of, and reconstructing the mechanisms behind, T10 and T7 deposition also improves the understanding of the formation of T9 and T8. Finally, the results of the feldspar OSL will be combined with the quartz OSL results of the lower terraces and the biostratigraphic information from Fisherton and Iblsey. Together this will further refine the chronology of Pleistocene landscape change and the model of terrace formation in the Avon valley and add to the understanding of Pleistocene terrace formation in general.

9.3 Hominin presence and behaviour in the Avon valley

The reconstruction and dating of the Pleistocene landscape and chronometric framework discussed above allows for the first time the significant sites from the Avon valley to be properly contextualised and interpreted in terms of hominin presence and behaviour. This section will first deal with the implications of the new terrace chronology for hominin behaviour and discuss when hominins were present where in the valley. The possible explanations for biface variability are discussed in terms the techno-typological choices made by hominins in shaping these stone tools and what the variation possibly means. The information from the Avon valley is then discussed within the wider context of the British Palaeolithic and Pleistocene landscape.

9.3.1 Chronology of the sites in the Avon valley

Previously, several attempts have been made to assess the age of the Avon Palaeolithic record. Based on height above the valley floor and the character of the gravel, Bemerton has been suggested by previous researchers to be of similar age as Milford Hill (Blackmore 1864; Read 1885; Westaway et al. 2006; Wymer 1999a). Further suggestions regarding the age of Bemerton and Milford Hill have been based on characteristics of the Palaeolithic record. Wymer (1999a) correlated Milford Hill to T7/T8 deposits downstream based on altitude and the similarity of the Palaeolithic finds. For the Palaeolithic of the Avon valley in general he speculated (an unsubstantiated) date of MIS 10-8 (ibid.). A comparison of the rich Palaeolithic deposits in the Avon valley with the better dated examples in the

Thames, led Maddy et al. (2000) to suggest a late Middle Pleistocene age for the Avon Palaeolithic record. The assumed absence of Levallois technology from Bemerton, Milford Hill and Woodgreen has been used to propose a pre MIS 9/8 age for these sites (Westaway et al. 2006). Artefact analysis carried out for this thesis showed that all three assemblages contain some possible Levallois tools and that the Woodgreen sample contains 5 possible Levallois tools. This contradicts the chronology proposed by Westaway et al. (2006) based on artefact technology alone, could indicate an MIS 9/8 age of the sites. However, although the proposed timing of the occurrence of Levallois artefacts seem to hold true in the Thames region (Bridgland and White 2014, 2015), the scarcity of the technique in the Solent region makes its use as an chronological marker less appropriate (Ashton and Hosfield 2010). Moreover, there are obvious dangers in using the appearance of certain technologies or types as a dating tool. This is illustrated by the drastic change in our understanding of the British Palaeolithic over the last 15 years (e.g. Parfitt et al. 2005, 2010) that warns against the acceptance of patterns and subsequently using them as chronologic indications.

OSL analysis carried out for this research on sand from T7 at Woodgreen provides the first direct chronometric age control of this prolific site. These results suggest the site dates to 350-300ka (MIS 10/9). This can be related to the dating results obtained from undifferentiated terrace deposits at Harnham (Bates et al. 2014). The age of these deposits was estimated on the basis of OSL analysis, amino acid racemisation, and biostratigraphic information to be 250ka (MIS 8). The comparable height above the floodplain of the terrace deposit excavated at Harnham and the terrace at Milford Hill may suggest a broadly similar age of these sites (Bates et al. 2014). Whether this age can be extended to Bemerton depends on the correlation of this deposit to that of Milford Hill. Bemerton is *ca*. 6m higher above floodplain than Milford Hill, which may suggest that Bemerton pre-dates Milford Hill. Long profile projections between Bemerton and Woodgreen show that Bemerton could also pre-date Woodgreen (Figure 9.2). The OSL results from Woodgreen indicate that this site pre-dates Milford Hill if the correlation of the latter with Harnham is accepted. As a result of the new dates from Woodgreen (this thesis, see section 7.3.5) and Harnham (Bates et al. 2014), it is now possible to suggest a new relative chronology of Bemerton, Milford Hill and Woodgreen. The Palaeolithic sites in the Avon valley fall within MIS 10-8. Based on the height above the floodplain Bemerton is the oldest site, followed by Woodgreen dated to around 300ka, and Harnham and Milford Hill being more recent and dating to ~250ka.

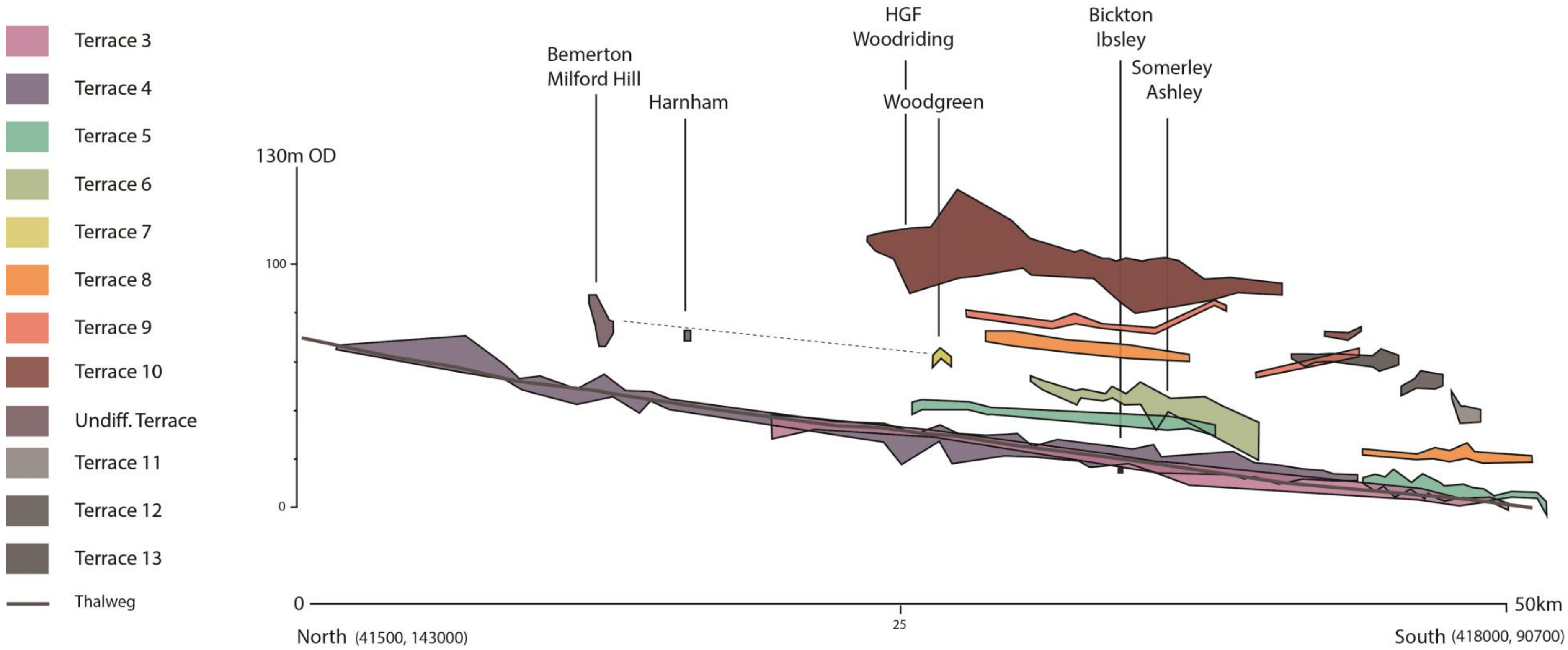


Figure 9.2 Long profile projection of the river terraces in the Avon valley based on the BGS borehole data, digitised for this research, in Rockworks. Terrace numbering is based on BGS mapping (1991, 2004, 2005).

9.3.2 Hominin presence in the Avon valley

The assessment of site formation and integrity discussed in Chapter 8 has demonstrated that the artefact concentrations at Bemerton, Milford Hill and Woodgreen were not the result of fluvial processes or collection history, but represent hominin presence at these locations. Analysis of the artefact assemblages from Bemerton, Milford Hill and Woodgreen indicate that bifaces were knapped at the sites and that the raw material used was sourced locally, predominantly from the river gravels which included rolled nodules from the chalk.

The large concentrations of artefacts found at Bemerton, Milford Hill and Woodgreen suggest that these locations were ephemerally revisited by hominins over a considerable length of time, possibly during all inhabitable periods within a glacial-interglacial/stadial-interstadial cycle. Hunting and gathering hominins were highly mobile exploiting recourses over extensive areas (Pettitt and White 2012). The accumulation of artefacts, and the reconstructed depositional context and analysis of their appearance suggests Bemerton, Milford Hill and Woodgreen were repeatedly revisited. Within the wider landscape used by hominins, what was it that caused them to revisit/ be attracted to such locations?

Firstly, the access to raw material for tool production could have attracted hominins to Bemerton, Milford Hill and Woodgreen (cf. Ashton and Hosfield 2010). The availability of flint and specifically large flint nodules as preferred blank types for bifaces can be related to the geographic distribution of the chalk bedrock. Where this is eroded or exposed, such as at cliffs or river incision, nodules are likely accessible (Ashton and McNabb 1994; White 1998). The evidence of local tool manufacture and use at the Avon sites, and their proximity to flint resources such as the river gravels and chalk bedrock may suggest that this was what attracted hominins repeatedly to these locations. The Avon sites are all located at or near the chalk and the use of flint nodules for biface manufacture is recorded at all three sites. At Milford Hill large flint nodules were significantly more often used as blank types than at the other sites and artefacts from this location are in general significantly larger than those from Bemerton and Woodgreen. This could reflect a difference in hominin technological choices and/or indicate a variation in blank type availability at the sites. Variation in the availability of fresh flint nodules from the chalk could result from a change in access to chalk outcrops through vegetation cover and/or changes in the local environment (for example bedrock erosion in a fluvial system liberating flint nodules). It could tentatively be suggested that the Avon valley during the occupation of Bemerton and Woodgreen, related to pre-MIS 9 and

MIS 9, was more densely vegetated than during hominin presence at Milford Hill during MIS 8. Alternatively, the difference between the sites can indicate a diachronic change in hominin behaviour where hominins at Milford Hill sourced flint nodules directly from the chalk.

Secondly, the Avon sites could be related to the presence of nutritional niches at these locations to which hominins were attracted or which they preferred (cf. Brown et al. 2013). This is more widely recognised in the distribution of large Palaeolithic sites in Britain and northern France, often situated in the middle-lower reaches of river valleys and at confluence zones (Brown et al. 2013). These locations could have provided nutritional niches as just up-stream of the estimated interglacial tidal limits the variety of plants, animals, and macro- and micronutrients is possibly optimal (ibid.).

Woodgreen is situated just up-stream the estimated interglacial tidal limit which could indicate that the area around Woodgreen presented a nutritional niche (Brown et al. 2013). The wider floodplains around confluence zones, such as around Bemerton and Milford Hill, and the presence of streams and rivers of variable sizes could have a similar impact on the availability of nutrients (Brown et al. 2013; Goebel et al. 2006). Additionally, at Woodgreen for example, the different geochemical and hydrological properties of the chalk and Tertiary bedrock result in different plant communities offering a wider variety of plant resources (Kruckeberg 2002). The three sites were visited over different periods of time, indicating that the optimal niche may have changed between these periods. The environment, available resources and visibility of raw materials changed throughout the Pleistocene climatic cycles, but significant differences in floral and faunal communities between the MIS stages in Britain (Ashton et al. 2006; Bridgland et al. 2013; Candy et al. 2015; Schreve 2001) may also have instigated different landscape use strategies between MIS stages. This could be the result of local environmental change or reflect a change in hominin behaviour for example through a shift in the suite of resources exploited by hominins or a change in emphasis on one or the other raw material available.

The relationship between site distribution and flint availability (as dominant raw material type) is complex and it is difficult to reconstruct the availability of flint in time and space, when taking into account environmental factors and changing technological choices of hominins. When discussing raw material resources, the nature of the preserved Palaeolithic record as mainly consisting of stone tools, has naturally led to a focus on the availability of workable stone in the landscape (Ashton and Hosfield 2010). This however neglects the question where hominins were sourcing other raw materials such as wood for spears or bones for tools (as is demonstrated by the evidence from Schoningen (Van Kolfschoten et al. 2015)). During the most likely period of occupation of the Avon sites hominins elsewhere in Britain and Europe were using a wide variety of technologies (Oakley et al. 1977; Thieme 1997; van Kolfschoten et al. 2015). Locations such as Bemerton, Milford Hill and Woodgreen may have provided a balanced access to a variety of resources, of which we are now only able to retrace the most durable.

It is unlikely we will ever be able to understand all the reasons why hominins revisited these sites and for these deep time periods it is particularly challenging to understand social or symbolic reasons. However, it is possible to discuss why and how these significant locations shifted within the valley based on the unprecedented high resolution reconstruction of the Avon valley Palaeolithic occupation through the geoarchaeological approach adapted in this research. The evidence of the ephemeral revisiting of sites such as these in the Avon valley has implications for the understanding of hominin landscape use and mental capacities.

The activities at these sites were most likely part of a wider network of landscape use (Pettitt and White 2012). The repeated visit of sites (these most likely also include locations of which we have no archaeological evidence) indicate spatio-temporal planning of activities and therefore knowledge of the landscape, memory and foresight. Hunter-gatherers moving around the landscape could also have encountered these sites by chance, and only then selected these places to carry out their activities. Hominins perhaps judged these locations on the basis of (the combination of) available recourses, and its suitability for the required task. This reflects the spatial organisation of activities that is tight in with the landscape and environment and the geographical distribution of resources. The Avon sites suggest that this landscape use, whether accidental or driven by complex spatio-temporal planning, changed over time. Bemerton and Milford Hill are both situated on the chalk and at the main Avon confluence, but differences in blank types and artefact size might indicate a difference in flint nodule availability or use. Woodgreen is located downstream of the chalk at the confluence of the Avon and an eastern tributary. Each site may have provided different advantages in terms of the availability of resources and access to raw material, and were selected to meet the needs of the time. In other words, the Avon sites could reflect a change in the availability of recourses or set of resources sought at particular locations by hominins, or it reflects a change in the 'way of doing things', in knowledge of the landscape, use of places, and spatio-temporal planning. This is possibly related to the knowledge, habits or preferences of hominins, transmitted and maintained hominin groups.

9.3.3 Biface variability in the Avon valley

The artefact analysis of the assemblages from the Avon sites offered a unique situation to study biface variability and address long-standing questions concerned with its significance in the British Palaeolithic. Significant differences in artefact size and shapes were found between the Milford Hill assemblage and Bemerton and Woodgreen. Milford Hill and Bemerton showed the most significant difference in shape. The assemblage from Milford Hill contained significantly larger artefacts and bifaces were significantly more pointed than those from Bemerton. Artefact analysis has also demonstrated that there is a significant relationship between blank type and artefact shape and seem to suggest that large flint nodules where either more available to hominins at Milford Hill than to those at Bemerton or were simply less often used at the latter. Thus even though both sites are located on the chalk, flint resources were variably available or used. The relationship between blank type and biface shape explains the difference seen at Bemerton and Milford Hill. The difference between Milford Hill and Woodgreen is less pronounced. This is interesting because between the three sites, Milford Hill and Woodgreen show a maximum difference in size, but less difference in shape. This shows that there is neither an exclusive relationship between artefact size and shape (contra McPherron 2006), nor an exclusive relationship between proximity of sites to the chalk (assumed to be related to flint nodule availability) and shape (contra White 1998). The results indicate that although biface shape is influenced by blank type and possibly re-sharpening, other mechanisms were in play.

Although all these sites seem to have been relatively short-lived activity areas, there are significantly different shapes at each site. The biface variability, when considered in conjunction with the temporal differences between the sites, likely reflects changing socio-cultural norms. The difference in biface shapes, especially clear in those from Bemerton and Milford Hill could reflect 'a way of doing things'. This could mean that biface production was learnt in a social setting in which the way to make a biface was learnt, by copying and communication. This does not necessarily need to reflect a preferred shape as a cultural symbol that hominins chose to make as an expression of being part of a culture (Wenban-Smith 2001). It could be a variation in the *chaîne opératoire* of biface production that is reflected in different biface shapes per group. The activity of raw material sourcing, blank type selection, the choice to re-sharpen a tool or produce a new one could be part of a set of activities that was just the way of doing things. This would integrate models of biface variability based on raw material availability (Ashton and McNabb 1994; White 1998), reduction (McPherron 1996) and socio/cultural explanations (Wenban-Smith 2004) and also join functional with more social aspects of hominin life.

If it is assumed that biface shape variation developed through young hominins copying/learning from others, in which personal or erroneous changes could occur, but also could reflect interpersonal relationships, biface shape variation within a group could drift over the time over which the assemblage accumulated (cf. Isaac 1972). The long-term spatio-chronological patterns observed in British biface variability have therefore been suggested to reflect the size of a groups' local operational area or inter-group networks (White and Pettitt 2011). The dating and artefact assemblages from Woodgreen and Milford Hill fit with the chronology proposed for biface variability by White and colleagues (White and Pettitt 2012; Bridgland and White 2014; 2015) in which sites containing ficrons and an absence of a strong Levallois element are dated to MIS 10-8. The more ovate dominated group from Bemerton could correlate to biface groups dated to MIS 11. The recognition of biface groups in assemblages that represent the ephemeral actions of hominins over hundreds or thousands of years is explained by the conservatism of the Acheulean (White and Pettitt 2012) that changes with the asynchronous, geographically discontinuous occurrence of Levallois technology (White and Ashton 2003; Hopkinson et al. 2013).

9.3.4 A local perspective on the British Palaeolithic

The British Palaeolithic has been characterised by early sporadic hominin presence since 0.9Ma followed by an increase of Palaeolithic sites dated to MIS 13 or MIS 11, and a decline afterwards with reoccupation occurring in MIS 3 (Ashton and Hosfield 2010; Ashton and Lewis 2002). This has been said to reflect hominin population size in Britain, decreasing because of the changing palaeogeography associated with the evolution of the Channel River increasingly inhibiting hominins to reach the region (Ashton and Hosfield 2010). However, the palaeogeography of the Channel region did not show a linear evolution toward a larger river forming an increasingly significant barrier for floral and faunal migrations. Instead, estimates of discharges of the Channel River over the last 350ka show differences in 'Fleuve Manche' activity and that discharges during MIS 10 and MIS 8 were significantly less than during MIS 6 and MIS 2 (Toucanne et al. 2009). The difference in the early Middle Palaeolithic record of the Thames and Solent areas, the former characterised by the appearance of Levallois technology dated to MIS 9/8, has also been linked to the changing palaeogeographic setting of Britain (Scott and Ashton 2011). The pattern reflects that observed on the continent and is therefore thought to be the result of northern and southern dispersal routes from the continent into the Thames and Solent regions respectively (Ashton et al. 2011). The young age of Harnham and the absence of Levallois and persistence of biface manufacture at this site, led Bates et al. (2014b) suggest that Harnham, together with sites such as Broom and Cuxton, represents the persistence of a British Acheulean industrial tradition from MIS 9 through to MIS 8 and not a recolonization of the area from the north-western continent.

The chronometric framework developed in this research relates the Avon sites to MIS 10-8. Within this framework a relative chronology of the sites is proposed in which Bemerton presents the earliest period (pre or early MIS 9), followed by Woodgreen (MIS 9) and Milford Hill (MIS 8). The detailed description of the depositional context at Milford Hill provided by Blackmore gives an opportunity to further reconstruct the timing of hominin presence at this site. At some locations at Milford Hill Blackmore noted a 'whitish sand and gravel' deposit in between dark red clayey gravel (comparable to that found at Bemerton) and the chalk bedrock. He describes this whitish fine gravel to be at places interbedded with white clay and sand layers. The white gravel and sand included a large quantity of *Helix hispida*, *Helix arbustorum*, *Pupa moscorum*, and *Zua lubrica*. These land snails were often found intact (Blackmore 'Locked notebook', Salisbury Museum, p.243). *Helix hispida* (Linnaeus) is associated with full-glacial cold and dry climates and loessic environments and *Pupa moscorum* (*Pupilla muscorum* (Linnaeus)) with cold and wet climates (Kaiser 1969). The latter are primarily found in early glacial and reworked loesses (ibid.). Together this possibly indicates the fluvial erosion of loessic sediments from the landscape, and deposition under gentle fluvial conditions as can be derived from the preservation of the snails. The whitish gravel is overlain by dark red, clayey gravel. The description of the boundary between the 'whitish' gravel and the red clayey gravel suggests this showed cryoturbation features (Blackmore 'Locked notebook', Salisbury Museum). Associated with the same white gravel and sand but found at another location, were a molar of a horse (*Equus*), boar (*Sus scrofa*) and mammoth (*Mammuthus*) tusk and 'a few' Palaeolithic artefacts (Blackmore 'Locked notebook', Salisbury Museum). The overlying clayey gravel contained the majority of the artefacts from Milford Hill (ibid.). The description of these sediments suggests that dry cold climate conditions were followed by wetter conditions resulting in the incorporation of fine sediments and land snails in the fluvial system at Milford Hill. Further increases in sediment supply and water velocities led to the deposition of the clayey gravels and incorporation of chalk from the valley sides (Harding and Bridgland 1998). This gravel included the majority of the artefacts although some were found in association with the underlying white sand and gravel. This reconstruction of the depositional environment at Milford Hill may suggest that hominins were present at this location during the early part of a cold-warm climatic transition (e.g. stadial-interstadial). The detailed recording of sedimentology, archaeology and fossil remains at Milford Hill has great research potential. Mapping the evidence noted by Blackmore may allow 2D and possibly even 3D reconstructions of the finds at this location. This offers a better understanding of the site and its formation processes and could inform targeted fieldwork. Research at Milford Hill could confirm the proposed chronology of this site and contribute to the understanding of hominin presence in Britain during a period for which Acheulean sites becomes increasingly scarce.

The Avon sites appear to date to the period during which a general decline of hominin presence in Britain has been suggested (Ashton and Hosfield 2010). This pattern of decline was supported by the work of Davis in the Solent region (2013), but the data presented in this thesis may suggest the picture is not quite as simple as previously thought. Ashton et al. (2011) suggested windows of opportunities for hominins to reach Britain over the last 450ka based on an interplay of sufficiently low sea levels for Britain to be connected to the continent, and warm enough conditions for hominins to spread north. One model is based on the changing palaeogeography and a constant hominin tolerance of cold conditions, the other is also based on the changing palaeogeographic setting of Britain but takes into account the increasing ability of hominins to adapt to cold climates (through clothing, shelter, control of fire). In the latter model, the windows of opportunity to reach Britain are more frequent as hominins are increasingly more capable of reaching Britain during cold periods when sea level stands were low. However, even in the second model the access to Britain decreases over time as subsidence of the Channel region and North Sea basin continues (Ashton et al. 2011). The presence of hominins in the Avon valley during a period when a general decline in hominin presence in Britain has been suggested may indicate that hominins were successfully adapting to cooler climates and improving their opportunities to spread into Britain.

The Avon Palaeolithic record may also represent a persistence of hominins in the region, possibly through to as late as 250ka as is suggested by the age of Harnham and Milford Hill. This implies a development of hominin adaptive capabilities to sustain their presence through to the cooler periods of MIS 9.2, MIS 8.6 and MIS 8.4 (Bates et al. 2014). The development of technological adaptations such as the use of clothing or shelter is untraceable in the archaeological record but evidence of hominin fire use in Britain dates back to MIS 11 (Preece et al. 2006). The possibly sustained presence of hominins in the Avon valley contributes to the understanding of the evolution of the hominin biogeographic range which is possibly increasingly maintained and expanded in cooler climatic conditions through technological, behavioural and possibly physiological adaptations.

Interestingly, at Woodgreen indications are found for the use of Levallois technique and possibly also at Bemerton and Milford Hill. If these populations present the predecessors of those at Harnham, the absence of this technique from the latter indicates that the use of Levallois was not sustained. The few examples of Levallois from Woodgreen and possible examples from Bemerton and Milford Hill perhaps indicate a ‘precocious’ use of the technique that did not develop further (cf. White and Ashton 2003). The technological innovations could possibly not be sustained in the smaller groups present in this region (Kuhn 2012), or may simply not have been necessary or useful.. This is consistent with the idea that Levallois technology developed independently based on a common technological ancestry of Acheulean populations and that technological change was not always maintained (Adler et al. 2014; Hopkinson et al. 2013).

9.3.5 Pleistocene landscapes and Hominin presence in the Avon valley

The terrace sequence of the Avon valley shows three types of terraces. The highest deposits (T10 and undifferentiated terraces in the New Forest Area) are draped over the landscape and form compound terraces. The well-developed strath terraces of T9-T5 form a staircase along the valley sides. The preservation of T9-7 mainly to the east of the valley and T6 and T5 to the west suggests lateral migration and erosion of the Avon, first migrating west and subsequently migrating east. The terraces on the modern valley floor are formed through cut-and-fill processes. The transition from T10 to T9 may be related to the MPT, although the exact timing of the fluvial change related to this transition is unknown and may have occurred considerable time before or after the Early to Middle Pleistocene boundary (set to 781ka) (Gibbard and Cohen 2008; Head et al. 2008). The dating of T5, and age estimate from Ibsley and Bickton suggest that T5 was deposited during MIS 6, the MIS 6/5 transition led to considerable valley incision represented by the break of slope between T5 and T4-1 on the west side and substantial erosion of T8-T5 on the east side of the valley. The timing of the formation of the valley terraces is therefore situated between the MPT and the MIS 6/5 transition. The OSL results suggest T6 is related to MIS 8/7 and T7 to MIS 10/9 (see Table 9.1).

Hominins were present in the valley between MIS 10-8, during which period the palaeo-Avon valley comprised a large floodplain, occupied by a braided river during cooler conditions and an astonishing/meandering river during warmer climates. The valley was flanked by well-drained flats of older river terraces to the east, and possibly more vegetated slopes to the west where the terrace deposits are mainly eroded away. Pollen found in sediments in T5 indicate the presence of birch and pine in the landscape, likely growing on the well-drained nutrient poor older river terraces during colder climate conditions. Grasses and willow could be found in the floodplain and reed on the water side. During MIS 5 the vegetation in the valley included tall-herb fen with holly shrubs (Barber and Brown 1987). This generally open landscape could have been induced by the grazing and migration of large herbivores. Although the Pleistocene river terraces in southern Britain are notorious for the lack of fossil preservation, the list of finds from the Avon valley collated by Delair and Shackley (1978) offers an insight in the types of animals that were present in the area. These include mammoths, aurochs, rhinos, horses, deer, and wild boar. The listed fossils are possibly mainly of the same age as the Fisherton brickearth (Delair and Shackley 1978). Fossils found at Milford Hill suggest horses, wild boar and mammoths were also present in the valley during hominin presence at this site. This research has demonstrated that hominins were present in the Avon valley pre-MIS 9. Possibly first sporadically as is indicated by isolated biface finds from the T10. The assemblages from Bemerton, Woodgreen and Milford Hill indicate repeated revisiting of these sites during pre-MIS 9, MIS 9 and MIS 8, respectively. This evidence from the Avon valley suggests that hominin landscape use varied over time, possibly instigated through a change in the availability of resources or set of strategies sought at particular locations by hominins. This could reflect a change in the 'way of doing things', in knowledge of the landscape, use of places, and spatio-temporal planning.

Chapter 10 Conclusions

10.1 Introduction

The research presented in this thesis aimed to reconstruct Pleistocene landscape change and hominin presence in the Avon valley; and, through the integration of this information into the wider understanding of the British Palaeolithic, improve our understanding of hominin behaviour. This thesis discussed the current knowledge of the Palaeolithic in Britain in its palaeogeographic context, identified the main shortcomings in our understanding of these subjects in the Avon valley, and how overcoming these could improve our understanding of hominin presence in this region and contribute to key questions in Palaeolithic research. The principal problems identified were: 1) insufficient study of the complex depositional environment of Pleistocene fluvial terraces to properly understand the geomorphological changes through time and the taphonomic impact of these on Palaeolithic assemblages ; 2) a lack of chronometric dating of these Pleistocene sediments; 3) a lack of any detailed study of the artefact assemblages from the key Palaeolithic sites in the Avon valley, their context, depositional history/taphomony and behavioural significance. This research applied a geoarchaeological approach to the study of the Avon Palaeolithic record to overcome these impediments and aimed to reconstruct the Pleistocene landscape, develop a chronometric dating framework, and analyse the Avon valley Palaeolithic record.

This was achieved through the study of Pleistocene fluvial terrace deposits, clast lithology analysis, and the examination of environmental indicators which have resulted in a reconstruction of the fluvio-geomorphologic processes that shaped the Avon valley. OSL dating of these sediments has provided a new chronometric framework permitting the first model of Pleistocene landscape evolution not to rely on speculative relative chronological markers. This reconstruction and dating of the Avon valley landscape forms the chronometric and environmental framework for its Palaeolithic record.

Analysis of the assemblages from the three key sites Bemerton, Milford Hill and Woodgreen has led to new insights in site formation processes and the spatio-temporal resolution of these artefact concentrations. Together this has led to a reconstruction of landscape change and hominin presence and behaviour in the Avon valley that contributes to our understanding of the landscape and hominin occupation of Britain during the Pleistocene. In summary:

- Three different types of terraces can be recognised in the Avon valley, indicating different formation processes that can possibly be related to major changes in the cyclicity of Quaternary climate fluctuations.

- The oldest terraces (O5-O1 and T10) are minimally separated in height and in places, form compound terraces. These indicate multiple depositional events which are alternated with periods of limited vertical erosion.

- The middle terraces (T9-T5) exhibit much clearer altitudinal separation and consist of a bedrock strath covered by coarse cold climate fluvial sediments. The main terrace-generating incision occurred during cold-warming periods (glacial-interglacial and/or stadial/interstadial). The subsequent period of sediment aggradation is accompanied by lateral erosion of the valley sides and the incorporation of fluvial sediments from preceding aggradation-events. This process of lateral erosion appears to have been particularly significant during the deposition of T4, which likely incorporates fluvial sediments of several preceding terraces, mainly eroded from the east side of the valley.

- The lowest terraces (T4-T1) exhibit minimal separation and formed through the filling of the spatially confined valley with eroded fluvial sediments from the higher terraces. Subsequent erosion and reworking of these sediments led to the formation of cut-and-fill terraces.

- OSL dating of the Avon valley terraces suggest that T10-T7 were formed before 300ka (MIS 9), T6 is formed between MIS9 and 7, and T5 is deposited during 200ka (MIS 6). A significant erosional and depositional event occurred during the MIS 6/5 transition which can likely be related to the deglaciation at the end of the MIS 6 glaciation. T4 to T1 formed through climate fluctuations during the Devensian.

- The reconstruction of the fluvio-geomorphological history of the Avon valley indicates that the Avon River laterally migrated west during the deposition of T9-T7 (before MIS 9) and east during the formation of T6-T5 between MIS 8 and MIS 5, but that by this period the river had incised sufficiently that the remnant floodplain fragments preserving large concentrations of lithics were not reworked. The extent and timing of lateral migration of the Avon resulted in the un-paired preservation of the majority of the terraces. This has important implications for predictive modelling and allows areas of potential Palaeolithic find-spots to be identified. This is of relevance to the aggregate industry and development.

- The chronometric framework developed in this research relates the three key Palaeolithic sites in the Avon valley to MIS 10-8. Within this framework a relative chronology of the sites is proposed based on the height of the sites above floodplain, in which Bemerton presents the oldest (pre or early MIS 9), followed by Woodgreen (MIS 9) and Milford Hill (MIS 8). Hominins bearing Acheulean technology were likely present in the Avon valley prior to MIS 10, as is indicated by the sporadic finds from the highest terraces in the valley. The assemblage from Woodgreen includes five possible Levallois flakes, indicating that this technique may have been precociously applied.

- The sites in the Avon valley present ephemerally visited locations which must have offered an attraction to hominins, likely through the availability of a combination of raw materials and presence of a variety of resources. The repeated revisiting of the sites suggests that within the wide network of landscape use certain locations formed focal places for a set of activities and access to resources.

- The network of hominin landscape use changed over time in the Avon valley, possibly reflecting a change in the availability of resources or set of resources sought at particular locations by hominins. This could be the result of transformations in the local environment and resource availability and/or reflect a change in hominin behaviour, in knowledge of the landscape, use of places, and spatio-temporal planning.

- The bifaces made, used and left at Bemerton, Milford Hill and Woodgreen show a variety of sizes and shapes. A significant difference between the shapes of bifaces from Milford Hill and those from Bemerton and Woodgreen was determined. The variability observed in the Avon valley is most likely influenced by the types of blanks used (cf. Ashton and McNabb 1994) and possibly to a degree also related to reduction strategies (cf. McPharron1996). However, no exclusive relationship existed between artefact size and shape (contra McPherron 2006), neither an exclusive relationship between proximity of sites to the Chalk (assumed to be related to flint nodule availability) and shape (contra White 1998). Instead this variability is attributed to, possibly diachronically changing socio-cultural principles, superimposed on raw materialcharacteristics.

- The Avon sites seem to date to a period for which the number of Palaeolithic sites declined relative to the preceding period of MIS 13-10 (Ashton and Hosfield 2010). This could indicate that the observed pattern of decline in sites is less-pronounced or non-existing and that the reinvestigation, dating and contextualising of historically collected sites like those in the Avon valley can contribute to a refinement of the understanding of the British Palaeolithic occupation.

- The Avon valley Palaeolithic sites demonstrate that hominins continued to reach Britain during a period for which a general decline in hominin presence has been suggested and has been related to its changing palaeogeographic situation (Ashton et al. 2011). This could suggest that hominins developed adaptations to colder climates which allowed them to spread north earlier in the season or climate cycle and/or more often. It could also indicate that our understanding of the Channel River as "barrier" needs refinement and that hominin adaptive and cognitive developments possibly also improved their capabilities to cope with the changing palaeogeography of the Channel region.

Further work

This research has demonstrated that a catchment focussed geoarchaeological investigation into known Palaeolithic artefact assemblages can make a significant contribution to: 1) the understanding of their spatio-temporal significance and 2) their integration into the wider narrative of the Palaeolithic of Britain. Even more could be made of the data presented here through the further development and refinement of the chronometric framework through the application of feldspar OSL dating. Feldspar has a higher saturation point and should allow the oldest terraces in the Avon valley to be dated. A refinement of the terrace chronology could further the understanding of the timing of the observed changes in terrace formation processes and its link to Quaternary climate cycles. The application of feldspar dating to the Pleistocene river terraces in the research area will represent a supplementary method extending beyond the use of quartz OSL dating in Britain. The comparison of the dating results from quartz and feldspar samples from this research will further methodological and analytical advances in the field of feldspar dating.

The analysis of the Palaeolithic record has demonstrated the value of historically collected artefact assemblages and the wealth of information present in museum collections and historic sources. Especially at Milford Hill this could be further exploited through continued investigation of historic sources and the 3D reconstruction of past excavations, exposures and discoveries. This will further the understanding of the depositional context of the artefacts and unique fossil finds at Milford Hill and could inform future fieldwork and policy making.

The reconstruction of the Pleistocene landscape and Palaeolithic occupation of the Avon valley has offered a local perspective on regionally observed patterns, providing a refinement of our knowledge of the British Palaeolithic. This research has demonstrated that a geoarchaeological and interdisciplinary approach to Palaeolithic records from fluvial and proximal contexts can provide new insights in the understanding of hominin adaptations and behaviour within the Pleistocene landscape.

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