CHAPTER 5

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

1. INTRODUCTION

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

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

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

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

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

2. BROOM: A RE-ASSESSMENT

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

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

2.1 The Palaeo-environmental & Geochronological Framework

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

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

2.2 Stone Tool Assemblage

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

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

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

2.3 Assemblage Characterisation

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

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

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

2.4 Assessing the Broom assemblage

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

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

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

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

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

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

3. MODELS OF CLAST TRANSPORTATION

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

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

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

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

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

(Hunziker & Jaeggi 2002: 1061–1062)

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

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

  (Muste 2002: 65)

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

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

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

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

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

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

(Church & Hassan 1992: 301)

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

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

(Malmaeus & Hassan 2002: 89)

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

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

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

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

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

4. EXPERIMENTAL ARCHAEOLOGICAL DATA

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

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

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

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

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

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

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

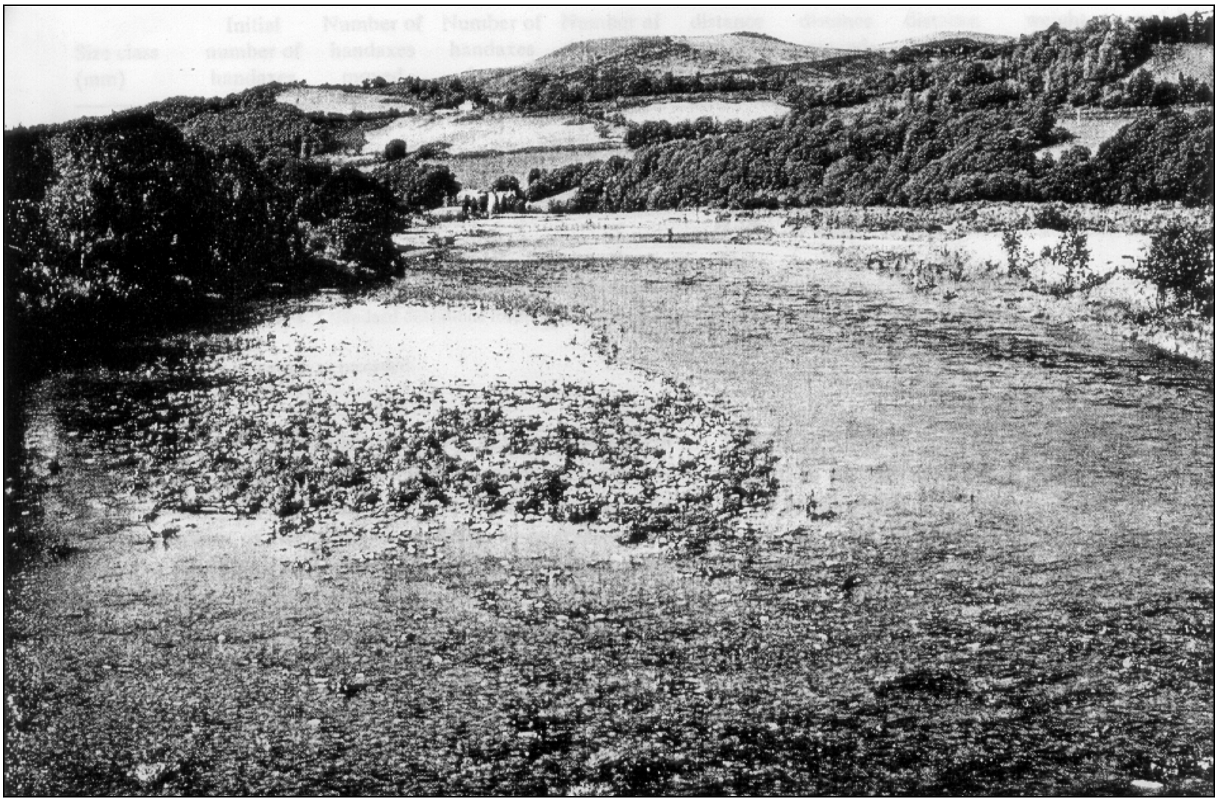

Figure 171: Afon Ystwyth at Llanilar, c. *1983 (Harding et al. 1987: Figure 1)*

Figure 172: Afon Ystwyth at Llanilar, January 2001

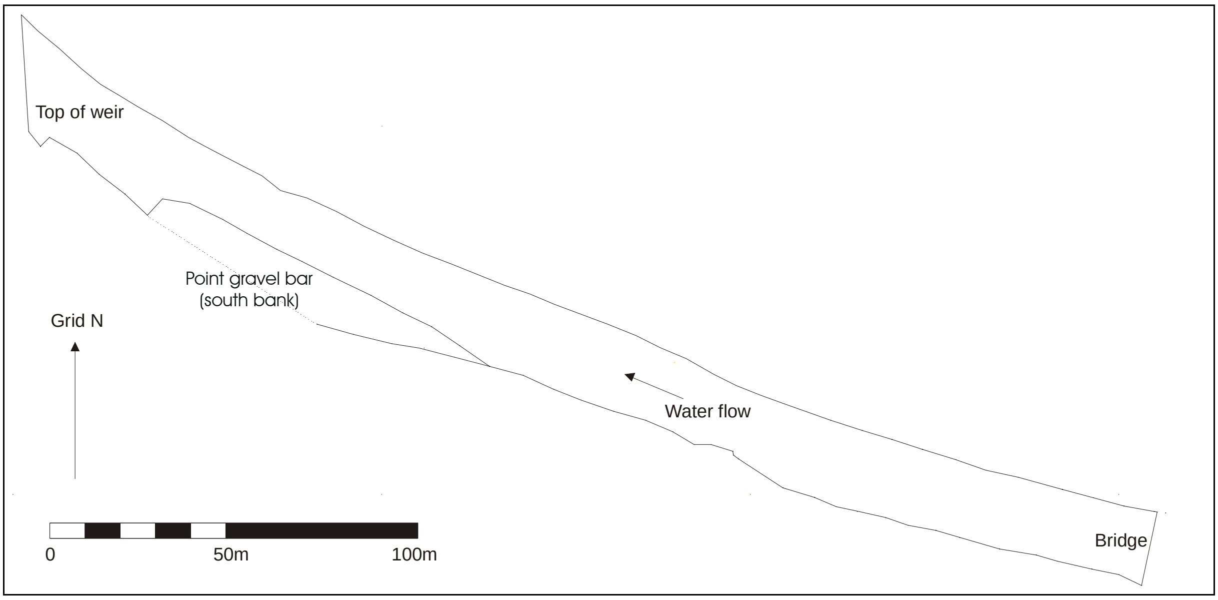

Figure 173: Llanilar study site at the time of current experiments (2000–-2003)

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

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

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

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

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

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

(Harding *et al.* 1987: 116)

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

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

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

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

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

4.1 Biface tracer experiments

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

- Llanilar biface tracer experiments. Bifaces were emplaced with the primary objective of studying the development of physical abrasion characteristics (arête widths, micro-flaking and percussion cones) in relation to the distances over which the artefacts were transported. Step length data was therefore a key secondary objective of the experiments. Bifaces were recorded prior to emplacement, with recorded data including morphology, technology and physical condition. Bifaces were emplaced either as new surface clasts (surface method) or by replacing an existing clast of comparable dimensions (replacement method), following the principle of scaling the tracer to the median of the bed-load (Church & Hassan 1992). A combination of the surface and replacement methods were employed to investigate the claims of: Church & Hassan (1992), that the probability of particle movement for exposed clasts is inversely related to its size; and of Malmaeus & Hassan (2002), that elevated particles are likely to start moving before embedded ones. Unfortunately, at the current time the recovered sample size has been too small to assess the model of Malmaeus & Hassan (2002).

All artefact positions were surveyed and the orientation and dip of the bifaces was recorded. A total of 49 bifaces were emplaced at the site (20 in January 2001, 5 in January 2002, 14 in December 2002 and 10 in March 2002). The Afon Ystwyth was prospected for transported bifaces in March, June, August and October 2002, and March and July 2003. At the time of writing, 10 (20.4%) have been recovered. This recovery rate compares poorly with the 45% achieved by Harding *et al.* (1987), although the Foot and Mouth epidemic in 2001 restricted access to the study site between January and December 2001, a period when up to 20 bifaces may have been available for recovery.

- Llanafan (Grogwynian Reach) biface tracer experiments. Bifaces were emplaced with the primary objective of studying the tendency of bifaces for entrainment and transportation or *in situ* burial. Biface morphology, technology and physical condition were recorded prior to emplacement, as with the Llanilar samples. The artefacts were emplaced either as new surface clasts or as replacement clasts, and their positions were surveyed. The orientation and dip of the bifaces was recorded. A total of 34 bifaces were emplaced at two sites. The first site was an area of semi-stable floodplain, consisting of exposed riverine sediment (including point bars) and vegetated floodplain. 25 bifaces were emplaced at this site (8 in September 2000, 16 in December 2001 and 1 in April 2002). The second site was a point/ midstream bar (depending on river water levels), lying at the eastern (upstream) end of the study site. 9 bifaces were emplaced at this site in June 2002. The floodplain was prospected for bifaces in January and December 2001, January, March, April, June, August, October and December 2002, and March and July 2003. At the time of writing, 10 (29.4%) have been recovered. This ratio compares favourably with that from Llanilar, but it is stressed that 6 of these bifaces had not been subject to any fluvial transportation.

In the discussion of the experiments at Llanilar and Llanafan, Afon Ystwyth flow and discharge rates are not highlighted here. It is emphasised that as associations between tracer transport episodes and individual high flow events could not be demonstrated (partially due to the recording intervals), specific discharge data was of limited importance. Furthermore, such data represent a process variable which cannot be determined with respect to Palaeolithic secondary context assemblages.

4.1.1 Llanilar Results

The 10 recovered bifaces were transported a range of distances, between 0.21m and 326.88m (Table 43). There was no clear relationship between size (using weight as a size index) and distance transported, although the general trend was towards a positive rather than a negative relationship ($r^2 = 0.3147$; $r=0.56$). This is supported by Einstein (1942) and Church & Hassan (1992), who also argued that there was no clear relationship between clast size and transport distances. The current Llanilar experimental results contrasted with Harding *et al.* (1987: 117) who argued for a significant negative relationship between distances transported and the biface length and weight, using stepwise multiple regression. We suggest that these data should be treated cautiously however, since they are heavily dependent upon the vagaries of artefact recovery, and the number and severity of flooding events associated with each entrainment period.

Biface #	**Weight (g)**	**Emplacement Date**	**Recovery Date**	**Linear Distance (m)**
6	567	22/01/2002	30/03/2002	137.70
7	332	22/01/2002	30/03/2002	0.40
19	502	19/01/2001	07/06/2002	326.88
18	638	22/01/2002	03/10/2002	131.76
95	473	14/12/2002	15/03/2003	194.97
27	279	14/03/2003	13/07/2003	0.21
29	189	14/03/2003	13/07/2003	0.46
30	546	14/03/2003	13/07/2003	6.51
35	298	14/03/2003	13/07/2003	6.78
36	406	14/03/2003	13/07/2003	0.31

Table 43: biface transport distances and weight data (Llanilar site)

However, it is notable that bifaces 6 and 7 were both emplaced (January 2002, using the clast replacement method) and recovered (March 2002) at the same time, and yet showed markedly different transportation histories. Biface 6 was transported 137.70m, while biface 7 moved just 0.40m downstream from its point of emplacement. Biface 7 had been buried by other transported clasts (Figure 178) and underwent minimal transport. It is impossible to assess whether it may have been entrained during subsequent flood events, although the data indicates the potential for material to be buried *in situ* — in other words, material is not inevitably transported shortly after entry into the system. In this respect, the current study supported by the comments of Harding *et al.* (1987):

"The axes behave in the same way as the local mobile sediment: if placed on an active gravel bar they may move and become buried, but if placed in slacker water they will not. In an environment of dynamic bedforms, transport is an episodic process involving a phase of movement, and then a prolonged phase of burial which be followed by renewed transport if those sediments are re-eroded again."

(Harding *et al.* 1987: 118)

Bifaces 6 and 7 therefore demonstrate the observations of Malmaeus & Hassan (2002) that:

"Given the complexity of bedload movement in gravel-bed rivers, the movement of individual particles appears to be a statistically random phenomenon."

(Malmaeus & Hassan 2002: 95)

With respect to biface burial, it is possible that a significant proportion of the unrecovered bifaces are currently buried within the experimental site. This is based partly on the evidence for biface burial (both at the Llanilar and Llanafan sites) and localised armoring development on the channel bed at Llanilar (Figure 179), but also by the absence of any evidence for bifaces accumulating at the downstream end of the experimental site. In such circumstances, the evidence would suggest that burial rather than river bed exposure and/or transportation is the predominant state for the experimental biface (following the conclusions of Harding *et al.* (1987) and the observations of Malmaeus & Hassan (2002). However, it is stressed that this conclusion is tentative, and that the removal of the unrecovered bifaces from the system (either through human interference or extremely high energy flooding events that transported the bifaces past the weir) should not be discounted.

The condition of the artefacts after transportation highlighted some interesting contrasts with the laboratory experiments of Chambers (in prep.). The transported bifaces displayed evidence of abrasion development, although the quantities of arête abrasion tended to be lower than the modelled quantities generated by Chambers' laboratory experiments for the demonstrated transported distances (Table 44). It is suggested that this contrast may reflect the presence of fluvial silt and algae growth on the biface surfaces and on the surrounding clasts within the channel. The growth of algae on the bifaces tended to occur rapidly (within 2 months of the emplacement of the bifaces within the channel during the spring of 2002) and it is suggested that these coverings (on both the clasts and the bifaces) may have reduced the impact of clast collisions and other mechanisms of abrasion development (particularly edge micro-flaking). There was no evidence of micro-flaking development on the biface edges (except for that relating to the original manufacturing processes). However, it is also stressed that other factors (e.g. contrasting flow velocities and suspended transportation) are probably of significance with respect to the differing abrasion development patterns seen in the field and these laboratory specimens.

By contrast however, the bifaces subjected to minimal movement (bifaces 7, 27, 29, 30, 35 and 36) all displayed greater quantities of arête abrasion than the modelled values generated in Chambers' laboratory experiments for the demonstrated (non-) transport distances. Combined with the evidence for localised *in situ* burial (e.g. biface 7), these bifaces are probably demonstrating the effects of abrasion damage sustained either during the process of burial or through bombardment to exposed surfaces by mobile particles, during episodes of partial burial. However, it should be stressed that issues of data accuracy do exist when recording arête widths < 0.1mm, and indeed that the majority of archaeological bifaces occurring in secondary contexts display arête abrasion values in excess of this threshold.

Figure 178: biface #7, Afon Ystwyth, Llanilar site (March 2002)

Biface #	Distance (linear (m)	Min. arête width (mm)	Max. arête width (mm)	Transport regime	Modelled distance (m)
6	137.70	0.03	0.09	Saltation	125-150
7	0.40	0.02	0.08	Saltation	100-125
18	131.76	0.03	0.10	Saltation	150
19	326.88	0.03	0.10	Saltation	125-150
27	0.12	0.01	0.06	Saltation	100
29	0.46	0.01	0.03	Saltation	30-40
30	6.51	0.01	0.08	Saltation	80
35	6.78	0.01	0.03	Saltation	40
36	0.31	0.04	0.2	Saltation	100-125
95	194.97	0.01	0.05	Saltation	90-100

Table 44: biface abrasion (field experiment data from Llanilar and laboratory flume data (Chambers in prep.)

Incipient cones of percussion, the result of direct impacts with other lithic materials (probably caused by artefact-clast collisions) were prominent on bifaces 6 and 19, and were present to a smaller extent on bifaces 95 and 18. They were not present on bifaces 7, 27, 29, 30 and 35. Biface 36 did not display any evidence of incipient percussion cones. However, given its manufacture in coarse-grained chert, the detection of these features would only be possible in the most extreme cases. Within fluvial environments, incipient cones of percussion may be regarded as being the result of either a mobile biface impacting upon the stationary bed clasts, or alternatively these cones may occur as the biface is stationery and struck by smaller (and therefore mobile) particles. The restriction of incipient percussion cones to the Llanilar bifaces transported over 100m may suggest however that their development is more commonly associated with active transport.

In general, the key conclusions from the Llanilar biface experiments are as follows:

- Bifaces have a tendency for both *in situ* burial and transportation.
- The tendency of an individual biface for burial or transportation relates not only to flow velocity (i.e. flood magnitude) but also to the local river bed morphology, as highlighted by Malmaeus & Hassan (2002), Hassan & Church (2002) and Hunziker & Jaeggi (2002). The potential for archaeological material to behave as clasts was also illustrated by Harding *et al.* (1987) during the earlier archaeological tracer experiments on the Afon Ystwyth.

- Bifaces may be subject to abrasion development while in phases of partial burial, as well as during periods of active transportation.
- The development of diagnostic transport features (e.g. edge micro-flaking and incipient percussion cones) may be hindered in fluvial environments with a significant vegetation (algae) component.

Figure 179: channel armoring at the Llanilar site. The coarse clast armor layer has been removed from the centre of the photograph during the recovery of biface #7 (compare with Figure 178).

4.1.2 Llanafan Results

12 bifaces were recovered from Llanafan, of which 6 showed no evidence of fluvial transportation. There was also no supporting evidence for fluvial activity (e.g. local clast orientations, silt[3] introduction or vegetation modification and/or transportation) within their vicinity. These bifaces (numbers 60, 62, 64, 69, 70 and 71) are therefore excluded from the following discussion.

The 6 entrained bifaces were transported a range of distances, between 2.42m and 35.67m (Table 45). There was no clear relationship between size (using weight as a size index) and distance transported, following Einstein (1942) and Church & Hassan (1992), although the general trend was towards a negative relationship ($r^2 = 0.3138$; $r = -0.56$). This partially supported Harding *et al.* (1987: 117) who argued for a significant negative relationship between distances transported and the biface long (A) axis and weight, using stepwise multiple regression (although this was based on work at the Llanilar site). We again suggest that these data should be treated cautiously however, since they are heavily dependent upon the vagaries of artefact recovery, and the number and severity of flooding events associated with each entrainment period.

[3] There is a wide range of fine-grained sediment types present on the Afon Ystwyth floodplain. These include silts, fine and coarse-grained sands, and fine granules. 'Silt' is employed in this report as a generic term for this material, although it is not being used *sensu stricto*.

The transportation distances appear to demonstrate relatively short step lengths (e.g. a *maximum* of 19.41m for biface 6[4]), although it is possible that some or all of the unrecovered bifaces were transported over much longer distances and would therefore have demonstrated longer and/or higher frequency step lengths had they been recorded. With respect to the recovered bifaces, these apparently short step lengths may be due to the absence of armoring on the gravel bar sites, which increases the potential for sediment re-working, burial of clasts (and artefacts), and the disruption of transport through local clasts traps.

Biface #	Weight (g)	Emplacement Date	Recovery Date	Linear Distance (m)
6	567	29/09/2000	19/01/2001	19.41
14	921	29/09/2000	19/01/2001	2.42
65	651	30/11/2001	15/07/2003	33.36
72	805	30/03/2002	14/12/2002	11.39
74	416	30/03/2002	14/12/2002	6.83
76	274	30/03/2002	15/03/2003	35.67

Table 45: biface transport distances and weight data (Llanafan site)

It is possible that a significant proportion of the unrecovered bifaces are currently buried within the experimental site. This is based partly on the evidence for biface burial at the Llanilar site, but also from bifaces 65 and 68 at the Llanafan site. Biface 65 was emplaced in November 2001, and was not relocated for 20 months despite site survey at two monthly periods over this interval. During this period there was substantial evidence for bar form modification and sediment transport (Figure 180), and it was presumed that the biface had probably been buried. The biface was recovered in July 2003 (Figure 183), *c.* 30m downstream in a small overflow channel on the floodplain. The relatively small transport distance makes it unlikely that the artefact had been exposed to surface movement throughout the 20 months (which included 2 winter flood seasons) and therefore indicates the potential for substantial periods of burial and the re-erosion of artefacts in response to the local dynamics of sediment transport.

Biface 68 was emplaced in November 2001, adjacent to scatter 4 (see below), and was regularly re-identified until March 2003. The biface was not transported but it gradually became covered by the surrounding silt sediments. It was unclear whether this was caused by the introduction of silt material into the vicinity or due to the effect of gravity and the weight of the biface (Figure 181–Figure 182). Ultimately the biface was completely buried between March and July 2003, and has yet to be re-located. Although the circumstances of burial were specific, it is argued that similar processes may occur in other fine-grained sediment environments (e.g. bar tail deposits and discontinuous sand bodies on bar tops, as well as floodplain surfaces).

The condition of the artefacts after transportation highlighted some interesting contrasts with the laboratory experiments of Chambers (in prep.). The transported bifaces displayed evidence of abrasion development, although the quantities of arête abrasion were greater than the modelled quantities generated by Chambers' laboratory experiments for the demonstrated transported distances (Table 46). There was evidence of transport-related micro-flaking development on the edges of biface 72, although in general it is absent. Incipient cones of percussion were present on the dorsal and ventral surfaces of bifaces 72, 74 and 76. In contrast with the Llanilar data, incipient percussion cones are present on bifaces transported over sub-100m distances, suggesting that they may also develop during non-mobile phases of fluvial entrainment. Combined with the evidence for localised *in situ* burial and interaction with local, mobile bed-load (e.g. biface 65, 72 and 74), all of these bifaces are probably demonstrating the effects of damage sustained either during the process of burial or through bombardment to exposed surfaces by mobile particles, during episodes of partial burial (Figure 184 & Figure 185). However, it should again be stressed that issues of data accuracy do exist when recording arête widths < 0.1mm, and indeed that the

[4] Potentially, biface 6 could have been transported over multiple phases — e.g. 3 step lengths of *c.* 6.4m each, although this could not be demonstrated due to the nature of the experimental equipment.

majority of archaeological bifaces occurring in secondary contexts display arête abrasion values in excess of this threshold.

Figure 180: floodplain overflow channel, Llanilar, Afon Ystwyth (January 2002). Note the transported sediment and vegetation flotsam and jetsam.

Biface #	**Distance (linear (m)**	**Min. arête width (mm)**	**Max. arête width (mm)**	**Transport regime**	**Modelled distance (m)**
6	19.41	0.02	0.04	Saltation	80
14	2.42	0.02	0.04	Saltation	70
65	33.36	0.01	0.08	Saltation	90-100
72	11.39	0.03	0.20	Saltation	125-150
74	6.83	0.03	0.20	Saltation	175
76	35.67	0.03	0.10	Saltation	125-150

Table 46: biface abrasion (field experiment data from Llanafan and laboratory flume data (Chambers in prep.)

In general, the key conclusions from the Llanafan biface experiments are as follows:

- Bifaces have a tendency for both *in situ* burial and transportation.
- Bifaces demonstrated potential for burial within fine-grained floodplain and bar form sediments.
- Transportation distances (and therefore step lengths) tend to be relatively short (this assumes that the majority of unrecovered bifaces were buried rather than transported downstream of the study area).
- Bifaces may be subject to abrasion development and related damage while in phases of partial burial, as well as during periods of active transportation.
- The development of incipient percussion cones may occur over short distances.

Figure 181: biface #68, emplaced at Llanafan, Afon Ystwyth (November 2001)

Figure 182: biface #68, becoming buried in fine-grained silt sediments, Llanafan, Afon Ystwyth (December 2002)

Figure 183: biface #65, recovered in July 2003, Llanafan, Afon Ystwyth

Figure 184: biface #72, Llanafan, Afon Ystwyth (October 2002)

Figure 185: biface #74, Llanafan, Afon Ystwyth (December 2002)

4.2 Flake tracer experiments

Flake scatters were emplaced at the Llanafan (Grogwynian Reach) site, to explore the transformation of flake materials as a consequence of fluvial disturbance and other aerial and sub-aerial processes. A total of 13 scatters were emplaced, of which 4 were knapped *in situ*, and 9 were pre-knapped and emplaced to mimic the spatial density of a scatter knapped *in situ*. Scatters were pre-knapped as it enabled the recording of flake weight and the a, b and c-axes. It also facilitated material identification and recovery. As the main focus of the experiments was flake movement, it was considered to be more important to record accurate size data than to create 'authentic' knapping scatters. Two flake dimensions (the a and b-axes) were recorded for the *in situ* knapped scatters. The orientation and dip of all flakes were recorded after the scatters were emplaced. 3 scatters were emplaced at Llanafan site two (the point/midstream bar at the upstream (eastern) end of the site), with the remaining 10 scatters emplaced at Llanafan site one (the semi-stable floodplain). The floodplain was prospected for flakes in January and December 2001, January, March, April, June, August, October and December 2002, and March and July 2003. Flakes were recovered from 11 of the scatters, with two scatters providing no returns (Table 47). Two scatters were fully re-excavated (scatter 3 was excavated in April 2002 and scatter 4 was excavated in July 2003).

4.2.1 Results

The results from the flake experiments are only summarised here, reflecting the quantity of data generated by the flake experiments. The most informative data on flake transport was recorded from scatters 7, 8, 10, 11 and 12. In all of these cases, there was no clear relationship between flake size (using weight as an index of size) and distance transported (illustrated here for scatters 12 in Figure 186; Einstein 1942; Church & Hassan 1992). However, it has been argued that clast dimensions and shapes rather than weight are a more significant factor with respect to transport distances (Wilcock 1997). It is notable however that there is also no evidence for a clear relationship (either positive or negative) between flake size (using a-axis x b-axis area as an index of size) and distance transported, illustrated again for scatter 12 (Figure 187). It is therefore argued that trends within the size class distribution of flake material (e.g. the predominance of small or large artefacts), cannot be taken as an indicator of the relative proximity (or not) of the artefact source(s) to the secondary context assemblage.

Scatter	Material recovered?	Emplacement	1st recovery	2nd recovery	3rd recovery
1	Yes	September 2000	January 2001	November 2001	April 2002
2	Yes[5]	September 2000	-	-	-
3	Yes	November 2001	March 2002	April 2002 (excavation)	-
4	Yes	November 2001	July 2003 (excavation)	-	-
5	No	January 2002	-	-	-
6	Yes	April 2002	June 2002	August 2002	October 2002
7	Yes	June 2002	October 2002	-	-
8	Yes	June 2002	August 2002	October 2002	-
9	Yes	June 2002	October 2002	-	-
10	Yes	August 2002	October 2002	-	-
11	Yes	August 2002	October 2002	December 2002	March 2003
12	Yes	August 2002	October 2002	December 2002	March 2003
13	No	October 2002	-	-	-

Table 47: flake scatter emplacement and recovery, Llanafan, Afon Ystwyth

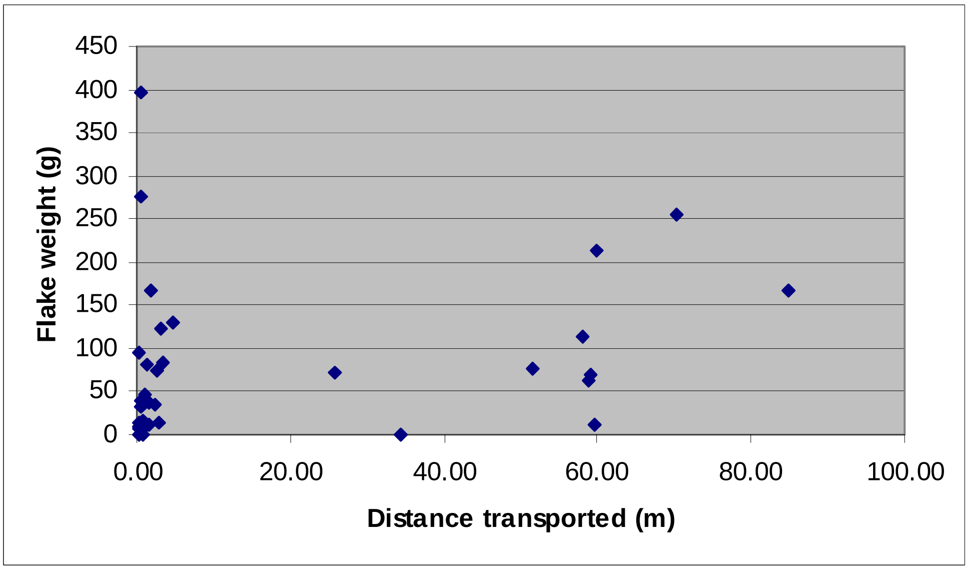

Figure 186: flake transport distances (August 2002/March 2003) vs flake weight (Scatter #12)

Flakes have been transported over a wide range of distances (Table 48), and it is apparent from flake scatters 11 and 12 that flakes survive transportation over a *minimum* of 80m with little or no evidence of substantial damage. Breakages tended to be minor (Figure 188), although it is suggested that more substantial breakages may occur over longer transportation phases. However, there was evidence of micro-flaking on a large proportion of the recovered flakes (Table 49; Figure 189). Chambers' flume research (in prep; Chapter 4) has related the development of micro-flaking to saltation transport, and this suggests that these flakes were probably transported in this manner. However, given the poor current understanding of suspended load transport (Muste 2002), this is a preliminary conclusion and it highlights the need for future modelling of flake transportation.

Most of the micro-flaking scars displayed on the transported flakes are small (sub-5 mm in all dimensions) and it is therefore highly unlikely that these micro-flakes would be recovered archaeologically. However, in

[5] Scatter 2 was not fluvially displaced throughout the period of the experiments and has been left *in situ* to explore longer-term processes of bioturbation and aeolian winnowing upon flake material.

those circumstances where such flakes were recovered from secondary context fluvial sediments, their presence should not be taken as an automatic indicator for *in situ* knapping activity.

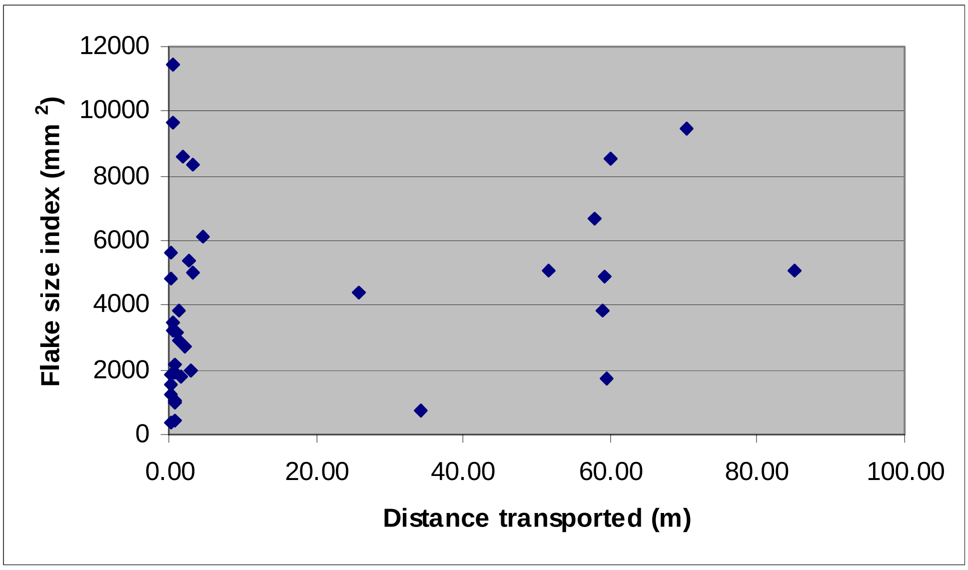

Figure 187: flake transport distances (August 2002/March 2003) vs flake size index (Scatter #12)

In some instances (Figure 190) the products of edge flaking through transport damage are larger (over 1.5 cm in at least one dimension), highlighting not only the potential for transport to modify the shape of flakes, but also for the products of these modifications to be mistakenly regarded as the results of hominid knapping activity. It should also be noted, that sustained episodes of micro-flaking produce scar patterns on flake edges that are reminiscent of intentional retouch (Figure 191). There is a single example of flake modification resulting in an artefact which could be classified as a flaked flake/notch (Ashton *et al.* 1991; Figure 192A & B).

Scatter	Transport distances (m)	
	Minimum	Maximum
1	0.46	16.33
3	0.15	2.88
6	0.05	34.53
7	0.09	1.57
8	0.48	21.52
10	1.32	29.34
11	0.07	82.34
12	0.14	84.95

Table 48: minimum and maximum flake transport distances, Afon Ystwyth, Llanafan

Scatter	# of flakes recovered	Broken flakes		Micro-flaking	
		n	%	n	%
8	21	3	14%	14	67%
10	26	1	4%	18	69%
11	13	1	8%	11	85%
12	10	2	20%	9	90%

Table 49: micro-flaking and breakage for 4 experimental scatters, Afon Ystwyth, Llanafan

Figure 188: scatter #8, flake #29. Note the small breakage on the top-right corner of the exposed face.

Figure 189: scatter #12, flake #22. Note the micro-flaking along the distal edge.

Figure 190: scatter #11, flake #20. Note the micro-flake scar (approximate dimensions 18 mm x 12 mm).

Figure 191: scatter #12, flake #30. Note the developing micro-flaking scar patterns, which if intensified through further transportation processes could ultimately be suggestive of intentional retouch.

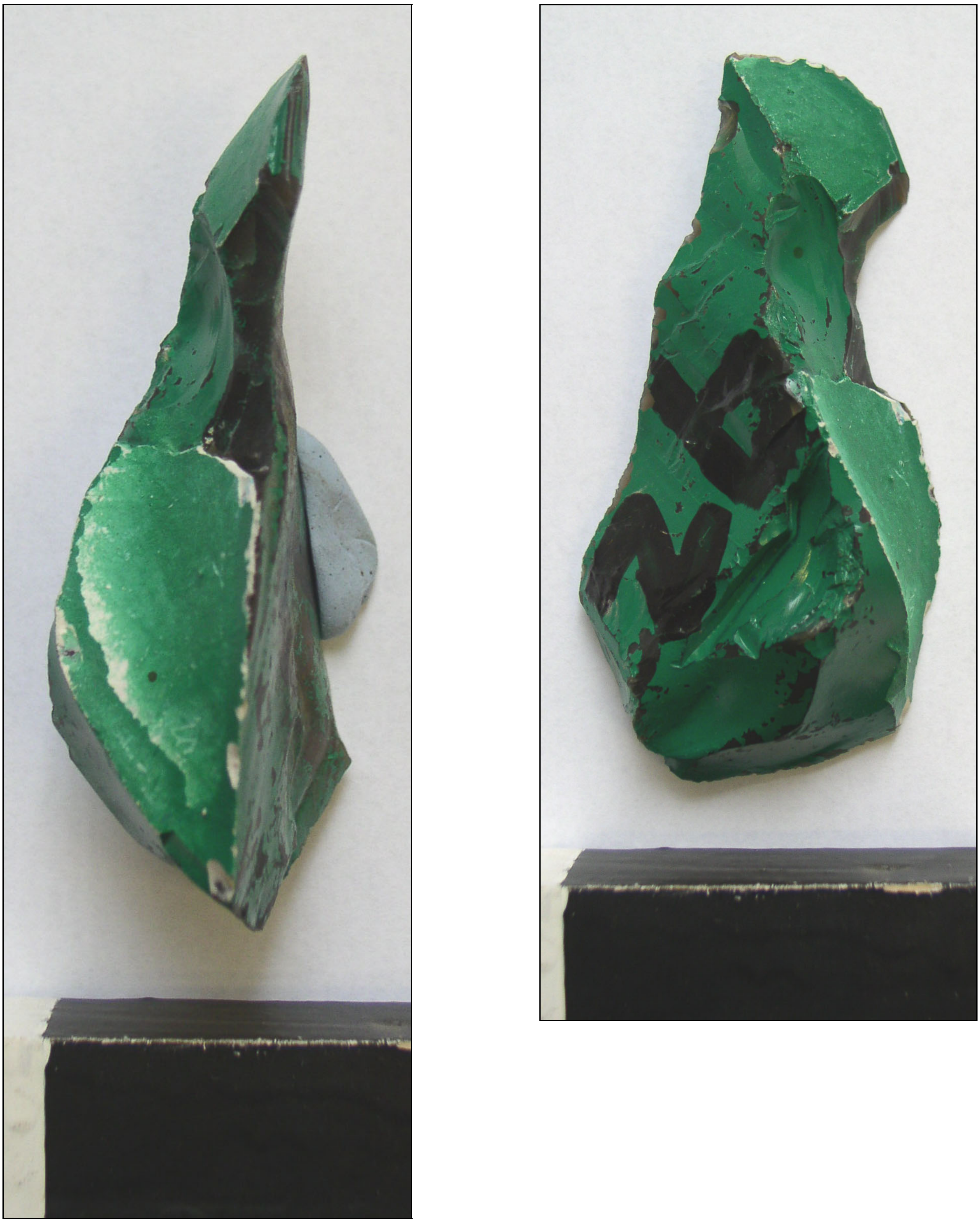

Figure 192A & B: scatter #10, flake #26. Note the 'notch' to the distal right edge.

The recovery of flakes in multiple phases indicated a gradual downstream dispersal of flake material from the original scatters. This is particularly evident for scatters 8, 11 and 12 (e.g. Figure 193 & Figure 194), where the flakes were dispersed less than 5m downstream during the first 2-month experimental period (Figure 193). In contrast, during the subsequent phases flakes were dispersed over much wider areas (Figure 194). Although these patterns could be interpreted through changes in flow velocities and water levels, it is significant that during the period August–October 2002, scatter 8 flakes underwent secondary dispersal over a 20m downstream catchment (scatter 8 flakes were primarily dispersed over an 8m downstream catchment during the period June–August 2002). In contrast, scatter 11 and 12 flakes were primarily dispersed over 2.5m and 5m downstream catchments over the same period (August–October 2002). This suggests that freshly knapped (emplaced) flake scatters display relative structural stability, prior to and during their initial dispersal through fluvial processes. This stability appears to be due to the spatial density of flakes within the scatters, resulting in high levels of flake interaction during entrainment and relatively short transport distances, as suggested by Malmaeus & Hassan (2002) and Hassan & Church (2001). This internal stability may be a partial factor in the high degree of preservation displayed by archaeological material in low energy sedimentary environments such as the Boxgrove beach (Roberts & Parfitt 1988) and the Hoxne lake shore (Singer *et al.* 1993).

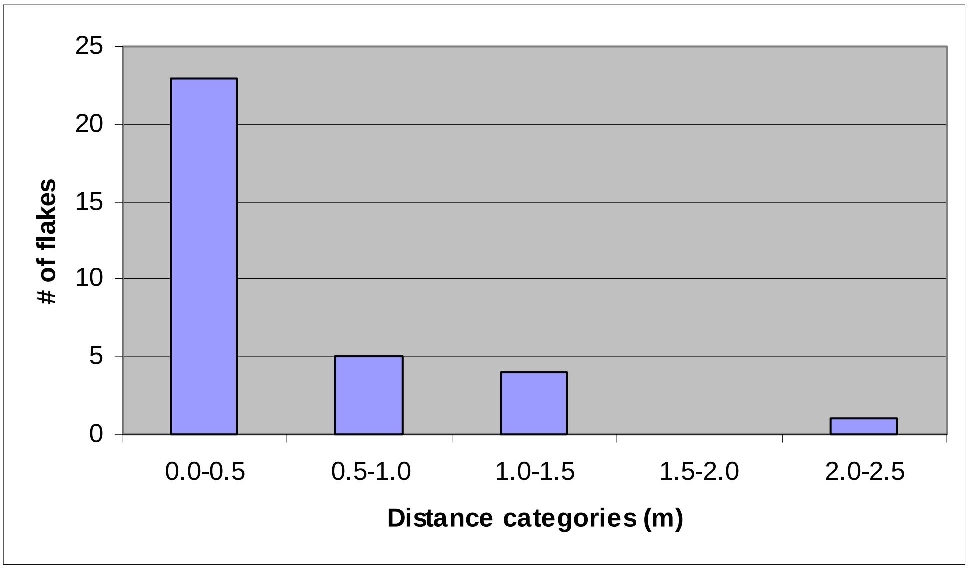

Figure 193: flake transport distances (scatter #11) — August/October 2002 (phase 1)

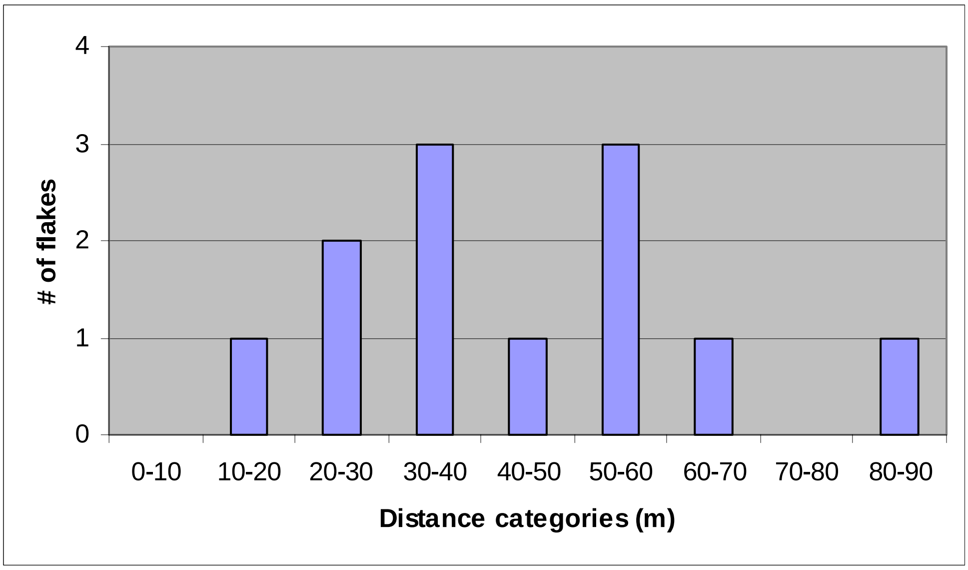

Figure 194: flake transport distances (scatter #11) — October/December 2002 (phase 2)

Overall, these data *suggest* that primary dispersal of flake scatters may be relatively limited, followed by more expansive secondary and tertiary dispersals (although the importance of flow velocities and local variations in gravel bar and channel bed morphologies are not discounted). This model for flake scatter dispersal and transportation indicates that the spatial density of flakes recovered in secondary context sedimentary units may provide an indicator of whether the original scatter has undergone limited or more extensive downstream dispersal.

While there does appear to be a degree of patterning related to phases of dispersal, it was also evident that flake dispersal patterns were influenced by the local morphology of the floodplain (Figure 195). Both smaller and larger flakes were trapped by local clast configurations, both on the submerged channel beds and on gravel bar surfaces, and also by local clusters of vegetation. It is currently difficult to assess whether these trapped flakes tend to be subsequently buried in these traps, or are winnowed out by subsequent flow and transported further downstream. However, the demonstrated tendency for flakes to be dispersed downstream over time suggests that the latter, rather than the former, is the case. In general therefore, while local channel and gravel bar morphology will influence short-term patterns in flake distribution, they will not prevent the widespread downstream dispersal of flake artefacts over the long term.

Figure 195: flake scatter #11, Llanafan, Afon Ystwyth. Note the trapping of small flakes between larger clasts

Scatters 8 and 10, and 11 and 12 were emplaced as pairs to investigate the potential spatial integration of knapped materials from behaviourally-separate episodes. Scatters 11 and 12 were emplaced at the same time (August 2002), while scatters 8 (June 2002) and 10 (August 2002) were separated by a two month period. In the case of scatters 11 and 12, material was spatially differentiated during the initial dispersal phase (Figure 196). However, during the secondary and tertiary dispersal phases, material from the two scatters became fully spatially intermingled (Figure 197).

In the case of scatters 8 and 10, a slightly different distribution pattern was seen. Prior to the emplacement of scatter 10 in August 2002, scatter 8 had already undergone an initial phase of displacement over short distances (Figure 198). Between August and October however, material from both scatters was fully intermingled (Figure 199). The more widespread initial dispersal of scatter 10 (compared to scatter 8) probably reflects seasonal flow variations, combined with its emplacement at the edge of the point bar site (i.e. the role of local topographic factors). In general however, it was clear from both scatter pairs that after initial phases of dispersal, it was not possible to differentiate flake material from separate scatters on the basis of their spatial distribution. This has clear implications for the interpretation of archaeological flake material recovered from secondary contexts, namely that the recovered spatial association of such material cannot be taken as a direct indicator of genuine associations and discrete knapping episodes. These experiments have demonstrated that material from unassociated behavioural episodes can quickly become compressed, and appear to represent the residue from an apparently single phase of knapping activity.

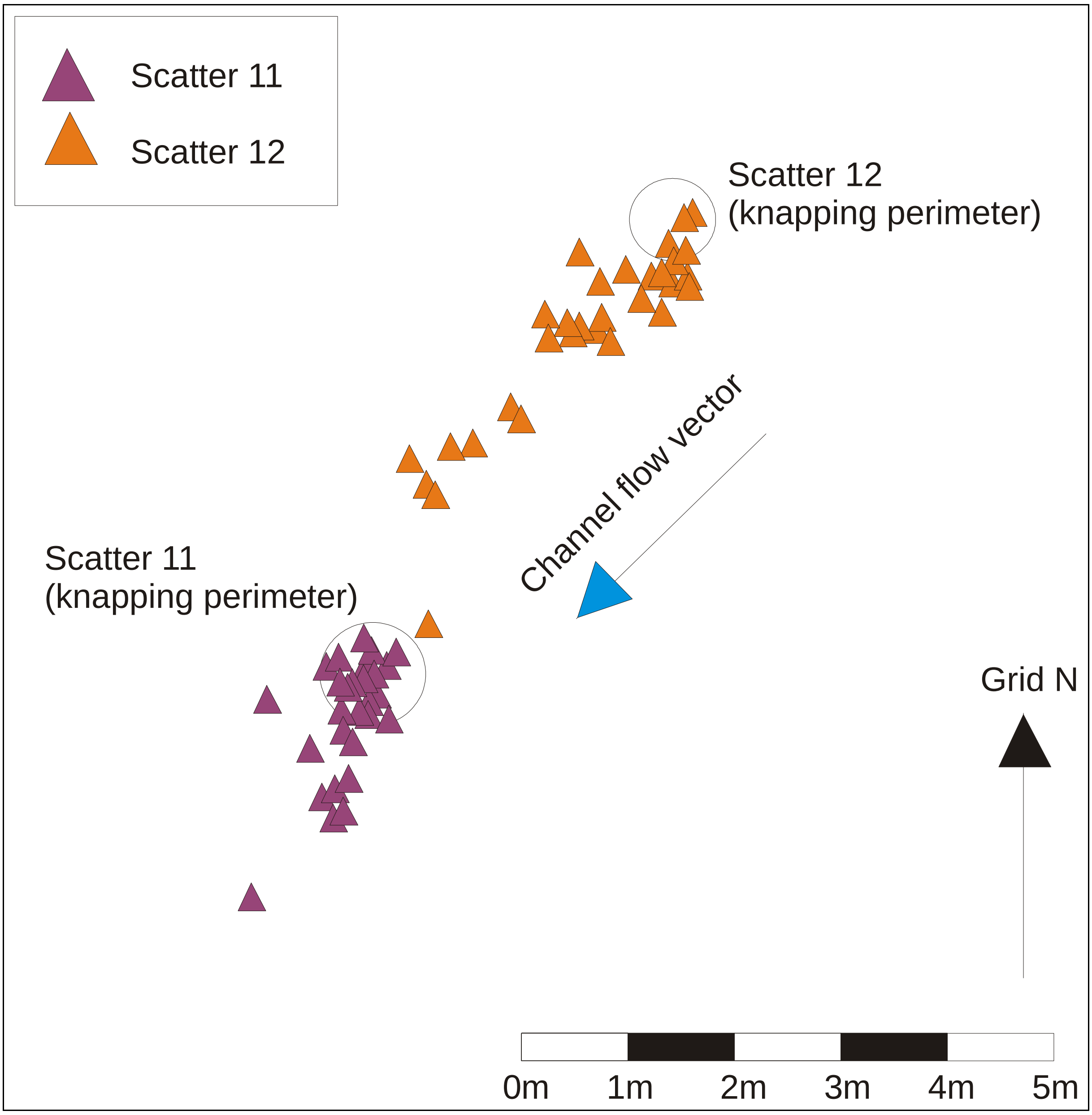

Figure 196: spatial distribution of scatter #11 and #12 flakes after initial fluvial dispersal

Analysis of flake (long axis) orientation after transport episodes indicated only relatively weak diagnostic patterning (e.g. there was relatively weak evidence for primary and secondary orientation axes). This contrasts markedly with the evidence from the clast fabric analysis of the Broom sediments (see Module 2), and may be due to the localised 'trapping' of flakes between larger clasts which results in 'random' long axis orientation patterns.

In a number of cases it was not possible to analyse flake orientation patterns after secondary and tertiary dispersal events, due to the very small sample sizes recovered. These include the secondary and tertiary dispersals of scatter 12 (n=6 and n=4 respectively), and the secondary and tertiary dispersals of scatter 1 (n=6 and n=4 respectively).

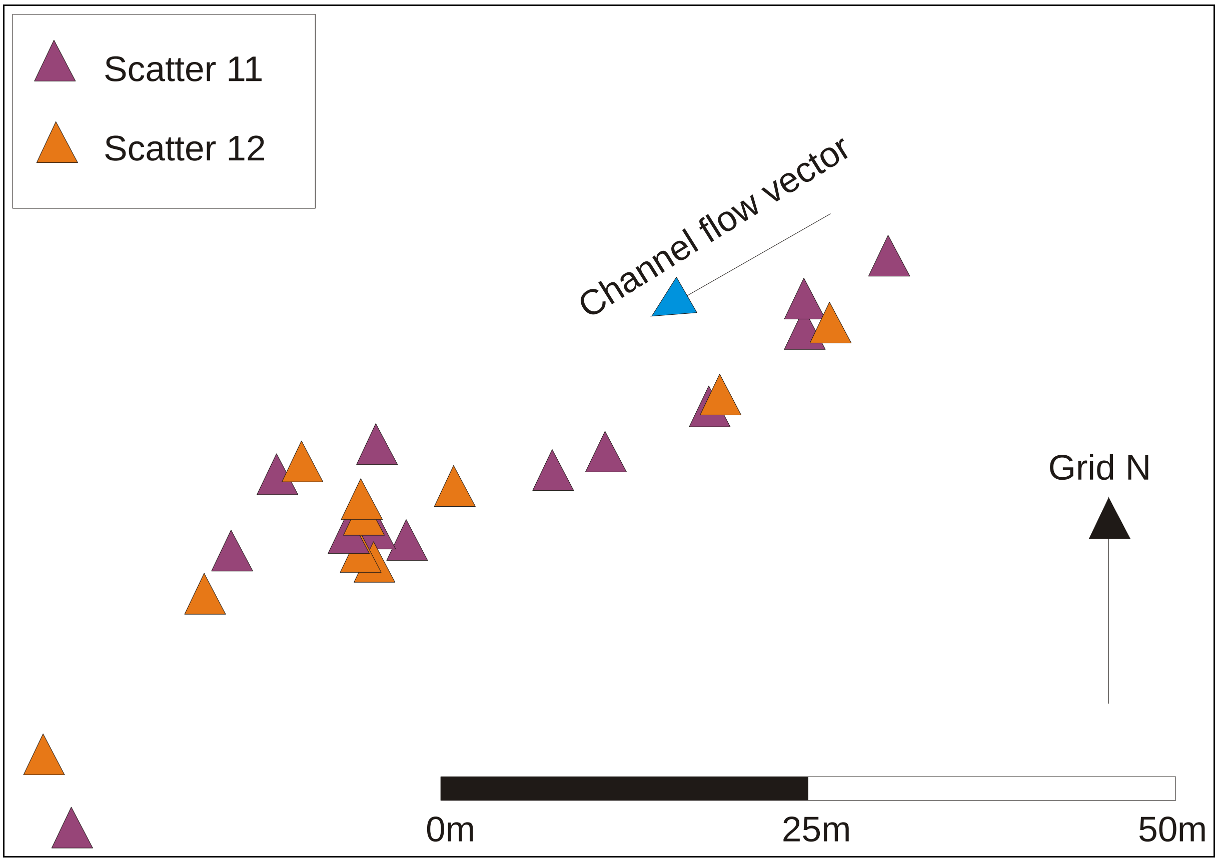

Figure 197: spatial distribution of scatter #11 and #12 flakes after secondary fluvial dispersal

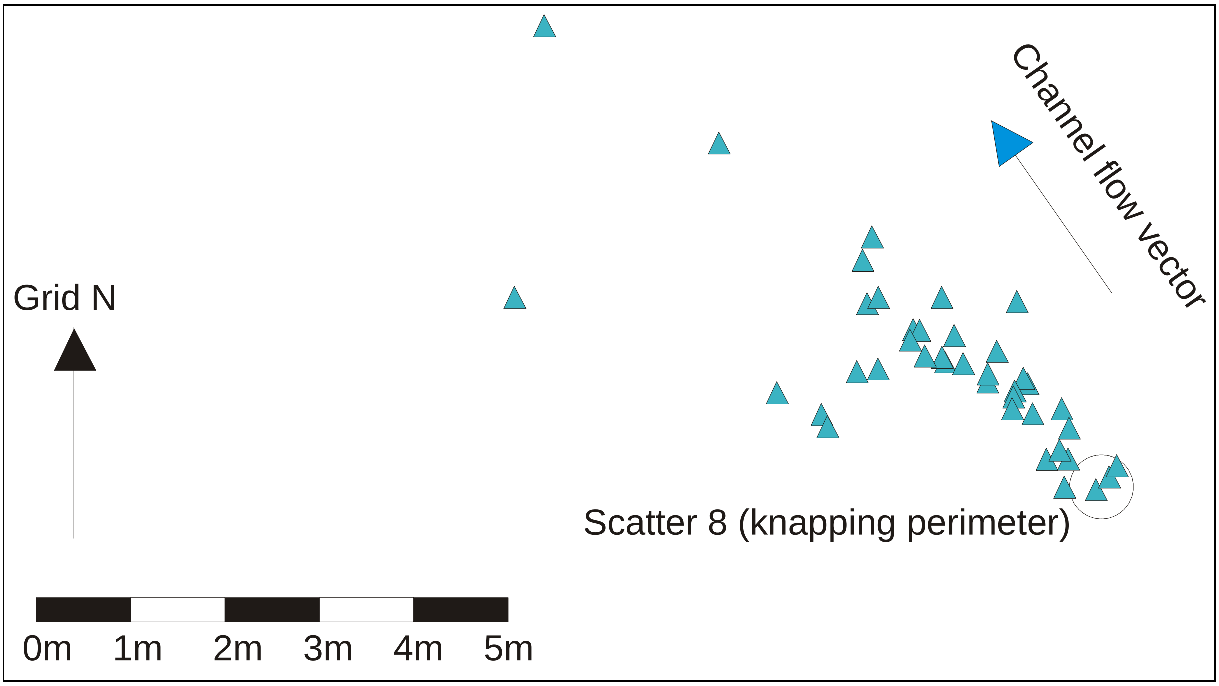

Figure 198: spatial distribution of scatter #8 flakes after primary fluvial dispersal

The primary dispersal of scatter 11 (n=30; Figure 200) suggests a primary axis of NNE–SSW, with a possible E–W secondary axis. However, flake long axes were also distributed in a range of other orientations. The primary and secondary axes show a partial correlation with the local flow vector (233°), suggesting that flake deposition after transport may occur as the long axis is aligned at right angles to flow. Unfortunately, the sample size is too small to sub-divide the sample by clast shape (prolate, oblate, blade and equant) and investigate this issue further (this is the case with all of the transported scatter data reported here). The secondary dispersal of scatter 11 (n=11) shows some similarities with the primary dispersal (Figure 201), with a primary axis of *c.* NE–SW and a secondary axis of WNW–ESE. However, the sample size is too small to place great significance on this data.

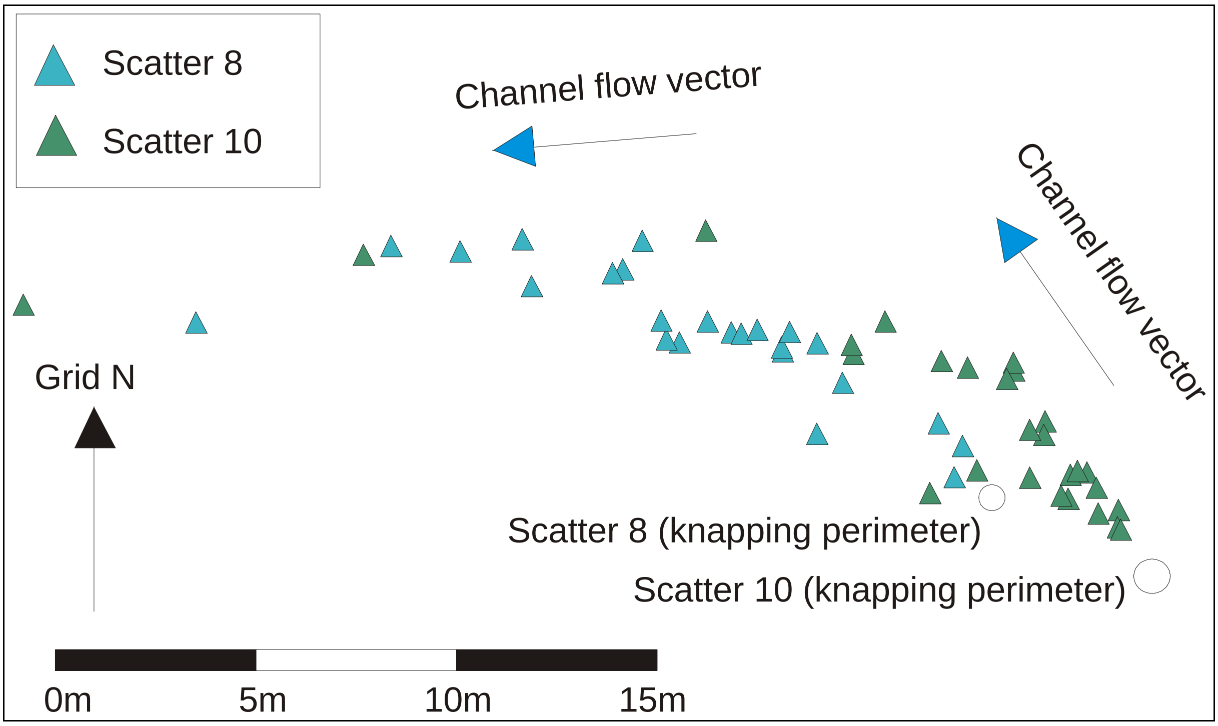

Figure 199: spatial distribution of scatter #8 and #10 flakes after secondary fluvial dispersal

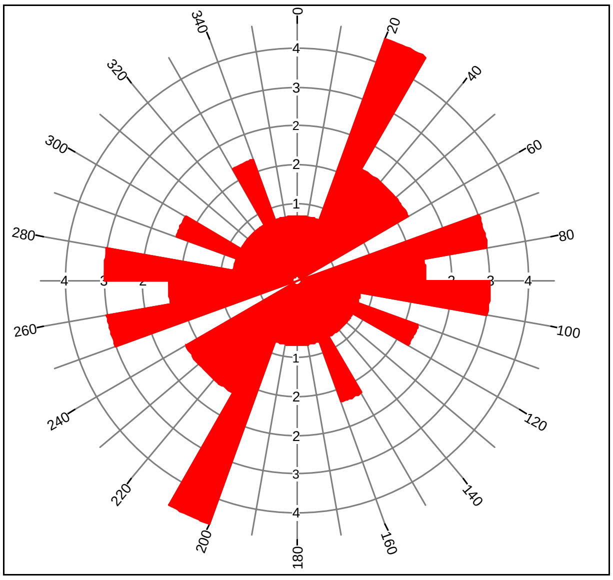

Figure 200: flake orientation (scatter 11, 1st dispersal). N=30.

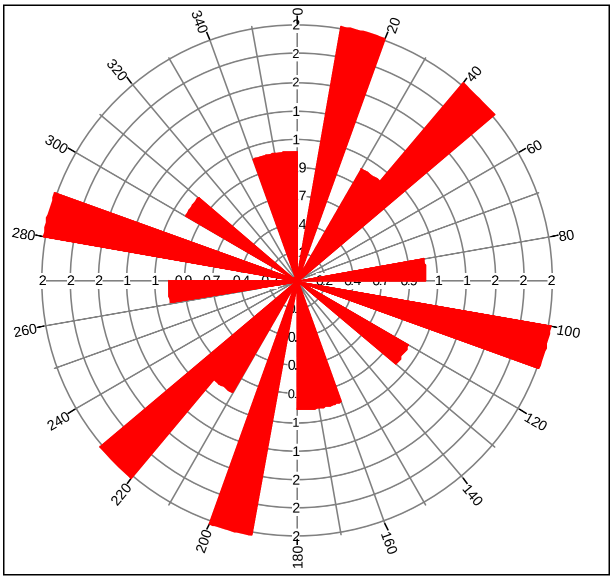

Figure 201: flake orientation (scatter 11, 2nd dispersal). N=11.

The primary dispersal of scatter 12 (n=32) shows no clear patterning with respect to a primary or secondary axis, although a WSW–ENE primary axis and NW–SE secondary axis is suggested (Figure 202). This shows some links with the local flow vector (233°), although in general, the data suggest that the localised trapping of flakes may be an additional major factor in the orientation of transported flakes. This is also the case with the primary dispersal of scatter 10, which shows no clear evidence of a primary or secondary axis.

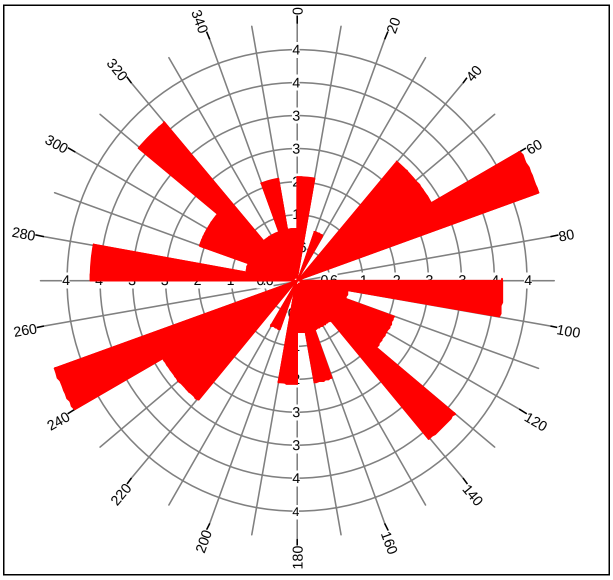

Figure 202: flake orientation (scatter 12, 1st dispersal). N=32.

In contrast, the primary dispersal of scatter 8 (n=38; Figure 203) displayed a clear primary (WSW–ENE) and secondary (NNE–SSW). These data show strong correlation with the local flow vector (339°), suggesting that in this case local flow was an important factor in the orientation of the transported flakes. The secondary dispersal of scatter 8 (n=23; Figure 204) also displayed a clear primary axis (NNE–SSW), although this axis demonstrated no clear association with the local flow vector (339°).

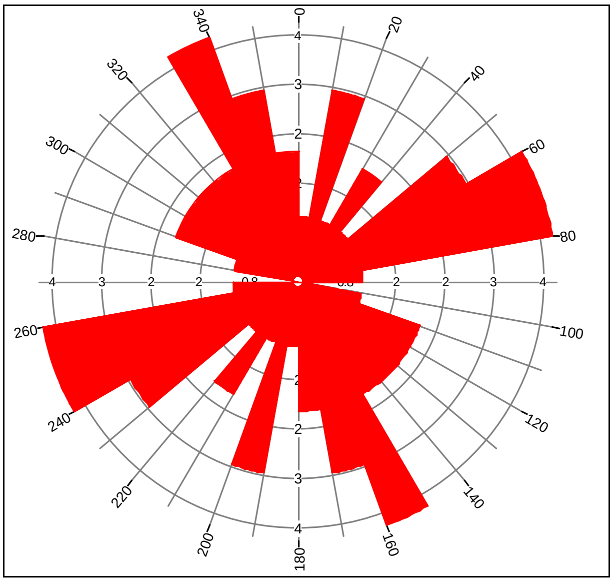

Figure 203: flake orientation (scatter 8, 1st dispersal). N=38.

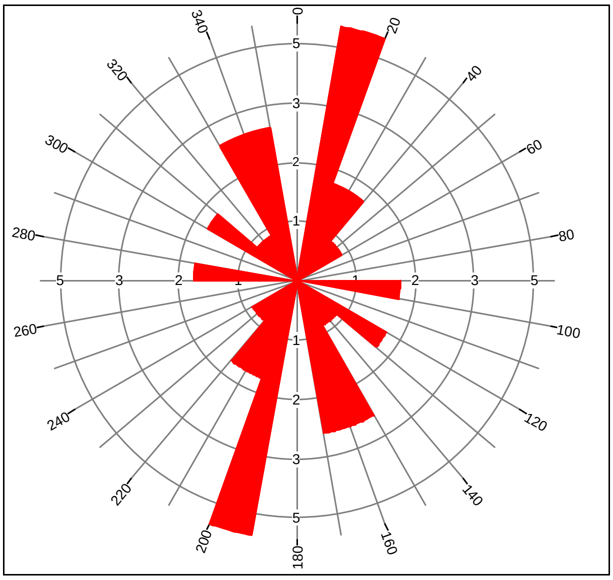

Figure 204: flake orientation (scatter 8, 2nd dispersal). N=23.

In general however, the flake fabric data suggested that flake orientation is not inevitably aligned with respect to local flow conditions, and that local trapping of flakes by larger clasts can play an important role in the alignment of transported artefacts.

Overall, the key conclusions from the Llanafan flake experiments are as follows:

- Flake scatters demonstrate a degree of structural integrity, with flakes being transported short distances (generally sub-10m) in the initial phases of fluvial dispersal.
- However, flakes are transported significant distances during subsequent dispersal phases (demonstrated minimum of 80m).
- Flakes are damaged during transport episodes, but while this damage may modify the specific morphology of individual flakes (see below), it does not modify them beyond the point of recognition as anthropogenic flakes.

- High percentages of the transported flakes display varying degrees of edge micro-flaking. As transportation distances and the quantities of micro-flaking increase, it is suggested that the micro-flaking can increasingly come to resemble intentional retouch.
- Flake material from separate scatters (knapped in relatively close spatial proximity) tends to become spatially indistinguishable during fluvial dispersal.

4.3 Floodplain morphology study

A photographic archive was recorded between May 2000 and July 2003, documenting the evolution of the Afon Ystwyth floodplain at the Llanafan (Grogwynian Reach) site (Figure 205–Figure 214). Specific focus was placed upon the development of floodplain vegetation and bar development at the two sites in Grogwynian Reach. Photographs of these sites are included for May 2000 (Figure 205), January 2001 (Figure 206–Figure 207), November 2001 (Figure 208–Figure 209), December 2002 (Figure 210–Figure 211) and July 2003 (Figure 212–Figure 213). All of the photographs were taken from the north, overlooking the Llanafan site. A photographic archive was not developed for the Llanilar site, as this reach of the Afon Ystwyth has been artificially engineered and discussions of fluvial development will therefore only focus on the Llanafan site (Grogwynian Reach).

Figure 205: Afon Ystwyth at Llanafan (Grogwynian Reach). May 2000. Note the midstream gravel bar in the bottom left of the photograph.

Figure 206: Afon Ystwyth at Llanafan (Grogwynian Reach). January 2000. Note the complex of midstream gravel bars in the left of the photograph.

Figure 207: Afon Ystwyth at Llanafan (Grogwynian Reach). January 2001. Note the midstream gravel bar in the centre of the photograph.

Figure 208: Afon Ystwyth at Llanafan (Grogwynian Reach). November 2001. Note the fragmentation of the midstream gravel bar complex, and the presence of semi-permanent vegetation on the 'dry' gravel bars above the water level.

Figure 209: Afon Ystwyth at Llanafan (Grogwynian Reach). November 2001. Note the fragmentation of the point gravel bar to the south of the main channel.

Figure 210: Afon Ystwyth at Llanafan (Grogwynian Reach). December 2002. Note the extensive midstream gravel bar.

Figure 211: Afon Ystwyth at Llanafan (Grogwynian Reach). December 2002. Note the point and midstream gravel bars to the north of the main channel.

Figure 212: Afon Ystwyth at Llanafan (Grogwynian Reach). July 2003. Note the extensive point gravel bar, the established vegetation in the stable parts of the bar, and the relatively narrow channel.

Figure 213: Afon Ystwyth at Llanafan (Grogwynian Reach). July 2003. Note the extensive point bars on both sides of the relatively narrow channel, and the contrasts in vegetation coverage across the floodplain to the south of the main channel.

Figure 214: bank erosion on the Afon Ystwyth, Llanafan (January 2002)

4.3.1 Results

The enclosed photographs of the Llanafan (Grogwynian Reach) study site (Figure 205–Figure 214) indicate five key trends in the development of the Afon Ystwyth channel and floodplain system between May 2000 and July 2003:

- Variations in bar type. This is primarily apparent in the barforms at the upstream end of the Llanafan study site (Figure 206, Figure 208, Figure 210, & Figure 212). In response to changes in water levels, the barform varies between a point bar complex, recorded in July 2003 (Figure 212), and a complex of midstream barforms intersected by minor channels in January 2001 (Figure 206), November 2001 (Figure 208), and December 2002 (Figure 210). The midstream barforms display varying levels of fragmentation in response to specific water levels (e.g. Figure 208), and this is also evident in the fragmentation of the point barform at the downstream end of the study site, during November 2001 (Figure 209).

- Variations in bar presence. This is primarily apparent in the barforms at the downstream end of the Llanafan study site (Figure 205, Figure 207, Figure 209, Figure 211, & Figure 213). A midstream barform is clearly apparent in May 2000 (Figure 205), January 2001 (Figure 207), and December 2002 (Figure 211), but is absent in November 2001 (Figure 209) and July 2003 (Figure 213). This is apparently due to variations in channel width and depth, water levels and (possibly) sediment transport.

- Vegetation development. At the micro-scale, this is most comprehensively documented in the barforms at the upstream end of the Llanafan study site, but it is also evident on the major point bar complex to the north of the channel. The patterns in the locations of semi-stable vegetation provide a 'negative' image of the position of the 'overflow' channels that fragment the barforms during periods of high water levels (e.g. Figure 208, Figure 209, Figure 210, & Figure 212). The presence of vegetation also indicates relatively highly elevated sections of the barforms, which are clearly rarely inundated by flooding. The presence of this semi-stable vegetation therefore indicates that, over relatively short periods (e.g. the 3 years of this study), the location of 'overflow' channels and the fragmentation of barforms follows repetitive patterns in response to high level flows and flooding events.

  Over slightly longer time-spans, the distribution of vegetation on the floodplain to the south of the main channel indicates shifting patterns in the distribution of the main channel (Figure 209 & Figure 213). From east to west, the transition from vegetation (grasses and shrubs) to bare gravel and silt, to partial vegetation (shrubs and some grasses) suggests the relatively recent existence of a major palaeochannel flowing from north to south across the floodplain.

- Variations in channel types and locations. The major channel of the Afon Ystwyth shows considerable variation in width between periods of low and high flow (e.g. Figure 209 & Figure 213). There is also an extensive development of multiple channels associated with the barform complex at the upstream end of the study site (e.g. Figure 208 & Figure 210). Finally, during periods of extremely high flows (e.g. November/December 2001), there is evidence of 'overflow' channels fragmenting the floodplain to the north of the main channel (Figure 209).

- Erosion. This is less apparent in the main photographic archive (due to the scale of the photographs), but there is extensive evidence of bank erosion at the downstream end of the study site (Figure 177 & Figure 214). It has not been possible to accurately measure the quantities of bank erosion that have occurred (due to difficulties of access), although the undercutting of the fence lines has provided a relative measure of erosion rates in this part of the Llanafan site.

The photographic archive has therefore indicated a number of trends in the evolution of the Afon Ystwyth floodplain at Llanafan. Variations in barforms and channel morphology would inevitably impact upon the local micro-conditions controlling clast entrainment, transport and deposition. However, the short-time scales of this study limit the data with respect to investigating floodplain erosion rates (through channel migration) which are pertinent to the issues of hominid 'site' erosion and the supply of artefacts into a fluvial system. To explore these issues, data is included here from a range of Welsh sites in the region of the Afon Ystwyth study sites (Macklin *et al.* 2002). These studies have highlighted four key trends:

- Floodplain change. Johnstone *et al.* (2002) explored the evolution of the Dyfi river terraces and palaeochannels during the Late Pleistocene, a period when glaciation supplied the Dyfi and other valleys with abundant supplies of coarse sediment. Detailed mapping of the Dyfi valley (Figure 215 & Figure 216) reveals the large numbers of palaeochannels formed by the river over the course of the Holocene. Although some of these palaeochannels may have been occupied simultaneously by the river (during the first half of the Holocene the river was braided), this mapping indicates the potential for extensive channel migration over relatively short periods.

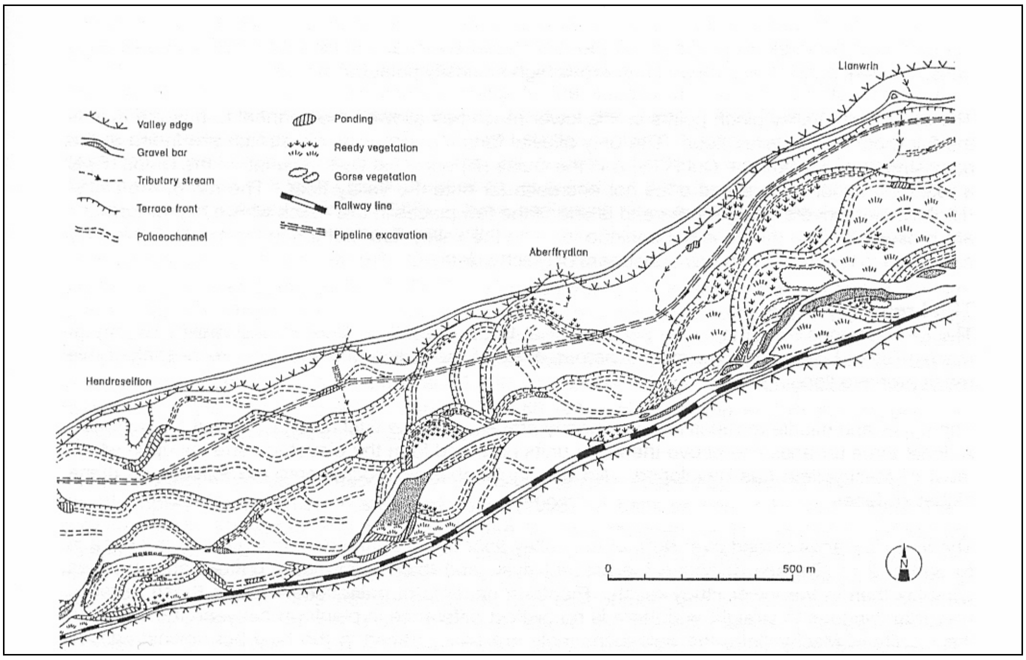

Figure 215: river terraces and palaeochannels in the lower reach of the Dyfi, mid-Wales (Johnstone et al. 2002: Figure 5)

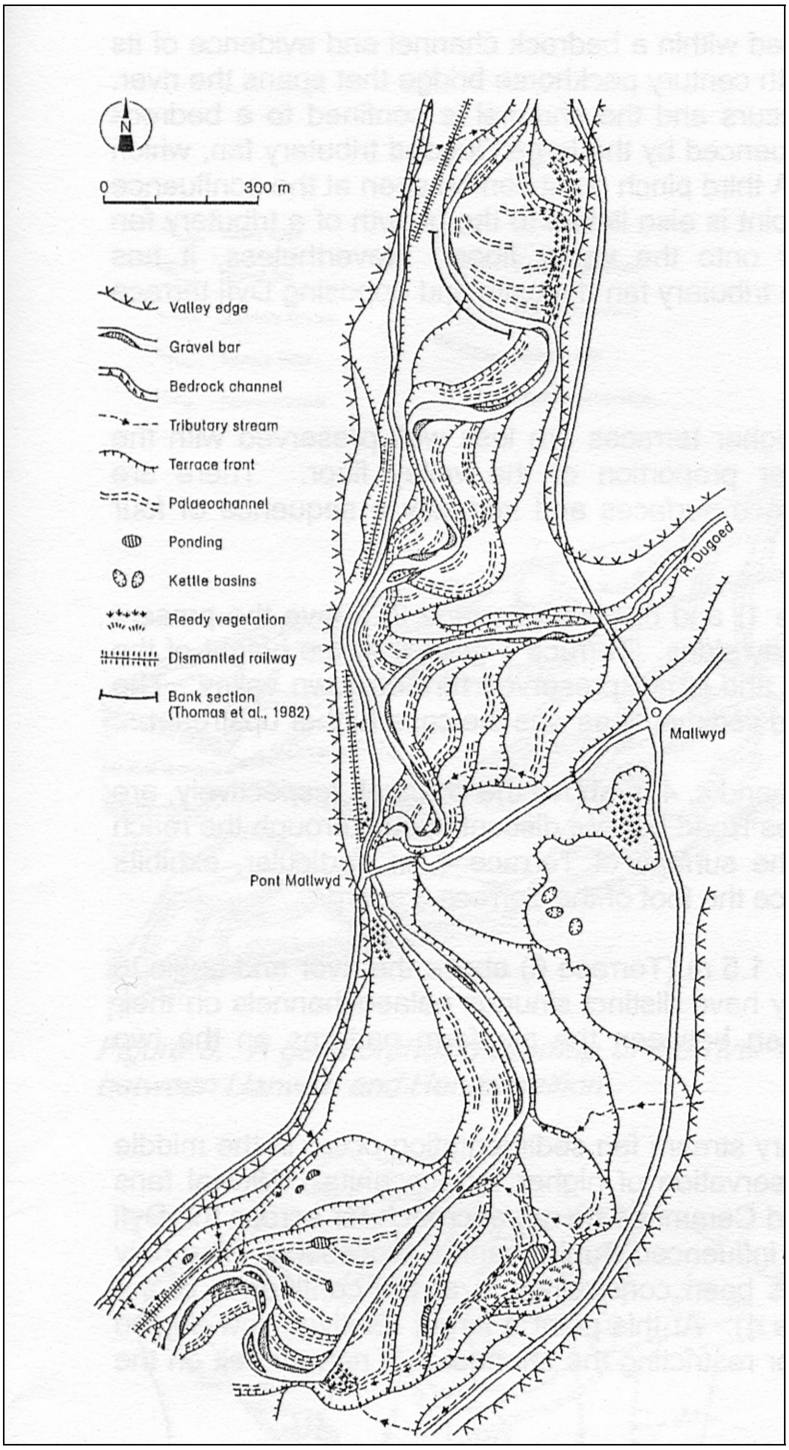

Figure 216: river terraces and palaeochannels in the upper reach of the Dyfi, mid-Wales (Johnstone et al. 2002: Figure 3)

- Vegetation and river channel stability. Gittins *et al.* (2002) explored changes in exposed river sediment (ESR) on three Welsh rivers (the Dyfi, Ystwyth and Rheidol) between 1890 and 1992. A reduction in exposed riverine sediment since the first half of the 20th century was documented, and was demonstrated to not be a result of coarse-grained gravels (> 2 mm) being flushed out of the catchment. By contrast, the reduction in sediment was demonstrated to be due to vegetation growth on bar surfaces. For example, in the Rheidol valley (Figure 217) the vegetated area on active and formerly active bar surfaces was 4 times greater that the amount of exposed sediment within the river in 1992. Although the causes for these processes were primarily anthropogenic (*ibid*: 55–56), the impacts of such vegetation growth (increasing bar and bank stability) are important to the understanding of relative rates of floodplain change during periods of varying vegetation cover in the Pleistocene.

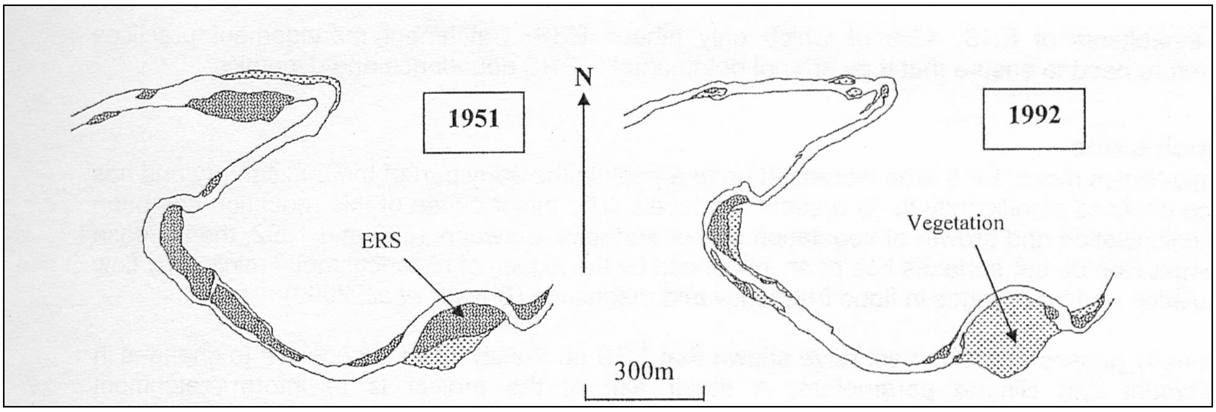

Figure 217: exposed riverine sediment reduction on the Afon Rheidol east of Capel Bangor between 1951 and 1992 (Gittins et al. 2002: Figure 7)

- Sediment transport. Brewer *et al.*'s (2000) study of sediment dynamics on Welsh rivers demonstrated that coarse-grained, gravel-sized material (> 2 mm) only moved a few 10s of metres during flood events. These comparatively short step lengths support the experimental results from the Afon Ystwyth and suggest that archaeological artefacts may have been transported through a series of transport/burial cycles (at least during phases of interglacial climate), with the majority of entrainment time being spent in a state of burial. This raises a key issue with respect to how much (if any) abrasion development occurs during periods of artefact burial.
- Channel change and bank erosion. Brewer *et al.* (2002) explored rates of channel change and bank erosion on the Afon Rheidol at the Felin Rhiwarthen and Lovesgrove meanders. Since these changes reflect both environmental (flood frequency and magnitude) and anthropogenic (metal mining and flow regulation) factors, specific rates (e.g. of bank erosion) are not of great relevance, although the magnitude of the maximum per annum erosion rates (e.g. between 1.4 and 7.9 m yr^{-1} at Lovesgrove) indicate the potential for relatively rapid erosion and channel change (Figure 218) under an interglacial climatic regime. Of greater interest is the observation that fine-grained sediments (silts and clays) form cohesive banks that are difficult to erode, whereas coarser-grained sediments (sands and gravels) form non-cohesive banks that erode more easily. These observations potentially suggest interesting patterns with respect to variable erosion rates (and therefore channel change) in different sedimentary regimes.

In general, these data emphasise longer time scales (ranging from 100 years to the entire Holocene) and provide evidence for relatively rapid processes of erosion, channel migration and floodplain evolution (albeit during an interglacial climatic regime). With respect to the erosion of primary context deposits, the entrainment of artefacts, and the formation of secondary context assemblages, these data suggest that individual 'sites' would probably be eroded rapidly over a short period rather than sporadically over millennia.

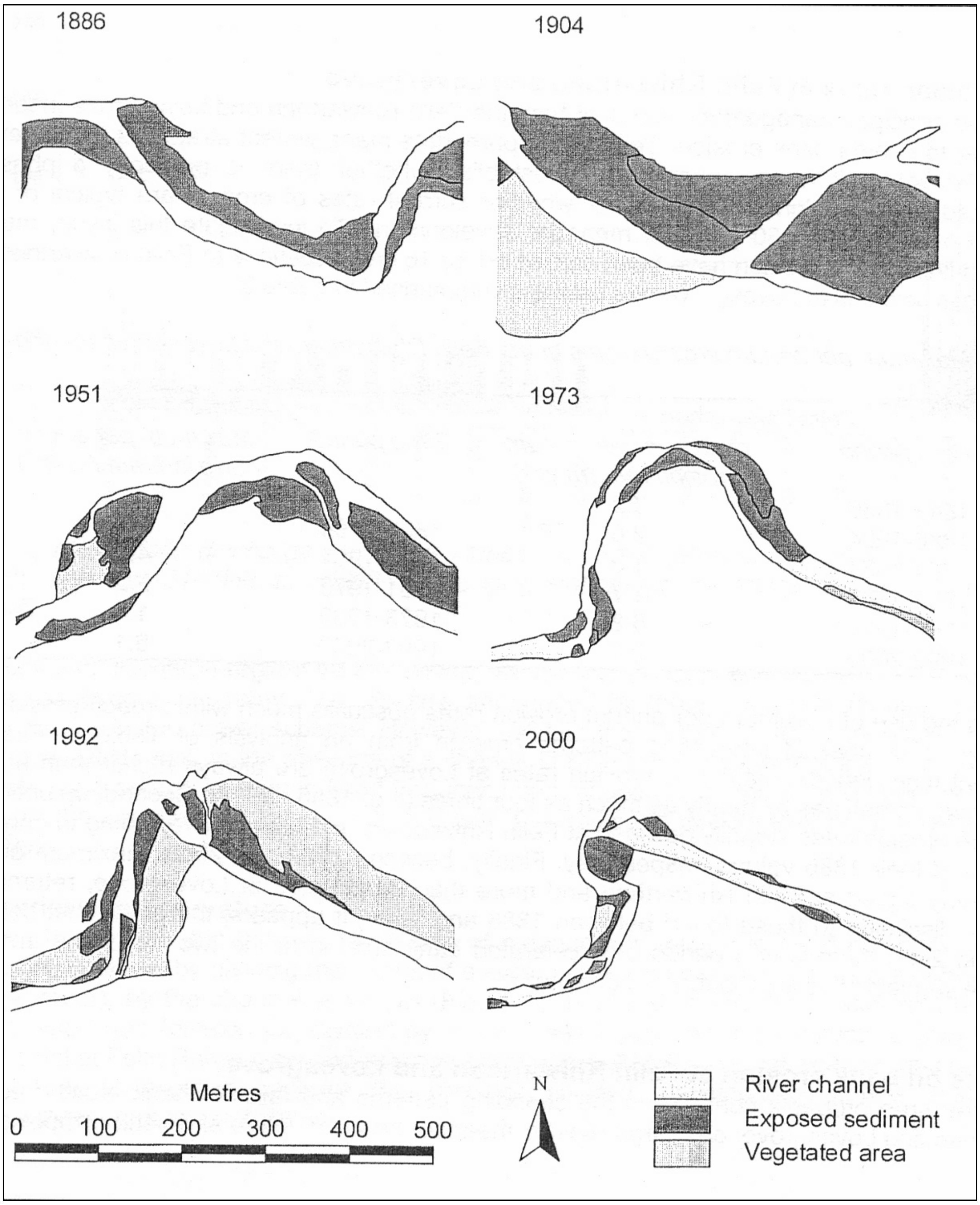

Figure 218: channel change on the Afon Rheidol at Lovesgrove between 1886 and 2000 (Brewer et al. 2002: Figure 3)

5. MODELLING ARTEFACT TRANSFORMATION

The following discussion draws upon the analysis of the Broom artefact assemblage (Chapter 5), the experimental fieldwork of Hosfield & Chambers (2002a; this chapter), the experimental laboratory work of Chambers (in prep; Chapter 4) and extant research in fluvial engineering (this chapter). The conclusions are not intended to apply to every secondary context Palaeolithic assemblage, but they do highlight two key factors for the interpretation of transported artefacts occurring within secondary context assemblages:

- The laboratory and field experiments of Chambers (in prep.) and Hosfield & Chambers (2002a) have highlighted a series of diagnostic indicators for artefact transport in gravel-bed river environments. These are arête abrasion (Figure 219), edge micro-flaking (Figure 220), and incipient percussion cones (Figure 221) on bifaces and flakes. The presence of all, or some, of these indicators can be taken as evidence that the artefact has been subject to fluvial transport. Chambers (in prep.) has highlighted five key variables:

- Arête abrasion does not develop in a uniform manner. This was demonstrated by the recording of 12 arête values on each face of the artefact, with each face divided into 6 zones (2 values per zone).
- The pattern of differential arête abrasion development can be used to indicate the type(s) of bed-load transport to which an artefact has been subjected (e.g. saltation and sliding).
- Biface morphology (cross-section profile) influences the mode of transportation. For example, plano-convex bifaces show a tendency to slide on the planar face.
- The development of edge damage (micro-flaking) only occurs during saltation transport.
- The presence of high, outlying arête abrasion values does not appear to be directly related to active transport. It is therefore hypothesised that archaeological occurrences of high, outlier values on bifaces relate to periods of partial burial, which leave exposed areas of the biface prone to intensive abrasion through collision with mobile clasts.

Figure 219: experimental biface displaying arête abrasion development

This research is fundamental to modelling the spatial origins of fluvially transported artefacts (as illustrated in the Broom case study of the previous chapter). However, the robusticity of the model would be improved by expansion of the experimental programme, with specific reference to:

- The burial of artefacts and the demonstrated development of associated damage.

- The modification of flake artefacts within a flume experimental environment.

It is clear however, that at a micro-scale, the entrainment, transport and deposition of artefacts is a stochastic process, due to variations in bed-form conditions (e.g. particle density and neighbouring particle proximity, particle elevation, armoring, and flow turbulence). Unfortunately, local geomorphological conditions cannot be known for archaeological materials. It is therefore stressed that the application of experimental transport data should seek to identify robust, over-arching patterns within secondary context archaeological assemblages.

Figure 220 experimental biface displaying micro-flaking edge damage

- The field experiments of Hosfield & Chambers (*et al.* 2000; 2002a) and Harding *et al.* (1987) combined with extant clast transport research have indicated the importance of relatively short step lengths and significant periods of burial. This has been demonstrated both for the gravel-bed rivers of mid-Wales (Hosfield & Chambers 2002a, 2004; Harding *et al.* 1987; Brewer *et al.* 2000), the Nahal Hebron in the Negev Desert and the Nahal Og in the Judean Desert (Hassan *et al.* 1991), and Harris Creek in British Columbia (Hassan & Church 2001). The demonstration of similar patterns in a variety of fluvial and climatic contexts would appear to indicate that these patterns of short step length and significant burial phases are a universal phenomenon. It therefore seems highly probable that similar patterns of clast dispersal would have occurred in the rivers of north-western Europe during the climatically-variable Middle Pleistocene. These data further emphasise the episodic nature of artefact transportation, and highlight the potential time depth that may exist between hominid discard, initial artefact entrainment within the fluvial system, and terminal deposition within the secondary context.

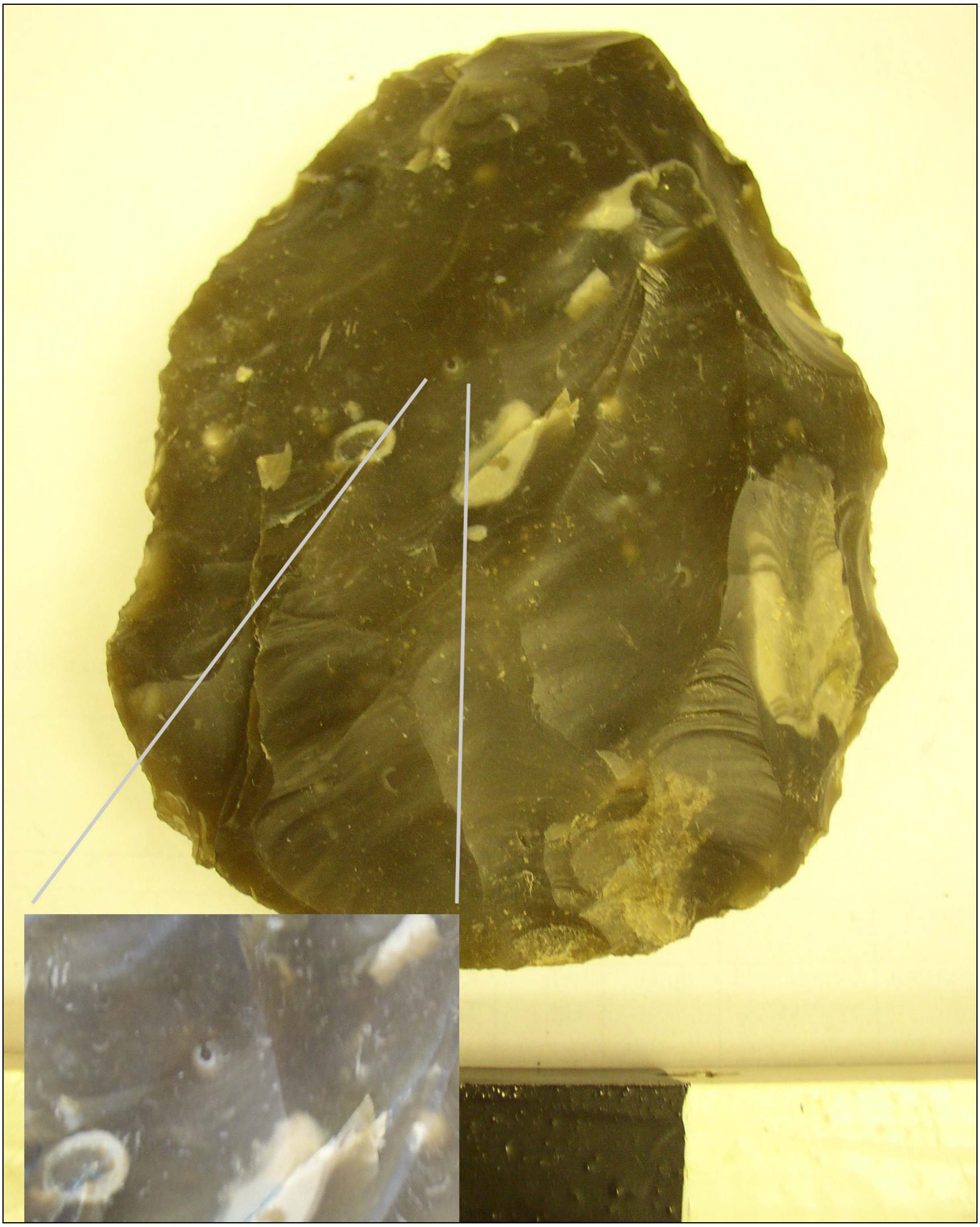

Figure 221: incipient percussion cones on experimental biface #6 (one of the cones is located in the centre of the inset)

These patterns reinforce the need (emphasised above) for continuing experimental and modelling research addressing the issues of:

- The duration of artefact burial phases.

- Abrasion development during phases of artefact burial, with particular reference to the identification of diagnostic abrasion signatures.

It is also stressed that the river systems utilised in modern experimental studies are all broadly acting under a global, interglacial climate, although some (e.g. Harris Creek) are strongly influenced by regional, cold-climate processes (annual snowmelt). We acknowledge that the processes of clast entrainment and transport in extreme cold-climate fluvial regimes remain poorly understood at the current time, due to an absence of suitable analogues. It is suggested here that in extreme, high energy fluvial conditions, associated with glacial meltwaters, particles may have been more prone to suspended load transport. Unfortunately, modelling suspended load currently presents major experimental problems, including the replication of flow velocities strong enough to induce suspension of large particles (bifaces) and the danger to flume equipment from large particles travelling at high velocities. Since suspended load artefacts sustain damage through their collisions with other suspended particles, key factors would appear to be flow velocity and the grain size distribution of the suspended load. From an archaeological perspective it is nigh on impossible to evaluate either of these variables for a specific assemblage.

6. SECONDARY CONTEXT ASSEMBLAGE FORMATION

The previous section discussed the experimental evidence for artefact transportation in fluvial systems, as recorded on the artefacts themselves. These data are important, given the widespread documentation of "waterworn" artefacts in Palaeolithic assemblages recovered from fluvial secondary contexts over the last 150 years (e.g. Evans 1872; Wymer 1968; 1999; Roe 1981). Despite this documentation however, there remains a considerable conundrum with respect to the formation of these assemblages:

"At sites where dense concentrations[6] of palaeoliths are found within river gravels, such as many of the sites in the Solent Area (e.g. Romsey, Hants; Bournemouth, Dorset; Dunbridge, Hants; Wood Green, Hants) it can be assumed that they have not travelled far from their place of discard. Some will be in relatively fresh condition, although rolling along river beds at times of spate soon dulls the edges of flint artefacts."

(Wessex Archaeology 1993a: 12)

However, recent examinations of both large and small secondary context assemblages have indicated that much of the material is relatively heavily abraded. This has been demonstrated for the assemblages from Dunbridge (Hosfield 1999, 2001; Chambers in prep.), Kimbridge (Chambers in prep.), Belbin's Pit, Romsey (Chambers in prep.) and Wood Green (Hosfield 1999, 2001) in Hampshire. There are two alternative explanations for these conflicting interpretations:

1. The material has been derived from local places of discard, with the short transport distances offering little opportunity for the widespread dispersal of the artefacts, resulting in the 'dense concentrations'. This interpretation must therefore assume that abrasion develops extremely rapidly over these short transportation distances.

However, the experimental evidence discussed above offers little support for the assumption that artefact abrasion of the magnitude seen in secondary context assemblages develops rapidly, leading into the second explanation:

2. The material has been derived from a mixture of local and distant places of discard, with the longer transport distances offering opportunities for a slower development of artefact abrasion and deposition over a wider catchment (i.e. apparently reducing the possibility of 'dense concentrations' being retained). The experimental evidence discussed above supports this model

[6] We stress that the term 'dense concentrations' is a relative one, and that even at these sites, the artefacts represent only a minor component of the sedimentary material. As an example, the Broom sites yielded *c.* 1,800 artefacts, but in February 1935, Pratt's Old Pit was producing 60 tons of gravel per day, and C.E. Bean estimated that 150 tons of gravel was yielding just six implements.

of longer transport distances and slower abrasion development. However, this interpretation leaves us with a key issue to resolve: what is the mechanism or mechanisms behind the formation of these 'dense' artefact concentrations? This question is critical to our understanding of archaeological secondary contexts.

6.1 Geomorphological models

Large-scale fluvial geomorphological processes would appear to be the most plausible solution to this question. In other words, the concentration of artefacts within fluvial secondary context deposits (where the artefacts show traces of fluvial transport) is due to the operation of natural formation processes. Three examples of these processes are included here to illustrate possible site formation mechanisms (there is some overlap between these categories, reflecting the fact that they cannot be considered in isolation).

6.1.1 Regional bedrock controls.

This model was presented by Hosfield (2001) and is therefore only summarised here. It stresses the fluvial bedrock of the Solent River basin and its impact upon river rejuvenation behaviour and terrace preservation conditions. Allen & Gibbard (1993: 520–521) observed the unidirectional migration of the Solent River and its major tributaries, including the Test and Avon rivers. Within the core of the Solent Basin, the Solent River and the lower reaches of its tributaries flowed predominantly over Tertiary clays and sands, in wide, shallow valleys. During episodes of downcutting (related to climatic cycles, sea-level rise and fall, and isostatic uplift) the rivers moved laterally, incising into the bedrock rather than the recently deposited gravel aggradations (Figure 222). The initial direction of this lateral river migration was determined by factors including local hydrology, slope of land, and topographical aspect. In contrast, towards the margins of the Solent Basin where rivers flowed over chalk bedrock, the valleys were narrow with steep sides. This pattern is evident for the Frome, upstream of Dorchester, and for the Test and Avon rivers to the north of Romsey, where they all flow over chalk. In these circumstances, Allen & Gibbard (*ibid.*) argued that the rivers would retain their original channel positions during downcutting events, as it was easier to erode former gravel accumulations than to cut a wider valley in the resistant chalk (Figure 223). The resultant valley patterns, lacking long terrace sequences, have been observed by Bridgland (1985: 29–30) for other chalk bedrock rivers in southern England.

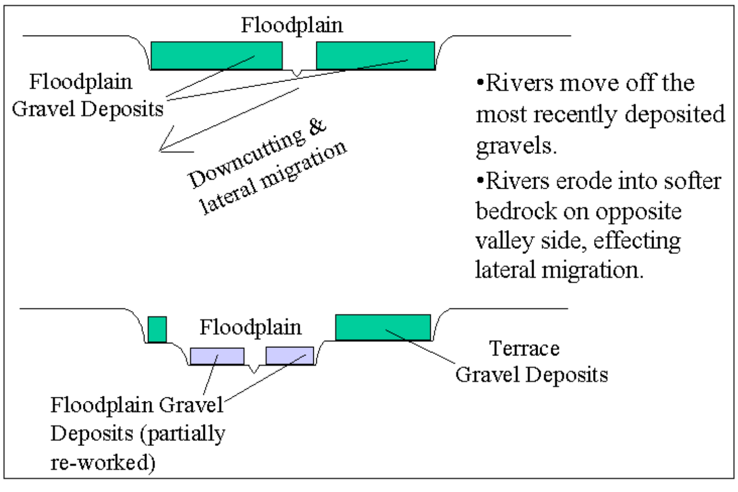

Figure 222: river rejuvenation behaviour and terrace preservation potential on Tertiary bedrock (Hosfield 2001: Figure 7)

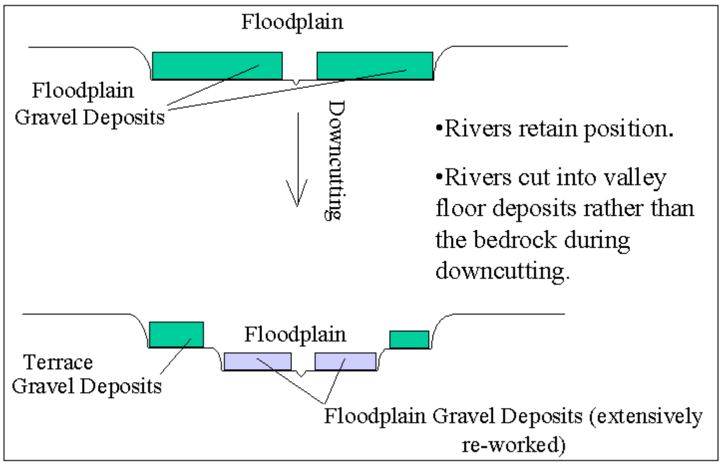

Figure 223: river rejuvenation behaviour and terrace preservation potential on Chalk bedrock (Hosfield 2001: Figure 8)

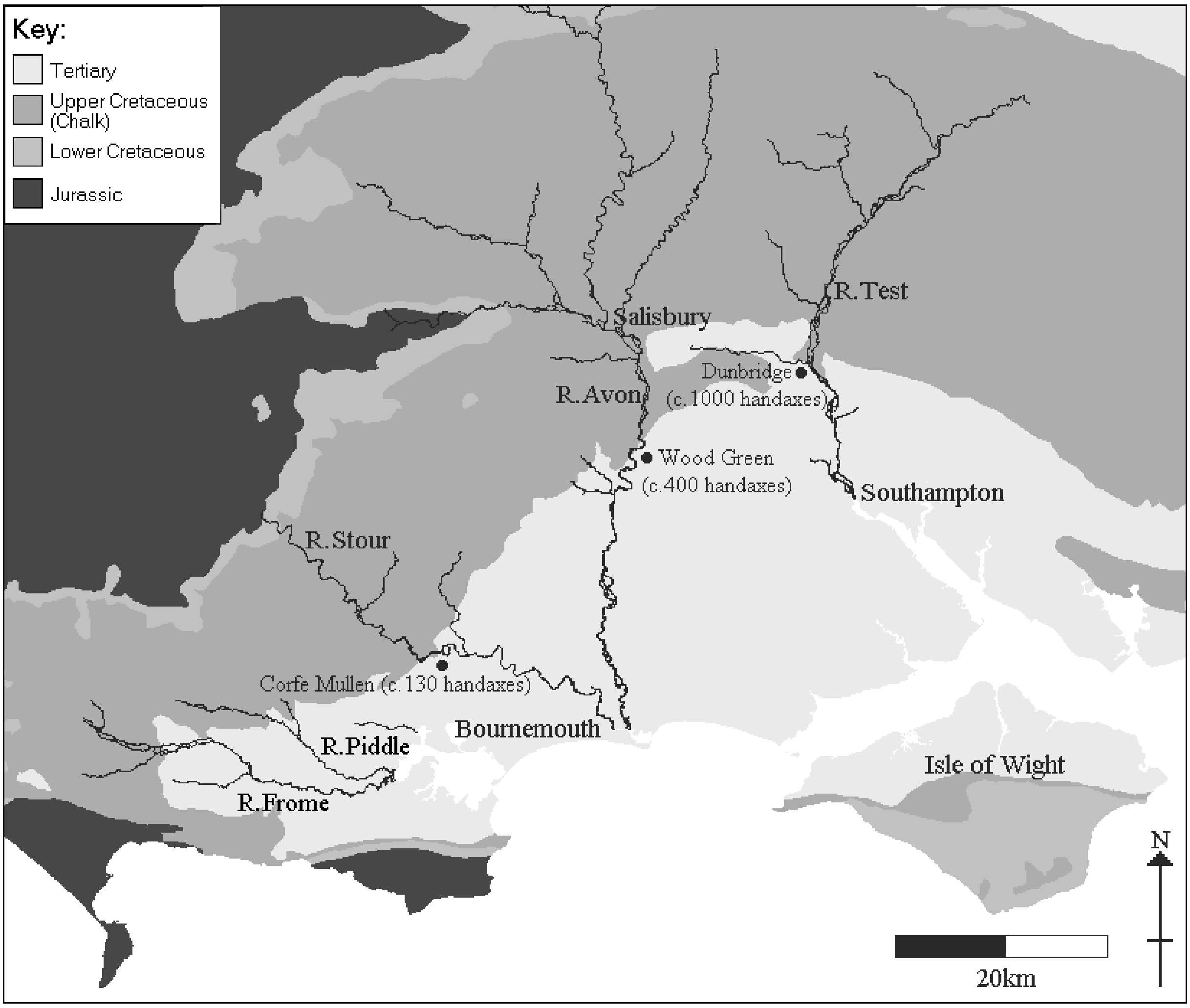

Figure 224: pre-Quaternary bedrock geology and selected Lower Palaeolithic findspots in the Solent River Basin (Hosfield 2001: Figure 10)

It is argued that the consequence of these bedrock-controlled processes is extensive sediment erosion in rivers flowing over chalk. Consequently, there is restricted development of floodplain deposits (potential terraces sediments), with sediments (clasts and artefacts) re-worked down the valley in a series of depositional/erosional episodes. These episodes presumably occur both between and during glacial/interglacial cycles, at micro (individual flooding) and macro (river rejuvenation and downcutting) scales. However, upon flowing from chalk to tertiary sand and clay bedrock (Figure 224), there is a transformation in the rivers' regime of erosion and deposition. Due to the channel's lateral migration behaviour, there is greater potential for the preservation of floodplain/terrace deposits. Sediments (clasts and artefacts) are therefore likely to be deposited and preserved as floodplain/terrace deposits, rather than undergo a further series of deposition/erosion episodes.

The archaeology of the Solent Basin supports this geological model of regional bedrock controls. The findspots of Dunbridge, Wood Green and Corfe Mullen (all producing at least 100 bifaces) are located immediately downstream of the transition from chalk to tertiary bedrock (Figure 224), suggesting that these assemblages were formed by the dumping out of sediments (clasts and artefacts) at these points in the rivers' reaches, and associated with the change in valley form and river behaviour.

6.1.2 Regional fluvial geomorphology.

This has links with the first model, but is essentially emphasising the generic role of major landforms upon fluvial depositional activity and the creation of local sedimentary traps as represented by fan gravels (Boggs 1987; Miall 1996). These influential landforms include the zones of transition from a constricted to unconstricted valley (e.g. as in the Solent River basin example above), areas in proximity to the junctions between tributary and major streams, and sudden changes in stream gradient (Miall 1996: 245). These are discussed by Miall (*ibid.*) with respect to the development of alluvial fan gravels, while Boggs (1987) also highlights outwash fans associated with melting glaciers. The key issue is that these geomorphological factors all influence fluvial behaviour and can be associated with major episodes of sedimentation (the deposition of alluvial or outwash fan gravels). As alluvial fan gravels produce highly diagnostic sedimentary signatures (Miall 1996), it should be possible to evaluate the potential impact of these processes upon the formation of secondary context assemblages.

6.1.3 Local fluvial geomorphology.

This final example emphasises the role of local geomorphological features and conditions, following their emphasis with respect to the processes of entrainment (e.g. Malmaeus & Hassan 2002; Hunziker & Jaeggi 2002). In this case, the focus is upon local geomorphological conditions which can result in repetitive sediment deposition in a spatially restricted area. Examples could include meandering rivers of high sinuousity (resulting in the development of extensive point bar features on inner bends (Miall 1996), the formation of major braided river bars (Nichols 1999), the local development of braidplains (*ibid.*), and the impact of contemporary river confluences (resulting in a highly local loss of river competence and the development of extensive bar features).

Although the duration and impact of these types of fluvial features has been well discussed with respect to historical time (e.g. Macklin *et al.* 2002), their significance over geological time is poorly understood, not least because of the difficulties of identification. They are therefore simply highlighted here as potential mechanisms by which transported material from disparate sources may be deposited, and preserved, in association within fluvial sedimentary units.

6.2 Site formation through time

Due to the history of collection associated with many of Britain's secondary context Palaeolithic assemblages (e.g. Roe 1981), it is often difficult to assess how densely concentrated the artefacts were in time (as represented by the vertical sedimentary sequences). In many cases, stratigraphic provenance data were not recorded, and in some cases spatial provenance was limited to the accuracy of parishes. Moreover, the question of temporal distribution is complicated by two key factors:

- Is it likely that floodplain 'sites' will be fluvially eroded rapidly or gradually? This has obvious implications for the supply of artefacts into the fluvial system, and for the chronology of their subsequent deposition. The data from the mid-Wales study rivers (Macklin *et al.* 2002), although providing a geographically restricted sample, suggests that erosion over historical (e.g. 10^1 and 10^2 years) rather than geological time (10^3 and 10^4 years) is more likely. This is based on historical mapping of floodplain and channel change, and the C^{14} dating of floodplain and terrace palaeochannels. Over Palaeolithic and Middle Pleistocene timeframes, these data therefore suggest that the erosion of sites is essentially a 'contemporary' process, rather than over tens of thousands of years. As these study rivers are interglacial fluvial systems, it is argued that under glacial conditions fluvial erosion rates would be even faster (reflecting the paucity of vegetation coverage).

- It has been demonstrated that artefacts within the same system will undergo different regimes of burial and transport. Is it likely that two artefacts, entering the system within 100 years of one another, will be deposited 10,000 years apart (the temporal magnitude of the Broom sedimentary sequence)? Based on the rates of erosion and channel change discussed above, this would appear to be unfeasible. It is accepted that artefacts may be deposited 10^1 or 10^2 years apart (due to localised variations in burial, transport, and barform preservation/erosion), but it is stressed that these timescales will appear 'contemporary' in light of current levels of geochronological resolution when dealing with Pleistocene sedimentary units.

In general therefore, when interpreting a dense artefact concentration of clearly transported material (e.g. Dunbridge) it is argued that once the artefacts were entrained within the fluvial system, they underwent the majority of their reworking over historical time-spans. This reflects demonstrated rates of channel migration and fluvial erosion, which indicate that the residues of human activity episodes (e.g. butchery sites on the floodplain) would be vulnerable to erosion and initial entrainment over decades rather than millennia. These data also suggest that individual channels only remain active over decadal rather than millennial timescales, implying that *recovered* artefacts must have been reworked relatively rapidly.

7. CONCLUSIONS

This chapter has sought to assess the relative homogeneity and/or heterogeneity in space and time of Palaeolithic stone tool assemblages occurring in secondary context aggregate deposits, with particular reference to:

- Physical processes of clast entrainment, transportation and deposition.
- The relative importance of three data sources: the physical condition of stone tools; the morphology of stone tools; and the stratigraphic context of stone tools.
- The integration of laboratory research; theoretical modelling; and experimental archaeological fieldwork.
- The implications of taphonomic studies to the interpretation of stone tool assemblages occurring in secondary context deposits.

7.1 Clast entrainment, transportation and deposition

Extant research in fluvial engineering and physical geography has indicated the highly variable nature of clast transport at the micro-scale, reflecting localised stream bed conditions. However, the research also indicates some robust trends of considerable importance to the interpretation of transported, secondary context assemblages — principally, the absence of any clear relationship between clast size and transport distances, and the tendency for short step lengths and long burial phases. The clast size/transport distance relationship data stresses the stochastic nature of clast transport and highlights the importance of interpreting derived assemblages on an artefact by artefact basis. The short step length/long burial phase data promotes caution in the interpretation of abrasion data as an index of transport distance and an indicator of catchment source areas. Consequently, as with the interpretation of the Broom and Dunbridge data (Chapter 4), focus is placed on highly robust patterns, rather than on high resolution trends. Finally, the identification of these trends has also highlighted the importance of further experimental research with respect to the duration of burial phases and the potential for abrasion development during periods of burial and partial burial.

7.2 Assessing stone tool assemblage data

With respect to the spatial homogeneity/heterogeneity of derived stone tool assemblages, artefacts' physical condition data is obviously of prime importance. However, the work of Chambers (in prep.; Chapter 4) has indicated the importance of the *état physique* approach, emphasising zonal arête abrasion, edge damage micro-flaking, incipient cones of percussion, and the role of artefact morphology (e.g. cross-section profiles) in transportation. In an ideal world, field data from the associated sedimentary units (e.g. grain size, bed-forms, clast and artefact fabric data) would be informative with respect to reconstructing transport histories, fluvial regimes, and therefore the spatial origins of the material. Unfortunately, given the fragmentary nature of fluvial sedimentary sequences and the highly variable nature of entrainment and transportation (see above), such an approach would involve an unacceptable level of generalisation. Moreover, for nearly all extant assemblages, sedimentary field data of the type referred to above was not recorded. Therefore, modelling the spatial component of secondary context assemblages must focus upon the *état physique* of individual artefacts.

In cases where stratigraphic provenancing data are available, this information is important for an initial, crude assessment of the temporal homogeneity/heterogeneity of derived stone tool assemblages (e.g. whether the artefacts were deposited in a single 'horizon' or throughout a sedimentary sequence). However, to make a detailed assessment requires a high resolution analysis of the preserved sedimentary sequence. This includes the geochronological framework (e.g. the duration of depositional events and sedimentary hiatuses (Chapters 2–3), and micro and macro-changes in the sedimentary sequence (represented by grain size distributions, sediment types, and bedforms). On a wider scale, understanding of 'site' formation processes are vital, with respect to the coarse-resolution chronologies of the initial entrainment of the artefacts (e.g. through floodplain 'site' erosion over historical rather than geological time-spans), and the depositional environment(s). Unfortunately, these data are often unavailable for extant assemblages, although the methodology is applicable to well-documented assemblages such as Swanscombe and Broom.

With respect to morphological data, the evidence from fluvial engineering research indicates that artefact size and dimensions cannot be used as an indicator of transport distances. However, this section has indicated the value of other elements of artefact morphology in the detailed assessment of transport history (e.g. the uses of cross-section profiles in Chambers' (in prep.) transport modelling methodology).

7.3 Integrating laboratory, field and desktop research

Correlation of Chamber's (in prep; Chapter 4) experimental flume research with the experimental fieldwork of Hosfield & Chambers (2002a, 2004; this chapter) has highlighted some robust patterns, most notably the rates and patterning associated with the development of arête abrasion on bifacial artefacts. The experimental research has also drawn clear links with the extant fluvial engineering research literature, through the stressing of local variations in field conditions (e.g. bed morphology) which have impacted upon individual clast transport behaviour.

However, it has been apparent from the field experiments that non-laboratory results will inevitably be more variable, reflecting the wider range of variable conditions, and in some cases unpredictable (e.g. the apparent role of algae in retarding abrasion and edge damage (micro-flaking) development). In contrast, the laboratory has provided tighter controls on experimental conditions and yielded data that is currently unknowable for field experiments (e.g. the mechanism of transport). The integration of the laboratory and field experimental research has therefore highlighted the need for further research, improved tracer recovery (magnetic tracers), improved data logging techniques (radio tracers) and the greater integration of archaeological and fluvial geomorphological research.

7.4 Taphonomy and secondary context assemblages

The demonstration of artefact transport patterns and damage development inevitably raises the problem of explaining the formation of large artefact assemblages within secondary contexts. It is clear that artefacts recovered from a single site have very often been transported a wide range of distances (based on the *état physique* of extant artefacts), while experimental fieldwork has demonstrated that materials from a single source will be dispersed over an increasingly wide area over time. The problem is therefore clear: derived artefacts originate from a wide range of sources, yet are ultimately deposited in a single sedimentary location. Why does this happen?

We suggest that fluvial geomorphological processes are the critical factor. Although hominid involvement is (inevitably) a required starting condition (e.g. the bifaces must be discarded in a valley for large concentrations to be formed downstream), it is fluvial processes and landforms that produce localised sedimentary traps within which fluvial material and entrained artefacts are deposited, after a wide range of transport histories. The significant geomorphological processes are argued to include river confluences (resulting in localised loss of stream competence and therefore extensive depositional activity), the impact of bedrock types and valley forms upon fluvial behaviour (sediment re-working and river incision), and local depositional environments (e.g. braidplains and large-scale barforms).

In conclusion, it is clear that secondary context assemblages are the product of artefact transportation and deposition. With respect to the homogeneity and/or heterogeneity of these assemblages, investigations must therefore consider the nature of clast transport within fluvial systems, the *état physique* of individual artefacts, and the taphonomic processes responsible for the deposition of sediments and artefacts in specific locations within fluvial landscapes. Through these approaches it is possible to begin to understand the nature of artefact discard and hominid behaviour within the contemporary fluvial landscapes of the Pleistocene.