River gravels and flakes: new experiments in site formation, stone tool transportation and transformation

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River gravels and flakes: new experiments in site formation, stone tool transportation and transformation

Robert Hosfield & Jenni Chambers

Introduction

This paper reports on a three year programme of experimental archaeology, undertaken in mid-Wales (United Kingdom) between 2000 and 2003. The experiments explored patterns in the transportation and transformation of replica Lower and Middle Palaeolithic stone tools within a fluvial system (the Afon Ystwyth gravel-bed river), and their implications for the formation of Middle Pleistocene archaeological assemblages in secondary context, fluvial settings.

The paper introduces the experimental site of Llanafan (Grogwynian Reach) on the Afon Ystwyth, and the procedures and key results of the work are summarised. The applications of the experimental programme are then explored with respect to the British Lower Palaeolithic site of Clacton (SINGER ET AL. 1973), and future directions for the experimental approaches discussed here are also highlighted.

This paper discusses the experiments concerned with the transportation and transformation of replica flake artefacts, as the ongoing replica biface experiments will be reported in a future publication.

Background

A key motivation for these experiments was the recent research emphasis upon the component of the British Palaeolithic record characterised by derived artefact assemblages occurring in fluvial terrace deposits (e.g. HOSFIELD 1999; 2001. WYMER 1999. ASHTON & LEWIS 2002). These types of assemblages form a critical, but previously under-studied, component of the archaeological record. The paucity of previous studies reflects the derived nature of these assemblages, which creates two major barriers to the straightforward interpretation of the data. Firstly, the age of the archaeology is commonly unknown, due to the traditional problems of: (1) establishing robust geochronological frameworks for the fluvial terrace deposits; and (2) the potential for the artefact assemblages to have been re-worked over time. Artefacts may therefore have been eroded from older fluvial terrace deposits and re-deposited into much younger sediments. Secondly, the spatial integrity of the archaeology is unknown, since all artefacts occurring in fluvial sediments in secondary context have, by definition, been transported greater or lesser distances downstream within fluvial channels.

Resolving the first of these two problems has been greatly assisted for British Pleistocene river systems by the recent research of BRIDGLAND (e.g. 1994; 1996; 2001) and MADDY (*ET AL*. 2001. MADDY & BRIDGLAND 2000), and new developments in optically stimulated luminescence dating (e.g. MURRAY & ROBERTS 1997. MURRAY & WINTLE 2000. TOMS 2002). Research into the problems of artefact re-working through time is also ongoing (HOSFIELD & CHAMBERS in prep.). However, understanding of artefact transportation and the spatial integrity of secondary context assemblages remains limited, with only a handful of studies undertaken during the last forty years (WYMER 1968. CLARK 1974. SHACKLEY 1974; 1975. ISAAC 1977; 1989. SCHICK, in BUNN *ET AL*. 1980. MURRAY 1985. SCHICK 1986. HARDING *ET AL*. 1987. SCHICK & TOTH 1993. MACKLIN 1995. HOSFIELD 1999). Many of these studies were conducted in markedly different African fluvial environments (CLARK 1974. ISAAC 1977; 1989. SCHICK, in BUNN *ET AL*. 1980. SCHICK 1986. SCHICK & TOTH 1993) and were therefore of limited relevance to the understanding of British Lower and Middle Palaeolithic stone tool assemblages. These African studies were also primarily concerned with simply identifying evidence for the past presence of fluvial processes, rather than assessing transportation distances, either relative or absolute. Research based in Britain has attempted to classify and quantify biface abrasion (WYMER 1968. SHACKLEY 1974; 1975. HOSFIELD 1999), and explore patterns of artefact movement and modification (MURRAY 1985. HARDING *ET AL*. 1987. MACKLIN 1995). However, the early biface abrasion studies (WYMER 1968. SHACKLEY 1974; 1975) were primarily developed to provide a means of assemblage comparison, and while the later work (HOSFIELD 1999) sought to relate biface abrasion with real world transport distances, it hugely over-simplified the processes involved. Finally, three studies of artefact movement and modification (MURRAY 1985. HARDING *ET AL*. 1987. MACKLIN 1995) emphasised the complexities of the issue of artefact derivation, and highlighted the stochastic nature of the transportation and depositional processes, but left a wealth of questions unanswered.

There was therefore a clear need for an expanded body of experimental data that addressed the issues of spatial artefact re-working and derivation. The current project sought to meet these needs and established two clear goals. Firstly, increasing understanding of the formation of secondary context stone tool assemblages with respect to: (a) the development of artefact damage as a result of fluvial transport; and (b) the spatial patterns of artefact dispersal as a result of fluvial transport. Secondly, applying the results of the experimental programme to the interpretation of British Lower and Middle Palaeolithic archaeological assemblages. With regard to flake materials, extant research had suggested (although rarely demonstrated) that the presence of particular types and size classes of flake artefacts within assemblages in fluvial settings was indicative of highly limited derivation processes (SCHICK, in BUNN *ET AL*. 1980. MURRAY 1985. HARDING 1998, 75). The testing of these assumptions with empirical data was therefore a central element of this research. The experiments were conducted in a British gravel-bed river system, reflecting the dominance of coarse-grained sediments in the secondary context fluvial deposits associated with the derived Palaeolithic stone tool assemblages of southern Britain (BRIDGLAND 1994. WYMER 1999).

Field Experiments

The experiments were carried out on the Afon Ystwyth in mid-Wales, at the Grogwynian Reach, Llanafan (national grid reference SN 709719; Figure 1 & Figure 2). The catchment area of the river was recorded as 152 km^2, with a valley gradient of approximately 4m km^{-1}, by HARDING *ET AL*. (1987, 116), although the Environment Agency document the river catchment as 169.6 km^2. The median grain size of the Afon Ystwyth sandy gravels is *c*. 16–32mm (classified as coarse pebbles after FRIEDMAN & SANDERS (1978)), 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). River discharges are gauged by the Environment Agency (http://www.nwl.ac.uk/ih/nrfa/) below the Llanafan study site at Pont Llolwyn (SN 591774) and averaged $9.4m^3s^{-1}$ in 2000 and $6.1m^3s^{-1}$ in 2001 (data for 2002 and 2003 is not currently available). The highest daily mean discharge was measured at $82.6m^3s^{-1}$ in 2000 (30th October) and $73.9m^3s^{-1}$ in 2001 (29th November). Average monthly discharge peaked in October, November and December in 2000 and in October and November in 2001 (Figure 3). During this period there were no discharges comparable to the

$300 m^3 s^{-1}$ documented by HARDING *ET AL*. (1987, 116) for extreme floods. For the previous study of HARDING *ET AL*. (1987) the mean annual flood was recorded as $90 m^3 s^{-1}$, although gravel sediments were observed to be in motion on several occasions at levels well below this discharge.

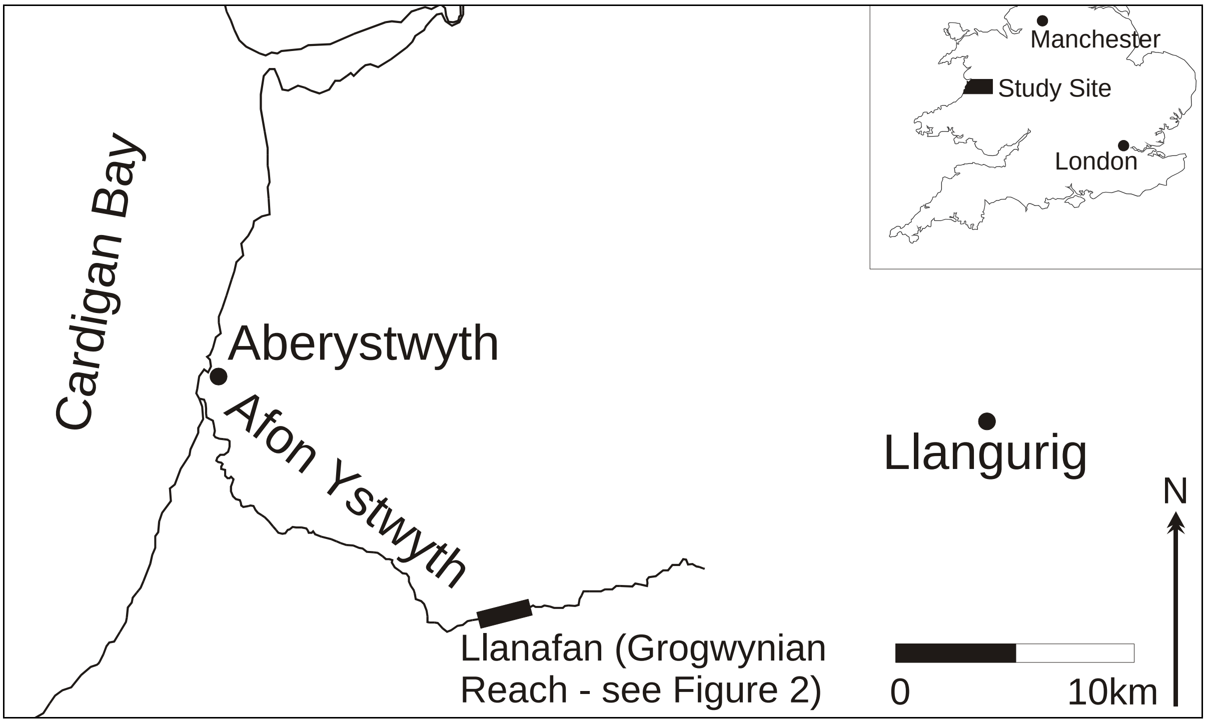

Figure 1: the Afon Ystwyth and Llanafan (Grogwynian Reach) study site, mid-Wales, UK.

Figure 2: 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 view is from the north) and the midstream bar at the upstream end of the visible channel (flow is to the west).

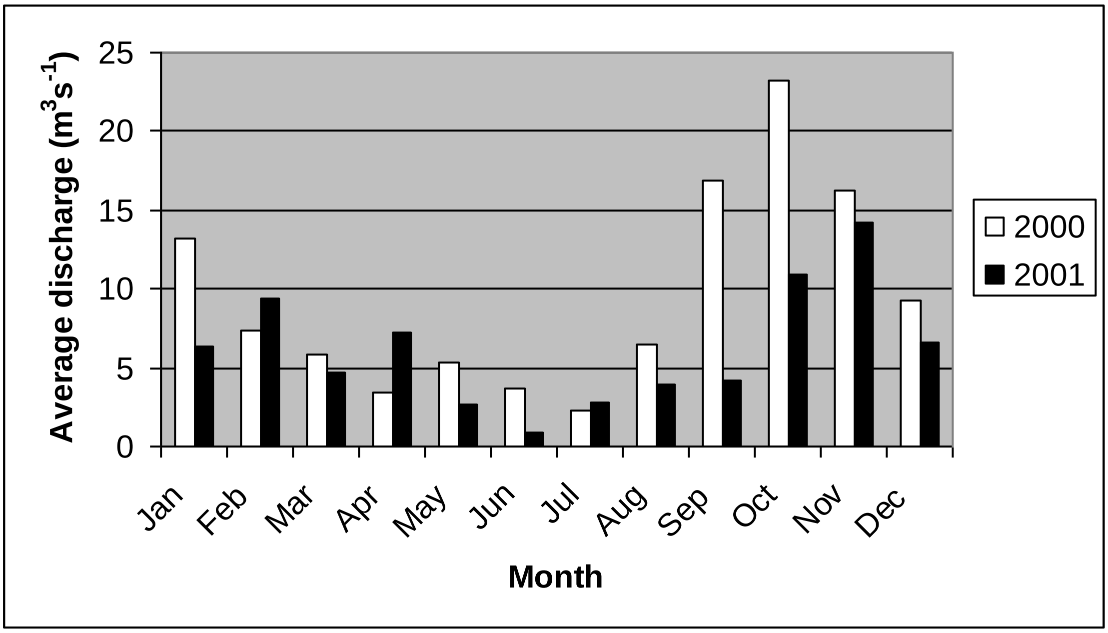

Figure 3: average monthly discharges (m^3s^{-1}) of the Afon Ystwyth for 2000 and 2001. Data from the Environment Agency (National River Flow Archive).

Specifically, the Llanafan (Grogwynian Reach) study site was selected for:

- The suitability of the Afon Ystwyth system for tracer-based experiments requiring gravel-bed fluvial environments, as illustrated by the previous research of HARDING *ET AL*. (1987. MACKLIN 1995). Specifically, the Afon Ystwyth at Llanafan is characterised by active bar development and the transport of bed materials (HARDING *ET AL*. 1987, 116).
- The absence of indigenous Palaeolithic material. There are no records of Palaeolithic artefacts having been recovered from the Afon Ystwyth valley, although Mesolithic and later prehistoric lithics have been recovered from the region. The dangers of contaminating the regional archaeological record were therefore greatly reduced.
- A river bed-load dominated by Palaeozoic shales and gritstones, which aided the recovery of tracers produced in exotic raw materials (flint and chert), and further assisted in their rejection as ancient archaeological artefacts.
- The extant topographic surveys of the site's floodplain and channels, undertaken by staff from the Institute of Geography and Earth Sciences, University of Wales, Aberystwyth, Wales, United Kingdom.

The Llanafan (Grogwynian Reach) study site is an excellent example of a meandering, gravel-bed river system (Figure 2). The site is dominated by a single channel, and includes a major point bar on the northern side of the channel. There are a number of smaller point bar and midstream bar features which appeared during periods of low river levels between 2000 and 2003. 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, reflecting the active nature of the system.

Replica flake artefact tracers were emplaced throughout the three year period of the experimental programme (September 2000–July 2003), with monitoring of the experimental site in January and December 2001, January, March, April, June, August, October, and December 2002, and March and July 2003. Fieldwork was not possible between January 2001 and December 2001 as an outbreak of Foot and Mouth prevented access to the site. The flake scatters were emplaced at the Llanafan 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 replicate the spatial density of a scatter knapped *in situ* (Table 1). 9 of the 13 scatters were pre-knapped as it enabled the recording of each flake's weight and c-axis, alongside the a- and b-axes measurements recorded for the flakes from the *in situ* knapped scatters. Since the main focus of the experiments was the observation of flake movement, it was considered more important to record accurate size data for the flake tracers than to create 'authentic' *in situ* knapping scatters. Pre-knapping the scatters also facilitated flake artefact identification and recovery, with the individual flakes marked and numbered prior to their emplacement (e.g. Figure 15). The orientation and dip of all flakes were recorded after the scatters were emplaced/knapped *in situ*, and upon the recovery of each flake. Finally, the three-dimensional positions of all flakes were recorded on a site grid, after emplacement/knapping *in situ* and upon the recovery of each flake. Scatters were recorded over multiple monitoring events, prior to the removal of the remaining flakes from the study site for laboratory recording. Consequently in the majority of cases the number of recovered flakes for each scatter declined over time (Table 2). However this was considered an acceptable compromise, as maximising the duration of the experiments increased the potential for gaining valuable flake dispersal data.

Flake scatters were emplaced at two main sites: site A was the semi-stable floodplain and point bar complex at the downstream end of the study site (Figure 4); while site B consisted of a point/midstream bar complex at the upstream end of the study site (Figure 5). 10 scatters were emplaced at site A (scatters #1–8, 10 & 13), and 3 scatters (scatters #9, 11 & 12) at site B (Table 1). Flakes were recovered from 11 of the scatters, with two scatters (#5 and 13) providing no returns (Table 2). Two scatters were fully re-excavated after dispersal, scatter #3 in April 2002 and scatter #4 in July 2003. For scatters #4, 6 and 8, more flakes were recovered than were initially recorded. In the case of scatters #4 and 6 this was partially due to the method of emplacement (*in situ* knapping), which resulted in some of the flakes being covered and obscured by larger artefacts, and therefore not being recorded at the emplacement stage. For scatter #8, the breakage of flakes during transportation produced re-fitting fragments, thus increasing the total number of recovered flakes. Flake breakage probably also contributed to the >100% recovery of flakes for scatters #4 and 6.

Scatter	**Method**	**Site**	**Emplacement Date**	**Original number of flakes**
1	Knapped *in situ*	A	September 2000	21
2	Knapped *in situ*	A	September 2000	38
3	Pre-knapped	A	November 2001	47
4	Knapped *in situ*	A	November 2001	133
5	Pre-knapped	A	January 2002	25
6	Knapped *in situ*	A	April 2002	47
7	Pre-knapped	A	June 2002	36
8	Pre-knapped	A	June 2002	36
9	Pre-knapped	B	June 2002	36
10	Pre-knapped	A	August 2002	36
11	Pre-knapped	B	August 2002	36
12	Pre-knapped	B	August 2002	36
13	Pre-knapped	A	October 2002	36

Table 1: flake scatter emplacement, Llanafan (Grogwynian Reach), Afon Ystwyth.

Scatter	Material recovered?	1st recovery		2nd recovery		3rd recovery	
		Date	Flakes recorded No. (%)	Date	Flakes recorded No. (%)	Date	Flakes recorded No. (%)
1	Yes	January 2001	11 (52.38)	November 2001	6 (28.57)	April 2002	3 (14.28)
2$	Yes	NA	NA	NA	NA	NA	NA
3*	Yes	March 2002	28 (59.57)	April 2002 (excavation)	18 (38.30)	-	-
4	Yes	July 2003 (excavation)	160 (120.30)	-	-	-	-
5	No	-	-	-	-	-	-
6	Yes	June 2002	56 (119.15)	August 2002	37 (78.72)	October 2002	27 (57.45)
7	Yes	October 2002	33 (91.67)	-	-	-	-
8	Yes	August 2002	40 (111.11)	October 2002	24 (66.67)	-	-
9	Yes	October 2002	36 (100.00)	-	-	-	-
10	Yes	October 2002	26 (72.22)	-	-	-	-
11#	Yes	October 2002	33 (91.67)	December 2002	12 (33.33)	March 2003	1 (2.78)
12#	Yes	October 2002	35 (97.22)	December 2002	6 (16.67)	March 2003	4 (11.11)
13	No	-	-	-	-	-	-

Table 2: flake scatter recovery, Llanafan (Grogwynian Reach), Afon Ystwyth. $ 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. * Scatter 3 surface flakes were removed in March 2002, prior to the excavation of the buried artefacts in April 2002. # Scatter #11 and 12 flakes were removed in December 2002, with further flakes recorded and removed in March 2003.

Figure 4: semi-stable floodplain and point bar complex (site A), Llanafan (Grogwynian Reach), Afon Ystwyth, January 2002. View is from the north and flow is to the west.

Figure 5: point/midstream bar complex (site B), Llanafan (Grogwynian Reach), Afon Ystwyth, March 2003. View is from the north and flow is to the west.

Results

The transported and transformed scatters revealed a number of patterns with respect to: the relationship between flake size and transport; micro-flaking, breakage and other modifications; and spatial patterning in flake dispersals.

Flake size and transportation

Flakes were transported over a wide range of distances, from less than 1m upto *c.* 80m (measured as a straight-line distance). Scatters #7, 8, 10, 11 and 12 provided five data-sets for examining the fluvial transportation of flake artefacts. In all cases, there were no clear linear relationships between flake size (using weight as an index of size) and distance transported, illustrated here for scatter #12 (Figure 6). However, it has been argued that clast dimensions and shapes rather than weight are a more significant factor with respect to fluvial transportation distances (WILCOCK 1997). Nonetheless, there is also no evidence for a clear linear relationship (either positive or negative) between flake size (using a-axis x b-axis as an index of size) and distance transported, again illustrated here for scatter #12 (Figure 7). Overall, the experiments indicated that patterns within the size class distribution of flake material (e.g. the predominance of small or large artefacts), recovered from secondary context assemblages, cannot be taken as an indicator of the relative proximity (or not) of the artefact source(s) at the scale of local catchments (10^2 and 10^3 metres).

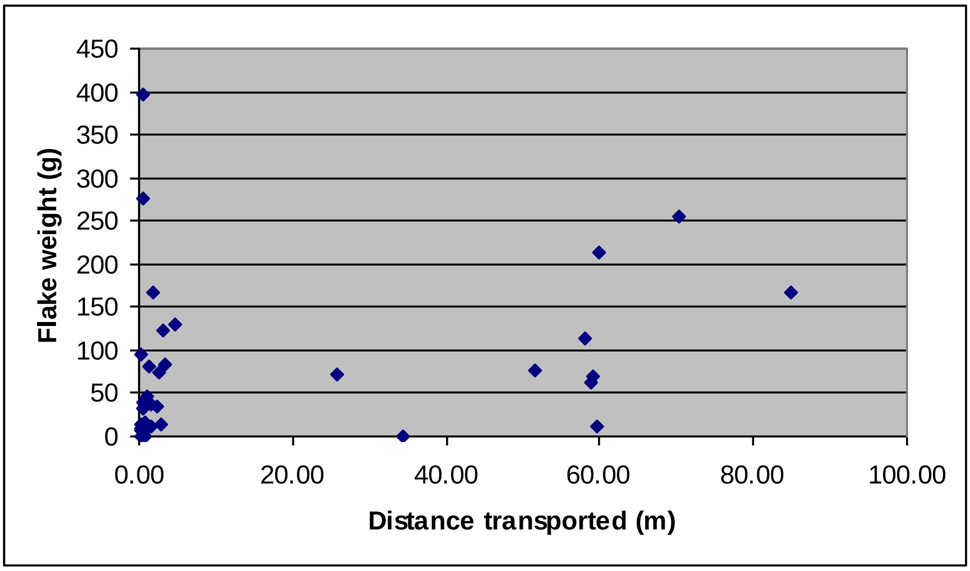

Figure 6: scatter #12 flake transportation distances (August 2002–March 2003) vs flake weight (n=36 & R^2=0.0699).

Flake micro-flaking, breakage & other modifications

Flakes have been transported over a wide range of distances at the Llanafan (Grogwynian Reach) experimental site (Table 3), and it is apparent from scatters #11 and 12 that flakes could survive transportation over a *minimum* of 80m with little or no evidence of substantial damage. Breakages tended to be minor (Figure 8 & Table 4), although it is suggested that more substantial breakages may well occur over longer transportation phases (and these comments obviously only refer to the recovered flake component). However there was evidence of micro-flaking on a large proportion of the recovered flakes (Table 4; Figure 9). Chambers' flume research (CHAMBERS this volume) 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 further modelling of flake (and other stone artefact) transportation in fluvial environments.

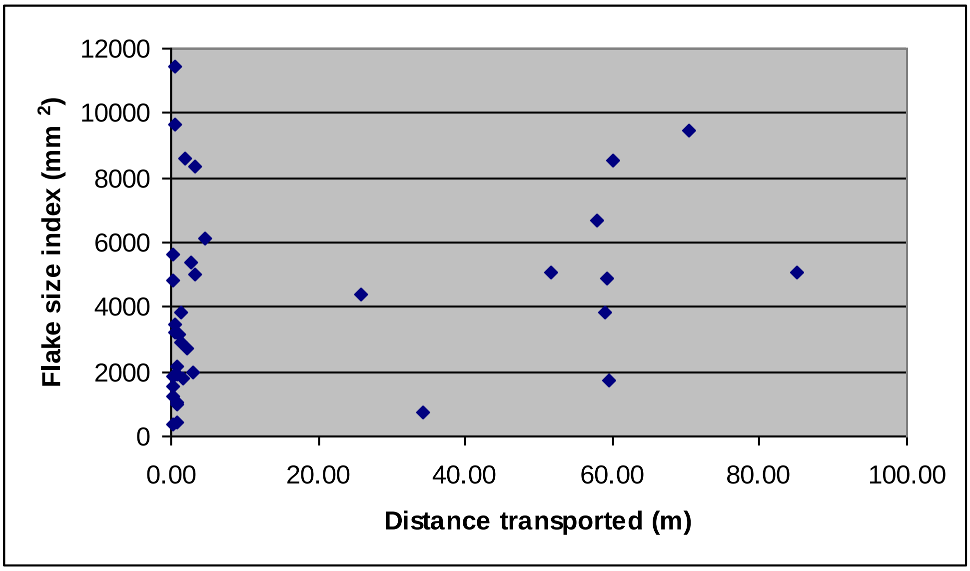

Figure 7: scatter #12 flake transportation distances (August 2002–March 2003) vs flake size index (n=36 & R^2=0.0640).

Scatter	Transportation 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 3: minimum and maximum flake transportation distances, Llanafan (Grogwynian Reach), Afon Ystwyth.

Scatter	No. of flakes recovered	Broken flakes		Micro-flaking	
		No.	%	No.	%
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 4: micro-flaking and breakage for 4 experimental scatters, Llanafan (Grogwynian Reach), Afon Ystwyth.

Most of the micro-flaking scars displayed on the transported flakes are small (less than 5mm in all dimensions) and it is therefore highly unlikely that these micro-flakes would be recovered archaeologically. However, in 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, although the artefact source would probably still be relatively local.

In some instances (Figure 10) the products of edge flaking through transport damage are larger (over 15mm 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. The experiments also indicated that sustained episodes of micro-flaking produce scar patterns on flake edges that are reminiscent of intentional retouch (Figure 11). There is even a single example of flake modification resulting in an artefact which would be classified as a flaked flake/notch (ASHTON *ET AL*. 1991; Figure 12).

Figure 8: scatter #8, flake #29. Note the small breakage on the top-right corner of the exposed face. The flake was transported 4.85m (straight line distance). Scale intervals=4 cm.

Figure 9: scatter #12, flake #22. Note the micro-flaking along the distal edge. The flake was transported 51.62m (straight line distance). Scale intervals=4 cm.

Figure 10: scatter #11, flake #20. Note the micro-flake scar (approximate flake scar dimensions 18 mm x 12 mm). The flake was transported 30.14m (straight line distance). Scale intervals=4 cm.

Figure 11: scatter #12, flake #30. Note the developing micro-flaking scar patterns, which if continued could ultimately be suggestive of intentional retouch. The flake was transported 57.99m (straight line distance). Scale intervals=4 cm.

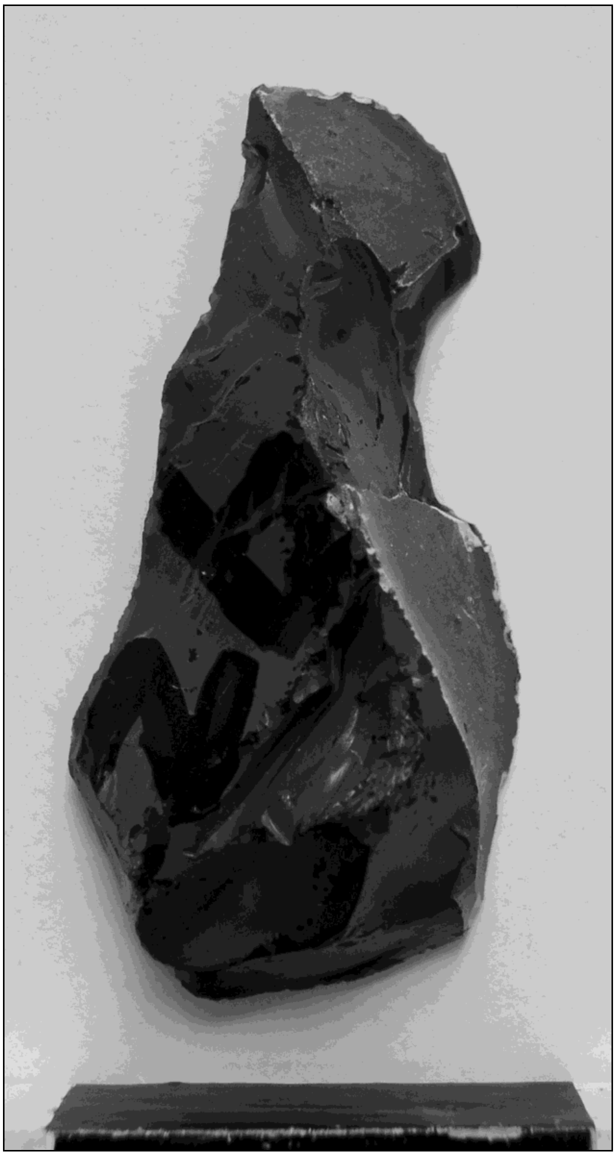

Figure 12: scatter #10, flake #26. Note the 'notch' to the distal right edge. The flake was transported 21.23m (straight line distance). Scale intervals=4 cm.

Spatial patterning in flake dispersals

The recovery and recording of flakes over multiple monitoring events indicated a gradual downstream dispersal of flake material from the original scatters. This is particularly evident for scatters #8, 11 and 12. In the case of scatter #11 (Figure 13 & Figure 14) flakes were dispersed less than 5m downstream during the first 2-month experimental period (Figure 13). In contrast, during the subsequent phases flakes were dispersed over much wider areas (Figure 14). These patterns could be interpreted through changes in flow velocities and water levels, but it is significant that during the period August–October 2002, scatter #8 flakes underwent secondary dispersal over a 20m downstream catchment (after undergoing primary dispersal 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 transportation distances, as suggested for natural clasts 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).

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 a useful indicator of whether the original scatter has undergone limited or more extensive downstream dispersal.

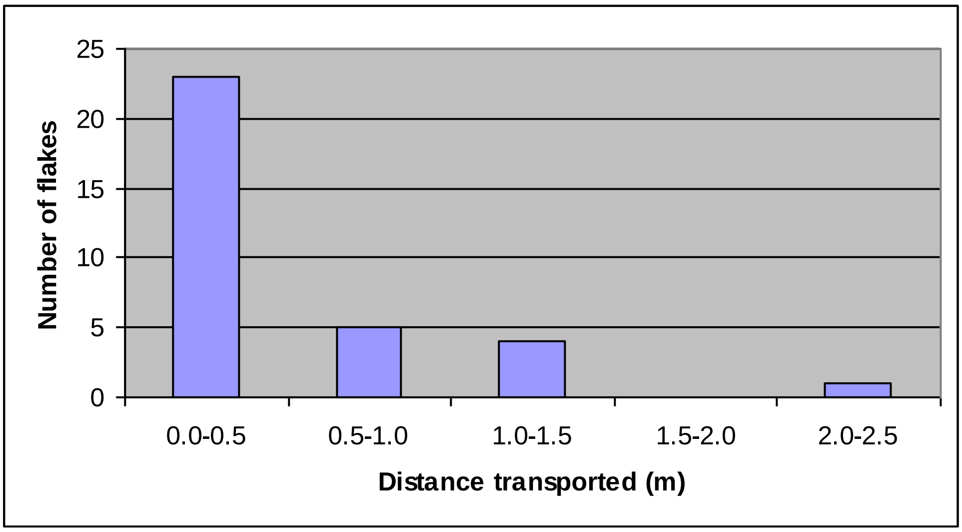

Figure 13: scatter #11 flake transportation distances, August–October 2002 (primary dispersal).

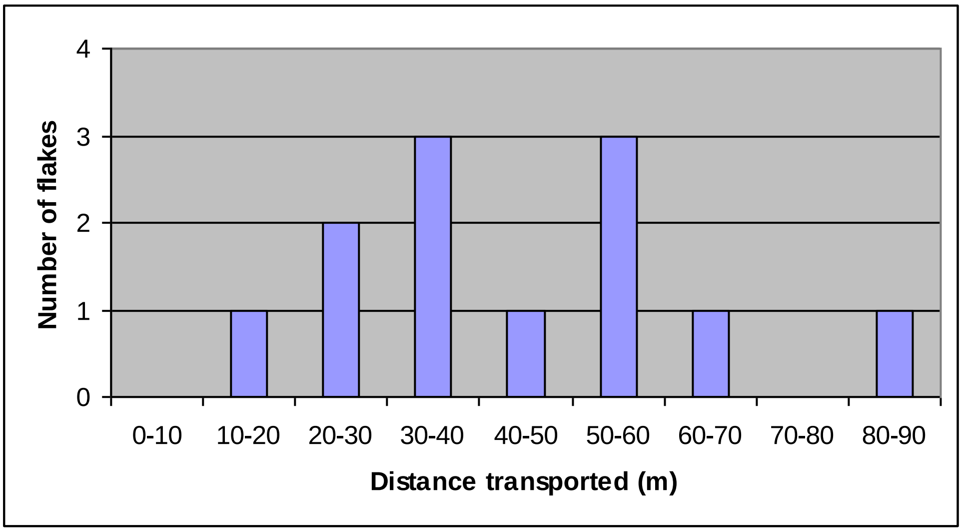

Figure 14: scatter #11 flake transportation distances, October–December 2002 (secondary dispersal).

It was also evident that flake dispersal patterns were influenced by the local morphology of the floodplain (Figure 15). 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. This was also indicated by the analyses of flake fabric (long axis orientation) after transportation episodes. The fabric data was not dominated by flakes lying either parallel or normal to the known flow directions at the experimental site, and this is probably due to the localised trapping of flakes between larger clasts which results in random fabric patterns. 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, local channel and gravel bar morphology will not prevent the widespread downstream dispersal of flake artefacts over time, although the trapping of transported flakes may result in fabric data that does not accurately reflect the local flow regimes.

Figure 15: flake scatter #11 after dispersal, Llanafan (Grogwynian Reach), Afon Ystwyth. Note the 'trapping' of small flakes between larger clasts and the colour marking and numbering of the pre-knapped scatter flakes.

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. Nonetheless, in both cases it was evident that after primary phases of dispersal, it was not possible to differentiate flake material from separate scatters on the basis of their spatial distribution (Figure 16 & Figure 17). 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.

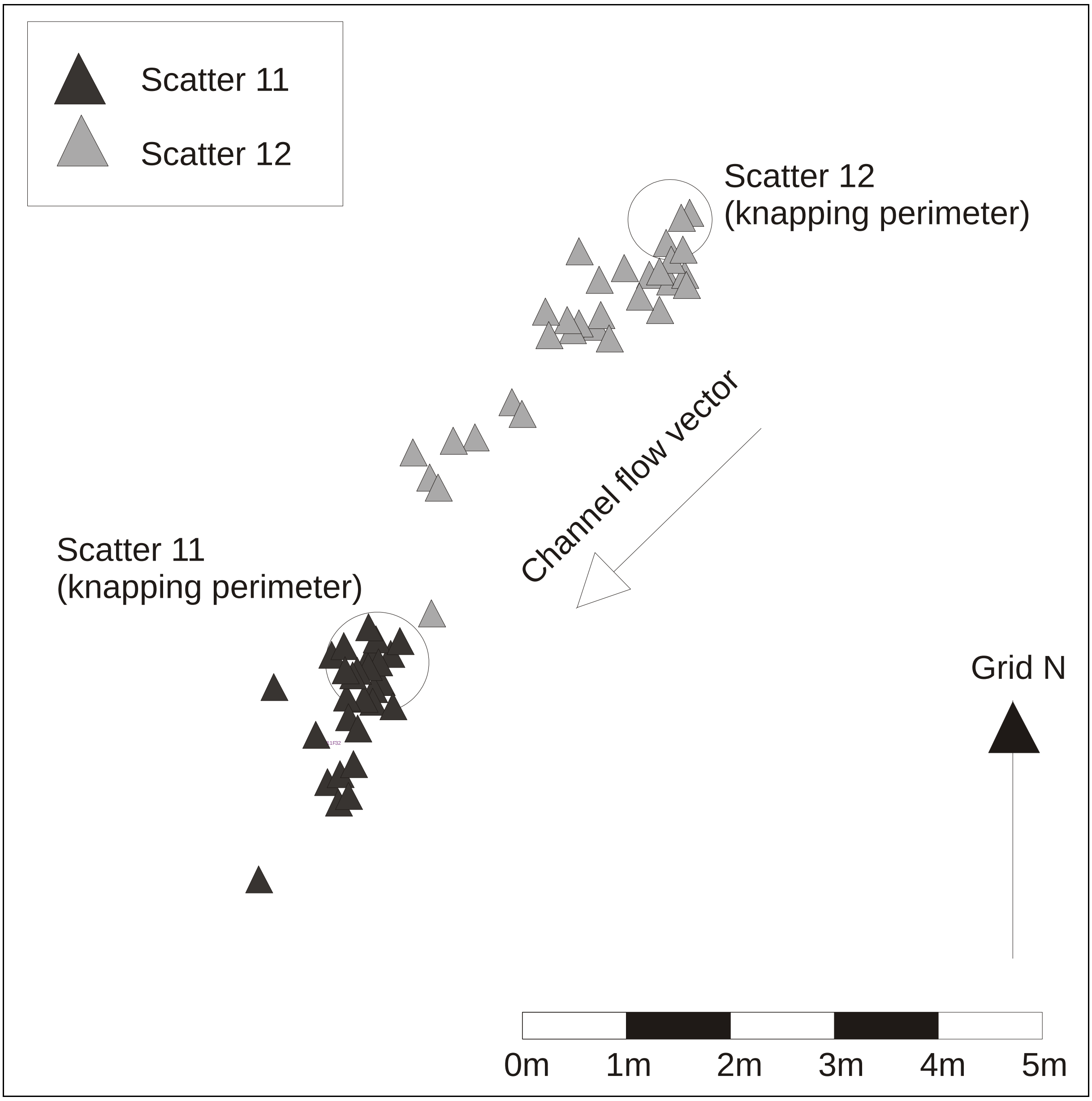

Figure 16: spatial distribution of scatter #11 and 12 flakes after primary fluvial dispersal.

Scatters #3 and 4 provided data regarding the vertical dispersal of flake artefacts within fine-grained sedimentary contexts. Both scatters were emplaced upon the floodplain, where the sediments consisted of a combination of silts, fine and coarse-grained sands, and fine granules. Between the emplacement of scatter #3 and its subsequent excavation (5 months), the flake artefacts were fluvially transported over short distances (a maximum of 2.88m straight-line distance), with 18 flakes (38.30% of the recovered artefacts) buried below the surface of the fine-grained sediments. The scatter #4 artefacts (on-site for 20 months) showed no evidence of fluvial transport, but 122 artefacts (76.25% of the recovered flakes) were buried within fine-grained sediments. It was not fully apparent whether the buried artefacts of scatter #4 were covered with wind-blown sediments or sank into the underlying sediments through gravitational processes (the absence of evidence for fluvial transport in the area of scatter #4 suggests that those artefacts were not buried with fluvially-introduced sediments). However, the characteristically small size and weight of the buried flakes (relative to the surface materials) suggests that the former model of burial is more likely.

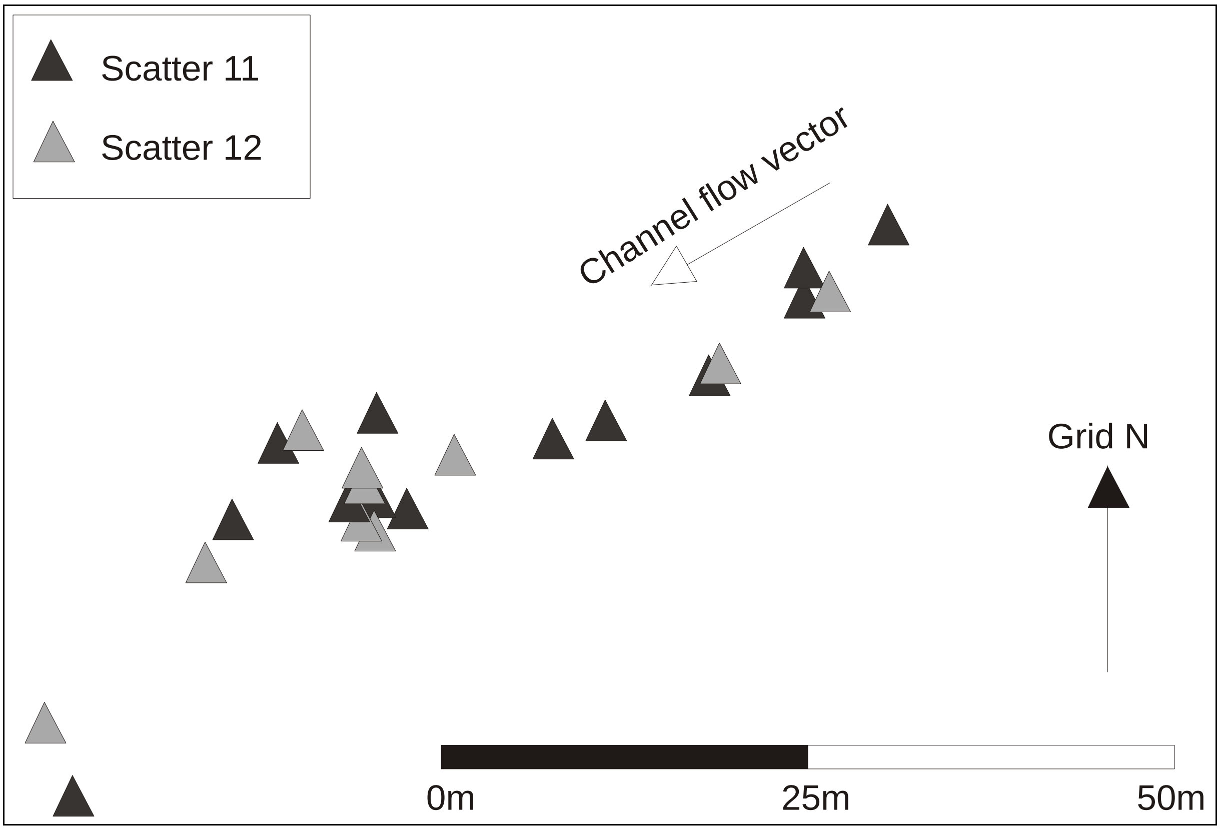

Figure 17: spatial distribution of scatter #11 and 12 flakes after secondary fluvial dispersal.

Excavation and three-dimensional, total station survey of scatter #3 revealed that flakes were vertically distributed over a range of *c.* 10cm (Figure 18), although the majority (86.96%) were distributed between 46.22m and 46.28m (site grid elevations). 28 flakes were recovered from the floodplain surface, with artefact heights (measured from the upper surface of the flakes) ranging from 46.23m–46.29m. This range reflected local variations in the floodplain topography (the surface of the 3.5m x 1m excavation area fell from 46.26m to 46.18m). 18 buried flakes were recovered during the excavation, with artefact heights ranging from 46.19m–46.28m. The overlap between the heights of the buried and surface flakes reflects the local topographical variations across the surface of the excavation area. Overall, the data indicate the potential for a flake scatter to be vertically dispersed over a short range, as a result of fluvial transportation, local topographical variations, and the introduction and re-distribution of fine-grained sediments resulting in the burial of artefacts. These results have interesting implications for the re-interpretation of extant excavation data from Lower and Middle Palaeolithic sites (explored in the following section).

In general, the key conclusions from the Llanafan (Grogwynian Reach) flake experiments include:

- Flake scatters demonstrate a degree of structural integrity, with flakes being transported short distances (generally less than 10m) in the initial phases of fluvial dispersal.
- However, flakes are transported significant distances during subsequent dispersal phases (with a demonstrated minimum of 80m).
- Flakes are damaged during transport episodes, but while this damage may modify the specific morphology of individual flakes, 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 increasingly comes to resemble intentional retouch.
- Flake materials from separate scatters (knapped in relatively close spatial proximity) tend to become spatially indistinguishable during fluvial dispersal.
- Flakes from individual scatters can be vertically dispersed in fine-grained sediments, over an observed range of *c*. 10cm, through the introduction and re-distribution of wind-blown and fluvial sediments.

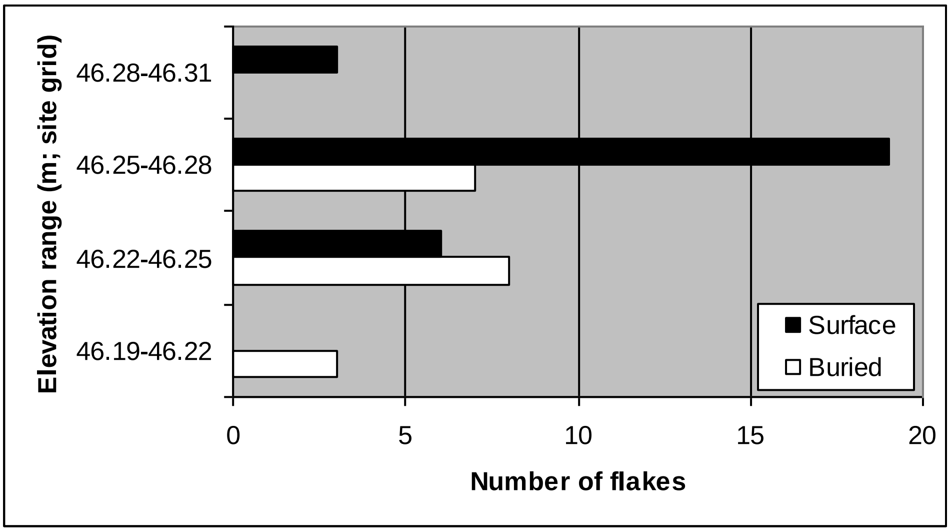

Figure 18: vertical distribution of scatter #3 flakes (buried and surface artefacts).

Applications

These experimental results have a number of interesting implications for the interpretation and re-interpretation of Palaeolithic archaeological assemblages from fluvial secondary contexts. Here, some of the results are discussed with respect to the Lower Palaeolithic site of Clacton-on-Sea in Essex, south-eastern England (SINGER *ET AL*. 1973). Of particular interest is the distribution and subsequent interpretation of the artefacts recovered from the gravel and marl sediments excavated during the 1969–1970 excavations directed by Ronald Singer (see SINGER *ET AL*. 1973 for full details of this work).

Mammalian remains were first recovered from the Clacton foreshore in the first half of the nineteenth century (BROWN 1838; 1840), drawing attention to the Pleistocene deposits at the site. Flint artefacts were first recovered at the end of the nineteenth century, while Hazzledine Warren collected large quantities of artefacts and faunal remains at exposures between Clacton Pier and Lion Point, from 1910 to 1950 (WARREN 1922; 1923; 1924; 1951; 1955). Of critical importance was the Clacton Channel, whose deposits consisted of the infillings of numerous small channels. Excavations in 1934 exposed fluvial marls, sands and gravels, and the freshness of the artefacts led OAKLEY & LEAKEY (1937) to argue that a working floor might lie in close proximity. Against this background, the Golf Course excavations were initiated in 1969. The excavations were confined to an area of rough hawthorn scrub ground, traversed by the projected direction of the Clacton Channel.

The 1969–1970 excavations exposed three major deposits (SINGER *ET AL*. 1973, 17–21):

1. Gravel: the Clacton golf course gravel beds lay upon a gently undulating London Clay bedrock surface. The overall thickness of the gravel was 1m, decreasing to the north and south (towards the margins of the channel). The configuration of the channel bed and 1969 borings indicated that in the area of these excavations the gravel covered an area of *c*. 16–25m wide, across a channel orientated in a general east–west direction. It was concluded that this was an additional, narrow channel segment, marginal to the larger river bed projected by OAKLEY & LEAKEY (1937). The gravel contained the majority of the artefacts and bones, and was very soft ('it was impossible to walk upon its surface without sinking several centimetres into it').
2. Marl: between 0.6m and 1.05m of dry, compacted, vegetated marl overlaid the gravels. The overall thickness of the marl varied in accordance with the configuration of the gravel surface, as the top of the marl was comparatively horizontal with little relief. Artefacts were distributed throughout the body of the marl, but faunal remains were rare.
3. Brown fissile clay: this deposit, consisting of a sequence of sandy clays between 70 and 90cm thick in total, overlaid the marl. Occasional artefacts were recovered, but it is assumed that they were derived from the earlier deposits below.

In the interpretation of the origins of the recovered lithic industry, SINGER *ET AL*. (1973, 23–28) drew a number of important observations and assumptions:

- Artefacts were present at all levels in the marl, lying horizontally or sub-horizontally. Those excavated at the very base of the marl were in contact with the underlying gravel.
- Artefacts were present at all levels in the gravel, although the majority were recovered from the top 30cm.
- The artefacts in the gravel were concentrated towards the line of the London Clay south bank (in the south-western part of the excavation).
- 'Many' of the gravel artefacts were in mint or extremely sharp condition (see below), although 'many others' were rolled to varying degrees.
- Artefact condition was represented in five categories:
    - Mint: as fresh as newly struck flint, lustreless, with crisp ridges between the flake scars.
    - Sharp: the flake has a slight lustre and the flake ridges are dulled.
    - Slightly rolled: the flake ridges have been abraded but nowhere reduced to facets of more than 1mm wide.
    - Rolled: the flake ridges are abraded to clear facets of more than 1mm but less than 2mm at any point.
    - Very rolled: the flake ridges are abraded to facets which exceed 2mm along some segments.
- Based on the above classifications, a greater majority of the mint/sharp artefacts occurred in the upper part of the gravel.
- It was stated that the amount of water transport required to transform a flake to a slightly rolled or rolled category is minimal and does not imply any 'great distance' of transport, probably tens of metres rather than hundreds. It is not apparent that this statement was based on any sort of experimental observation.

Based upon these observations and assumptions, SINGER *ET AL*. (1973, 28) concluded that:

"A study of the distribution of the artefacts within each stratigraphical layer, taking into account their condition, suggests that at least some of them are the direct result of human activity upon the spot. *In the gravel, about half of the artefacts would be in this category,*

whereas the remainder may have been derived from some earlier source at the time of the formation of this channel. The underived artefacts within the gravel may, of course, have accumulated slowly through periodical visits of hunters over a long period, or be the litter from just one or two short occupations of the nearby stream bank. The absence of conjoinable flakes and cores favours the former interpretation. *There is nothing in the stratigraphy to show this and the presence of artefacts throughout the body of the gravel is thought to have been caused mainly by disturbances of the deposit by the movements of men and animals….There is a much higher proportion of underived to derived material in the marl (about 80 per cent) than there is in the gravel and this underived material must date to the time of the formation of the marl. It is difficult to see why any of the material should be rolled at all, although most of it is only very slightly rolled…The following stages of the flint industry are thus reflected in the stratigraphy:*

Stage 1. Derived artefacts within the basal gravel of the golf course channel.
Stage 2. Underived artefacts within the basal gravel of the golf course channel.
Stage 3. Underived artefacts within the marl partly filling the channel.”

(SINGER *ET AL*. 1973, 28–29, our emphasis)

However, the recent experiments on the Afon Ystwyth produced a number of results that are relevant to the assumptions and conclusions applied to the data from the 1969–1970 Clacton excavations, principally:

1. In no cases were the ridges on the recovered flakes abraded to 1mm (in the majority of cases abrasion was less, sometimes considerably so, than 0.5mm (500μm)). More detailed data on flake abrasion was not recorded since the flakes were spray-painted for the purposes of identification, and it was acknowledged that the development of abrasion would be influenced by the paint coverings. Nonetheless, the physical condition of the recovered experimental flakes contradicted SINGER *ET AL*.’s (1973) assumption that the amount of water transport required to transform a fresh flake to a slightly rolled or rolled state was minimal. Rather it suggested that such a transformation would require fluvial transportation over hundreds of metres at the least. The experimental data also suggested that flakes falling into any of SINGER *ET AL*.’s (1973) five categories (mint, sharp, slightly rolled, rolled, and very rolled) could have been fluvially transported.
2. The initial structural integrity and limited dispersal of flake scatters, followed by more widespread dispersal during subsequent phases.
3. The vertical distribution of the experimental flakes in fine-grained sediments (scatters #3 and 4), over a range of *c*. 10cm.
4. The influence of local topography upon the dispersal patterns evident in the recovered experimental flakes.

Based upon these observations, we propose the following provisional statements with respect to the interpretation of the artefacts from the marl and gravel:

- The ‘underived’ flakes in the marl (between 0.6 and 1.05m thick) are likely to reflect multiple, separate knapping activities/discard events, occurring on distinct landsurfaces (at different elevations) and at different time periods during the accumulation of the marl deposit. The limited vertical dispersal of the Afon Ystwyth experimental scatters suggest it is unlikely that flakes from a single landsurface could have been subsequently vertically distributed throughout the 0.6m–1.05m thick marl.

- All of the flakes in the gravel were fluvially derived, reflecting: the condition of the transported experimental flakes from the Afon Ystwyth; and the absence of conjoinable flakes and cores in the Clacton gravel deposits. The variable conditions of the artefacts (both at the same and different heights below the top of the gravel) probably reflect different spatial sources in the local landscape and different transport histories for individual artefacts.
- The concentration of artefacts towards the London Clay south bank probably reflects local fluvial depositional conditions, rather than an immediately adjacent source on the south bank.
- Overall, the artefacts in the gravel are not the direct result of human activity on the spot, although the activity would have been in the local landscapes, probably within tens and hundreds of metres of the findspot. The most likely model therefore favours the second of Singer *et al.*'s (1973, 60–61) five possible interpretations: they were derived at the time of the gravel formation from earlier surfaces or deposits.

While this remains an interim, provisional application of the Afon Ystwyth data to extant archaeological evidence, we feel that it highlights the importance of experimental approaches and geoarchaeological data for the interpretation of Palaeolithic assemblages in fluvial secondary contexts.

Conclusions & New Directions

In conclusion, the flake artefact experiments on the Afon Ystwyth indicated a number of important patterns with respect to the structural integrity and dispersal of flake scatters, the damage and modification of flakes during fluvial transportation, and spatial and vertical patterns of flake dispersal in a gravel-bed river environment. Despite the low-tech nature of the work, recovery of the replica flake artefact tracers was generally good, and in its first phase the project has produced a wide range of valuable experimental data.

Nonetheless, it is clear that considerable further work is required, particularly with respect to the vertical dispersal of fluvially transported flakes within gravel deposits (e.g. fluvial bar structures), the abrasion of flake artefacts, and the need for longer running experiments permitting observations of flake dispersal and modification over (ideally) decadal timescales. Nonetheless, the initial Afon Ystwyth experiments have demonstrated the value of experimental geoarchaeological work and its importance for the interpretation and re-interpretation of Palaeolithic assemblages recovered from fluvial secondary contexts.

Summary

Die globalen archäologischen Befunde des Unteren und Mittleren Paläolithikums sind oft durch Steinwerkzeuge charakterisiert, die in einem sekundärem Kontext in fluvialen Sedimenten vorkommen. Diese Befunde repräsentieren einen signifikanten Anteil des archäologischen Gesamtbefundes (insbesondere in Nordwestern Europa) und haben dennoch typischerweise wenige Untersuchungen auf sich bezogen. Dies spiegelt vielleicht eine weitverbreitete Einstellung in Bezug auf die komplexen taphonomischen Prozesse wieder, die mit diesen Funden assoziiert sind. Die erste Erkenntnis, daß diese Steinwerkzeuge durch die fluviale Umwelt transformiert ('Wasserabgenutzt') und/oder transportiert worden sind, stammt aus dem späten 19ten Jahrhundert. Trotz dieser jahrhundertealten 'Erkenntnis' haben die relevanten Prozesse der Abnutzung und Modifikation sowie der Fundformation wenig archäologische Beachtung erhalten. Wenn archäologische Experimente stattgefunden haben, dann waren diese typischerweise (aber nicht nur) auf afrikanische Umwelten (d.h. die Arbeit von Glynn Isaac und Kathy Schick) und auf *in situ* Fundbestände bezogen. Wenige Arbeiten

haben sich mit der Dynamik von Bewegungen der archäologischen Befunde in hoch energiegeladen fluvialen Umwelten in Nordeuropa auseinander gesetzt.

Dieser Bericht legt die erste Phase von experimentellen Programmen (2002/2003) dar, die Artefakt-transport, -modifikation und -deposition in einer gerölligen Flußbettumgebung untersuchen. Der Afon Ystwyth in Wales, GB, wurde als Analogie zu einem Flachland Geröllflußbett im mittlerem Pleistozän ausgewählt. Eine Reihe von replizierten Steinabschlägen (stammend sowohl von bifazieller Manufaktur als auch direkter Kernabschlagreduktion) wurden über einen Zeitraum von drei Jahren im Fluß plaziert und wieder geborgen. Angaben zur Transportlänge, räumlicher Streuung (inklusive Artefaktausrichtung und horizontaler Lagerungswinkel in Bezug auf die Wasserströmung), Artefaktmodifikation (Microabschläge/abnutzung der Kanten), Bruchmuster und Bergungsraten wurden gewonnen. Die Untersuchung haben außerdem einige unerwartete weitere Resultate hervorgebracht, insbesondere in Bezug auf Windstreuung von Witterungsausgesetzten leichteren/kleineren Artefakten im Laufe der Zeit, sowie die graduelle Verschüttung durch feinkörnige Sedimente von Abschlägen die auf einem Ausuferungsraum abgelagert wurden.

Die Experimente haben das Überlebenspotential von archäologischen Abschlägen in hoch energiegeladen, fluvialen Umwelten nach Transport über Distanzen von mindestens 80 Metern indiziert. Dies bestärkt das Fehlen von Beweisen (im Gegenteil zu echten Beweisen der Abwesenheit) in Form von transportierten Abschlägen in Bezug auf die begrenzten archäologischen Abschlagsammlungen aus den fluvialen Ablagerungen des Pleistozäns, die ja aus industriellen Flußaushebungsaggregaten des 19ten und 20ten Jahrhunderts stammen. Die nur leichten Modifikationen der transportierten, experimentellen Abschläge haben weitere Implikationen für die Interpretation von archäologischen Funden. Die potentiellen Applikationen dieser experimentellen Befunde werden deshalb kurz in Bezug auf die englische Fundstelle Clacton-on-Sea (Golf Course Fundstelle, Unteres Paläolithikum) dargestellt.

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Captions

Figure 1: the Afon Ystwyth and Llanafan (Grogwynian Reach) study site, mid-Wales, UK.

Figure 2: average monthly discharges (m^3s^{-1}) of the Afon Ystwyth for 2000 and 2001. Data from the Environment Agency (National River Flow Archive).

Figure 3: 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 view is from the north) and the midstream bar at the upstream end of the visible channel (flow is to the west).

Figure 4: semi-stable floodplain and point bar complex (site A), Llanafan (Grogwynian Reach), Afon Ystwyth, January 2002. View is from the north and flow is to the west.

Figure 5: point/midstream bar complex (site B), Llanafan (Grogwynian Reach), Afon Ystwyth, March 2003. View is from the north and flow is to the west.

Figure 6: scatter #12 flake transportation distances (August 2002–March 2003) vs flake weight (n=36 & R^2=0.0699).

Figure 7: scatter #12 flake transportation distances (August 2002–March 2003) vs flake size index (n=36 & R^2=0.0640).

Figure 8: scatter #8, flake #29. Note the small breakage on the top-right corner of the exposed face. The flake was transported 4.85m (straight line distance). Scale intervals=4 cm.

Figure 9: scatter #12, flake #22. Note the micro-flaking along the distal edge. The flake was transported 51.62m (straight line distance). Scale intervals=4 cm.

Figure 10: scatter #11, flake #20. Note the micro-flake scar (approximate flake scar dimensions 18 mm x 12 mm). The flake was transported 30.14m (straight line distance). Scale intervals=4 cm.

Figure 11: scatter #12, flake #30. Note the developing micro-flaking scar patterns, which if continued could ultimately be suggestive of intentional retouch. The flake was transported 57.99m (straight line distance). Scale intervals=4 cm.

Figure 12: scatter #10, flake #26. Note the 'notch' to the distal right edge. The flake was transported 21.23m (straight line distance). Scale intervals=4 cm.

Figure 13: scatter #11 flake transportation distances, August–October 2002 (primary dispersal).

Figure 14: scatter #11 flake transportation distances, October–December 2002 (secondary dispersal).

Figure 15: flake scatter #11 after dispersal, Llanafan (Grogwynian Reach), Afon Ystwyth. Note the 'trapping' of small flakes between larger clasts and the colour marking and numbering of the pre-knapped scatter flakes.

Figure 16: spatial distribution of scatter #11 and #12 flakes after primary fluvial dispersal.

Figure 17: spatial distribution of scatter #11 and #12 flakes after secondary fluvial dispersal.

Figure 18: vertical distribution of scatter #3 flakes (buried and surface artefacts).

Table 1: flake scatter emplacement, Llanafan (Grogwynian Reach), Afon Ystwyth.

Table 2: flake scatter recovery, Llanafan (Grogwynian Reach), Afon Ystwyth. $ 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. * Scatter 3 surface flakes were

removed in March 2002, prior to the excavation of the buried artefacts in April 2002. # Scatter #11 and 12 flakes were removed in December 2002, with further flakes recorded and removed in March 2003.

Table 3: minimum and maximum flake transportation distances, Llanafan (Grogwynian Reach), Afon Ystwyth.

Table 4: micro-flaking and breakage for 4 experimental scatters, Llanafan (Grogwynian Reach), Afon Ystwyth.