

LIKE A ROLLING STONE? THE IDENTIFICATION OF FLUVIAL TRANSPORTATION DAMAGE SIGNATURES ON SECONDARY CONTEXT BIFACES

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INTRODUCTION

The physical condition of bifaces recovered from high-energy fluvial depositional contexts, such as river gravels, has long been utilised as an indicator of the degree of transportation they have been subjected to (e.g. Wymer 1968). This paper briefly reviews extant methodologies used to describe biface physical condition, emphasising the value of both quantitative *arête* recording techniques and the consideration of the *état physique* of the entire biface. Major findings from a programme of flume-based biface transportation and modification experiments are presented, demonstrating that gross factors of artefact morphology influence transportation type, and that, in turn, transportation type influences the character and distribution of damage sustained. It is argued that the data generated from these experiments can be used as the basis for modelling the type and duration of fluvial transportation secondary context bifaces have sustained, facilitating assessment of the spatial intensity of hominid activity associated with fluvial Palaeolithic findspots.

THE INTERPRETATIVE CHALLENGES OF SECONDARY CONTEXT BIFACE ASSEMBLAGES

The Lower Palaeolithic record of northern Europe is dominated by assemblages of stone tools recovered from high-energy fluvial gravel deposits. This pattern is particularly evident in the British Lower Palaeolithic record, with its fragmented fluvial deposits and sparse evidence for primary context sites. The secondary context Palaeolithic assemblages recovered from British fluvial deposits are typically comprised predominantly of biface tool forms, reflecting the typological biases of the antiquarian collectors active during the late 19th and early 20th centuries (Hosfield 1999). These assemblages can consist of as many as several thousand artefacts and represent a substantial archaeological resource.

Unfortunately, due to the problems historically associated with the dating of fluvial sequences and the derived nature of these artefacts, secondary context assemblages have remained under-studied. However, as improved geochronological frameworks (e.g. Bridgland 1994, 1996, 2001; Maddy *et al.* 2001) and absolute dating techniques such as Optically Stimulated Luminescence (e.g. Murray & Wintle 2000; Toms 2002) are developed for Pleistocene fluvial sequences, and in the light of the research potential afforded by the Aggregates Levy Sustainability Fund, it is an opportune time to re-evaluate the spatial derivation and interpretive potential of secondary context artefacts.

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EXTANT METHODOLOGIES FOR ASSESSING SPATIAL DERIVATION THROUGH ARTEFACT PHYSICAL CONDITION

Artefact physical condition has long been used as an indicator of the degree of fluvial transportation that individual bifaces have been subjected to. Attention has most commonly focused on the abrasion damage sustained by biface *arêtes* (flake scar ridges) as they are ground down through contact with clast bedload and/or suspended particles during fluvial transportation. Assessment of this abrasion is the most commonly utilised proxy for artefact spatial derivation through fluvial transportation: the greater *arête* abrasion demonstrated by a secondary context biface then the greater distance it is considered to have been transported from its original discard location within the Palaeolithic landscape.

Arête abrasion descriptions have been most commonly based on simple visual assessment of the *arête* widths undertaken with the naked eye. Naturally, such descriptions varied from researcher to researcher, though an attempt at standardising the terminology was offered by Wymer (1968: plate *xi*), who suggested five abrasion categories (mint, sharp, slightly rolled, rolled and very rolled) with the most heavily abraded categories displaying *arête* widths of $\frac{1}{32}^{\text{nd}}$ and $\frac{1}{8}^{\text{th}}$ of an inch respectively. This standardisation theoretically allows different workers to utilise a single semantic framework. However, it should be emphasised that the standardisation of a subjective classificatory system does not in itself reduce the potential inter-observer variability inherent in the unaided visual assessment of *arêtes*.

The need for a quantitative method for measuring *arête* abrasion was addressed by Shackley in the 1970s (1974, 1975) who examined abraded bifaces with a x75 microscope, calibrated to $\frac{1}{1000}^{\text{th}}$ of a millimetre (1 micrometer/ $1\mu\text{m}$), enabling the widths of individual *arêtes* to be accurately and objectively measured. The examination of *arête* widths at this level of magnification led to the recognition that artefacts that appear unabraded to the naked eye may actually demonstrate significant transportation damage.

Shackley (1975) measured 25 *arête* widths from locations across each biface and combined their widths to produce an average observed *arête* width representative of the entire artefact. This methodology was applied to both experimental (tumbling mill abraded) and archaeological examples, and the data used to generate six indices that described biface abrasion. To facilitate the quantification of results with those of previous researchers (Shackley 1975: Table 7; Table 1) proposed a scheme for correlating these indices with the widely employed verbal classificatory terminology.

<i>Visual Descriptive Category</i>	<i>Shackley's Index Value</i>	<i>Arête Width (μm)</i>
Mint	0	0–10
Very Fresh	1	10–20
Fresh	2	20–50
Slight Abrasion	3	50–100
Abraded	4	100–200
Heavily Abraded	5	200–300
Very Heavily Abraded	6	300+

Table 1: Correlation of abrasion indices and visual descriptive terms (Shackley 1975: Table 7)

Shackley's methodology offers an objective technique for assessing the abrasion damage sustained by secondary context bifaces. However, this methodology remains largely unused,

perhaps reflecting the labour and time intensive nature of the technique. Literature searches have revealed only one extensive application; the research of Hosfield (1999), who modified Shackley's methodology by reducing the number of *arête* widths recorded from each biface to 15, thus speeding up the recording process. However, to date assessments of the physical condition of secondary context artefacts remain commonly based on unaided visual assessment of *arête* width (e.g. Marshall 2001).

To assess the validity of unaided visual classification of biface *arête* abrasion, an experimental assessment was recently undertaken at the University of Southampton (Chambers 2004, in press). Twenty one volunteer archaeologists, with a variety of lithic analysis experience, were asked to visually assess the abrasion damage preserved on eight bifaces randomly selected from the Lower Palaeolithic assemblage recovered from fluvial gravels at King's Park, Bournemouth, southern England. Volunteers were asked to assign each biface to one of the abrasion categories devised by Shackley (1975), shown in Table 1. Eighty six percent of the unaided visual assessments of biface abrasion made during this experiment (n=146/168) were incorrect when compared to microscopic measurements of *arête* abrasion. The abrasion of each biface was both under and over estimated by different subjects, irrespective of their degree of experience of lithic analysis, indicating that the accuracy of unaided visual assessment of biface *arête* abrasion would not be improved by simply rescaling the *arête* widths associated with each of Shackley's indices. Of the 14% (n=22/168) of correct *arête* abrasion assessments, 82% of these (n=14/22) were made by volunteers who considered themselves as 'expert' lithic analysts. However it should be remembered that this also means that these 'experts' incorrectly (and inconsistently) assessed *arête* abrasion in 85% (n=82/96) of cases (Chambers 2004, in press: Table 2).

This experiment demonstrated that unaided visual assessment of *arête* abrasion is both highly variable, and commonly inaccurate, suggesting that techniques designed to quantitatively measure *arête* widths, such as those of Shackley (1975) and Hosfield (1999), offer more consistent and more accurate data returns than unaided visual assessment alone. Therefore, despite their time-consuming nature, these techniques should be more widely utilised in the description of the physical condition of secondary context bifaces. I would further argue that refinements to existing microscope *arête* recording methodologies will allow a more detailed assessment of the transportation history of individual artefacts than is currently achieved.

MAXIMISING MICROSCOPE METHODOLOGIES

Extant microscopic methodologies for assessing biface *arête* abrasion record a series of *arête* widths across the individual biface, which are then combined to generate an average observed *arête* abrasion value. This average value is used to describe the extent and character of abrasion damage preserved on that biface, a valid approach only if *arête* abrasion is typically a homogenous phenomenon. However, examination of biface assemblages recovered from the gravels of the extinct Solent River system appears to indicate that abrasion development on individual bifaces is more commonly heterogeneous than homogenous. For example, during the examination of 238 bifaces sampled from five River Solent assemblages less than 10% of the sample (n=20) demonstrated homogenous *arête* abrasion damage (Chambers 2004).

The apparent scarcity of homogenous *arête* abrasion development has profound implications for abrasion assessments that combine artefact *arête* data as an average value. Following the methodology of Hosfield (1999), if fifteen recorded *arête* widths generated an average abrasion value of 200µm for an individual biface one cannot determine whether this describes

an abrasion distribution of: fifteen *arête* widths of 200µm; ten *arête* widths of 100µm combined with five *arête* widths of 400µm; or fourteen *arête* widths of 100µm combined with a single *arête* width of 1600µm. Each of these very different distributions would generate an average abrasion value of 200µm for the artefact. As it is difficult to envisage the same transportation history creating all of the distributions suggested above, it is considered that reconstructions of artefact transportation history can only be more meaningfully undertaken when the character of *arête* abrasion distribution can be evaluated.

To these ends a zone-based *arête* recording methodology has been proposed (Hosfield *et al.* 2000; Chambers 2004; Figure 1), whereby *arête* data are recorded systematically through the division of the biface into 'zones'. Each face is divided into six portions, from which two *arête* widths, representative of damage within that zone, are recorded.

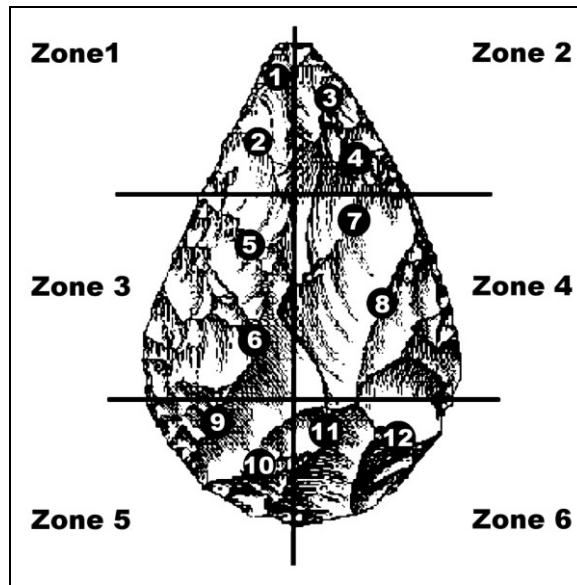


Figure 1: A zone based *arête* abrasion recording methodology

The systematic nature of this recording method allows the data to be presented in graphic format (Figure 2), rather than as numeric data or summary values (Table 2). This facilitates assessment of the distribution of abrasion damage across the artefact and the identification of any areas of concentrated abrasion damage. The ability to plot the distribution of *arête* abrasion allows detailed comparisons to be made between the abrasion damage preserved on archaeological specimens and that shown to develop on replica bifaces transported over known distances under controlled experimental conditions, providing a mechanism with which to model biface spatial derivation.

BIFACE TRANSPORTATION AND DAMAGE DEVELOPMENT: FLUME EXPERIMENTS

Flume experiments were undertaken to assess the damage sustained by replica bifaces during fluvial transportation. A flume environment was used as this provides far greater control, data return and artefact recovery than field based artefact transportation experiments can provide. However, complementary field experiments documenting biface and flake transportation behaviours have been undertaken in mid-Wales and are reported elsewhere (e.g. Hosfield *et al.* 2000; Hosfield & Chambers 2004, 2005).

<i>Face A</i> <i>Arête No.</i>	<i>Arête</i> <i>Width (μm)</i>	<i>Face B</i> <i>Arête No.</i>	<i>Arête</i> <i>Width (μm)</i>
A1	100	B1	100
A2	300	B2	200
A3	400	B3	200
A4	200	B4	300
A5	600	B5	600
A6	1000	B6	1100
A7	1100	B7	1700
A8	1800	B8	400
A9	500	B9	900
A10	400	B10	1000
A11	300	B11	700
A12	400	B12	800
Average arête width = 629.166 μm (0.69 mm)			

Table 2: Hypothetical sample of biface arête abrasion data, recorded using the zone based methodology described in Figure 1

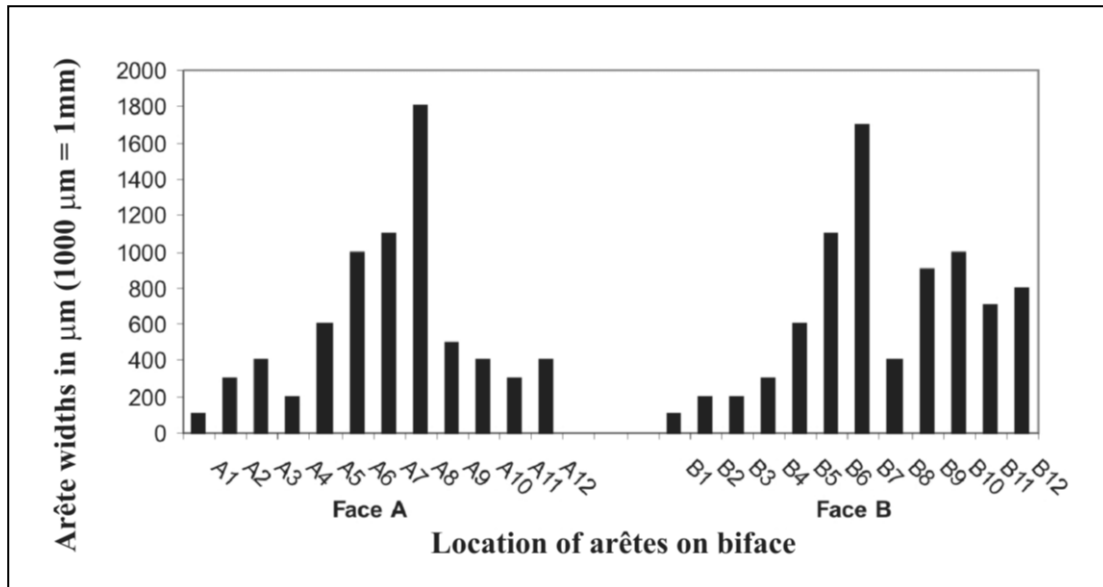


Figure 2: Graphical presentation of biface arête abrasion data (as shown in Table 2)

The flume experiments were devised primarily to assess the relationship between artefact transportation duration and damage development. Flume apparatus was considered preferable to other experimental equipment, such as the tumbling mill apparatus used in previous biface abrasion experiments (e.g. Shackley 1975; Hosfield 1999), as within the flume artefacts are free to undergo natural lateral movement. Therefore the resultant artefact damage is considered to more closely reflect that which would be sustained in genuine fluvial conditions than the damage produced in the rather more artificial conditions of tumbling mills where movement is entirely rotational.

Research in the fields of civil and hydraulic engineering has identified two main modes of fluvial transportation, suspended-load and bed-load transportation. During suspended-load transportation the particle (e.g. clast or artefact) is totally entrained within the fluid flow and maintains no contact with the underlying bed material. In contrast, during bed-load

transportation contact is maintained to some degree with the underlying bed-load material during either rolling/saltation and/or sliding motion (e.g. Lee *et al.* 2002; Van Rijn 1984). The flume experiments focused on the damage artefacts sustain during bed-load transportation, reflecting both the uncertainties regarding the role of suspended-load in biface transportation, and the difficulties associated with inducing the suspended transport of biface-sized particles under experimental conditions. It was also considered that any damage sustained during suspended-load transportation would be more closely related to the character and distribution of other suspended particles than to linear transportation distance, therefore any data generated would have been of limited applicability to extant secondary context biface assemblages.

Replica bifaces of lenticular and plano-convex forms were manufactured in fine-grained (flint) and coarse-grained (greensand chert) raw materials, permitting the assessment of the effects of raw material and gross morphology on transportation and damage development. During these experiments the plano-convex bifaces were transported a total distance of 250m and the lenticular forms were transported for a total of 1000m in a 12m, glass-walled tilting flume. The dominant mode of bed-load transport (e.g. rolling/saltation or sliding) was noted during each flume run. Damage development was regularly recorded; during the first 100m of transportation artefact physical condition was recorded after every 10m, between 100–250m artefacts were recorded after every 25m of transportation and beyond 250m recording took place after every 50m of transport, generating 90 discrete snapshots of the relationship between specific transportation distances and resultant damage development.

FLUME EXPERIMENTS: RESULTS

- **Artefacts of different raw materials develop transportation damage at differing rates**
Prior to the flume experiments, freshly knapped artefacts made of fine-grained raw materials were characterised by lower *arête* widths than the coarse-grained artefacts. These variations in *arête* widths prior to any transportation reflect the different grain sizes of the two materials; the fine-grained flint produces thinner and sharper *arêtes* than does the coarser-grained chert. During the first 400m of transportation the flint bifaces developed *arête* abrasion at a slower rate than the coarse-grained chert bifaces. Beyond 400m this pattern was reversed.

- **Artefact damage during transportation is not limited to *arête* abrasion**
Several researchers (e.g. Wymer 1968; Harding *et al.* 1987; Petraglia & Potts 1994) have noted the presence of edge damage on fluvially transported artefacts. However, this phenomenon has not previously been related to either *arête* abrasion development or transportation duration. During the flume experiments edge damage in the form of micro-flaking was noted to develop after only 30m (chert biface) and 40m (flint biface) of rolling/saltation transportation, and, as such, was more readily discernable to the naked eye than *arête* abrasion at these transportation distances. Micro-flaking continued to increase during rolling/saltation transportation, becoming more intense as transportation distances increased. During sliding transportation edge damage did not develop, as during this type of movement the artefact does not rotate around its midline axis and the edges are therefore not subject to the impact or crushing forces of rolling/saltation motion.

Biface edges can also suffer more substantial modification during transportation; between 800m and 850m a single larger removal was detached from the dorsal tip of biface No. F1. This flake was approximately 1.5cm long and 0.8cm wide. Although this flake could not be recovered from within the flume, it notably modified the shape of the tip of the biface. It is

postulated that similar occurrences during the fluvial transportation of Palaeolithic bifaces may have altered tip shapes substantially, and therefore caution is advised in assigning behavioural significance to minor variations in the tip typologies of secondary context assemblages (see Hosfield & Chambers 2005 for consideration of flake alterations during fluvial transportation).

- **Artefact morphology affects transportation type**

The flume experiments revealed that gross morphological factors of artefact shape affect artefact transportation. On introduction to the flume lenticular bifaces quickly became orientated perpendicular to the flow direction and once in this orientation movement was initiated. Artefacts then demonstrated a clear preference for rolling and/or saltating motion, with only occasional, laterally limited, episodes of sliding motion. In contrast, plano-convex bifaces became orientated parallel to flow, always resting on their planar face, and demonstrated a preference for sliding motion. During sliding motion the planar face remained in almost constant contact with the gravel bed of the flume. These trends were observed in both raw materials, irrespective of flow magnitude or flume profile angle, suggesting that these preferences relate to physical factors of gross artefact morphology rather than more subtle and variable anthropogenic characteristics such as typology and size.

- **Transportation type affects the damage artefacts sustain**

As described above, two clear movement preferences were identified during the flume experiments: rolling/saltation or sliding motion. Artefacts typically demonstrated a single strongly dominant mode of movement during each traverse of the flume. These repeated movements during transportation result in the development of different damage signatures (summarised in Table 3). The identification and differentiation of these different damage patterns only becomes possible through the proposed zone-based *arête* recording methodology.

ROLLING/SALTATION DAMAGE PATTERN

Bifaces that have been moved by rolling/saltation sustain *arête* damage that is highly variable across each face, with the *arêtes* in the thickest zones of the artefact typically becoming more heavily abraded. While intra-face *arête* variability is high, the range of *arête* widths from each face is similar (as shown for a flint biface in Figure 3), irrespective of transportation distance or raw material.

Bifaces that have moved by rolling/saltation demonstrate more substantial edge damage in the form of micro-flaking than those moved by sliding motion during which significant micro-flaking was not seen to develop. This damage is considered to relate to the grinding and/or impact forces inherent in rolling/saltation motion. Micro-flaking intensity was seen to increase as transportation distance increased on both the flint and the chert lenticular biface, though it was slightly more pronounced on the flint biface.

SLIDING DAMAGE PATTERN

Only plano-convex bifaces demonstrated any sustained transportation via sliding motion. As this sliding occurred exclusively on the planar face, leaving the convex face upwards, this motion preference is attributed to the physical factors of the gross morphology of the plano-convex form. The *arête* abrasion to the planar face of the transported plano-convex bifaces is more homogenous than that preserved by their own convex faces (Figure 4), or by either face

of the lenticular bifaces moved by saltation (Figure 3).

<i>Biface ID</i>	<i>Number of Recording Events</i>	<i>Dominant Transport Mode</i>	<i>Face A Arête Damage</i>	<i>Face B Arête Damage</i>	<i>Other Damage</i>
No. F1 (flint)	30	Saltation	Highly Heterogeneous Range of both faces highly comparable	Highly Heterogeneous Range of both faces highly comparable	Substantial edge micro-flaking; single 'large' flake removal; scratches
No. Ch2 (chert)	30	Saltation	Highly Heterogeneous Range of both faces highly comparable	Highly Heterogeneous Range of both faces highly comparable	Substantial edge micro-flaking
No. F9 (flint)	15	Sliding	Moderately Homogenous Range of both faces differs moderately	Highly Heterogeneous Range of both faces differs moderately	Very limited edge micro-flaking
No. Ch1 (chert)	15	Sliding	Highly Homogenous Range of both faces differs substantially	Highly Heterogeneous Range of both faces differs substantially	Very limited edge micro-flaking

Table 3: Summary of artefact transportation trends and resultant damage documented during the flume experiments

It is considered that this homogeneity results from the planar character of the face in contact with the bedload; little vertical differentiation can be made between the *arêtes* of different zones of the planar face, and all are therefore more or less equally exposed and vulnerable to grinding as they slide across the gravel bed. In contrast, the convex face of plano-convex artefacts shows high levels of *arête* abrasion variability, resulting from a differential susceptibility to clast collisions. Only the *arête* abrasion of the planar face can therefore be related in any meaningful way to fluvial transportation distances. The predominantly sliding motion of the plano-convex artefacts did not result in damage to the biface edges.

ARCHAEOLOGICAL APPLICATIONS OF THE FLUME EXPERIMENTAL DATA

The flume experiments have revealed several factors of value for the interpretation of the derivation of secondary context biface assemblages: different raw materials develop damage at different rates; artefact shape influences the type of motion induced by fluvial forces; these different movement types produce different damage signatures; and biface damage during transportation is not limited to *arête* abrasion.

The application of the proposed zone-based *arête* recording methodology facilitated the identification of specific distributions of abrasion damage that related to different types and durations of bed-load transportation. The current programme of experiments has produced 90 individual signatures of the damage that develops over known transportation distances of up to one kilometre. It is considered that the value of this experimental data set lies in its use as a scalar framework against which to assess the range of biface damage present within secondary context assemblages. Through the comparison of archaeological abrasion/damage signatures

and experimental data a modelled transportation distance for individual bifaces can be generated (due to space constraints this process will be fully outlined in a future publication). When extended to populations of artefacts (entire assemblages or samples only) the homogeneity or heterogeneity of the spatial derivation present within secondary context assemblages can be determined (Chambers 2004, in press), permitting a greater understanding of hominid land use as represented by patterns of artefact discard.

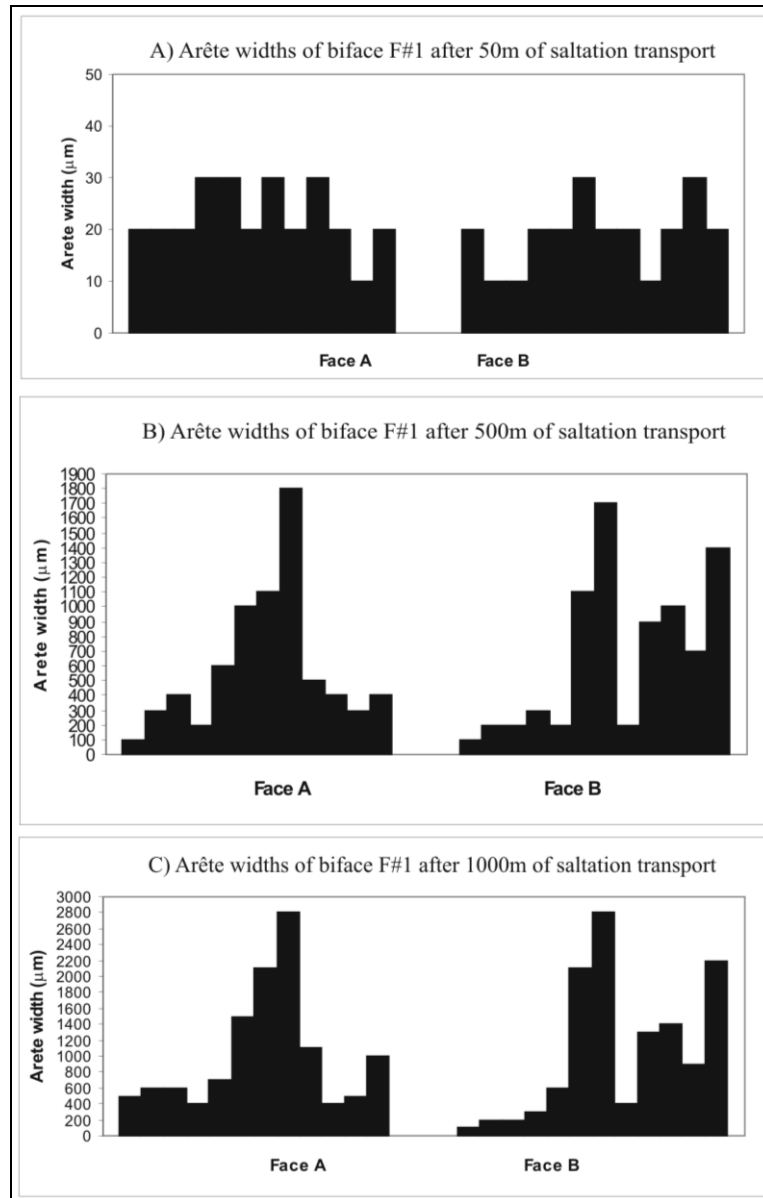


Figure 3: Plot of arête widths of lenticular flint biface (No. F1) after A: 50m, B: 500m, C: 1000m of rolling/saltating transportation. Note high intra-face arête width variability and general consistency of inter-face values.

For example, if an assemblage of secondary context bifaces demonstrates similar modelled spatial derivation distances for all of the artefacts (irrespective of how great or small this distance is) then that assemblage may be described as being of homogenous spatial origin (although it may, of course, be highly time-averaged). This allows the identification of favoured places, locations that, for whatever reason, were repeatedly the focus of hominid activity within the Pleistocene landscape. Alternatively, if the spatial derivation modelling of

an assemblage shows a wide distribution of distances then hominid activity should only be described as more widely distributed throughout the local river valley, without any discrete focus for biface discard.

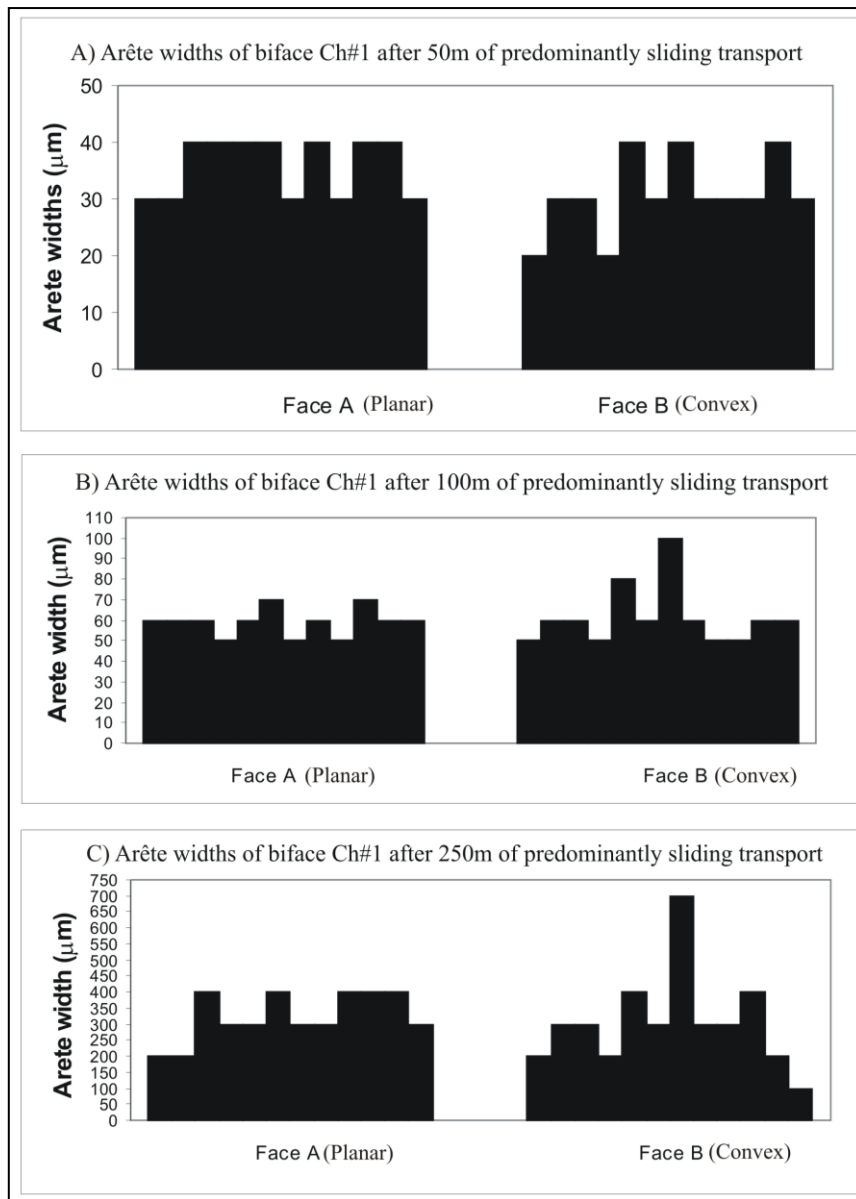


Figure 4: Plot of arête widths of plano-convex coarse-grained greensand chert biface (No. Ch1) after A: 50m, B: 100m, C: 250m of sliding transportation. Note relative homogeneity of arête abrasion sustained by planar face (Face A).

CONCLUSIONS AND FUTURE RESEARCH

During fluvial entrainment and transportation bifaces may develop a range of damage characteristics, including *arête* abrasion and edge damage. By considering the distribution of this damage we can model in greater detail the transportation histories of individual bifaces, and, in turn, entire secondary context assemblages. This modelling is only possible through reference to artefact damage development patterns observed in an experimental context.

The current experimental programmes have demonstrated that patterns of biface damage development are related not only to the duration of their fluvial transportation, but also to factors of artefact morphology, raw material and transportation type. The flume experiments have documented the relationship between damage development and bed-load transportation. It is hoped to enhance the experimental data sets through further laboratory and field experiments to examine the role of non-active transport episodes in artefact damage development (e.g. aeolian abrasion, damage during burial) and extended bed-load transportation experiments.

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