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Stone Tools and Paleolithic Settlement in the Iberian Peninsula

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The assemblages from four sites in Spain and Gibraltar form the basis of a study that addresses the behavioral significance of the variability in Middle Paleolithic chipped stone artifacts. Quantitative analysis of artifact edge morphology forms the primary focus of this work.

It is suggested that (1) morphological variability is generally continuous for the features examined, (2) retouched and unretouched lithics are extremes in a continuum of the degree of edge use, (3) lithic morphology is dynamic and artifacts may be multi-functional and (4) lithic morphoplogy is conditioned by the time of discard in the use-life of the artifact. Retouched artifacts may be more the end result of the extent and nature of the use of their various edges than preconceived tools determined by cultural traditions or intended function.

These results are applied to a study of Middle Paleolithic settlement strategies using data from the four primary sites of the study and an additional five sites in the Iberian peninsula. Differences are noted between upland and lowland strategies. Upland sites may represent more of a 'forager' strategy, with frequent, short-term occupations of sites. Lowland sites seem more characteristic of a 'collector' strategy, with longer occupations and less frequent visits to sites. Settlement response to changing Upper Pleistocene environments during the onset of the last glacial may include a shift to a more 'forager'-like strategy in lowland settings.

Most archaeologists would agree that chipped stone artifacts form the primary record of prehistoric hunter-gatherer behavior due to their long-term durability as well as their economic importance. This is especially true for the Middle Paleolithic, where lithics are often the only certain, surviving record of human behavior. However, in spite of considerable study — including experimentation, ethnoarchaeological investigations, the development of many classification systems, and descriptive reports — many questions remain about the behavioral significance of lithic variability in these Pleistocene assemblages. Hence, the Middle Paleolithic of the western Old World has become an arena for continuing investigation and debate on the relationships between lithic variability and human behavior. Past interpretations have centered around a 'culturalist' position, in which most significant recognized variability is seen as a result of cultural tradition or style, and a 'functionalist' position in which the same variability is considered to be a result of the uses for which artifacts were intended. These different views of the interpretation of lithic variability have come to be called the 'Mousterian debate'.[2]

The 'culturalist' position is exemplified in the writings of the late François Bordes (Bordes 1973; 1981; Bordes and de Sonneville-Bordes 1970). From the late 1940s through the early 1960s, Bordes, along with Maurice Bourgon, developed a standard typology for retouched tools from Middle and Lower Paleolithic assemblages of south-western France that is still widely used throughout the western Old World (Bordes 1961). He felt that French Middle Paleolithic assemblages could be grouped into six industries on the basis of

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[2] Often a third position is also associated with this debate, one that ascribes variability to change through time (e.g. Mellars 1965; 1969; 1986). However, this constitutes more an observation about patterning in the temporal distribution of variability than an explanation for this patterning. Possible reasons for change through time include both culturalist explanations such as cultural drift and functional explanations such as adaptation to changing Upper Pleistocene environments (Barton 1988, 101–102; Jelinek 1988).

relative frequencies of these artifact types — Typical Mousterian, Mousterian of Acheulean Tradition types A and B, Denticulate Mousterian, and Charentien Mousterian with Quina and Ferrassie variants (Bordes 1972).

In spite of detailed studies of stratified Middle Paleolithic sites and associated contextual data, Bordes could find no association between these industries and paleoenvironmental variations or evidence related to subsistence. Nor was there any apparent chronological order to the industries (but see Mellars 1965; 1969; 1986). This led Bordes and many others to suggest that all industries represented more or less the same range of economic activities, and that differences between the industries must be attributable to culturally determined traditions for making different versions of functionally equivalent tools (e.g. Bordes 1973; Bordes and de Sonneville-Bordes 1970; Laville 1980, 208–15; Butzer 1981). This interpretation implies that these Middle Paleolithic industries represent cultural units that were essentially stable over tens of thousands of years. It also suggests that, although these groups occupied the same geographical region (and often the same sites over time), there was either little interaction between the different groups, or that interaction had minimal effects on the way chipped stone tools were manufactured.

Although the 'functionalist' position, in its current form, derives from the work of Freeman (1964), it is best exemplified in the literature by the writings of Lewis Binford (Binford 1973; Binford and Binford 1966; 1969). Variability in the form of chipped stone artifacts is interpreted by the 'functionalists' primarily as the result of differing tool designs that are best suited for achieving various, primarily economic, tasks. Additionally, Binford points out that there is no known ethnographic parallel for stable, non-interacting social groups that occupy the same region, as is implied by Bordes's interpretation of the lithic data.

Binford used factor analysis, with the relative frequencies of Bordes' tool types from a series of French and Near Eastern assemblages as data, to identify groupings of tool types that cross-cut Bordes's industries (Binford and Binford 1966). He then interpreted these groupings as 'tool kits', associated with activity sets such as butchering or hide preparation.

It is not the intent here to present yet another detailed methodological and theoretical critique of these positions. It is of value, however, to point out that both positions share several working assumptions (implicit and explicit) that are integral to their interpretations of the lithic data. The first is that the relevant unit of analysis for studying lithic variability is the whole piece. That is, lithics are treated as complete tools, much like modern screwdrivers or hammers, with differing characteristics such as one or two retouched edges. Because virtually all Middle Paleolithic retouched pieces, in at least most of the western Old World, can be classified into one of the 63 tool types defined by Bordes, it is generally assumed that morphological variability is adequately and accurately characterized by this typology.

Another important assumption is that retouched pieces represent tools with preconceived forms. That is, through retouch, the maker created a tool whose form was shaped by the task for which it was intended and/or the maker's traditionally inspired concepts of how this particular tool should be made. A further implication is that variability is deviation from the desired form, due to the differences in knapping skill, constraints of the raw material and available or utilized technology. For these reasons, retouched tools are considered the most informative of chipped stone artifacts for interpreting human behavior. Unretouched pieces, on the other hand, are considered to be waste by-products of tool manufacture (i.e. debitage) or blanks with an unrealized potential for being transformed into tools.

Finally, the assumption that the morphology of finished tools remained relatively static throughout their use lives is implicit in these interpretations. Therefore, the tools found at sites to a large degree reflect the maker's intended form, so that there are relatively straightforward relationships between form and function or form and cultural traditions. This means that it should be possible to identify discrete tools or tool classes associated more or less exclusively with specific activities or activity sets. Morphological differences between such tools are then attributable to either association with different activities or, if associated with the same activities, to derivation from different, culturally influenced, concepts of the proper form for that tool.

THE SITES AND THEIR ASSEMBLAGES

A group of Middle Paleolithic assemblages was studied in order to reassess the behavioral significance of variability in chipped stone artifacts and the assumptions that form the bases for these inferences. A fundamental objective was the quantitative analysis of variability in retouched tools, focusing on artifact edges, in order to identify and explain patterns of morphological variability. At the assemblage level, the results help to clarify the links between artifact morphology and the processes of lithic production, use, and maintenance. At a broader scale, patterns of lithic variability are used as a data base for reconstructing Middle Paleolithic settlement strategies in the Iberian peninsula.

1,093 retouched tools from assemblages at four sites in the Iberian peninusla form the primary data base for this study. Two of the sites, Cova del Salt and Cova del Pastor, are located near the town of Alcoy, in the coastal mountains of eastern Spain, midway between Valencia and Alicante.

Cova del Salt was excavated by a team led by Luis Pericot and Vincente Pascual, during two field seasons in 1960 and 1961 (Barton 1988, 37–40; Villaverde 1984, 280). Several limited excavations took place at Cova del Pastor. Initial work was done by a group of local *aficionados* (M. Brotons, J. Pastor and H. Garcia) in 1951. Subsequent excavations were conducted by A. Seguí (Seccíon de Arqueología del Centro Excursionista de Alcoy) in 1976 and Emilio Cortell and Jose Mª Segura (Museo Arquelógico Municipal de Alcoy) in 1982 (Barton 1988, 40; Villaverde 1984, 294).

The other two sites are Gorham's Cave and Devil's Tower rock shelter, on the western coast of Gibraltar. Gorham's cave was excavated by J. d'A. Waechter between 1948 and 1954 (Waechter 1951; 1964). Devil's Tower rock shelter was excavated by Dorothy A. E. Garrod in 1925 and 1926 (Gorrod *et al.* 1928). The collections are housed in museums in Alcoy and Valencia (Spain), London (UK), and Gibraltar (see Barton 1987; 1988).

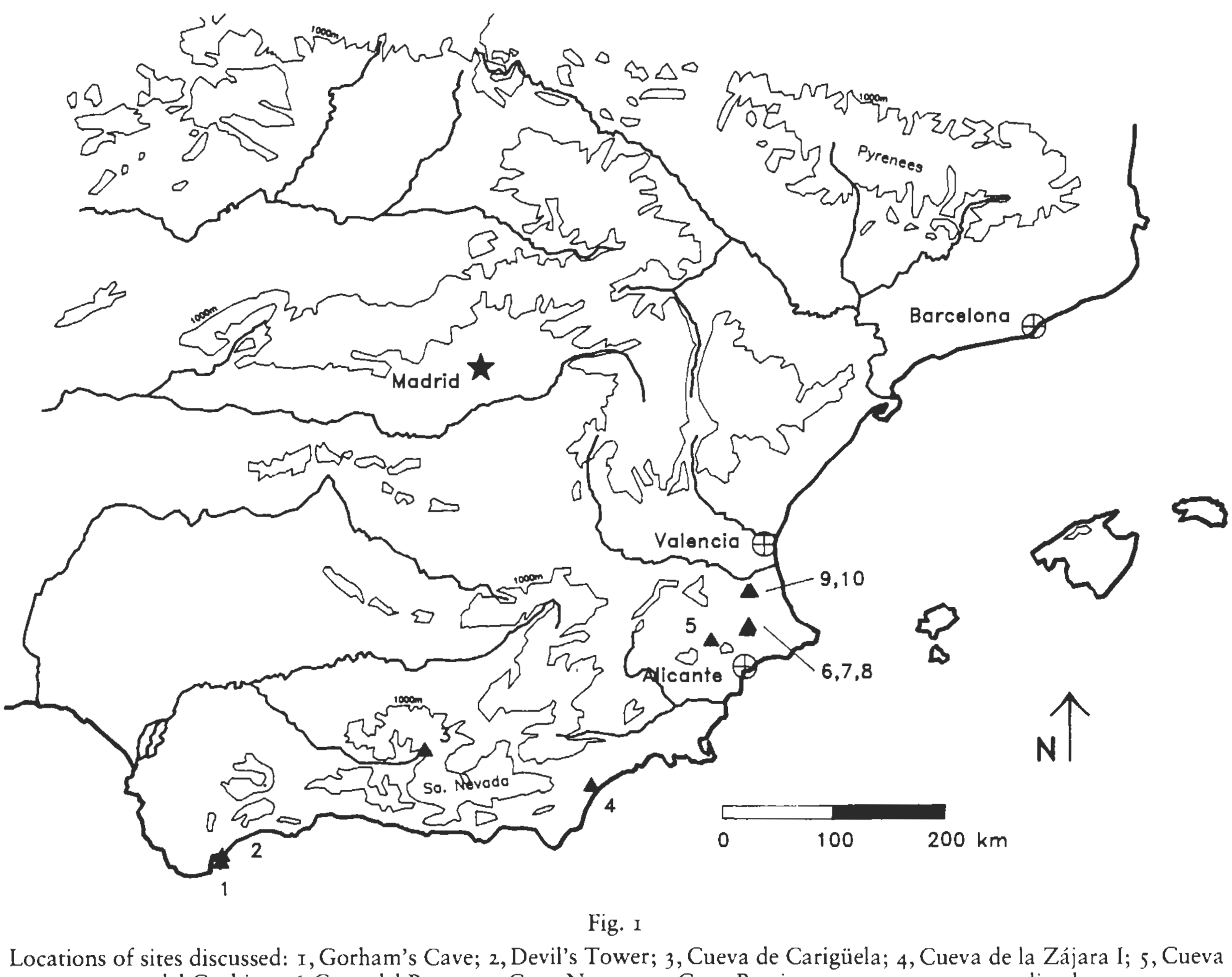


Fig. 1

Locations of sites discussed: 1, Gorham's Cave; 2, Devil's Tower; 3, Cueva de Carigüela; 4, Cueva de la Zájara I; 5, Cueva del Cochino; 6, Cova del Pastor; 9, Cova Negra; 10, Cova Petxina. 1,000 m contour outlined

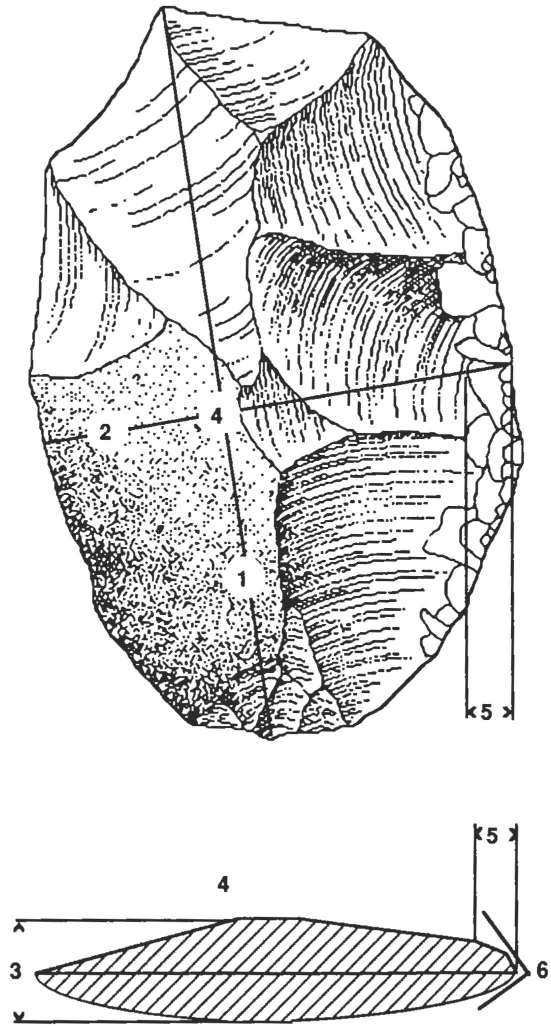
Data from the four primary sites of the study are augmented by published information from five other sites in eastern and southern Spain. These are Cova Negra (Villaverde 1984), Cova Petxina (Villaverde 1984; Mueller-Wille 1983) and Cueva del Cochino (Villaverde 1984; Mueller-Wille 1983) in central eastern Spain, Cueva de la Zájara I (Vega 1980) on the south-eastern coast, and Cueva de Carigüela (Mueller-Wille 1983; de Lumley 1969) in the Sierra Nevada of southern Spain (fig. 1).

Data for this study consist primarily of a series of quantitative measurements of morphological attributes. Importantly, these include attributes intended to objectively characterize macroscopic variability in edges. As edges most often represent the utilized portion of lithic artifacts, any specific associations between artifact morphology and function should be reflected in these edge attributes. They also permit measurement of the degree to which edges were used and modified. Finally, because the number, location, and nature of the retouched edges on lithic artifacts form the primary criteria differentiating the types in Bordes's classification scheme (and indeed many other typologies), the edge attributes permit a quantitative examination of the basis of this system.

Attributes recorded for both retouched and unretouched edges include the linear extent and position of edges along the piece margin, edge angle, and whether the edge terminated in a break. Additional measurements made only on retouched edges include the invasiveness of modification, the shape of the edge outline (in radius of curvature), and the linear extent of step-flaking, if present. The number, location and type of any sub-edges (e.g. a notch on a scraper edge) were also noted, as was the category of retouch (parallel, scalar, etc.). A total of 3028 edges was measured.

In order to assess variability associated with manufacture rather than use, attributes related primarily to processes of flake production also were recorded. These include dimensional measurements (length, width and thickness), type of raw material, platform shape and type of preparation, the pattern of flake scars on the exterior surface, the amount of cortex on the exterior surface and the degree (if any) of heat alteration. Some of these measurements are illustrated in figure 2. (See Barton 1987; 1988, 112–18 for a description of measurement techniques.)

Finally, both individual edges and whole pieces (or 'tools') were classified using Bordes's typology. For edges, of course, only single-edged types could be used.



Key to Measurements
1. length
2. width
3. thickness
4. location of thickness measurement
5. invasiveness
6. edge angle

Fig. 2
Selected attributes measured on tools

For example, an edge could be classed as a single convex side scraper (type 10) but not as a double convex side scraper (type 15). This provides summary information about edge configuration and a basis for comparison between quantitative and typological assessments of lithic variability. In addition, use of this typology is necessary to compare the results of this attribute analysis with data from other assemblages not analyzed in this way.

RESULTS

Lithic variability and behavior[3]

Individual attributes. Some of the most notable features of artifact morphology are that variability is predominantly continuous and unimodal, and tends to be normally distributed. This is apparent in figures 3 to 5 which display variability in several attributes measured for edges from the primary sites of the study (Cova del Salt, Cova del Pastor, Gorham's Cave and Devil's Tower). There is an overall lack of distinct multiple modes, or peaks, in the distributions that could indicate the existence of distinct tool classes. Since more than a single type of task was performed during the Middle Paleolithic, this suggests that most retouched edges are multifuntional rather than designed for specific tasks or task sets.

Edge shape is the only attribute that shows exception to this pattern of unimodality. Figure 4 shows the frequency of different edge shapes for all retouched edges. Edge shape was measured as radius of curvature and converted to an index (Shape Index, or SI)[4] such that straight edges have a value of zero on the horizontal axis, increasingly convex edges are indicated by higher positive values (to the right on the horizontal axis) and concave edges have negative values. Variability in shape is continuous for the great majority of retouched edges. While these edges range in shape from convex to concave, most are slightly convex (mode = 1.119 for SI, equivalent to a radius of curvature of 38 mm) — the shape of the edges of most unretouched flakes. However, there is also a minor, secondary peak at the extreme concave edge of the distribution in figure 4. This latter group of edges is composed primarily of notches (see overlain distribution of notched edges in fig. 4) and may represent an edge morphology distinct from other concave edges. The bivariate distributions of attributes discussed below seem to support this distinctiveness. Additionally, the shapes of very rarely occurring burins and piercers could not be accurately represented as radii of curvature and also may represent other distinct edge shapes.

Not only do these attribute data fail to provide evidence for more than two distinct 'types' of retouched edges, they also suggest that retouched edges may not be qualitatively different from unretouched edges. Figure 5 displays the distribution of edge angles for unretouched edges, marginally retouched edges (those with retouch extending less than 2 mm into the piece), and scraper edges (representing edges with more intensive retouch), as well as the combined distribution of all retouched and unretouched edges. While marginally retouched edges tend to have steeper edge angles than unretouched edges, and scraper edges have the steepest edge angles, there is considerable overlap in the distributions of these three edge groups. Moreover, the combined distribution of all retouched and unretouched edges displays a continuous,

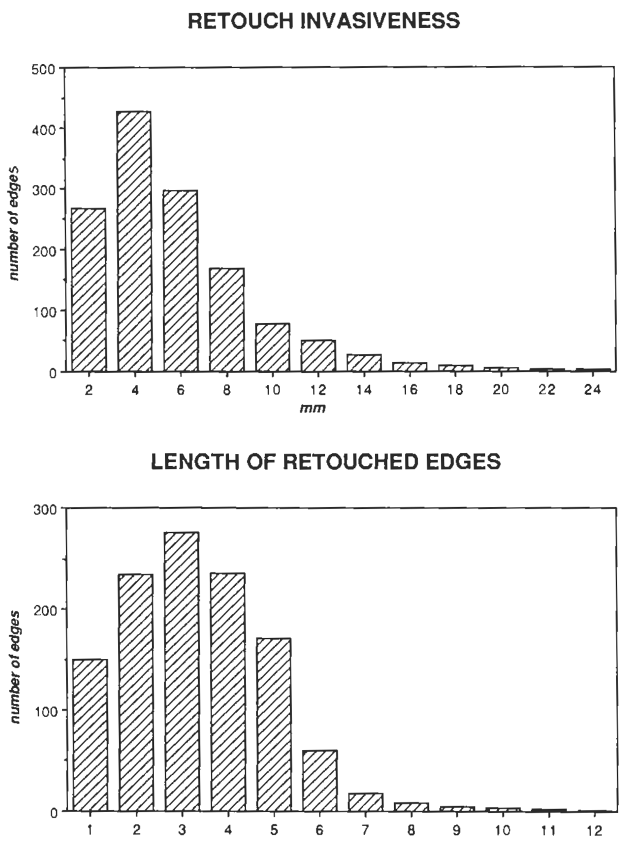


Fig. 3

Histograms of retouch invasiveness and edge length for complete retouch edges

[3] All statistical analyses were performed with micro- (SPSS/PC) and mainframe (SPSSx) versions of the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL).

[4] Edge shape was measured as the radius of curvature of edge outlines, positive for convex edges and negative for concave edges. It was converted to an index, Shape Index or SI., according to the formula $SI = \log_{10}\left(\frac{500}{r}\right)$ for $r > 0$ and $SI = -\log_{10}\left(\frac{500}{r}\right)$ for $r < 0$, where $r = \pm$ radius of curvature. Thus, for SI, straight edges have a value of zero and extremely concave or convex edges have high negative or positive values respectively. A numerator of 500 was used because $r = \pm$ 500 mm could not be distinguished from a straight edge. Also, because the area under a curve varies geometrically with the radius of curvature (i.e. r^2), a log function of shape is more easily displayed and interpreted.

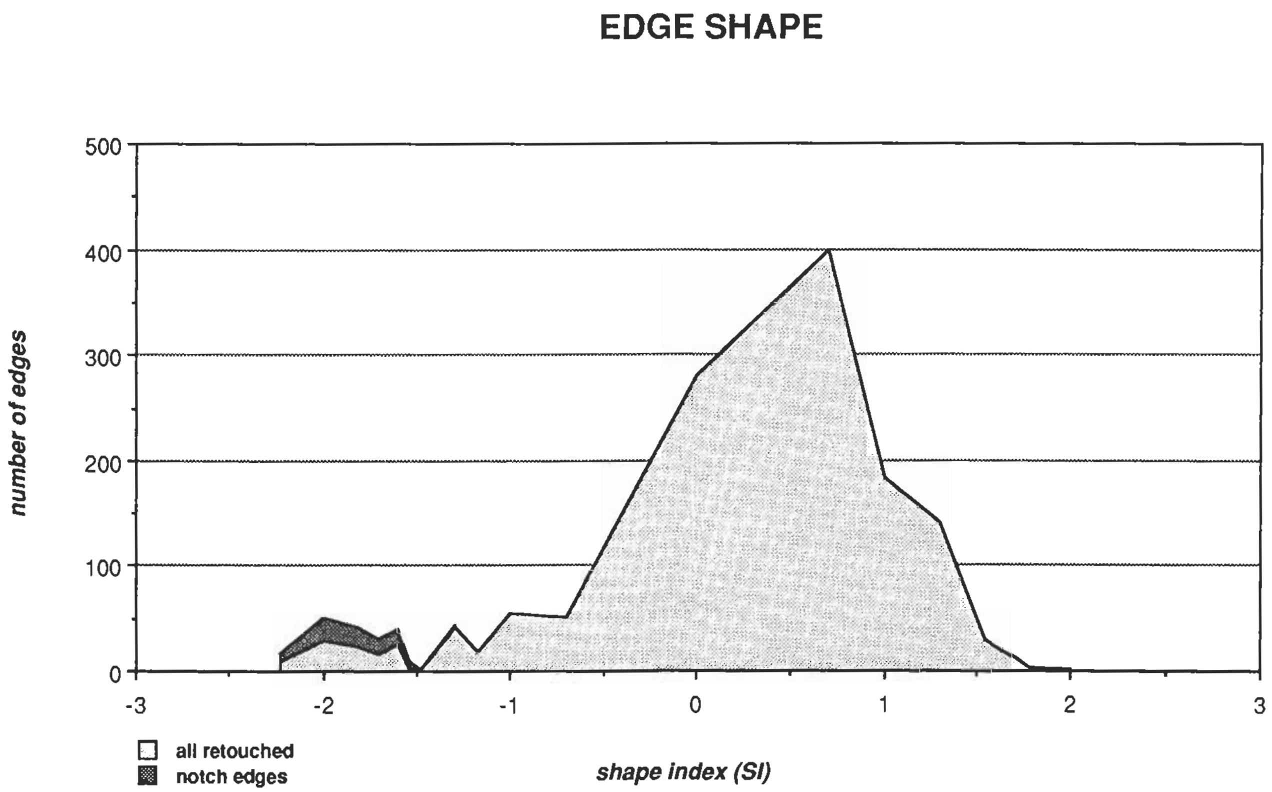


Fig. 4

Frequency distribution of edge shape (Shape Index) for all retouch edges overlain by the frequency distribution for notched edges. Convex edges have positive values for SI, concave edges have negative values and straight edges have a value of zero

normal distribution (Mean = Median = Mode =55°, σ = 14°). This suggests that the distinctions of unretouched, marginally retouched, and invasively retouched are simply arbitrary divisions of a single continuous distribution of edge morphology rather than qualitatively different edge classes.

Relationships between attributes. Although distinctive edge configurations that might indicate numerous specific tool types are lacking for the Middle Paleolithic assemblages studied, there is considerable variability in edge morphology. Patterns apparent in the bivariate relationships between edge attributes suggest models to explain this variability.

On the whole, relationships between edge attributes are non-linear. However, the range of variability in some attributes seems to covary with the value of other attributes. For example, figure 6 is a scatter plot of edge angle versus the retouch intensity (represented by invasiveness, or the distance that retouch scars extend inward from the piece margin) for all retouched edges. Among edges with minimal (i.e. less intensive) retouch, edge angles can vary greatly. However, edges with more intensive retouch tend to have only relatively steep edge angles.

A similar pattern is seen in figure 7 for the relationship between retouch intensity and relative width (piece width/piece thickness). Edges with minimal retouch occur on pieces with a wide range of relative widths, while intensively retouched edges occur only on relatively narrower, thicker pieces (i.e. pieces with low values of relative width).

These patterns appear to represent, in part, mechanical relationships between attributes, based on the degree to which use, resharpening and consequent edge reduction has taken place. As an edge is resharpened, the minimum edge angle that can be maintained becomes steeper and the flake it is on becomes relatively thicker and narrower. If this model is correct, there should be a generally negative relationship between relative width and edge angle. That is, steep edges should tend to occur on relatively narrow, thick pieces and acute edges on wider, thinner pieces. This is the case, as can be seen in figure 8 (R = −.35).

The model described above explains why minimum edge angle increases and maximum width/thickness decreases with the increasing amounts of retouch on edges. However, it does not explain several other significant features of the distributions seen in figures 6 and 7. Minimally retouched edges have wide ranges of values for both edge angle and relative width. Also, the maximum angle of retouched edges in figure 6 (85°–95°) and the minimum relative width for retouched pieces in figure 7 (width/thickness = 1) remain relatively constant, regardless of retouch intensity. These patterns of variability can be explained by discard behavior. The

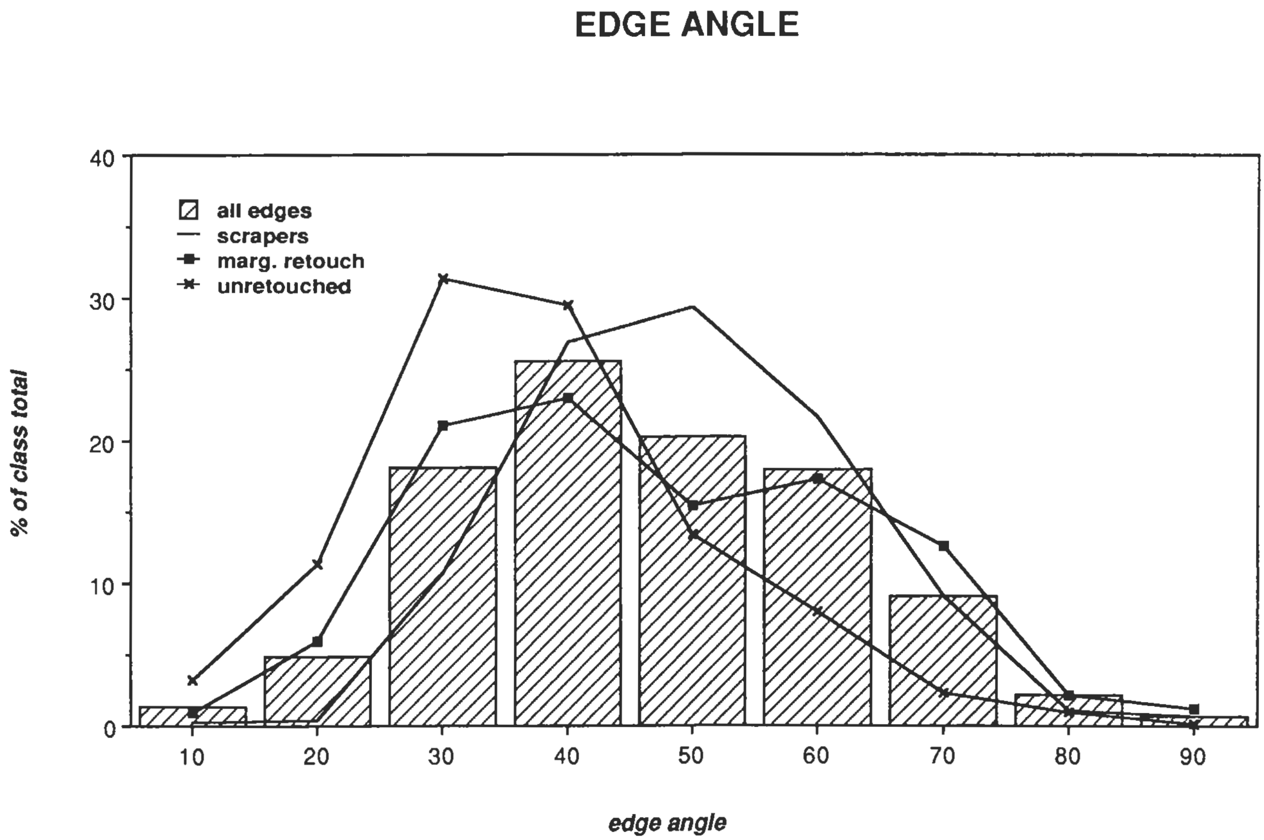


Fig. 5

Frequency distribution of variability in edge angles for sidescraper edges, marginally retouched edges, unretouched edges and combined group of retouched and unretouched edges

maximum edge angle in figure 6 represents the point at which edges become too steep to remain useful for most activities, no matter how much they are retouched. Likewise, minimum relative width in figure 7 indicates the point at which pieces become so narrow and thick that they are discarded.

In other words, with respect to edge angles, edge rejuvenation will only be taken to the point that the angles become too steep to be considered usable, at which time the edge will be abandoned. Subsequently, another edge on the same piece may be used or the piece may be discarded. For pieces with initially steep edge angles, this point is reached with only minimal resharpening, while pieces with initially acute edges can undergo considerable edge maintenance before reaching this point. However, these latter pieces, with a potential for considerable resharpening, also may be discarded before their edge angles reach such a discard controlled limit. The more these edges are resharpened, of course, the closer they approach to the maximim edge angle considered usable. This results in a wide range of variability for the angles of minimally retouched edges, an increasingly restricted range for more intensively retouched edges and a maximum value for edge angles that remains relatively constant regardless of the amount of retouch edges experience.

Likewise, pieces initially close to the minimum usable relative width will be only minimally resharpened at most. While wider and thinner flakes have the potential for undergoing considerable edge rejuvenation, they too may be discarded prior to experiencing the maximum resharpening acceptable. The result, again, is a wide range of variability in width/thickness for minimally retouched edges, more restricted variability for heavily retouched edges and a constant minimum value of width/thickness.

This model is schematically summarized in figure 9. The top row represents wide flakes with acute edges and the lower rows represent increasingly narrower pieces with steep edges. Note that all pieces are discarded when they reach an equivalent maximum edge angle. However, there is a greater potential for variability in the edge angle and relative width of discarded pieces that are initially wider and thinner than for thick, narrow flakes.

In addition to the edge rejuvenation/discard limit model, another process affecting variability in edge morphology is suggested by the relationship between edge angle and the linear extent of retouch along piece margins (fig. 10). It is apparent from the scatter plot in figure 10 that increasing length of retouch is associated with steeper minimum edge

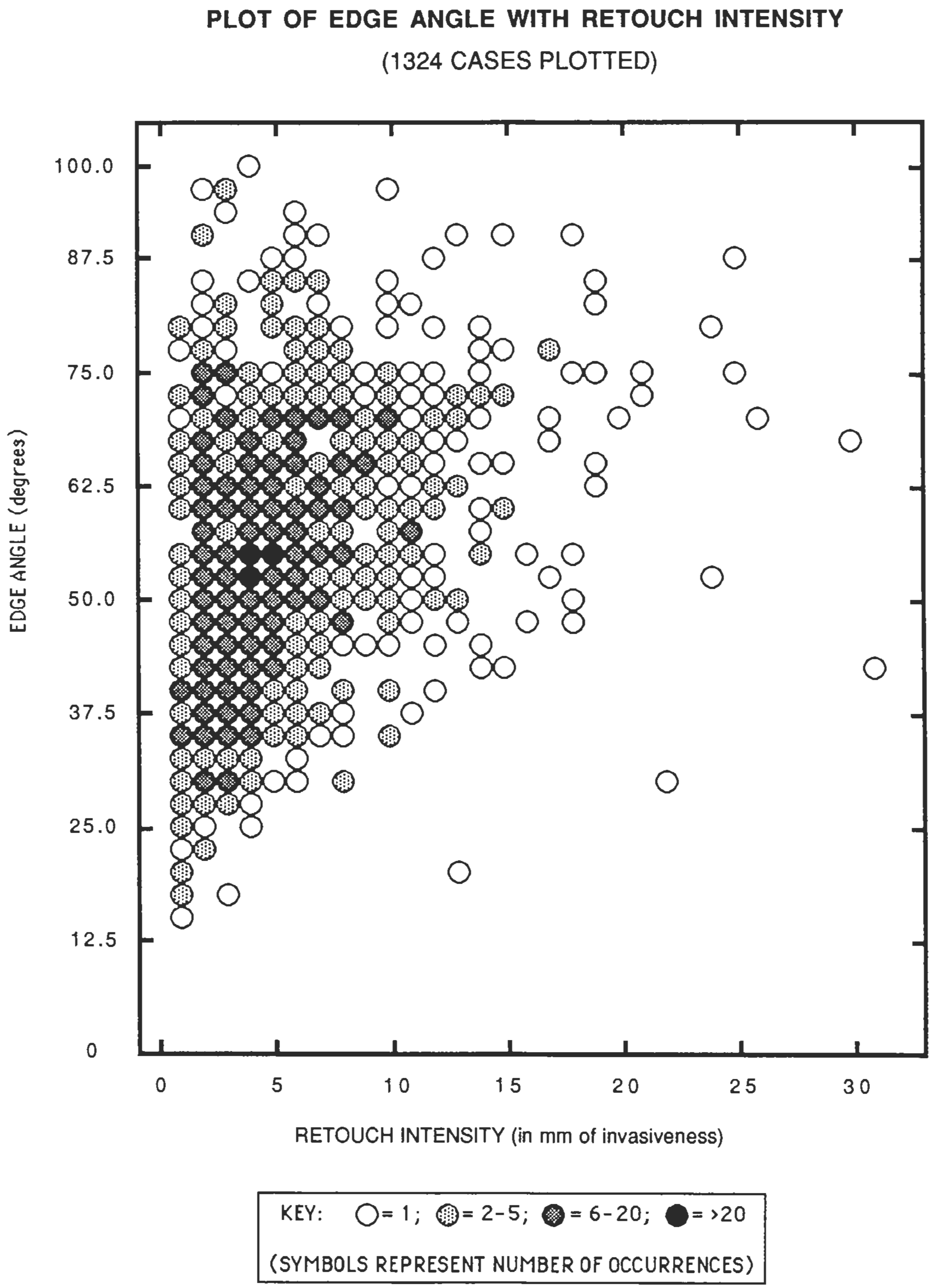


Fig. 6

Scatter plot of edge angle vs. retouch intensity (measured by invasiveness) for all retouched edges

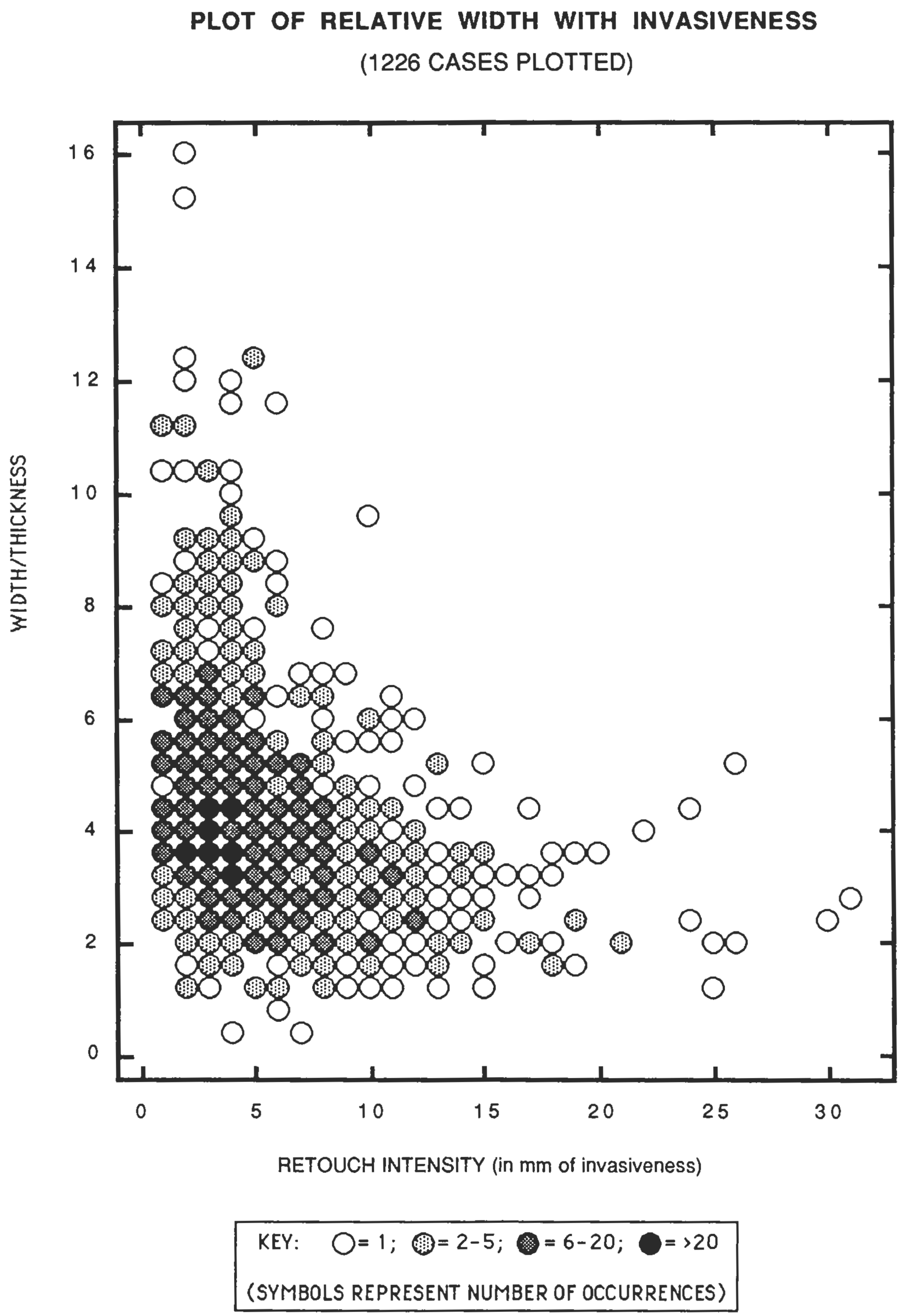


Fig. 7

Scatter plot of relative piece width (width/thickness) vs. retouch intensity (measured by invasiveness) for all retouched edges

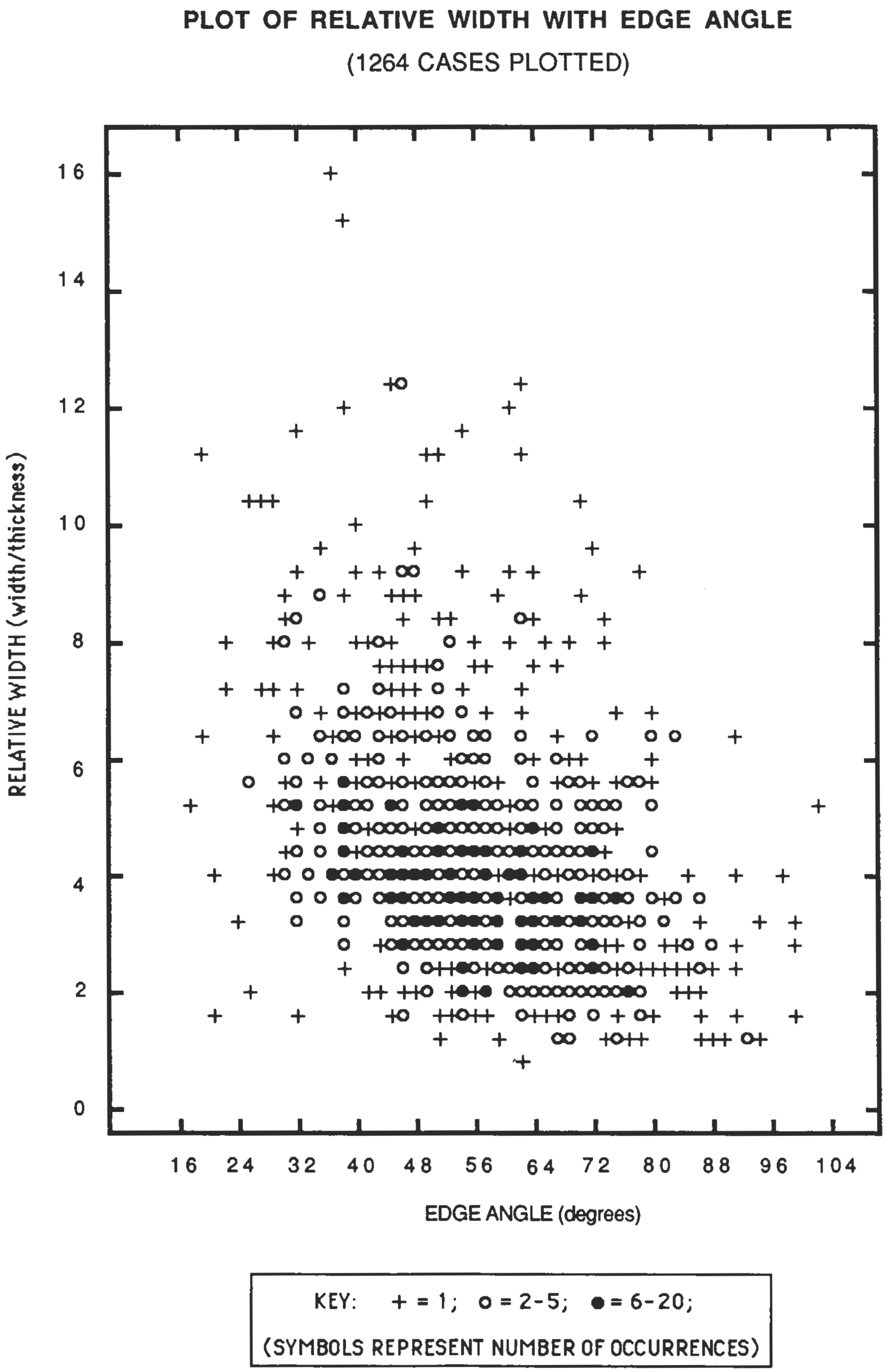


Fig. 8

Scatter plot of relative piece width (width/thickness) vs. edge angle for all retouched edges

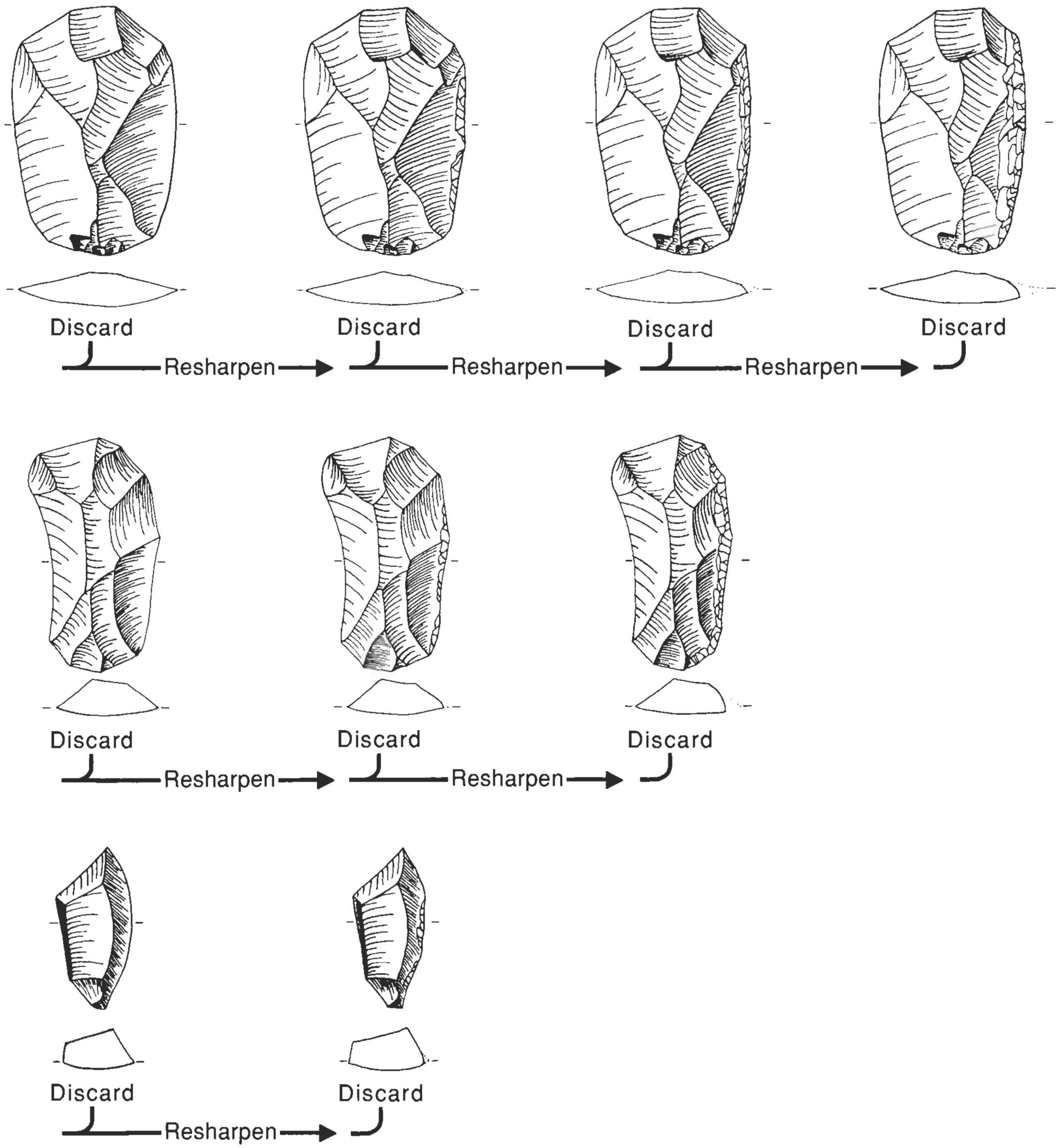


Fig. 9

Schematic representation of rejuvenation/discard model for idealized flake artifacts. The top row represents relatively wide flakes with acute edges. These can undergo considerable edge rejuvenation, but also may be discarded prior to experiencing the maximum resharpening possible. Although a maximum usage edge angle has been reached on the right-most piece of the upper row, it is wide enough that a second edge could be used and resharpened. The bottom row represents narrow, thick flakes with steep edges. With only minimal edge rejuvenation, such pieces soon become too narrow and their edges too steep to be used further. The center row represents flakes intermediate in width and edge angle. The maximum edge angle permitted is equivalent on all pieces angles as well as a more restricted range of edge angles. Maximum edge angle also varies, however, declining from about 95° for the shortest retouch edges to about 65° for those with the longest extent of retouch. If the maximum edge angle reflects the point at which pieces are discarded because their edges are considered too steep to be desirable, these data suggest that edges on which use and rejuvenation are linearly extensive reach a limit much sooner than edges on which retouch is concentrated in short segments. That is, among the assemblages studied, the longest edges are discarded when their edge angles reach about 65°, while the shortest edges may have edge angles up to 95° before they are discarded.

This appears to represent two different patterns of edge use. With one pattern, edge use and associated resharpening take place along a significant segment of a piece perimeter, the entire lateral margin of a flake for example. The more the edge is used and rejuvenated, the longer the zone of retouch becomes. As indicated above, rejuvenation also is accompanied by an increase in edge angle and a decrease in relative width. Eventually a point is reached where the piece is discarded. On those edges where considerable resharpening is possible, retouch can be relatively extensive. Pieces classified as side scrapers are the most common examples of pieces which have experienced an extensive pattern of use and resharpening. Edges exhibiting this pattern of use are found on the majority of pieces in the assemblages studied. Based on the attribute distributions discussed above, such pieces are quite likely non-specialized and multi-functional.

Alternatively, use may be concentrated on a limited edge segment. In figure 10, maximum edge angle increases with a decrease in the length of retouch. That is, steeper edge angles are permitted on increasingly shorter lengths of retouch. This suggests a pattern in which use and rejuvenation are concentrated in increasingly restricted areas of piece perimeters. Notches exemplify such edge use. With continued use, a notch will deepen and narrow, and any associated modification (including edge damage from intensive use as well as intentional resharpening) is thus concentrated in an increasingly restricted area of the margin. Apparently the upper limit of edge angles considered usable is considerably higher for edges exhibiting a concentrated use pattern compared with those exhibiting an extensive pattern. Among the assemblages studied, edges with concentrated use are much rarer than those with extensive use and may be associated with a more limited suite of activities.

An analogous dichotomy in edge morphology has been noted by Roland (1981), Dibble (1988) and Jelinek (1988) who see Mousterian lithics as primarily divisible into a scraper group and a denticulate/notch group. Dibble and Jelinek also suggest that denticulates may simply represent edges used repeatedly as notches. Although denticulates are relatively rare in the assemblages studied here (considerably less than 10% of the formally retouched tools — i.e. essential count — for all assemblages except Gorham's Cave level G (Barton 1988, tables 4.4 and 4.5)) they are more similar to notches than scrapers with respect to edge angle and invasiveness (table 1). This would lend support to the idea that these two artifact types are manifestations of the same concentrated pattern of edge use, their difference being due to the degree to which piece margins were reused in this way.

TABLE 1: COMPARISON OF SCRAPER, NOTCH AND DENTICULATE EDGES FOR EDGE ANGLE AND INVASIVENESS

		Descriptive statistics	
Edge type		*Edge angle*	*Invasiveness*
Scrapers	$\bar{X}$	53.7°	5.8 mm
	σ	12.0°	2.9 mm
	n	812	814
Denticulates	$\bar{X}$	62.4°	6.7 mm
	σ	8.9°	3.3 mm
	n	54	54
Notches	$\bar{X}$	66.3°	6.3 mm
	σ	12.8°	3.9 mm
	n	93	93
		T-Test of means	
Edge type		*Edge angle*	*Invasiveness*
Scrapers and denticulates	T	128.1830	3.7430
	α	$<<0.001$	<0.001
Notches and denticulates	T	6.7590	1.2142
	α	<0.001	>0.1

It should be noted that extensive and concentrated patterns of edge use are not limited to scrapers and notches. As indicated above, many denticulates may represent the recurrent concentrated use of a single edge. Other denticulates, however, may simply be heavily and coarsely resharpened extensively used edges. Pieces classified as Mousterian points, limaces, end scrapers and backed knives generally also would fall into the extensively retouched group. Those typed as end scrapers, piercers or borers, truncations and marginally retouched pieces could be grouped into either category depending on the extent of retouch.

Furthermore, these two patterns of edge use are not mutually exclusive. As noted above, there is continuous variability in all relevant attributes (e.g. length of retouch, edge angle, invasiveness) and, as is apparent in figure 10, these two patterns are not discontinuous. Significantly, a few edges showed evidence of both concentrated and extensive patterns of edge use. For example, 79 extensively retouched edges also included sections that would be classed as notches.

Multivariate analysis. It is apparent from the discussion above that variability in Middle Paleolithic artifacts is manifest in a variety of morphological features and results from the sometimes complex interactions of a suite of human behaviors associated with manufacture and use. Factor analysis provides one way in which such complex variability can be simplified and made more interpretable. In the method used here, a principal components analysis was applied to a group of attributes to produce a reduced set of new variables, or components, that account for the variance in the original variables (Davis 1973, 478–500; Nie *et al.* 1975, 465–73) The components derived were subjected to a varimax rotation to produce orthogonal factors. A three factor solution (with

TABLE 2: FACTOR ANALYSIS RESULTS

Rotated factor matrix			
Variable	*Factor 1*	*Factor 2*	*Factor 3*
Piece length	.86785	.23721	−.03310
Total retouch length	.82161	.06700	.07891
Piece perimeter length	.71945	.52471	.08704
Total step flaking	.57739	−.22374	.34262
Piece width	−.01062	.87363	.08837
Piece breadth	.23660	.80137	.11818
Mean invasiveness	.07540	.11514	.74324
Mean edge angle	−.01584	−.04247	.69772
Piece thickness	.18642	.21315	.68860

Factor	*Eigenvalue*	*% of variability explained*	*Cumulative % explained*
1	3.14374	34.9	34.9
2	1.42204	15.8	50.7
3	1.32967	14.8	65.5

eigen-values above 1.00) accounted for 65.5% of the variability in the artifacts measured (table 2). These factors appear to support the interpretations of lithic variability suggested above.

The first factor is composed primarily of piece length, the total length of retouch and the total length of piece perimeters. This seems to reflect variability between extensively utilized edges and those with concentrated use. Piece length, extent of retouch and total perimeter length are associated in a fairly straightforward manner. Extensively retouched edges are only possible on pieces with extensive perimeters, which tend to be longer peices. Width contributes most strongly to the second factor. As discussed above, width (relative to thickness) is both affected by and partly determines the intensity of edge use and subsequent rejuvenation. Other studies (e.g. Dibble 1987) have also suggested that flake width is an important determinant of the extent to which edges may be resharpened prior to discard. The most significant contributors to the third factor are invasiveness, edge angle and thickness. This grouping seems to reflect the degree to which edges were resharpened and, hence, the intensity of edge use.

In summary, retouched 'tools' seem more likely the end result of the extent and nature of the use on their various edges than planned tools for which the maker had some form of 'mental template'. In turn, primary factors contributing to variability in edges are the dimensions of the original flake used, whether edge use was extensive or concentrated, and the intensity of edge use and subsequent rejuvenation.

Assemblage variability and settlement

The preceding discussion presents a set of models for interpreting morphological variability in chipped stone tools. These models are useful for reconstructing Middle Paleolithic behavior related to the production and use of these artifacts. At a broader scale, these models also can be applied to regional variability among assemblages. Assemblages from nine Iberian peninsula sites are examined in this way, focusing on Middle Paleolithic settlement strategy and its response to environmental change. The sites include the four whose collections were studied in detail and are discussed above and five additional sites from eastern and south-eastern Spain (fig. 1) for which published data are available.

Published lithic data from these additional sites are primarily in form of the relative frequencies of Bordesian tool types within each assemblage. However, frequencies of certain types can indirectly reflect edge variability. For example, the frequency of side scrapers among retouched pieces (indicated by scraper index, or 'IR', in typological studies) closely mirrors the frequency of extensively retouched edges, while the frequency of notches, along with piercers and burins, reflects the frequency of edges with concentrated retouch and distinctive shapes (Barton 1988, 84–88). Additionally, published descriptions of these assemblages include information more directly comparable with that of the edge study described above, including the frequency of marginal and invasive retouch and the frequency of steeply retouched edges.

Two further measures of assemblage variability were examined for the nine sites. The fraction of an assemblage exhibiting retouch provides a measure of the overall intensity of use of lithic raw material (Rolland 1977; 1981). Also, the density of lithic artifacts per cubic meter of deposit was calculated where possible. After differences in sedimentation rates are taken into consideration, artifact density provides additional information about the nature of lithic use and site occupation.

Geographic contexts. The sites are associated with geographically and environmentally distinct settings. Salt, Pastor and Cochino are located in the eastern mountains of the peninsula at elevations of 600–800 m. At an elevation of 850 m, Cueva de Carigüela is in the Sierra Harana, a member of the south-eastern mountain group that also includes the Sierra Nevada. Cova Negra and Cova Petxina also are located in the eastern coastal mountains, but closer to the Mediterranean and at lower elevations (*c.* 100 m). Cueva del la Zájara (elevation, 111 m) is located along the south-eastern coast, while Gorham's Cave and Devil's Tower are a few meters above sea level along the southern coast, in Gibraltar.

All the sites are rock shelters or caves. While almost certainly this is not representative of the range of Middle Paleolithic settlements, *in situ* open sites are little known in this region and even less studied. The walls of caves and shelters constrict the horizontal distribution of cultural materials and tend to encourage the regular superimposition of occupational residues in stratigraphic sequences of assemblages. In spite of the fact that such assemblages probaby represent accumulations of artifacts discarded over unknown time spans rather than residues of single occupations by coherent social groups, they still provide information about variation in artifacts and associated human behavior within the context of space, time and environment.

Temporal contexts. Deposits at Cova del Salt seem to span both the early last glacial (oxygen isotope stages 5d–5a, *c.* 118,000–75,000 BP) and pleniglacial (stages 4–2, *c.* 75,000–10,000 BP), based on sedimentological and faunal evidence. However, cultural material at the site appears to be restricted to the early glacial, after which time the site was abandoned. The assemblage from Cova del Pastor is of more questionable chronological context, but may be associated with the middle pleniglacial (stage 3 *c.* 60,000–40,000 BP) (Barton 1988, 19–28).

Deposits at Cova Negra have been assigned by Villaverde (1984, 168–75) to the last interglacial (stage 5e, beginning at *c.* 128,000 BP) through the early pleniglacial (stages 4 and 3) on the basis of sedimentological evidence. However, cultural material has been found only in strata deposited after the last interglacial.

On the basis of sedimentological data and radiocarbon dates, Gorham's Cave deposits appear to span the last interglacial through the recent (oxygen isotope stages 5e–1). Sedimentological evidence also suggests that the artifact bearing deposits at Devil's Tower range from the last interglacial through the first part of the last glacial episode (stages 5e–3) (Barton 1988, 40–48).

Stratigraphic sequences of Middle Paleolithic assemblages also are present at the other four sites, but their temporal placement within the early Upper Pleistocene is considerably less certain (Barton 1988, 89–95).

Paleoenvironmental contexts. The reconstruction of the paleoenvironmental contexts for these assemblages can only be accomplished at a relatively gross scale and is based primarily on sediments and faunal remains from the four primary sites of the study and Cova Negra (Barton 1988, 17–55). Still, environmental variability in both space and time is apparent.

In upland areas, environments of the early glacial seem to have been relatively mesic, though not identical to those of today. With time, however, there is evidence for increasingly colder temperatures, changes in the amount or distribution of precipitation, and an altitudinal decline in life zones with associated changes in the distributions of fauna and flora.

Lower elevations, and especially coastal areas, seem to have experienced considerably less extreme fluctuation than the uplands during the Upper Pleistocene. However, eustatic fluctuations in sea level altered the land area available to Middle Paleolithic hunter-gatherers at coastal sites. Additionally, fluctuations in effective or absolute precipitation seem to have occurred. Changes in temperature and in the composition of the fauna seem to have been minimal for the Gibraltar sites and more marked at the slightly higher elevations of Cova Negra and Cova Petxina.

Settlement strategies. Both environmentally and on the basis of similarities in their lithic assemblages, the nine sites fall into an upland group, at locations more than 600 m above sea level, and a lowland group, at locations less than 150 m above sea level (fig. 1). The upland sites include Cova del Salt, Cova del Pastor, Cueva del Cochino and Cueva de Carigüela. Gorham's Cave, Devil's Tower rock shelter, Cova Negra, Cova Petxina and Cueva de la Zájara I comprise the lowland group.

In general, assemblages from upland sites tend to have higher frequencies of scrapers among retouched pieces (mean IR = 70.9, n = 14 assemblages), compared with assemblages from lowland sites. However, there are fewer retouched pieces relative to unretouched pieces ($\bar{X}$ = 13.2%, n = 32), and retouch is less intensive on those pieces where it does occur. Finally, overall lithic densities are comparatively high ($\bar{X}$ = 320.9 pieces/m^3, n = 7). Lithic raw material does not outcrop at Cova del Salt and is not reported to outcrop at the other upland sites.

While there is greater variability among the assemblages of the lowland sites, there is still a general tendency toward lower frequencies of scrapers (mean IR = 62.9, n = 21) and more pieces with concentrated retouch or with distinctive edge shapes such as notches, piercers and burins ($\bar{X}$ = 12.1%, n = 21 for lowland sites vs. $\bar{X}$ = 6.0%, n = 14 for upland sites). Retouched pieces also exhibit a more intensive degree of modification and are more frequent in most of these assemblages ($\bar{X}$ = 44.3%, n = 18). This does not include Gorham's Cave, however, in which retouched pieces make up a mean of 1.0% over 12 assemblages. However, this low frequency may be explained by factors of raw material availability (Barton 1988, 102–103). Finally, there are considerably lower overall densities of lithic artifacts in the deposits of these sites ($\bar{X}$ = 24.2 pieces/m^3, n = 19) than can be accounted for solely by variation in sedimentation rates between upland and lowland sites (Barton 1988, 108). With the exception of Gorham's Cave, where quartzite beach cobbles occur in frequency at the site (Barton 1988, 102–103), availability of lithic raw material seems analogous to the upland sites.

These patterns suggest that upland and lowland sites played different roles in Middle Paleolithic settlement strategies. In one possible model, upland sites represent short-term occupations within a system of residential mobility and a forager mode of subsistence (Binford 1980). Considerable settlement mobility would permit regular replenishment of lithic raw material while short-term occupations of the sites would not necessitate intensive use of this resource. Hence, there would be a tendency toward the production of new flakes rather than resharpening of used ones. This, along with repeated visits to the sites, would encourage the deposition of denser quantities of lithic debris, relatively little of it modified. Finally, the short-term, relatively unspecialized occupations, typical of a forager strategy, might encourage the use of fewer, multipurpose edges (e.g. 'scrapers' and marginally retouched flakes) rather than a larger number of more specialized edges.

Lowland sites, on the other hand, would represent less frequent but longer occupations more characteristic of logistic mobility and a collector subsistence strategy (Binford 1980). The supply of stone would be replenished less frequently, encouraging conservation of this resource through edge maintenance or resharpening. There would be a greater tendency to rework a used edge rather than strike a new flake. This would produce lower lithic densities in site deposits, but more evidence for intensive use of the pieces that are present. The need to use sub-optimum pieces (e.g. broken flakes and shatter) in order to conserve lithic resources might also be expected to produce a wider diversity of edge configurations. Furthermore, the greater variability in edge morphology apparent in assemblages from these sites also may be indicative of the wider variety and more specialized nature of the activities that characterize the logistic base camps of collectors.

These different settlement strategies are probably linked to spatial and seasonal variations in the distributions of plant and animal resources and to the distribution of inorganic features of the landscape such as water, suitable camp sites and usable stone. Temporal and spatial variability in the fauna represented at Cova del Salt, Cova Negra and the Gibraltar sites are suggestive in this respect (Barton 1988, 29–34, 50–52). Unfortunately, there are insufficient data at this juncture to propose specific differences in the distribution of resources or their utilization that may be the source of this patterning.

While upland and lowland sites may represent either different, possibly seasonal, aspects of a single type of settlement pattern or two distinct adaptive strategies, diachronic variability in lowland assemblages seems to favor the latter possibility. Assemblages at lowland sites become more similar to those at the upland sites through time, showing trends towards lower amounts of retouch in assemblages, higher lithic densities and less morphological variation with more extensively retouched edges. This may be a reflection of the way in which Middle Paleolithic hominids adapted to environmental change. With the approach of the full glacial, lowland areas experienced changes in temperature and precipitation and a concomitant decline in life zones, becoming environmentally more like upland regions of the early glacial. The inhabitants of these areas may have altered their settlement strategies toward an upland pattern as a means of coping with these changes.

DISCUSSION

While it is apparent that the scenario presented above remains more an hypothesis to be tested than an explanatory model, it illustrates the type of questions that can be posed by taking a non-traditional approach to the chipped stone artifacts that comprise the primary data base for the study of Paleolithic hunter-gatherers. Rolland's (1977; 1981) study of large-scale distributional patterns for Middle Paleolithic assemblages and Dibble's (1984; 1987; 1988) work with traditional Mousterian tool classes are further examples of such an approach. Although derived from different avenues of research, taken together, these investigations represent a growing consensus about the nature and behavioral significance of Middle Paleolithic assemblages (see also Jelinek 1988). This view differs considerably from the assumptions about the significance of variability among Middle Paleolithic chipped stone artifacts that are common to both sides of the Mousterian debate and seems potentially more productive than many previously advanced explanations of lithic variability (see Barton 1988, 99–110). It is useful to summarize the aspects of lithic assemblages derived from this approach.

(1) Variability in Middle Paleolithic retouched artifacts is primarily continuous. In most cases, traditional tool types, such as those defined by Bordes, represent arbitrary divisions of this continuous variability rather than morphologically distinct artifact groups that might be associated with specific tasks or styles. For the assemblages studied here, as well as Middle Paleolithic assemblages elsewhere in Western Europe (Dibble 1988; Jelinek 1988; Rolland 1981) it appears that most artifacts can be divided into two broad 'tool' classes. One class consists of artifacts exhibiting an extensive use pattern and includes various side-scraper types in traditional lithic systematics. The other class is those with concentrated use, including notch and denticulate types. Differing amounts of edge use and rejuvenation within these classes account for most observed variability in Middle Paleolithic assemblages.

(2) Continuous morphological variability is not limited to retouched pieces. Retouched 'tools' and 'debitage' simply represented opposite ends of a continuum, associated with the intensity of edge use and subsequent rejuvenation.

(3) Rather than being the static product of a preconceived mental template, lithic morphology is more often dynamic and can change during the use life of an artifact. Factors that can affect morphology include original flake dimensions, extensiveness of margin use, intensity of edge use and associated edge maintenance, availability of raw material and intensity of site occupation. This is not to imply a lack of planning for lithic artifacts on the part of Middle Paleolithic hominids. However, this planning may be more associated with the production or selection of unretouched flakes than the subsequent modfication of these flakes through retouch (Fish 1979, 133–35; Rolland 1981).

(4) As both a cause and result of such morphological dynamism, lithic artifacts often may be multifunctional over the course of their use lives. The effect of this is that the morphology seen by the archaeologist will only clearly reflect the last use made of a piece. This has been termed the 'Frison effect' (Jelinek 1976) after Frison's (1968) pioneering study of an assemblage from a North American Paleoindian kill site.

(5) Virtually all lithics found at sites are discards. That is, they entered the archaeological context because they were no longer of value to the makers and users. Some pieces were discarded after minimal or no use, while others experienced considerable reworking prior to discard. The form of a chipped stone artifact recovered at an archaeological site may be as much or more a function of the point in its use-life at which it was discarded than the uses to which it was put or the

cultural identity of its maker. Recognition and interpretation of such variability in discard behavior is a vital part of using lithic assemblages to provide information on past human activities and organization.

These characteristics of Middle Paleolithic assemblages have significant implications for Paleolithic archaeology. They may in part explain why, after more than a century of concerted study, we still know so little about Pleistocene hunter-gatherers. We have been asking inappropriate questions of our primary data base. Studies of Paleolithic assemblages have focused primarily, if not exclusively, on retouched tools while the major thrust of such studies has been the identification of social groups and/or the reconstruction of the relative importance of different activities.

The current study and similar ones mentioned above strongly suggest that there is often a lack of simple form/function or form/culture relationships for chipped stone artifacts. Retouched tools in particular will tend to have complex life histories from which specific functions or stylistic elements may be difficult to extract. However, these lithic artifacts with the most confused life histories have formed the basis of virtually all interpretations of past activities and social organization, especially for studies with a primary typological focus. Conversely, until recently, the great bulk of chipped stone assemblages, including those with the simplest — and, hence, the potentially most readily interpreted — life histories (i.e. debitage) have been largely ignored.

This does not mean that lithic artifacts are of little interpretive value in Paleolithic archaeology. As is illustrated above, chipped stone in general and retouched tools in particular, can play a useful role in providing information about settlement systems and related behavioral patterns such as intensity of site occupation, degree of mobility and intensity of raw material use (see also Clark 1989; Hayden 1987; Henry 1989; Jelinek 1988; Roland 1977; 1981). However, the specific activities that took place at sites, may be better inferred through such techniques as refitting (i.e. core reconstruction) and microwear studies of utilized but unretouched 'debitage' than from morphological studies of retouched 'tools' (for example, Cahen *et al.* 1979).

The identification of discrete cultural groups on the basis of lithic variability appears to be considerably more difficult due to the characteristics of such assemblages pointed out above. This is exacerbated by difficulties in identifying assemblages derived from single occupations by such discrete groups and problems of establishing contemporaneity between assemblages at different sites to even the generational level.

The behaviors associated with the production and use of chipped stone that are suggested in the preceding discussion do not seem limited to Neandertals, and may apply to lithic technology in general (Clark 1989; Henry 1989; Gould *et al.* 1971). If so, this research may have wider applicability, beyond the Middle Paleolithic, to any society for which chipped stone artifacts constitute a primary archaeological data base. It underscores the importance of incorporating information about processes of production, use and discard into interpretations of these lithic artifacts. By so doing, it is hoped that this work can contribute both to a better understanding of these ubiquitous indicators of the human past and of the hominids who made them.

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