CONTRIBUTIONS
OF THE
UNIVERSITY OF CALIFORNIA
ARCHAEOLOGICAL RESEARCH FACILITY

Number 42 **December 1979**

METHODS IN ARTIFACT ANALYSIS: A STUDY OF UPPER PALEOLITHIC BURINS

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I. Paleolithic Burins and Artifact Analysis

The oldest examples of burins, nearly two million years old, have been identified by M. Leakey in the earliest Oldowan industries found in East Africa (1971:7). From that epoch until the end of Paleolithic times burins were made by prehistoric craftsmen in Africa and Europe. The older examples are variable and poorly standardized, so that in some cases it is even doubtful whether the burin was formed intentionally. Towards the end of the Pleistocene, however, and in the Upper Paleolithic especially, we have evidence of the greatest development of burins, both in their diversity of forms and in their degree of standardization. Stone industries such as the Perigordian and Magdalenian in France are rich in burins; and these tools predominate in the Magdalenian assemblages.

By the end of the Pleistocene burins are also a common, though less highly uniform, tool shape in North America and Asia. J. Epstein maintains that burins found at the Levi Site in Central Texas, dated at 10,000 ± 125 years B.C., are the oldest New World burins. Epstein believes their technological roots were in Asia, where burins have been dated as early as 13,000 B.C. (1963:194).

Recognition of burins in paleolithic assemblages throughout the world evidences the regularity of certain characteristics that we use to define these tools, as well as their probable, numerous uses in paleolithic cultures. The functions of burins, and their significance in prehistoric economies are two main questions of burin research. Yet because we must of necessity deal with inanimate materials from remote time periods our interpretations of prehistoric lifeways must remain somewhat speculative. We can, however, examine the validity of our inferences about the significance of burins as prehistoric records. By appraising the questions we ask and the methods we use to try to answer them, we can reveal certain problems of artifact analysis, be they limitations of stone tools or of analytical methods. Such understanding will delimit the scope of meaningful interpretations that we can deduce from paleolithic burins.

This paper focuses on the relationship between the behavior of the prehistoric artisan and the prehistorian. We will study burins as references for the artisan's behavior, considering them as end products of a series of mental and physical tasks performed by the prehistoric toolmaker. Assuming that the burin was the toolmaker's response to certain needs, what were his possible choices when he conceived, fabricated, and used the burin? The process can be schematized as follows:

ARTISAN'S NEEDS: a tool for shaping bone or wood;

ARTISAN'S CHOICES: for instance, to use a raw flake, or scraper, or burin;

ARTISAN'S DECISION: to make and use a burin:

a) choice of one of the fundamental burin techniques and a detailed form;

b) choice of a specific application.

Based on this theoretical chain, I will examine the methods by which archeologists infer meaning from stone artifacts. How does the burin express any of the decisions or actions of the prehistoric craftsman? Keeping in mind the main topics of this study, the nature of the artifactual data, and the nature of our models and methods, burins can be investigated in the following manner:

ARCHEOLOGIST'S QUESTIONS:

1) Given a particular task, what are the relative efficiencies and "predictabilities" of the tool forms from which the artisan can choose?

2) Having chosen to make a burin, are all the burin techniques equally "easy"? Are the resultant forms all equally predictable, given the specific raw materials?

3) Are the burins resulting from each technique equally suitable for all tasks? Or are some forms better suited for some tasks; for example, are dihedral burins better for grooving and break burins better for shaving?

ARCHEOLOGIST'S OPERATIONS:

1) Burin Typology and Attribute Analysis: what are the consistent intrinsic, or arbitrary, differences among burin forms, and to what degree are these differences due to choices for specific forms or techniques?

2) Experimental Burin Replication and Utilisation:

a) what are the mechanical contingencies in burin manufacture?

b) what are the functional implications, if any, of the different burin forms and/or techniques?

Thus, in sketching the relationship between the assumed behavior of the prehistoric artisan and the analytical operations of the archeologist, I hope to make explicit some of the branching pathways of logic that are involved in pursuing various anthropological objectives; and hence, at least to make apparent some of the methodological choices that should be confronted.

Assumptions

Several assumptions are made when formulating models to explain the intrinsic nature and cultural significance of stone artifacts. First is the assumption that all cultural behavior is rationally patterned (Binford and Binford 1969; Ascher 1961). This is not to say that all human behavior is rational, but that human adaptations to the environment, including technological implementations, resulted from a sequence of rationally patterned activities. We also logically assume that the transmittance of cultural beliefs, traditions, and technologies, both amongst individuals and through time, was a rational human process. This implies that there are conceptual, or cognitive, likenesses between prehistoric and modern men. To extend this axiom, we assume that the nature of humans to reason and to act self-consciously, and to apply these cognitive abilities to technological problems, is an essential character of humans, at least since the emergence of *Homo sapiens sapiens* some 40,000 years ago.

Thus, experiments in tool manufacture and utilization can be considered as reasonable replications of the probable activities of prehistoric men. Work by persons such as F. Bordes and D. Crabtree have emphasized experimental reproductions of stone tools to understand what stone tools may indicate about the probable mental and technological steps followed by the prehistoric artisan (Bordes 1965; Crabtree 1975).

Second, and contingent on the first, we assume that "artifacts produced from the same scheme or used according to the same scheme exhibit similarities which permit their division into groups which reflect those schemes" (Ascher 1961:806). More simply stated, we assume that stone artifacts can be classified to reveal the design norms and/or functional categories probably employed in paleolithic cultures. It follows that morphological typologies, which describe the variations in stone tool forms, may serve as a means of describing and comparing variation in cultures through time and space. That is, that typologies may enable us to recognize, among other things, culture historic and culture geographic entities. Clearly, they may also permit the recognition of intra-cultural groups or activities.

In artifact analysis we are concerned with the validity of the analytical methods and the probability of the results. We gain confidence in our inferences by correlating them with evidence found in ethnographic studies and alternative testing methods, and, as archeological research advances, in the plausibility of our prehistoric reconstructions. Yet what actually happened in paleolithic times, we must admit, remains distant from the methods or aims of prehistory. Instead, we pursue those avenues of investigation that will continue to expand the scope and credibility of the prehistoric picture we recreate.

Methods

To most archeologists description and classification of stone artifacts logically occurs as the first step in analysis. Tool forms are divided into categories. These categories may be defined in terms of clusters of items that resemble each other, or on the basis of the existence of one or more characteristic features. In practice these two procedures overlap. Most typologies have involved intuitive recognition of categories, but recently more attention has been paid to making the criteria and logic of typological methods more explicit.

Typology is based on the assumption that the majority of paleolithic artifacts represent "ideal" tool forms conceived by the prehistoric craftsman to meet his technological needs. "What counts, what is new for each major epoch is the conception of the tool" (Bordes 1947:28).* The "ideal type", defined by D. de Sonneville-Bordes, is "the greatest possible number of characters that are found coexistent on the greatest possible number of artifacts" (1966:4).** Thus, based on our knowledge of lithic technology and variations in tool forms, we intuitively isolate all the possible technological and morphological characters that seem essential and constant. By correlating the greatest number of characters within arbitrary, yet seemingly distinct, limits of morphological variability, we place the defined artifact into a type category that presumably represents the prehistoric type. The classified tools can then be ordered by the "méthode Bordes" to describe statistical variations of tool types within assemblages, and to suggest unique cultural traditions (Bordes 1950).

Descriptive classifications, like those produced by Bordes (1961), de Sonneville-Bordes/Perrot (1954-6), and Tixier (1963), have often been criticized for their subjective, arbitrary nature. Morphological typology, it must be emphasized, is descriptive by nature, and does not attempt to analyze technological or functional aspects of stone tools. Various type names like side scraper or burin should not impose assumed functions on the tool, although they often suggest such interpretations. A common, widely-agreed upon set of definitions for stone tools permits archeologists to communicate at least a summary of their artifactual data to others.

The most important criticism of typology is not that it is descriptive instead of interpretive, but that the types determined by the prehistorian may not necessarily be valid indications of the types actually conceived by the prehistoric person (Ford 1954; Rouse 1960; Clarke 1968, 1972). Because informed intuition plays the major role in determining the "ideal" type to which each tool conforms, typology should be regarded as a method for comparing tool types and assemblages. The "méthode Bordes", for example, allows us to compare stone industries, and hence to check the utility and accuracy of the typology as a descriptive tool. Finally, because we cannot verify if our classifications would have been meaningful to our prehistoric ancestors, we should not consider typology as a means for indicating real or valid prehistoric tool types.

The artifacts themselves, on the other hand, are "expressions of the ideas and behavior of the people who made them," expressions which fulfilled technological needs in prehistoric cultures (Phillips *et al.* 1951:61). Replicative experiments and quantitative analyses, based on an explicit understanding of artifact morphology, can provide us with insights into likely prehistoric behaviors and economic patterns. Interpretation of artifacts, then, is the second aspect of artifact analysis.

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* Author's translation of: "Ce qui compte, ce qui est nouveau à chaque grande époque, c'est la conception de l'outil."

** Author's translation of: "Le type idéal...est le plus grand nombre possible de caractères trouvés coexistants sur le plus grand nombre possible d'exemplaires."

Four main kinds of information can be recognized: the mode of manufacture (technology); the tool form (morphology); post-manufacture damage, including use damage; and potential tool uses. Attribute analyses are performed to examine patterns of artifact variability that may be culturally significant, that may be expressed quantitatively, and that may not be discernable or explainable by typological methods. Study of lithic technology, examining flaking patterns on paleolithic tools and replicating these forms, reveals the limitations of raw materials and the conceivable procedures and physical constraints of the artisan. Testing stone tools for possible uses on the variety of materials commonly associated with the artifacts in the Paleolithic, such as bone, wood, antler, or stone, can indicate their potential uses or limitations. Lastly, edge-damage analysis of the replicated burins, used for putative paleolithic tasks, tests hypotheses about tool functions, and allows for comparisons with edge-damaged paleolithic tools.

Models

From these descriptive and analytical methods, several models have been devised to write prehistory. G. Isaac (1972) describes three models that generally serve as the basic schemes for interpreting paleolithic artifacts. The first is called a traditional, or phylogenetic model, and is used to compare paleolithic industrial complexes. Using this model we reconstruct a culture history that displays the development and succession of paleolithic cultures. The culture-historical method is based on the assumption that distinctive designs and combinations of designs are particular to human groups that share a common culture or derive from a common cultural "stock". Morphological typology, whereby tool forms are described, defined, and classified, has been the principle method for identifying and ordering prehistoric assemblages.

A second model is a functional, or activity-variant one. Whereas the traditional model considers artifact and assemblage variability only as an indication of differences between cultural entities (limited in time and space), the functional model concerns itself with differences that can arise within one cultural entity. We assume that these variations resulted from differing needs for particular tool forms at various localities where different tasks were performed. Moreover, the emphasis of the functional model is the study of past lifeways: the interaction of prehistoric man with the environment; his behavior and the economy of his culture. Replication experiments, attribute and edge-wear analyses, and comparisons with ethnographic data when available, provide the means for augmenting our understanding of the possible functions of paleolithic tools.

A third model allows for the fact that a proportion of the variation in artifacts and assemblages, which cannot be accounted for by the other explanations, may be best treated as random (Isaac 1972).

While neither descriptions nor analyses of stone tools provide absolute, accurate explanations of artifact variability, or of the lifeways of the paleolithic cultures from which they originated, they do oblige the prehistorian to learn to "read" stone tools, and to investigate the limitations of the data, the validity of his analytical methods, and the plausibility of his inferences.

II. Burin Typology

Definitions

Burin typologies differ from classifications of entire assemblages because they are attempts to characterize only part of the prehistoric toolkit. They cannot be used to make temporal distinctions between assemblages. Such particular burin forms as the bec de perroquet (Magdalenian VI), and the Raysse/Basseler and Noailles burins (Perigordian V) typify certain cultural horizons; but these forms, as temporal indicators, are scarce in the archeological record. Instead, the preponderance of Upper Paleolithic burins exhibit a surprising uniformity over several tens of thousands of years and a wide area. This fact, coupled with the apparent simplicity of burin forms and their assumed functional diversity, seems to have stimulated over 100 years of burin research.

Brézillon (1968) and Movius (1966, 1968) have written useful surveys of the history of burin identification and classification. Yet neither the validity nor utility of the numerous schemas published during this century has been evaluated.

The definitions of the "typical" burin form have varied little in the last 70 years. Basic terms in the definition of the general burin include 1) a sharp bevelled edge; 2) the removal of one, or several, burin spalls, producing the characteristic burin facets; and 3) the resultant dihedral, or trihedral, angle (fig. 1a). It is widely agreed that the burin bit (or biseau in French) is the primary morphological, and hence, discriminatory feature of the tool. Specifying the typical burin facet and dihedral angle as defining terms for the burin, Tixier states: "Only the pieces that possess the trace, clearly visible, of at least one removal, obtained by the burin blow technique, should be placed in the category of burins" (1963:67).*

Movius *et al.* (1968) describe the characteristic burin biseau as the end-product of a two step process. In the first step the artisan either creates a striking platform, or chooses a preexisting surface from which the burin spall or spalls may be removed. Then he removes the spall or spalls by the *coup du burin* technique, thus forming the sharp, burin cutting edge (1968:20).

In order that a general agreement be reached for the definition of the "typical" burin, two recent definitions of the burin form by F. Bordes and H. Movius will be used:

> The burin is a blade or flake showing, most often at the end, one or several dihedral angles formed either by the intersection of two or more removals, of which the orientation is more or less perpendicular to the flat surface of the tool, or by the intersection of one or more removals of this type and a truncated or broken edge (Bordes 1961:32).**
>
> The burin was an all purpose cutting tool....In general, it exhibits a relatively narrow cutting edge, normally mounted at right angles, or nearly so, to the ventral plane (or bulbar surface) of the blank on which the piece is made (Movius *et al.* 1968:20).

One might add to these definitions that the *coup du burin* generally involves a blow

* Author's translation of: "Ne doivent être placées dans la catégorie des burns que les pièces comportant, nettement visible, la trace d'au moins un enlèvement obtenu par la technique du *coup du burin.*"

**Author's translation of: "Lame ou éclat présentant, le plus souvent en bout, un ou plusieurs angles dièdres formés soit par l'intersection de deux ou plusieurs enlèvements dont le plan est plus ou moins perpendiculaire au plan d'aplatissement de l'outil, soit par l'intersection d'un ou plusieurs enlèvements de ce type et d'une troncature retouchée ou d'une cassure."

removing a spall that is detached along the length of the edge, across the thickness of the stone blank, and not from the edge onto the dorsal face as in a normal retouch removal (Some exceptions to this criterion--as in all typological descriptions--are the plane and Raysse burins. Yet, at this point in the study recognition alone of those exceptions should suffice).

As Brézillon notes, classification of burins, unlike the common definition have been numerous this century (1968:166). The classifications have emphasized to varying degrees certain aspects of burin form and technology. They have been based on:

a) the position of the burin bit in relation to the working axis of the support (median, asymmetrical, or lateral burins) (fig. 1b-d);

b) the burin bit in relation to the plane surface (usually dorsal) of the support (plane burin) (fig. 1e);

c) the composition of the burin edge (burin on truncation or break, dihedral burin, multi-facetted burin) (fig. 2a-d);

d) the distinctive shapes of burins (busked burin, burin bec de perroquet) (fig. 2e,f);

e) the form of the support possessing a burin (burin on a flake, burin on a tanged piece) (fig. 2g,h) (1968:167).

Typologies

The first recognition of the burin, though it was neither named as such nor classified, may have been by Lartet and Christy in *Reliquiae Aquitanicae* (1875). They described the formal characteristics of burins found on pieces with end-scrapers on the opposing end. "The small end suddenly tapers to a wedge-shaped point, produced usually by two or more bold lateral fractures, perpendicular to the flat face, and at an angle to the axis of the flake....In either case the pointed end is fit for insertion in a handle" (1875:A. Plate VII, p.23).

Two years later L. Leguay (1877) explicitly mentioned the burins he had found. Searching for stone tools which could have been used to engrave bone, he discovered that burins, often found in the same Upper Paleolithic sites containing engravings, possessed a point strong enough to withstand the energetic grooving activity. He learned through experimentation with burins he had found, and with similar ones he made, that such a pointed tool, like a carpenter's chisel, could have adequately performed the task (1877:285). Thus, in this early example of experimental archeology, Leguay described the significant form and possible function of burins. G. de Mortillet attested to Leguay's discovery: "It is Mr. Leguay who determined the attributes of the flint burin" (Movius 1968:313-14).*

Based on the form and the number of burin facets, Bardon and the Bouyssonies classified the various burin forms from La Grotte Lacoste (1910). They believed that the varieties they distinguished were "perfectly characteristic" (1910:31). Four main types, each presumed to possess one or several unique functions, were distinguished.

Burin Classification, after Bardon *et al.* (1910)	
I. Dihedral	
II. With Multiple Facets	1. Busked 2. Polyhedric 3. Nucleiform or Prismatic
III. Truncation	
IV. Diverse, incl. Break	

This early classification shows how the burin was classified by certain technological features of the burin bit. As J. Tixier says, "the name burin immediately evoques the 'burin

*Author's translation of: "C'est M. Leguay qui a bien déterminé les attributions du burin en silex."

technique', and not the action of engraving" (1963:51).* The name burin implies a technique of fabrication whose result is visible in the form of the burin bit. The label truncation describes the burin form that was produced by the truncation technique. The same applies to the dihedral, multiple-facetted, and break burins. The form and technique of burins are interchangeable terms when classifying burins; but, when studying the style and function of burins, these two elements should not be mixed indiscriminately. Functionally the form and technique of burins may be distinct components; this question will be examined later in the functional and attribute analyses of burins.

In 1911 M. Bourlon published a burin classification based on the already common notion that the biseau form was the essential part of the burin. Bourlon noted that his classification derived from that of Bardon and the Bouyssonies (1911:267). He borrowed numerous terms from them while further subdividing and complicating their scheme. His typology divided the biseau into two families: those with rectilinear bits and those with polyhedric bits. He assumed that the first kind of burin was used, like a chisel, for cutting narrow, v-shaped trenches in bone and antler (fig. 3a); the second form, likened to an end-scraper, was considered to have been used for cutting round, u-shaped gutters in such materials (fig. 3b) (1911:267-8).

Burin Classification, after Bourlon (1911)	
Family	Genus
I. With Rectilinear Bits	1. Dihedral 2. Angle 3. On Pointed Blades 4. Single Blow
II. With Polygonal Bits	1. Busked 2. Prismatic 3. Angle-Multiple Facetted

Lastly, his study described and classified lateral and transversal burin spalls, their presumed modes of removal, their utility in reconstructing methods of burin manufacture, and their possible functions as tools (1911:272-78).

Although Bourlon gave credit to Bardon and the Bouyssonies, his typology differed fundamentally from theirs. He typed the basic burin forms by the morphology of the biseau, and then subdivided the scheme further by distinguishing different techniques of manufacture. Thus, in these the two early typologies two primary methods emerge for classifying burins.

1) The first method is to describe burin morphology by the technique of manufacture (dihedral, truncation, or break) used to produce the edge on which the defining burin spall(s) is (are) removed.

2) The second method is to classify burins simply by the form of the biseau edge, rectilinear or curved.

It must be emphasized that these two schemes have provided the basis for *all* further morphological typologies.

The most important element in Bourlon's article is his discussion of the steps involved in burin fabrication (1911:272-6). He remarked that the removal of the burin spall would decrease the width of the support, and new retouch would decrease the length. Also, the conchoidal depression left by the departed burin spall would indicate the steps of fabrication. For instance, on a dihedral burin, the depression on one burin facet represents the last burin spall to have been removed. The other depressions were removed by subsequent burin blows; only the depression of the last blow is visible. Observation of the presence or absence of this

*Author's translation of: "Le terme burin évoque immédiatement la 'technique du coup du burin' et non l'action de buriner."

feature would demonstrate on truncation burins whether the truncation was produced before or after the burin blow. It might indicate whether the burin was resharpened or whether the truncation served a function apart from the assumed biseau function.

M. Burkitt's burin classification (1919-1920) closely resembled that of Bourlon. The burins were divided into two main groups entitled screwdriver types (or burins à biseau rectiligne, as Bourlon called them), and gouge-like types (or burins polygonals). Burkitt also suggested the same functional hypothesis as Bourlon.

Burin Classification, after Burkitt (1920)	
I. Screwdriver	1. Dihedral 2. Single Blow 3. Angle
II. Gouge-Type	1. Angle 2. Plane 3. Single Blow 4. Polyhedric 5. Busked

The next important step in burin classification, by H.V.V. Noone, appeared in 1934. His typology was based on the technique of fabrication, rather than the form. "The technique was employed to shape what we consider as the essentially distinctive component of the burin: the burin bit with a controlled edge, clearly limited in length" (1934b:478).*

Burin Classification, after Noone (1934)
I. On Facets (Dihedral)
II. On Retouch (Truncation)
III. On Small Facets (Carenated)

As seen above, the technique of burin manufacture is a major descriptive factor in developing a formal burin typology. Noone's main categories of burins à lamelles and burins à retouches, based on the sketches he provided, are by any other name dihedral and truncation burins. Noone said that the burin bit, produced on the thickness of the piece, characterizes the burin and indicates its function. As in earlier classifications, the technology of the burin is directly correlated to the assumed burin function, while no evidence is given to support such a claim.

Speaking of burins in 1947, F. Bordes said that "the diverse burin types, in terms of their fabrication techniques, can be classified in two groups: burins on truncation and dihedral burins" (1947:10).** De Sonneville-Bordes and Perrot included the burin on a break as a third main burin type in their *Lexique typologique du Paléolithique Supérieur* (1956). Tixier (1963) also divided burins into the same technological groups: dihedral, truncation, and break.

The classification of burins by de Sonneville-Bordes and Perrot takes into account the wide-range of visible variations in both burin form and technique. Their burin type list for the Upper Paleolithic, providing categories for all the burin forms known at that time, should be recognized for its value as the most comprehensive and widely used typological system published to date. Burins are classified by their technique of manufacture: dihedral or truncation; their general shape, such as busked or plane; by distinctive forms, such as Noailles or bec de perroquet; and the shape of the support: nucleiform.

*Author's translation of: "La technique employée pour façonner ce que nous considérons comme le trait essentiellement distinctif du burin: son biseau à tranchant restreint-nettement limité en longueur."

**Author's translation of: "Les divers types de burins peuvent, du point vue technique de fabrication, se ramener à deux: burins à troncature retouchée et burins à deux enlèvements convergents *(coups-de-burin).*"

Burin Classification, after De Sonneville-Bordes and Perrot (1956)	
I. Dihedral	1. Simple 2. Multiple Removals
II. Busked	
III. Bec de Perroquet	
IV. On Truncation	1. Simple 2. Multiple 3. Multiple Mixed
V. De Noailles	
VI. Nucleiform	
VII. Plane	

The further description and definition of Raysse/Basseler burins and carinated burins since the original publication of that list *(e.g.,* Movius and David 1970) evidences the need for re-evaluation of burin typologies and typological theory, both of which we sometimes consider as being immutable and definitive. In recent years efforts by prehistorians including J.-M. Bouvier, J. Sackett, and D. de Sonneville-Bordes have been made to expand the Upper Paleolithic type list to include recent archeological finds (J.-M. Bouvier, personal communication).

G. Laplace-Jauretche produced a burin typology in 1956 in which he divided burins into dihedral and non-dihedral (truncation or lateral) types. A second study by Laplace in 1964 departed from the earlier scheme, and instead he divided burins into nine "primary categories". These groups, nevertheless, can be reduced to the three technological categories of dihedral, truncation, and break burins.

Cheynier devised a classification of burins in 1963 that repeated essentially all that de Sonneville-Bordes and Perrot stated in 1956.

Burin Classification, after Cheynier (1963)	
Groups	Categories
I. Bevel, or Slant	1. Simple 2. Double
II. Angle	1. Truncation 2. Break
III. Gouge	1. Busked 2. Polyhedric 3. Nucleiform
IV. On Notch	1. Flake 2. Blade
V. Bec de Perroquet	
VI. Microburin	

The explication of burin morphology by Leroi-Gourhan *et al.* (1966) is a concise summary of the various notions of burin typology. Basically, they organized burins into two classes, those made by the removal of one or two burin spalls, and those with multiple removals. Further distinctions were made about the symmetry of the biseau in relation to the axis of the piece, and about the nature of the truncation.

Pradel, in 1963, argued an interesting point about the dihedral form of burins. He said that since the active part of all burins is formed by a dihedron, or dihedral angle, all burins are by definition "dihedral" (1963:432). Thus, he maintained that dihedral cannot be used as a criterion for subdividing burins. His classification of burins in 1963, based on the fabrication technique, divided burins into two main categories.

Burin Classification, after Pradel (1963)	
I. On Non-Retouched Truncation	1. On Pre-Existing Surface (Break) 2. On Inverse Removals (incl. Dihedral, Plane, Polyhedric)
II. On Retouched Truncation	(incl. Truncation, Noailles, Bec de Perroquet)

This classification closely resembles Noone's scheme (1934a,b).

Pradel produced another typology in 1966 that differed little from his initial classifications, or even the earliest ones of Bourlon or Burkitt. The burins were classified by the form of the burin bit, either as rectilinear or curved, its position on the support, and its technique of manufacture. In 1971 Pradel published an English translation of his 1966 burin typology.

Burin Classification, after Pradel (1966)	
I. Rectilinear	1. Axis 2. Angle 3. Plane
II. Broken, or Curved	1. Axis 2. Angle 3. Plane 4. Angle-Plane 5. Keeled

Intestesting to note are Pradel's efforts to provide numerical data on the length and bit angle of burins. This is the first attempt in all the burin research to use quantified attributes to indicate burin morphology. Also provocative is Pradel's assertion that his hierarchical classification "is not abstract, arbitrary, or theoretical, but *realistic,* since it takes into account every important characteristic of structure (which implies possibilities of use) and of technique of manufacture" (1971:563). While his classification appears valid within the parameters of typology, his justification stretches beyond the limits of acceptable artifact analysis.

In summary, several significant elements emerge from a review of burin typology. One is that although numerous burin typologies have been published, they have not advanced our understanding of burins much beyond what was recognized more than 70 years ago. The burin, in all its variability, is still a relatively simple tool, both technologically and morphologically. This is evidenced by the two basic schemes of burin classification that have been repeatedly and redundantly used in at least ten different typologies. Burin classifications are either detailed descriptions of the form and position of the burin biseau (rectilinear or gouge-type), or of the burin edge resulting from one or several of the possible techniques of manufacture (truncation, dihedral, or break).

While burin forms have been more than adequately described, the question of what can be revealed by these classifications seems to have been neglected--at least by the above typologists. Possible burin functions are always stated as being obvious, inherent aspects of burin morphology. Assuming that we can investigate the stylistic and functional significance of burins, we must more rigorously test our assumptions. Only in recent years have prehistorians begun to examine systematically the relationships between the morphology of burins and their assumed functions or idiosyncratic styles. Also, the various components of the burin bit, and their relation to the entire piece, have never been studied quantitatively to determine if intuitive typologies are valid representations of presumed, inherent types, or whether they merely indicate arbitrary divisions in burin variability.

Burin classifications have been too often devised without consideration of previous efforts, the utility of typology in general, or the necessity for corroborative tests and analyses. While experimental and quantitative analyses do not necessarily reveal previously unknown patterns, nor do they always require that we devise new typologies, they clearly serve to illustrate the assumptions and limits of burin typology.

III. Technology and Function

Technology

The technology of burin manufacture, surprisingly enough, has been little discussed in the literature on burins. The various classifications based on burin techniques have never been tested experimentally to identify the mechanical contingencies in burin manufacture, even though these contingencies, due both to the raw material and to the techniques of the artisan, determine the resultant tool form.

The anvil technique is described by L. Leakey (1956) as a method commonly used in the Upper Paleolithic to make burins (fig. 4a). In cookbook fashion Leakey outlines the steps involved in manufacturing burins.

> A blade-flake is taken and one end is trimmed a little on both sides, to remove part of the sharp edges and to make a rough point. Then the point is held lightly on the edge of an anvil stone with the cutting edge vertical to the plane of the anvil stone. A sharp tap is now given to the edge of the flake, thereby causing the tip of the blade resting on the anvil to receive the force of the blow by ricochet. Provided that the tip is held at the correct angle on the anvil, this causes a long narrow flake to be removed from the upper edge of the blade. By turning the blade over, a similar flake can be removed from the opposite side. The intersection of these two flake scars at the tip of the flake will produce a burin of the *bec-de-flute* type (1956:137).

Leakey concludes by saying that there are "innumerable minor variations" to this technique (1956:137).

For this investigator, the anvil technique has proven to be one of the most difficult, if not time consuming, methods for manufacturing burins. Personal experiences in knapping burins, and communication with Bruce Bradley, have revealed some of Leakey's "minor variations" that have proved to be much simpler and more efficient for producing a burin.

One technique is to flake the burin by holding the support in the air, instead of on an anvil (fig. 4b). After having made a point on one end of the flake or blade by small retouch (like the first step in Leakey's process), the piece is held out in front of the artisan, freely in the air. Then, the hammer, preferably a soft hammer like antler, held in the other hand, is brought down upon one of the sides of the point, near the tip. If struck at the proper angle, the burin spall flakes off. Repetition of the same technique on the other side of the point, now half burin facet/half truncation, will produce a dihedral burin. Leaving the tool as it appears after the first burin blow creates a truncation burin.

A similar technique is to hold the hammer fixed, and to strike the moving, pointed blade upon it (fig. 4c). This method allows one to better control the point of impact of the burin blow. For break burins, because the break is usually perpendicular, or nearly so, to the axis of the piece, the burin spall is most easily removed if the piece is held fixed while the hammer is brought down on the edge.

A third technique for manufacturing burins is pressure flaking. B. Bradley (personal communication) has said that burin facets sometimes result when he utilizes specialized New World techniques to reproduce Paleo-Indian stone points. J. Epstein notes the presence of pressure-flaked burins on Paleo-Indian bifaces and laurel leaves from Texas (1960:95). W. Irving also indicates the presence of pressure-flaked burins in Paleo-Indian and Paleo-Eskimo assemblages (1955:381).*

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*F. Bordes, in an article in *Quartär* in 1967, strongly criticized Semenov's recognition of pressure-flaked burins in Central Europe, arguing that percussion flaking would have been a far easier and quicker method to

Burins can be easily resharpened, removing more burin spalls in order to reduce the size of the burin bit, or to resharpen the edge during use of the tool. As noted in Bourlon's work (1911), the spalls are useful indicators of the steps in burin production.

The importance of technical features in burin typologies, in contrast to the lack of experimentation on burin technology, indicates the need for controlled tests using the various burin techniques. With replicative experiments* we can comprehend those aspects of variation which result from the artisan's choices: his use of soft of hard hammer, movable or fixed, the angle and force of the burin blow, and the types of retouch. Such experiments can also demonstrate which variations of burin form are probably due to inherent limitations of the raw material or to chance. A more detailed and systematic investigation of burin technology may also reveal the relative predictability of the different burin techniques, their importance in burin typology, and those variations of form which may be due to the stylistic or functional choices of the artisan.

Function

Functional interpretations of burins, like burin classifications, are especially numerous. Almost every prehistorian who has handled, described, and written about burins has proffered theories about their functions.

Notions of burin function, most often derived from intuition rather than experimental research, are based on two main assumptions. The first assumption is that the form of the burin is directly related to its function. The second, almost synonymous with the first, assumes that the burin is inherently related to the material it was probably used to shape.

Lartet's identification of the burin form, as seen in the text and drawings (1875:A. Plate VII, pp. 22-3), leaves little doubt as to his belief in the implicit association between burin form and function. Lartet, however, believed that the pointed end opposing the end scraper, now recognized to be a burin, was a tang for hafting the tool.

Subsequently, with the identification and classification of of the burin as a unique tool form, other functional interpretations developed. Capitan believed that the Magdalenian burin bec de perroquet served as a fine-tipped graver to make small grooves in bone (1917:14). Bourlon (1911), Burkitt (1920), and Noone (1934a,b), each suggested that rectilinear, or dihedral, burins were used to produce v-shaped grooves in bone, while polyhedric burins were used to produce u-shaped channels (fig. 3a,b). Noone also believed the latter form to be a scraper for wall-engravings. Pradel stated similar notions in his classification of burins. His ideas were based on the assumption that the function is directly related to the form of the burin bit (1966:494-5).

Numerous other functions have been described in the literature, but have not been experimentally tested. J.D. Clark suggested that burins could have been used to groove and slot shafts, so that stone blades and barbs could be inserted into position to make weapons (1959:177). Bardon and Bouyssonie included, among other ideas, the cutting of thongs and lashes from the skins of animals with burins (1910:34). Epstein, speaking specifically about Texas burins, considered their possible usage to split reeds, rather than bone or antler (1960:96).

L. Leakey succinctly explained the second assumption about burin function:

> For it was only when the burin became a *common* tool of the Stone Age cultures that we find bone and antler and even ivory being utilized on a big scale to make awls, harpoons, arrow-points, etc.. In other words, it was the invention of the burin that made it possible for prehistoric man to extend the range of materials over which he had mastery and which he could turn into weapons (1953:62).

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fabricate burins. Bordes was obviously unfamiliar with the New World burins that do seem to evidence this technique.

* See Chapter VI: Experimental Fabrication and Utilization.

In other words, Leakey suggested that it was the burin that was used to fabricate bone tools, and it was the habit of making bone tools that created the need for manufacture of burins.

This notion appears as early as 1877 in the work of Leguay. In his search for a stone tool that could have been used to shape bone and antler Leguay found that burins, among a variety of paleolithic stone tools, worked best. Thus he concluded that burins were engraving, or chiseling, tools. Visible edge-damage on the burin proved to Leguay that engraving was undoubtedly the burin's function (1877:286).

Leguay's analyses point out an early example of how specific functional interpretations, when not submitted to experimental testing, become accepted as inherent aspects of stone tools. Not until 1954, when Clark and Thompson investigated grooving and splintering techniques with burins, was any systematic experimentation done with burins.

T. Prideaux, in Time-Life's *Cro-Magnon Man* (1973), provided a comprehensive listing of most imaginable functions for the burin. Prideaux described the burin as a tool to make other tools, a tool to cut, groove, incise, chisel, scrape, splinter, sharpen, and shape bone, ivory, antler, wood, and sometimes stone into needles, points, awls, spear points, lances, and barbed harpoons (1973:66). He said that it may have also been used to engrave soft stone and bone implements, or decorate walls with artistic designs. Capitan pointed out numerous sites including Cap Blanc and the Grotte de Poisson that have parietal sculptures, which he presumed were engraved with burins (1917:14).

The process of grooving and splintering bone and antler was thoroughly researched by Clark and Thompson in their article, "The Groove and Splinter Technique of Working Antler in Upper Paleolithic and Mesolithic Europe" (1954). Based on observations of grooves seen in paleolithic antlers and bones, on replicative experiments with fresh antler, and on comparisons with Eskimo practices, they concluded that the groove and splinter technique "was in fact an integral part of the Upper Paleolithic blade and burin tradition" (1954:154). Their conclusions were also corroborated by the numerous burins and bone tools found at many sites from various palaeolithic epochs. Clark and Thompson noted the appearance of the groove and splinter technique and associated burins at Paleo-Eskimo sites, in the French Aurignacian, Magdalenian, and Azilian complexes, in the Proto-Maglemosian Mesolithic at Star Carr, the Hamburgian in Germany, and generally in the European Upper Palaeolithic from northern Spain to central Europe, to northern Germany and to southern Russia (1954:148-60).

Additionally, Clark and Thompsons' comparisons of the paleolithic materials with modern Eskimo cultures, and their replication of burins and bone tools, offer the first example of a relatively complete experimental investigation of burin function. Their methods support the strong possibility that burins were used to groove and splinter antler.

The actual replication of the groove and splinter technique, and subsequent fabrication of a bone needle with the splinter, is depicted pictorially by J. Tixier in *Cro-Magnon Man* (1973). Tixier first makes a burin, then grooves and splinters an antler with it. He fashions the splinter into a needle using a smoothing stone and a stone perforator. Again, the imitative process confirms the plausibility of this burin function.

Interpretations of burin function associated with bone and antler tools, however, are sometimes skewed by the nature of the archaeological record. Bordes mentions that the Aurignacian was rich in bone tools and poor in burins, while the Perigordian, on the contrary, had an abundance of burins and a scarcity of bone implements (1967:53). For the Aurignacian artifacts, tools other than burins were probably used to work bone, wood, and antler. In the Perigordian we assume that more bone tools were made than the few, ill-formed ones found. As L. Leakey states about Paleolithic bone tools in general, "the dominance of stone over other materials is apparent rather than real" (1956:128). To what extent this dominance of lithic remains in the Perigordian is real can only be inferred from correlative studies of the geological and climatic influences on artifact deposition and preservation, chemical leachings of soil, and the likes.

Thus, in associating burin function with other material remains we must recognize distortions in the paleolithic record due to the conservation and sampling of the remains. Only the best preserved sites and industrial complexes can provide reliable information about functional relationships between stone and other artifacts.

F. Bordes has produced several works on burins, including an experimental study of bone tool fabrication with burins. Probable functions that he suggests include wood working with robust burins (1965:3), and tracing, or initial grooving, with plane and Corbiac burins (1970:108). His most important contribution was the article "Utilisation possible des côtés des burins" (1965). Testing his hypothesis that the burin facet edge, or flank, could be utilized more efficiently than a blade to shape bone tools, Bordes smoothed and polished Magdalenian-type bone awls and needles using only this edge. He was able to control the size and thickness of the small shavings removed with the burin flank. In this manner Bordes experimentally demonstrated a burin function which had neither been suggested nor tested before. His convincing results, apart from typical functional interpretations that suggest that the burin bit was used perpendicular to the plane of the worked surface, emphasize the need for more imaginative hypotheses and functional tests.

A. Rigaud (1972) described the angles of the burin point and edges, and their possible modes of usage. He postulated that the essential purpose in removing burin spalls was to obtain the burin flank, which he considered the main working part of burins. To test his hypothesis Rigaud applied the burin bit (in various positions), as well as end scrapers, retouched and unretouched blades, and polishing stones, to leather, wood, soft stones, antler, and bone. Rigaud compared the effectiveness of the different tools, and their resultant edge-damage, in flaking, shaping, and cutting non-lithic materials. He observed that the burin was the most effective tool in working other materials, and that the biseau flank was the most effective part of the burin. Although his results do not prove, as he claims (1972:108), that the burin flank was the main consideration in manufacturing burins, they do provide ample additional documentation of Bordes's demonstration (1965) that the biseau flank is capable of being a strong, functionally active part of the tool.

M. Newcomer, in an experimental study of bone tool fabrication (1974), employed burins, broken blades, truncated blades, end-scrapers, and retouched and unretouched blades to splinter and shape antler and bone into tools. Using the flank of the burin biseau, as described by Bordes (1965) and Rigaud (1972), Newcomer smoothed antler and bone blanks into some 20 awls and points. He then studied the resultant edge damage on the burins.

Although Newcomer was able to conclude that longitudinal facetting on bone tools was evidence of finishing with the biseau flank, he also demonstrated that such manufacture traces on bones were similarly produced by a variety of flaked stone tools. He found that all of the tool types were effective in finishing the bone tool. It was impossible, he concluded, to designate which stone tools were used to finish the bone artifacts because of too many variables affecting the fabrication traces. Newcomer also said that "Rigaud's confidence in attributing traces of manufacture on Paleolithic bone tools specifically to 'burin facets', 'end-scraper or blade', or 'polisher' seems a little optimistic in light of my own experiments, which only permitted a distinction between scraping with a stone tool and grinding" (1974:151).

In contradistinction to works like those by Bordes, Semenov has said that "the presence of a burin facet, which is regarded as the morphological trait of burins, is not a criterion of function in all cases" (1964:98). Rather, Semenov maintained that burins may have also been facetted to create a tang for hafting (see Lartet 1875:A. Plate VII), a handle for grasping, or to quickly blunt a sharp edge instead of using pressure retouch (1964:98).

In the introduction to Semenov's *Prehistoric Technology,* M. Thompson noted in confirmation of Semenov's results, that an experimental burin he had made "was not held like a knife, but at right angles to the groove" (1964:x). He said that the burin had to be held in the fist, necessitating a wooden handle for it, because the "secret of the (grooving) operation is simply brute force; the whole strength of the trunk and shoulders must be brought to bear" (1964:x).

Semenov and Thompsons' remarks bear witness to the need for sound, yet diversified experiments to test possible burin functions. Experimental studies like those of Bordes (1965), Clark and Thompson (1954), and Newcomer (1974), are highly suggestive of probable burin functions as suggested in burin typologies. Based on these studies, then, it seems unquestionable that the prehistoric artisan could have used the burin bit to splinter bone and antler, and then employed the biseau flank to fashion the splinter into a point, awl, or needle. But, as Newcomer pointed out, so could have end-scrapers, retouched and unretouched blades, and other stone tools been used to do the same. The distinction between possible and actual uses of stone tools, therefore, is a fine one that should be clearly acknowledged in functional analyses.

The simple burin apparently served as a multi-purpose tool, performing various functions to meet specific technological and economic needs of the palaeolithic toolmaker. It might best be compared to a modern screwdriver, which can be used in numerous ways in addition to turning screws.

Perhaps several comments by A. Semenov and F. Bordes best summarize the functional research about burins:

> The problem of burins and burin facets is one of the weakest points in typological description of palaeolithic tools. Even upper paleolithic burins made of prismatic blades were serviceable only if they had their parts properly formed (Semenov 1970:5).
>
> Realistically, the utilization of burins, considered in all their variety, poses many unanswered questions (Bordes 1967:53).*

Edge-Wear

The last method of functional research on burins is edge-wear analysis. Noone, in 1934, was the first to mention visible edge-damage on burins. Noticing squills on the edge of dihedral burins, along with broken tips and broken edges on truncation burins, he suggested that such damage indicated the force exerted by the craftsman on the edge of the burins while working hard materials.** Noone did no further analyses to test his observations.

In 1947 Peyrony *et al.* also spoke of traces of edge-damage on burins, specifying blunted burin edges which were presumably sharp immediately after the burin's fabrication. Because tne damage was localised on the burins, and usually restricted to burins among the tools examined from the Vézère and Corrèze river valleys, Peyrony *et al.* attributed the damage to the use of the burins for sculpting hard materials. As seen in the functional interpretations of burins, Noone's and Peyrony's analyses of burin edge-damage have assumed *a priori* a specific function for burins and then produced the evidence needed to support those claims.

Bordes noticed damage on burins that he assumed to be functional edge-wear (1967:66). Semenov also discussed various kinds of edge-wear visible on burins (1964:96-100). Low-powered microscope analyses of this wear confirmed to him that the burin was used for more than just engraving or grooving. Semenov said the traces indicated that some burins were used in a circular motion, like a screwdriver or drill, or used like whittling knives or chisels on the ventral surface of the tool. Semenov's conclusions, however, seem to have varied with the diverse functions he sought to reveal by micro-wear analysis.

Newcomer briefly discussed the edge wear which resulted on burins while working bone and antler (1974). He noticed small irregular chips unlike intentional retouch or truncation. When using the damaged burin he found that these irregularities reduced the efficiency of the tool, thus obliging him to resharpen the burin by removing another burin spall (1974:149). Extensive use of burins for diverse activities, however, can greatly complicate interpretations of

* Author's translation of: "En réalité, l'utilisation des "burins" considerés dans toute leur variété, pose des questions non résolues."

** Keeley has said that functional edge-damage and micro-wear are due to the nature of the shaped materials, as well as the force exerted by the artisan on the stone tool (1977).

edge-damage and microwear. Keeley has emphasized that tools which were apparently used for numerous activities, on numerous occasions, were near impossible to interpret using even his sophisticated techniques, such as an electron microscope analysis of edge-wear (1974, 1977).

The best systematic work on burin edge-damage has been done by Pradel (1973a, 1973b). His primary concern was to develop a functional classification of burins based on their wear patterns. The main catĕgories he examined were:

1) the morphology and origin of the edge-damage stigma;

2) localisation of the stigma;

3) the nature of burin functions based on their edge-damage (1973b:90).

For the first category Pradel noted that edge damage produced by utilization was the most pronounced. Abraded burin edges indicated to Pradel evidence of prolonged work. He said that damage due to fabrication appeared to have been regularly removed, but that various kinds of stigma, ranging from slight abrasions to large chips, graded ito one another. Pradel noted the confusion that occurred when he compared long, detached chips with abraded, retouched areas. The long chips appeared to be intentionally retouched, yet he found that they occasionally resulted from utilization on hard objects. The abrasions on retouched areas, regarded as functional edge damage, sometimes were produced to intentionally sharpen the burin bit (1973b:90-2).

Describing the localities of burin edge damage, Pradel said that it was found primarily on the biseau flank. He also noticed that edge damage could be found, in decreasing order of frequency, on the entire burin bit, on one or two of the biseau facets, on the truncation, on a smooth edge, adjacent or not to the bit, or on both the bit and another part of the tool. He emphasized that functional interpretations are limited when only the burin bit is studied.

> When one speaks of a burin, the tool comprised essentially of the burin bit edge and its support, it is understood that the bit is the functional part. Yet, study shows that another part of the tool was used, and for various functions of which some are unlike engraving (1973b:95).*

Pradel also cited the existence of used, resharpened, and un-employed burins in the same archeological levels.

Based on the description of edge-damage characters, Pradel then considered the possible functions of burins. He concluded that busked and carenated burins, with significant edge damage, were probably used on hard, resistant materials. Dihedral burins, with small damage flakes, were probably used, when precision was needed, to cut bone and wood and to make groovings. Other descriptions of possible burin functions repeat what Pradel earlier stated in his typologies. These include the burin bec de perroquet to make fine engravings, the Corbiac burin to trace lines in bone or antler (Bordes 1970), and biseau flanks to shape and smooth bone points and needles (Bordes 1965; Rigaud 1972) (1973b:93-96).

Edge-wear and micro-wear analyses of burins may eventually provide further insight into some of the precise functional roles of burins. Pradel's systematic and explicit discussion of his methods, goals, and results, provided a useful functional analysis. His research seems especially convincing when compared with other experimental burin investigations. L. Keeley's micro-wear studies with an electron microscope indicate possible breakthroughs in both the theory and method of edge-wear analyses (1974, 1977) Meanwhile, we must remember that stone tools used by rational beings were subject to the needs, whims, and fits of outrage of those people, all of which must have affected both the tools's use and wear. Functional analyses remain the most uncertain aspect of lithic analysis, due both to the complexity of human activity and the versatility of so many artifact forms.

* Author's translation of: "Quand on parle de burin, donc d'outil essentiellement constitué par une arête et son support, on pourrait sous-entendre que c'est celle-ci qui travaille. Or, l'examen montre qu'une autre partie de l'instrument a été employée et cela à des travaux fort divers dont certains sont différents de l'action de buriner."

IV. Attribute Analyses

Theory of Numerical Analysis

Some archeologists do not believe that stone artifacts should merely be used to distinguish lithic assemblages or discern horizons of prehistoric occupation. They also view stone tools as prehistoric variables that may permit us to interpret the complex interaction of culture and the environment. As remnants of a cultural system stone artifacts may help to provide information on topics such as raw material resources, subsistence activities and prehistoric economies, types of encampments and their internal spatial and social organization, tool form and function, and, ideally, the behavior of the prehistoric craftsman (Spaulding 1960).

In 1953 Spaulding complained of artifact analyses based on intuitive, qualitative criteria. He said that traditional methods failed to reveal sufficiently the cultural implications of artifacts, and that intuitive typologies did not express culturally meaningful categories. By traditional typological methods artifacts and assemblages are classified either by those characteristics that are obvious and happen to make an impression on the observer, or by all of their attributes weighed equally. In either case, Spaulding noted, interpretations are rendered less precise when artifacts are intermediate in form to several categories, or when there is a great amount of morphological variability, with seemingly irregular attribute patterns (1953:307).

Based on the assumption that artifacts possess inherent attribute clusters which are culturally significant and potentially expressable quantitatively, numerical artifact analyses were developed (Spaulding 1953, 1960). Spaulding suggested statistical methods which he felt would reveal inherent patterns of artifact variability, and possibly allow archeologists to construct non-arbitrary typologies.

The result of computer simulations, as Doran says, is a "simplified and abstract representation of the true situation" (1970:297). The statistical methods do not indiscriminately manipulate the data and produce significant patterns; the techniques do not replace our need for typological studies. Instead, in a numerical analysis a set of quantified variables are manipulated using certain, specific statistical functions. Numeric and graphic representations of the transformed variables result. Quantitative methods are not used in lieu of intuitive, qualitative typologies. They provide, as Hodson says, "informed intuition", or results that can be used to test traditional schemes, and which can be extended to problems beyond the scope of typologies *(e.g.,* tool function and idiosyncratic style; spatial organization of tools in situ) (Hodson *et al.* 1966:311). "The attempt to create computer simulations will certainly encourage that clarity, precision, and objectivity of thought which so many are seeking" (Doran 1970:297-8).

D.L. Clarke, in *Analytical Archaeology* (1968), outlined the hierarchy of artifact systems in prehistoric cultures. Artifacts can be considered at four basic levels:

I) "Assemblage: an associated set of contemporary artifact- *types;*"

II) "Type: specific artefact-type; an homogeneous population of *artefacts* which share a consistently recurrent range of attribute states within a given polythetic set. Levels: type group, specific type, subtype;"

III) "Artefact: any object modified by a set of humanly imposed *attributes;*"

IV) "Attribute: a logically irreducible character of two or more states, acting as an independent *variable* within a specific artefact system" (1968:188)

From these categories, then, we are able to clarify the objectives of quantitative artifact analysis. The objectives, as will be seen in this analysis, do not necessarily coincide one-to-one with a specific interpretative level for artifacts; rather several goals may be applied to one, or several, artifact categories. Basically, artifacts can be analyzed to characterize assemblages, to discover intrinsic modalities of form (non-arbitrary types), or to discover functional aspects of particular tools. This analysis will focus on the burin at the artifactual and attributal levels, so as to examine the possible idiosyncratic (stylistic) or functional aspects of its form.

The definitions suggested by J. Sackett (1966, 1969) for the components of an attribute system are particularly useful, and will be used in the burin analysis reported here. They are as follows:

A) Attribute system: "an ensemble of sets or classes of attributes that are used to codify variation among a specified group of artifacts;"

B) Set: "a class of attributes that all refer to the same dimension;"

C) Dimension or Variable: "an aspect or parameter of formal variation among artifacts;"

D) Attribute: "a distinctive property or unit of a dimension or variable, representing one of two or more possible expressions of that dimension" (1966:359-60, 1969:1126).

In summary, the nature of the data determines the objectives of the study and the particular numerical methods that can be applied. The goals of the research, as well, limit the kinds of data sets and mathematic manipulations. Thirdly, the numerical analyses reveal the utility of the artifact model, the variability of the data, and the significance of the sample size. Thus, quantitative artifact analysis comprises an intricate, interrelated system of data, theory, and methods. Explicit consideration of each of these elements must be made to insure a valid and useful analysis (For extensive discussions of analytical theory and model formulation see D.L. Clarke 1968, 1972).

Past Attribute Studies

Three attribute analyses of particular concern to us are the burin analyses by Ronen (1970), Demars (1973), and Gunn (1975). Each of these investigators used attribute systems and numerical methods to examine variation in burin forms.

Ronen compared the burins from Aurignacian assemblages at Volgleherd, Germany, with burins from Aurignacian complexes in Southwestern France. Using two attributes as criteria: 1) the manufacture technique (dihedral, truncation, or break), and 2) the form of the working edge (rectangular, rounded, triangular, semi-round, or oblique), Ronen classified all the burins from two layers at Vogleherd. He stated that these variables are merely comparative standards, and that "whether these technical and formal features are purely functional, or compound functional and stylistic traits, is irrelevant to our present study" (1970:47).

Ronen used crosstabulations to calculate the frequency distributions of techniques and biseau shapes on the burins in each Vogleherd Aurignacian horizon, and to calculate the frequencies of each burin manufactured by a certain technique and possessing a distinct form. In the first crosstabulation Ronen found that there was a distinct resemblance between the two Vogleherd levels studied: both had a high percentage of burins on truncation and a low percentage of dihedral burins. Each horizon also had a high percentage of burins with an oblique working edge. Ronen's choice of burin form as a criterion of variability, however, best emphasized the presence of busked and carenated burins, typical burin forms in Aurignacian assemblages. Thus, he chose a variable that distinguished the oblique, or rounded, working edge of certain characteristic Aurignacian burins.

Frequencies of the form-technique correlation in the second crosstabulation indicated that the technique and shape covary numerically; that is, that they are interdependent variables. Thus, in both crosstabulations the results reiterated relationships already expressed in the two attributal criteria. It should be noted, too, that attribute analyses often reveal, numerically and graphically, redundancies in form-technique relationships. Recognition of this fact can help to improve the design of attribute analyses and the interpretation of the results.

Ronen then compared the Vogleherd burins with French Aurignacian burins, and found the greatest statistical resemblances to be between the German burins and the French burins made outside the Dordogne, particularly in Corrèze. Comparing the German and French Aurignacian burins by cumulative curves that described the frequencies of the technique and form, Ronen concluded that a cultural identity probably existed between Vogleherd and certain French Aurignacian assemblages (outside Dordogne).

Ronen's analysis of burins, as markers of the cultural affinities between German and French Aurignacian industries, demonstrated his impressions about the two data sets. Although his use of a limited attribute system and frequency distributions helped to confirm his hypothesis with useful graphs, neither his methods nor results made explicit the inherent limitations and redundancies of the analysis. Ronen did not clarify the inherent relation between the various morphological characteristics of Aurignacian burins, and between the well-established role of such tools as cultural markers. Thus, he failed to recognize the value of his study: to objectify intuitive impressions about distinctive tool forms and culturally unique assemblages. Ronen's study points out the need for well-defined models, more discrimination in choosing variables, and a greater willingness to recognize the restrictions of numerical artifact analysis.

Demars's study of burins in 1973 is better only with respect to his research objective: to define truncation burins, burins on pointed blades, and Raysse burins using attribute analysis. The use of an attribute analysis to reveal distinct variables of burin morphology, and from them, construct better typologies, falls within the scope and interests of numerical analysis. His methods, however, fail to produce any more significant results than those already obtained by more traditional methods of artifact analysis.

Using Movius *et al.* (1968) as a guideline for choosing attributes pertinent to his objectives, Demars first measured the angles of the burin blow and the preparatory truncation or retouch (both with regard to the working axis of the tool) on the truncation and pointed-blade burins. One notices that these are measures of cojacent angles bound to one another both mechanically and numerically. A correlation graph exhibited this interdependency: the truncation burins clustered in two distinct groups either on the right or left side of the graph, depending on whether the truncation was right or left. The pointed-blade burins clustered with obliquely truncated burins in a group that Demars cautiously described as being not clearly distinct (1973:46). The graphs indicate no distinctions, clear or opaque, between the two burin forms, and Demars's conclusions tend only to pronounce opinions unrelated to the analyses. It should be iterated that the utility of an attribute analysis is limited by the significance of the variables used. Only if they reflect functionally important or stylistically sensitive qualities can the analysis provide useful insights.

Next, assuming that the width of the biseau might be larger on burins on pointed blades because the biseau usually appeared in the median position, Demars measured the bit width on truncation and pointed-blade burins. He found that the width maintained a constant range of variation (3-5mm), regardless of the burin technique. Lastly, he measured the angle of the biseau, and ascertained that the variation of burin angles (primarily between 50 and 70 degrees) was due to the various positions of the biseau on the blank, and not to any technique or resulting form. No correlation of this proposition, that the relation between the bit angle size and its angular position is independent of manufacture contingencies, was made. Again, his deductions appear to stem from extensive elaborations of a few obvious characteristics.

In concluding Demars stated that the distinction between truncation burins and pointed-blade burins would be based on their different technique of manufacture, not their assumed different functions. This is a logical redundancy of burin nomenclature: truncation and pointed blade are names indicating different aspects of burin form, one being related to the technique of manufacture, the other to the form of the blank chosen. In effect he provided no new or illuminating definition of these burins, as he originally proposed, nor did he adequately describe the morphological variation upon which he based his conclusions. The attributes were either redundant, repeating similar dimensions with different terms, or were intrinsically linked to the research objectives so as to guarantee beforehand the conclusions at which they arrived. Demars realized the theoretical need for carefully chosen attributes, but was not critical of his own choices.

In analyzing both studies one must remember that frequency distributions do not assess the meaning or significance of variable associations, though they do describe the nature of variation within specific dimensions. Specific correlation measurements are necessary to obtain meaningful correlations and to insure valid inferences. Intuitive associations of frequency distributions, as seen in both Ronen's and Demars's studies, diminish the value of these analyses. These studies are useful, nonetheless, as demonstrations of the simplified numerical expressions produced in numerical analysis, as well as some of the common mistakes made.

The third burin analysis by Gunn (1975) is the most interesting of the three. Seeking to develop "a model for treatment of stone tools in a dynamic, functional context," Gunn created a theoretical model that combined burin attributes of shape, technique, and wear with hypotheses about the physics of tool manipulation, primitive economy, and function (1975:9). Then, by a numerical analysis he generated "types that can be readily interpreted in functional terms" (1975:10).

Gunn developed a geometric model, in the form of a hemisphere, to serve as the theoretical environment of the tool's use. The ground plane represented the working surface of the material, and the dome included "all the possible orientations of burins in relation to the working surface" (1975:10). The functional orientations of burins in the hemisphere were based on their microscopic edge-wear indicating directions of movement, observations about the physics of tool manipulation, and the shape of the tool. Each orientation was recorded as a strike point, or extension of the working axis of the burin, drawn on the dome. Based on the possible burin orientations and the presumed locations of their strike points, Gunn hypothesized three functional burin types. The first was a postern burin (mostly truncation and break burins) used for planing. The second was a side burin (dihedral) used for grooving; and the third was an upright burin (again mostly truncation and break burins) used for scraping.

In a cluster analysis of orientation strike points in the hemisphere, Gunn found that his hypotheses were confirmed for the postern and side burins. A second cluster analysis reconfirmed his first findings, while it subdivided the upright burins into four groups. From this he reasoned that the burin used in an upright position functioned in numerous activities, such as for scraping, cutting, or chopping. Although the functional types seem acceptable within his model, his results produced a series of idealized burin forms that bear little resemblance to known burins. His interpretations would have been even more convincing had he correlated the idealized tools with paleolithic burins. Also, Gunn did not consider the possibility that the different burin forms could have been used in various ways for several different tasks. In seeking to devise a functional model he oversimplified the variety of functions for which different burins were probably used.

Gunn's study seems to hold great promise, nevertheless, for functional interpretations of tool types. His model incorporates burin morphology and edge-wear, as well as assumptions about tool manipulation and prehistoric economies. It is a system that comprehends both the typological and experimental aspects of functional typology. Lastly, Gunn admitted that "the system suggested here is certainly artificial, due to the nature of the data and the limitation of scope to one techno-type" (1975:15-6). His model, because of its careful design and limited application, is convincing in this first application.

Burin Attribute Analysis: Purpose

Burin classifications and analyses in the past have stemmed from the assumption that the burin bit, or biseau, as the single-most important element on the burin tool, represents a stylistic and/or functional choice of the artisan. Conclusions from these past studies *(e.g.,* Pradel 1971, 1973a; Ronen 1970; Demars 1973) have merely restated the the archaeologist's opinion about the prehistoric artisan's behavior in fabricating burins. The biseau itself: its technique of fabrication, its form and position, and its association with the support piece, has not yet effectively been analysed to confirm, deny, or amend earlier intuitive analyses.

Spaulding's belief that culturally meaningful, inherent patterns of variation occur within artifacts, and that they can be revealed by appropriate statistical analysis, provides the stimulus for this experimental study. I have sought out two samples of Upper Paleolithic burins (see below) and have explored aspects of their morphology using quantitative, univariate and multivariate, methods. The goal of this burin attribute analysis is to examine numerically the variation of burins as expressed in their attributes, and thereby to contribute to improved understanding of the anthropological meaning of burin variation. The analysis comprises three steps:

1) To determine which attributes of burin form (technique, support shape, and biseau attributes) exhibit distinct modes of variation that may have been imposed or selected for by human action;

2) To determine which attributes are mutually intercorrelated;

3) To determine the consistent clusters of attributes such as might define non-arbitrary, or recurring, burin forms.

Methods*

The *Statistical Package for the Social Sciences, SPSS* (Nie *et al.* 1975) provided a series of computer programs suitable for the analysis of attribute frequencies and associations. The first two steps required an r-mode strategy, whereby properties of the variables were examined. In the first step a FREQUENCY subprogram was used to compute frequency distributions, and related statistics *(e.g.,* mean, mode, standard deviation, etc.) for each dimension.

In the second step three different analyses were conducted. The FACTOR subprogram performed a principal components analysis (PCA) on the interval- and ratio-scaled data. This program described the behavior of variables: how the attributes of one dimension covaried with those of another dimension. It calculated a correlation coefficient for each pair of dimensions to describe the significance of the covariation. By repeating the correlation of variables using their coefficients the factor analysis produced new compound variables, or a set of principal components. This reduced set of principal components represented the most significant correlations among the attribute classes.

Because factor analysis measures the greatest linear correlation between variables, or the correlation between the total range of variability represented by two variables, all the attributes of each criterion must be included in the analysis. Pearson's r, upon which factor analysis and PCA depend, applies only to continuous, covarying attributes with approximately normal distributions. Attributes of mutually-exclusive variables, like the raw material (flint or obsidian), or support form (flake or blade), cannot be used in such an analysis because not all the attributes of each dimension can be simultaneously correlated (For further examples of PCA see Binford and Binford (1966); Cowgill (1970); Azoury and Hodson (1973)).

The largest correlation coefficients, which indicated the most significant variables influencing the principal components, emphasized those variables or dimensions that were best for the following statistical analyses. A CROSSTABS subprogram executed a crosstabulation of the type number and manufacture technique with the various dimensions of the burin bit. The

* Detailed explanations of the various numerical methods can be found in Cowgill (1968); Doran (1970); Doran and Hodson (1975); Hodson (1969a and b); Hodson *et al.* (1966); and Sackett (1969).

burin types, technique of maufacture, and support form, because they were nominal values, could not be used in the other multivariate analyses. Crosstabulations provided bivariate frequency distributions of nominal variables with interval- and ratio- scaled dimensions. The program also provided a Chi-square statistical significance test for measuring the departure of observed attribute combination frequencies from those that would be expected given a null hypothesis of no preferred association. That is, the expectation that the frequency of each set of attribute combinations would be predictable simply from the overall frequency of each set of attributes was tested.

In the last part of step two, a SCATTERGRAM subprogram was used to correlate the different biseau dimensions with one another, and with dimensions of the support. The result was a bivariate plot of the relation between two variables.

The third step of the analysis used a Fortran program* to graph the individual burins in a principal components matrix. Thus, in this q-mode analysis (regarding the burins on the case level) the position of each artifact was determined by the relative weight of all its variables on each of the component axes. By graphing each burin using its principal component values, the most significant relations, or clusters, of burin forms were indicated. Any form correlation clusters that emerged could be used as the basis for defining non-arbitrary burin forms, or to test the validity of existing classifications (For an example of such a q-mode analysis see Azoury and Hodson (1973)).

Data Collection

To facilitate the data collection and analysis within a limited time period, the burins were codified in terms of the two-dimensional geometric properties of the biseau and support form. For simple dihedral, truncation, and break burins, all of them possessing rectilinear bits, it is assumed that they have similar functional capabilities. More precisely, we shall assume that the burin was used with the bit perpendicular to the plane of the worked surface, or with the edge of biseau flank (fig. 27b,d). In either case the contact between the burin and the worked surface is reduced to a point. The biseau, forming a dihedral or trihedral angle at the tip, and a dihedral angle on the edge, can be measured in the two dimensions where the assumed functional point is formed.

Measurements of the thickness of the burin bit or support piece, the number of spall removals, the obliquity of the biseau with respect to the planar surface of the support, and the form of the truncation were not considered essential variables in a study of simple, technical burins. Also, both burin samples are from Magdalenian assemblages, which are typically composed of these basic burin types. Such industrial complexes do not usually contain busked, carinated, Raysse, or other polyhedric burin forms; none were found among the burins studied. Such attributes, nevertheless, should be included in comprehensive analyses of larger, more complex burin clusters (*e.g.,* Upper Perigordian or Aurignacian complexes).

The following dimensions were measured using metric calipers, measuring boards, and protracters. The technique and support form were distinguished visually, except when blade/flake distinctions were at the limit of the length:width ratio (2:1). In these cases, the support was measured.

1) the form of the support:

i. blade--where the length is greater than or equal to twice the width of the piece;

ii. flake--where the length is less than twice the width.

*Michael Schwartz (Department of Anthropology, University of California, Berkeley) developed this program and graciously allowed me to use it in these analyses.

2) the technique of manufacture--the method of preparation of a platform comprising half the burin bit, prior to the removal of the spall defining the burin (figs. 5,6):

i. dihedral--the burin bit is formed by the meeting of two dihedral facets;

ii. truncation--the burin bit is formed by the meeting of a dihedral facet and a pre-existing truncated edge;

iii. break--the burin bit is formed by the meeting of a dihedral facet and a pre-existing broken, or natural, surface.

3) the angle of the burin bit--this is an interval-scaled measure, defined as the angle formed by dihedral facet and the opposing facet formed by one of the three techniques (fig. 5a-c).

4) the symmetry of the burin bit in relation to the working axis--a ratio-scaled measure, it is determined by intersection of the angle bisector of the burin bit (drawn to the mid-point of the biseau width line) and the working axis of the support (fig. 5d-f).

5) the length of the burin bit projection--interval-scaled, it is the length of the burin bit angle bisector extended to the midpoint of the bit width line (fig. 6a-c).

6) the width of the burin bit projection--interval-scaled, it is the maximum width of the bit, drawn at the base of the biseau (the maximal extension of the burin facets on both sides of the bit) (fig. 6a-c).

The above dimensions describe the burin bit: its technique of manufacture, its angular form, its position on the planar support, and its dimensions of length and width. The following two dimensions describe the support.

7) the length of the working axis--interval-scaled, it is the maximum length of the working axis (fig. 6d-f). This line is perpendicular to the piece width.

8) the width of the working axis--interval-scaled, it is the maximum width of the support directly below the maximal extension of the biseau facets (fig. 6d-f).

The data, recorded as individual tools in rows and their dimensions in columns, were then punched onto IBM cards for the statistical analyses, which were performed on a CDC 6400 at UC Berkeley. The data was coded in the following manner:

Columns 1 and 2: **TYPENO,** the de Sonneville-Bordes/Perrot type number, originally designated for each burin examined. Both burin samples were classified by this investigator.

Column 4: **SUPPORT,** the form of the support, with blades numbered 1, and flakes numbered 2.

Column 6: **TECHNIC,** the technique of manufacture, with dihedral numbered 4, truncation numbered 5, and break numbered 6.

Columns 8-9: **BITANGLE,** the angle of the burin bit, with each angle measured to the nearest 5 degrees; an angle of 37.5 degrees was read as 40 degrees, as was an angle of 42 degrees. (The angles that are labeled at 99 degrees include the 11 burins with angles over 95 degrees. There were 7 burin angles with a measure of 100 degrees, 3 at 105 degrees, and 1 at 115 degrees. The two column code for burin angle prevented using three digit angles, but it did not affect the analyses.)

Columns 11-12: **BITSYMM,** the symmetry of the burin bit in relation to the working axis, with each angle measured to the nearest whole degree, from 0 degrees to a maximum of 57 degrees; the measures were then combined (or recoded) by the computer into larger numerical groups, beginning with 0 degrees, then 3, 6, 9, and so on, to improve the graphic representations.

Columns 14-15: **BITPROJ,** the length of the burin bit projection, was measured to the nearest whole millimeter, and then regrouped to read every other millimeter for graphing, such as 4mm, 6mm, 8mm, etc..

Columns 17-18: **BITWIDTH,** the width of the burin bit, was measured to the nearest whole millimeter, and then regrouped to read every third millimeter, 3mm, 6mm, 9mm, etc..

Columns 20-21: **SUPLNGTH,** the length of the working axis, was measured to the nearest whole millimeter, and then regrouped to read every fourth millimeter, 16mm, 20mm, 24mm, etc..

Columns 23-24: **SUPWIDTH,** the width of the working, was measured to the nearest whole millimeter, and then regrouped to read every third millimeter, 15mm, 18mm, 21mm, etc..

Study Samples

The first group of 64 burins analysed are from the French Magdalenian site, La Madeleine (Table 1). The tools constitute a part of the Miles Burkitt collections of Dr. J.D. Clark, who graciously permitted me to utilize the collections and his laboratory.

These tools from the La Madeleine site are without stratigraphic or cultural indications, and so their value as prehistoric markers, other than as functional implements or representative tool types, is negligible. They were useful, however, as an experimental set on which the methodology of this study could be developed. Collected during the early part of this century, they were probably obtained in surface surveys and test trenches that lacked accurate coordinate measurements or stratigraphic indications. For these tools it will be assumed that they are derived from a distinct Upper Magdalenian horizon. The interpretations, therefore, will be of a set of tools made by a group of Magdalenian artisans with presumably similar cultural beliefs about tool manufacture and use.

Burins from the Upper Paleolithic site at Solvieux, France, provided another sample of Magdalenian burins. Dr. J. Sackett, director of archeological research at Solvieux, was extremely generous in allowing me to collect data in his laboratory and in sharing with me his expertise about numerical analyses.

A sample of over 500 burins from a single level at Solvieux was measured. To insure a more reasonable sampling, and to make the study feasible within considerable time constraints, a random sampling of half of the burins of each tool type inspected (the tools were classified by this investigator for this study) were then included in the analyses. Thus, 252 burins, or one-half of all the burins measured were analyzed (Table 2).

To avoid any confusion with the Solvieux studies being conducted by Dr. Sackett and his co-workers at UCLA, and to emphasize that this study was conducted independently of any research being done by the Solvieux investigators, the Solvieux burins will hereafter be referred to exclusively as the "study sample". It should be clearly understood that the data presented for the "study sample" burins have been independently collected for the special purposes of the experimental quantitative study of burin morphology reported here. The sample used was not extracted in such a way that the results can or should be used to characterize the burin assemblage for normal comparative purposes. Hence, no inferences about the Solvieux site or data, or about the methods or results of the Solvieux investigators, should be drawn from this study.

The 64 burins from La Madeleine and the 252 "study sample" burins include measures taken from each of the burin bits found on multiple or mixed burins. Because the aim of the study is to investigate the morphological variation of isolated burin bits, and their relation to the support, every biseau, regardless of associated burins, was measured for its attributes.

V. Numerical Results

Initially several remarks must be made about the La Madeleine burins (Table 1). Being the first set of burins examined, their frequency distributions were computed manually to determine potentially significant variables, and to design the most effective attribute analysis. When the SPSS results for the La Madeleine burins were compared with those of the Solvieux burins the insufficiency of the small La Madeleine sample became apparent. Frequency distributions of some of the attributes *(e.g.,* bit angle, or bit symmetry) indicated a minimal amount of clustering at any interval, sometimes showing modes determined by as few as 7 or 8 burins (figs. 7,8). Crosstabulations of the bit angle and symmetry with the support form and technique displayed characteristically low chi-squares, indicating the probable absence of a statistical relationship between the variables (figs. 9,10). The large values for the significance factors indicated that these relationships probably occurred by chance, a result due to the small sample size. The original utility of the La Madeleine burins, nevertheless, should not be understated; as a set of variable burin forms they were essential in developing the attribute system and choosing the numerical methods for this study.

Statistical analyses were also performed on all 316 burins to test the relative importance of the La Madeleine sample in relation to the "study sample" burins. Results from the frequency distributions, factor analysis, and crosstabulations on all the tools produced statistics and graphs so closely resembling the "study sample" results that the total sample and the "study" sample could be considered the same. The 252 "study sample" burins (Table 2), dominating the 64 La Madeleine burins by a factor of 4, controlled the results on every test, and were totally unaffected statistically by inclusion of the La Madeleine burins. Thus, the most meaningful inferences about burin morphology are based on the sample of "study" burins. Unless otherwise stated, the discussions of the results will refer only to the "study sample" burins.

Step I:

To determine the modes of variation among the burin variables--the first step in the analysis--frequency distributions were calculated for each interval- or ratio-scaled attribute. For burin bit angles (labeled *bitangle)* the mean and median angle was 70 degrees,which is similar to Demars's findings (1973:46) (fig. 11). The large standard deviation of 14 probably resulted from the large range (60 degrees) of burin angles measured. The distinct unimodal distribution of burin angles, and the kurtosis index (-.4) imply that the curve is 'higher' and less spread than a true gaussian distribution, with most angles grouped at approximately 65 degrees. Hence, we see a regular patterning of burin angle variation between 55 and 80 degrees, both limits being within the range of the standard deviation. The percentages of burins with angles less than 50 degrees, or greater than 85 degrees was minimal.

A frequency distribution of the biseau symmetry (labeled *bitsymm)* evidenced a trimodal distribution with the largest mode at 3 degrees, and lesser modes at 21 degrees and 33 degrees (fig. 12). This variable was the only one of the six used in this study that exhibited several distinct modes of variation. All the others were clearly unimodal. These three modes appear to correlate with the intuitively designated classes of burin symmetry: 3 degrees being the mean value of median burin symmetry, 21 degrees for asymmetric burins, and 33 for lateral burins. Although they may in part be due to the investigator's unconscious bias for recurring measures at or near 3, 21, and 33mm, the pattern seems to be more strongly related to morphological and technological factors than to measuring difficulties.

Frequency distributions of the biseau length and width (labeled *bitproj* and *bitwidth* respectively) described metric dimensions of the biseau (figs. 13,14). The shape of the frequency histograms are similar for the two variables, and both are significantly skewed positively. These limits indicate the probable mechanical constraints determining the maximum or minimum size of the biseau. For both of these dimensions it appears that the variation is not random, but restricted to precise clusters of variation.

The clustering of the biseau projection about 12mm, (mean=15, median=14, mode=10), and the biseau width at 18mm, (mean=20, median=18, mode=18), describe a mean height to width ratio of 2 to 3. Translated into angular measure that is approximately 70 degrees, the mean angle for all of the "study sample" burins. Thus, the numerical relationship between the biseau length and width indicates a redundancy of variables between the metric dimensions of the biseau and its angular measure.

Frequency distributions of the dimensions of the support length and width (labeled *suplngth* and *supwidth)* produced histograms similar to those of the linear bit dimensions (figs. 15,16). Both graphs are skewed positively, and both dimensions evidence a major cluster about a single mode of variation. The mode of the support length is at 60mm, with a major cluster of variability from 48 to 64mm; the support width has its mode at 30mm, and a major cluster from 21 to 36mm. The relationship between these two variables, as for the measures of the burin bit, logically appears constrained by flint mechanics, with excessively small values, outside the normal range of variation, rarely occurring.

Step II:

The second step of the attribute analysis was to determine which attributes were intercorrelated. Using the six continuously measured variables: burin bit angle, bit symmetry, bit projection length, bit width, support length, and support width, principal components analysis was used to compute the strongest correlations among the burin attributes, and the principal components established by these associations (fig. 17). The strongest correlation coefficient was for the biseau projection and biseau width, a measure of .77. The variables of biseau length and width both express aspects of the size of the biseau. The bit projection bisects the vertex of a triangle described by the burin bit; the bit width forms the base of the triangle. The two variables, because of their geometric interconnectedness, produce redundant measures of the biseau size. They express the same dimension, while neither seems to be a more useful variable of burin diversity.

A moderately strong correlation of the biseau width with the support width (.51) indicated a similar correspondence between these dimensions (fig. 17). They represent certain aspects of the support size, and are often adjacent and/or parallel to one another. The two dimensions of the support form, length and width, evidenced the third highest correlation coefficient, .45 (fig. 17). These also are measures of size that one would expect to correlate significantly.

In the principal components analysis three components, or vectors, were found to account for 80 percent of the variation among the burins (fig. 17). The first component, which contributed 40 percent of the variance, clearly represents the size variability of burins. It is weighted almost equally by the biseau projection (eigenvector = .49), biseau width (.57), support length (.41), and support width (.48). As mentioned in the theoretical discussion of attribute analysis, the highest correlations, and most significant principal component, are usually expressions of size. Component 1, representing the greatest percentage of burin variation, is determined by the four size dependent variables.

The second principal component, on the other hand, evidences the burin variability influenced by the biseau angle and symmetry (fig. 17). It described 25 percent of all variation, with the biseau angle influencing it most heavily (eigenvector = -.70), and the biseau symmetry somewhat less (-.55). Component 2 can be considered as an expression of the angular variability of the burin biseau.

The third principal component, which described 15 percent of burin variation, cannot be explained as easily as the other two. All the variables, except the biseau angle, contribute significantly to this component; the eigenvectors of the five variables range from .57 for the support length to .32 for the biseau width, with values for the biseau symmetry, biseau projection, and support width between them. The significance (or insignificance) of the percentage of variation represented by this component is also indicated by the small eigenvalue (.89). Generally it is accepted that in principal components analysis those components with values less than 1.00 can be disregarded. (Component 1 has an eigenvalue of 2.39; Component 2 has one of 1.51.) Nie *et al.* note that "since discriminant functions are derived in the order of their importance, this process can be stopped whenever the relative percentage is judged to be too small" (1975:442). Coupled with the complicated meaning of this component, the eigenvalue for component 3 indicates that only the first two principal components should be examined in the q-mode analysis. Nevertheless, this third component will be used in the analyses if only to see if any patterns or clusters emerge when it is correlated with the other principal components.

Two important intercorrelations were revealed using the r-mode factor analysis. The first is the strong interdependency, or redundancy, of the variables that describe the size of the support and the burin bit. The biseau projection and width, and the support length and width, each evidence strong correlation coefficients; and they all influence nearly equally the largest principal component. Second, the strong association of the biseau angle and symmetry, and their weight on the second principal component, suggest that they are the most important variables describing the "technical" burin. It is these various aspects of the biseau that have been considered as the essential morphological aspects of the tool. They appear to be the variables that should be examined most closely in the following analyses.

One possible criticism of the principal components analysis may be that there were too few variables used, along with too many redundant ones, both of which could account for the restricted correlations and limited number of important principal components. Although the redundant dimensions were not recognized explicitly before the analyses, it is believed that technical burin forms are best described and codified in terms of their two-dimensional variation. The limited number of variables, rather than being too few in number, may instead indicate the restricted variability of simple burins. Their clustering into two distinct principal components supports the hypothesis that most significant burin variation is expressed by the biseau angle and/or its symmetry.

The next analyses in step two examined the variation of the biseau variables with respect to the other metric variables, and to the nominal values of the support form and manufacture technique. The first tests were crosstabulations of biseau angles and symmetries with their support form, either blade or flake, and their manufacture technique: dihedral, truncation, or break. The angles were adjusted to read every 10 degrees, thus 35 and 40 degrees were printed as 40 degrees, 45 and 50 as 50 degrees, 55 and 60 as 60 degrees, and so on. Correlation of the bit angle with the support form (the nominal equivalent of support length and width relationship) demonstrated two main modes of variation: on blades the frequencies clustered at 60 and 70 degrees, and on flakes they clustered at 70 and 80 degrees (fig. 18). The large chi-square of 20 reveals an appreciable deviation from chance association ($p<.003$); so the null hypothesis can be discounted and we may conclude that there is a systematic relationship between the angle and support form. The contrast between the forms of burins on flakes and on blades is not dramatic, with a mean difference of only 10 degrees, but it does indicate that burin angles, determined in part by the width of their triangular base, are limited by the size of the support.

The crosstabulation of the biseau angle and the technique of manufacture, however, reveals more about biseau variability. A distinct mode for the biseau angle was seen for each technique: from 60 to 70 degrees on dihedral burins, from 70 to 80 degrees on truncation burins, and from 80 to 90 degrees on break burins (fig. 18). The extremely large chi-square (82) emphasizes that the probability of these differences between the sets being due to chance is vanishingly small ($p<.0001$); or that there exists a regular relationship between the angle of the burin bit and its method of manufacture.

Crosstabulations of the bit symmetry with the support and technique were also calculated. The angles were redefined in terms of symmetric labels to facilitate reading the crosstabulation, and to investigate the validity of bit symmetry with its typological nomenclature. Using Movius *et al.*'s criteria for symmetry (1968:33-4), median burins were defined as having a symmetry angle from 0 to 15 degrees, asymmetric burins being 16 to 30 degrees, and lateral burins being 31+ degrees. On blades median burins occured 56% of the time, while asymmetric burins occurred 27% of the time, and lateral burins 17% of the time (fig. 19). On flakes the variation was 48% median, and 27% for both asymmetric and lateral burins. The chi-square of 4 indicated that the observed configuration could occur about once in seven times by chance ($p \sim .13$), and that the significant correlation, if any, between bit symmetry and support must be regarded as weak. The observed tendency for blades to carry median burins seems justifiable when one considers that the narrower blade support could best maintain a burin angle in the solid median part of the support.

The crosstabulation of bit symmetry and the technique of manufacture demonstrated modes of symmetry variation that resemble the trimodal frequency distribution of bit symmetry, and the findings in the bit angle-technique crosstabulation (fig. 19). Dihedral burins are predominantly median (63%), while they are occasionally asymmetric (27%), and rarely lateral (10%). Break burins vary in the opposite fashion; they are lateral most often (73%), sometimes asymmetric (27%), and never median (0%). Truncation burins vary more evenly, being median about half the time (48%), and asymmetric and lateral a fourth of the time each (27%).

Thus, we see that dihedral burins most often possess small angles which are in the median position. Truncation burins have larger angles and are mostly asymmetric. Lastly, break burins have some of the largest angles, which are most often laterally situated. The numerical relationship between the two biseau angle variables, and their technique of manufacture, demonstrates that the angular measures of burin form covary with the technique used to produce them. Two possible explanations for this association are either that the artisan chose a particular technique, which determined the burin form; or that the artisan chose to make a particular form, which in turn demanded a particular technique. The use of a specific technique, in turn, would theoretically produce a biseau angle and symmetry that would be interdependent, as well as predictable. The mechanical contingencies affecting the two possibilities will be examined in Chapter VI.

A scattergram of the biseau angle and symmetry, the last part of step two, reveals the interdependent behavior of these two variables (fig. 20). Though the two variables have a low correlation coefficient (.35) they do covary in a linear fashion, as seen in the graph. As the angle increases, then so does its asymmetry; in other words, as the angle increases the biseau point moves from the center of the piece to the side. The largest burin angles (found on break burins) statistically are skewed the furthest from symmetry with the working axis, and are generally lateral break burins.

Finally scattergrams were produced which graphically exhibited the correlations (already defined with correlation coefficients in the PCA) between the biseau and support size dimensions, and the two principal factors with the support dimensions. Graphs correlating the bit length and bit width (.77) (fig. 21), the bit width and the support width (.51) (fig. 22), and the support length and the support width (.45) (fig. 23) evidence strong linear correlations, a pattern which can be inferred from their strong correlation coefficients. These graphs are useful for pictorially representing the relationship denoted numerically with the correlation coefficient, but do not reveal any hitherto unrecognized patterns of variability.

Step III:

Based on the above results we would expect to see the burins cluster into three groups. One would consist of burins with small angles and a median symmetry. They would mostly be dihedral, with some truncation. The second group would be of burins with medium sized angles, and a variety of symmetries; they would mainly be truncation, with some dihedral and break burins. The last group would contain the lateral burins with large angles; most of them being break burins, with some truncation burins.

The last analysis plotted all the burin cases on the principal components matrix to determine those clusters of burins that might determine non-arbitrary burin forms. The Fortran program, having calculated the weight of each burin's attributes on the principal components, (the original data × each eigenvector), then plotted each case in a matrix with the horizontal axis being one component, the vertical axis being another. Three plots were made: in the first the axes were component 1 (size) versus component 2 (angle) (fig. 24); the second had component 1 versus component 3 (fig. 25); the last was component 2 versus component 3 (fig. 26). Each burin was indicated by a letter representing its type class from de Sonneville-Bordes and Perrots' type list so as to allow for comparison of their typology with the principal component plots. Thus, it was possible to observe the relative positions of the burins with respect to their three principal components of variation, and in relation to an extant classification.

It should be stated initially that in all three plots no distinct clusters appeared. As was expected, multivariate analysis did not reveal any hitherto unknown patterns about simple burins. The q-mode plot of the burins did not cluster them into new and easily readable classes. Instead, initial inspection shows that there are no distinct differences, or modes, among these burins. Yet on closer analysis of the different plots several interesting patterns become apparent.

In the first plot the burins showed no pattern with respect to the size axis (fig. 24). One large cluster placed most of the burins in the middle of possible size variations. There was an approximately even, or random, distribution of the various recognized burin sizes. With regard to the vertical axis, representing variation in burin angular measures, the artifacts evidenced a gradual change in forms, ranging from median burins on top to lateral burins on the bottom. A closer look at the plot shows that the burins with the largest values for component 2 are mostly median and asymmetrical dihedral burins and oblique truncation burins. As the values decrease along the ordinate axis the types of burins become more varied. More concave and convex truncation burins are found. This middle area is the most compact, suggesting the greatest amount of burin variability. For the burins with the smallest component 2 values another group, though with imprecise limits, can be seen. Most of the burins in this area are lateral burins; they include the break, lateral and transversal truncation, and lateral dihedral burins.

Despite the lack of any significant clusters in the first plot, an interesting pattern does emerge that resembles the general scheme of de Sonneville-Bordes and Perrots' typology. Artifact size does not clearly affect burin forms. The angular component of burins, however, produces a distribution much as the other attribute analyses suggested. Median burins, and hence, those with the smallest angles, grouped at one limit of component 2. Lateral burins with the largest angles were closely related at the other limit. Between them a large variety of burin sizes and angles were clustered. Generally speaking, then, the burin typology currently in use seems to adequately express the most important morphological aspects of burins: biseau symmetries and their covariant angles. Yet it should be understood that, as regards typological schemes, the technical distinctions only define arbitrary zones in a continuum of forms.

The plot of burins on a matrix comprising components 1 and 3 did not reveal either clusters or patterns that allowed for interpretation (fig. 25). The most dense area of the plot had a large number of median and asymmetric dihedral burins and oblique truncation burins. These are also the most frequent burin types that were analysed.

The last plot using components 2 and 3 produced a pattern similar to that in the first plot, but which was even more easily identifiable (fig. 26). The median and asymmetric burins, made either by dihedral or truncation techniques, were clearly the burins with the largest component 2 values, grouped towards the right along the abscissa. To the left, denoting lower values for the angular measure component, there is a more loosely clustered group of lateral burins, being dihedral, truncation, and break. Again we can see that the biseau angles determine the most apparent--and significant-- burin variation, a fact which coincides with the general burin classes used in current burin typology.

No pattern could be seen for the burins along the ordinate axis, which represents the indeterminate third principal component.

In final response to step three, which asked what are the consistent clusters of attributes that might define non-arbitrary burins forms, the results from the q-mode analysis confirm what was expected. Along principal component 2, a new measure that described the angular variation of the biseau, the burins demonstrated approximate patterns or groups patterns of variability. The median dihedral burins and oblique truncation burins, with small angles, loosely clustered, as did the large angle, lateral break and truncation burins. The middle group of burins were mostly truncation, which are well known to exhibit the greatest amount of variability. The two essential variables affecting this component, biseau angle and symmetry, are obviously two important criteria for burin typology. Yet, as seen in the earlier numerical tests, these two variables are interdependent. This fact, coupled with our recognition of the tedious job of measuring angles as opposed to the easier task of estimating symmetrical classes, affirms the utility of the de Sonneville-Bordes/Perrot scheme. By subdividing burins according to their symmetry they have created an accurate, yet concise, representation of a major part of burin variability.

In terms of the burins themselves, the morphological variation of simple, technical burins appears limited to two principal components, or "engineering" variables. Component 1, accounting for 40 percent of burin variation, was a description of burin size. While size may have been an important factor to the Upper Paleolithic artisan when making and using burins, it was not important for this study. It was initially assumed that size was not a significant technological or functional aspect of burins. Instead, the emphasis was placed on component 2, which accounted for 25 percent of burin variation, and which represented variability in the biseau angle and its symmetry. The other statistical tests affirmed the assumption that the variation of the biseau shape correlated strongly with its contingent technique of manufacture. Thus, it seems clear now that the two main "engineering" variables, or principal components, must be studied in association with the technology by which they were formed. From these results experiments can be developed to test conceivable conceptual and procedural templates of the artisan who fabricated and used burins. The attribute analysis demonstrated which formal elements should be considered in classifying burins and analysing them functionally. Also, it has been seen how the variables used in this study may be too limited for an analysis of more complicated burin forms. Some variables that might be considered are the forms of different burin truncations, and the thickness of the biseau.

None of the numerical tests provided any explanations--causal or motivational--for the correlation of the biseau angles with the technique. Again, we ask to what degree the burin techniques influence biseau morphology. This is important both with regard to deducing the possible behavior of the artisan who made burins, and to establishing with more confidence the utility of the de Sonneville-Bordes/Perrot typology (1956), that most commonly used for Upper Paleolithic tools. In the next chapter this form-technique relationship will be tested experimentally.

Finally it may be said that this attribute analysis repeats statistically, graphically, and at great length the relationship between burin technique, biseau angle, and symmetry which has been recognized and described in burin typologies for many years. Essentially that comment is true; yet more can be said in favor of the attribute analysis than that it is a device for picturing intuitive understanding. Statistical and graphic displays of the burin variation succinctly described morphological patterns which have provided the basis for all burin typologies, yet have never been explicitly depicted. Immediate, intuitive reactions were confirmed, in this case, but confirmed nonetheless with objective, reproducible methods.

The lack of dramatic results does not demonstrate that the statistical analyses of burins have been of no value. This preliminary experiment with statistical methods in burin analysis has revealed much about both the usefulness of numerical analyses, and the nature of the burin data. A summary of these statistical findings, and their relationship to the experimental results, is given in Chapter VII.

VI. Experimental Fabrication and Utilization

Experimentation with burins was divided into two parts: fabrication and utilization. In the first section, the experiments were intended to determine the mechanical contingencies of burin manufacture, and how these findings correlated with the numerical results. Briefly, the numerical results indicated that the biseau angle and its symmetry were the two most significant variables of burin morphology. They are interdependent expressions of the biseau shape and position. More notably, the biseau angle and symmetry covary trimodally in association with the burin manufacture technique.

The first experimental step, then, was to determine the mechanics affecting the biseau--technique relation. Based on the above data it appears that each of the burin techniques permits a limited range of convenient angles to be formed. By convenient is meant the most likely angle to result. The technique used to prepare the preparatory burin edge, or striking platform, produces various surfaces that can be flaked easily and efficiently with a *coup du burin.* The resultant biseau angle seems to depend almost entirely on this preparation technique and burin blow. In other words, it is the shape of the striking platform, determined by the burin technique, that controls the angle and symmetry of the resulting burin biseau. For example, breaks on burins usually occur perpendicular to the working axis of the support. The burin blow, attacking one of the pointed edges of the break, usually removes a spall that is perpendicular to the break; hence, the lateral symmetry on break burins. A truncation at the extremity of a blade also requires a similar blow, which also produces a characteristically large biseau angle.

The correlation of the technique with the position of the biseau, like the above association between the angle and technique, also seems to be best explained by referring to burin technology. Dihedral burins are made most often on oblique, dihedral facets, which in turn position the convenient angle in the center of the piece. Truncation burins, with the most variation in their preparatory surface, can accommodate more variability in biseau symmetry. The break on a blade usually requires a burin facet that is usually perpendicular to the break. It seems likely, therefore, that the technique chosen to fabricate the striking platform is the determining criterion of the biseau form.

To test these hypotheses, first the mechanical contingencies of burin manufacture were studied, and then a series of burins were replicated.

Burin Mechanics

To fabricate a burin it was necessary to have on the support at least one pointed corner upon which the *coup du burin* could be delivered. This point, or lip as it sometimes appeared, could be either a natural or retouched point, but it had to present an angle less than 90 degrees. The acute angle was necessary in order to provide an edge from which a spall could be removed.

The easiest method for producing the striking platform, or point, was to truncate the thin end of a flake or blade into a point-- which, if left in that state, would be considered a pointed blade (fig. 4c). Sometimes when the blade was thicker it was easiest to grind the point, using a hard hammer with the support resting on an anvil. On breaks or transversal truncations it was necessary to produce a small notch on one of the sharp edges perpendicular to the break (fig. 4b). This notch reduced the angle between the striking platform and the edge near the break, and directed the force of the burin blow.

The techniques used to remove the burin spall as the same as those described in Chapter

II. By fixing the hammerstone, and striking the support piece on it (fig. 4c), it was very easy to remove spalls from pointed blades. The blow went directly onto the strike point, and the burin spall detached along the prepared edge. Also, the largest burin spalls, sometimes as large 50 mm, were removed by this technique. If only one spall was removed from the pointed blade then it remained what would be called an oblique truncation burin. If both burin facets were made then a dihedral burin resulted. Thus, the relationship seen between median dihedral and oblique truncation burins in the principal components plots was clearly determined by the artisan's decision to stop after he produced only one burin facet. Why the artisan might have stopped at this stage, or why he preferred a truncation burin to a dihedral burin, are questions which need to be investigated in further studies.

The method of fixing the support, and then striking the hammer down on the point (fig. 4b), proved to be less efficient. It was more difficult to guide the hammer precisely onto the point such that the spall followed the edge of the piece. If the blow was not exact it tended to shatter the tip, or to produce spalls on either the dorsal or ventral surfaces of the support. The spalls ran adjacent to the edge, rather than on it. They were also usually smaller than those produced with the fixed hammer, and were often less than 15 mm in length.

On supports with break platforms or with lateral truncation then the moving hammer technique was necessary (fig. 4b). After having notched one edge, and made the point where the edge meets the perpendicular striking platform, then the hammer was struck upon it. By moving the hammer down the length of the support, against the perpendicular platform, it was easy to both hold the piece and remove the spall. Attempts to either strike the hammer across the width of the piece (on the break platform), or to bring the support down onto the fixed hammer, were awkward and imprecise. In the latter case, in order to remove a spall along the edge, it was necessary to hold the piece with one edge resting in the hand. The lack of control due to holding the piece across its width, and the chance of injury, are both increased greatly when using this technique.

An antler soft hammer proved useful for the preparatory retouch, but was not hard enough to efficiently remove large burin spalls. Numerous strenuous blows were required with this hammer to create a large facet. A hard hammerstone, on the contrary, was very efficient for both the preparation and removal of the burin spalls. The force of the blow needed to remove spalls was considerably less with the hard hammer. Interestingly the lightest force needed to remove a spall was with a fixed hammer and a moving support piece. Then the spalls flew off in regular and rapid succession. It should also be noted that burin spalls come off the support delivering a characteristic ping. Thus, one could generally judge the success or failure of the attempt by the resultant sound.

The angle of the burin blow was approximately perpendicular to the platform and strike point, regardless of the technical type, or position of the hammer and support. One can imagine this by striking a pencil point on the edge of a table. To break that point it must strike the table at an angle of approximately 90 degrees. The flaking motion is an arc whereby the moving support or hammer rolls off the other fixed implement.

Fabrication Results

To test the hypotheses about the burin technique, which comprises the platform preparation and the *coup du burin,* 20 burins were made by each: dihedral, truncation, and break. No attention was given to either the biseau angle or symmetry. The only important factor was the rapid production of burins. In this way more emphasis could be placed on the mechanical contingencies determining burin fabrication. The biseau angle and symmetry were measured for each burin, while the more subjective variables of time, efficiency, and ease of the different techniques were also considered.

Of the 20 burins made by each technique half were made in flint and half in obsidian. All were made with relative ease in a period of about one and one-half hours. The average biseau angles and symmetries produced for burins in each category were almost identical to the statistical results for the "study" burins. For the experimental dihedral burins the mean angle was 64 degrees, the mean symmetry 7.5 degrees; the statistical means for the "study" dihedral burins were 63.5 degrees for the bit angle, and 13.5 degrees for the symmetry. The experimental truncation burins had mean angles of 76 degrees for the biseau angle, and 27 degrees for the symmetry. The "study" truncation burins had a mean biseau angle of 77 degrees, and mean biseau symmetry of 19 degrees. For the experimental break burins the average bit angle was 77 degrees, and the average bit symmetry was 36 degrees; "study" break burins had an average biseau angle of 76.5 degrees and biseau symmetry of 38.5 degrees.

The variation of biseau forms, therefore, can be predicted using its manufacture technique as the criterion. The similarity between the experimental and observed results supports the hypothesis that the angular component of burin variability is determined almost entirely by the technique, which is to say the platform preparation and burin blow. What remains visible on the prehistoric artifact is only the use of a particular preparation technique. The blow that removed the characteristic spall can be inferred from the mechanical contingencies recognized above. In any case, what we classify as the technique of burin fabrication is clearly one of the primary determinants of burin form.

To confirm this finding, an experiment was done to try to produce distorted burins, or tools with specific angles and symmetries. First, striking platforms with particular symmetries were made. On median preparations using a moving hammer 10 asymmetric burins were attempted; only 4 were successful. No lateral burins were achieved in 10 further tries using the same techniques. When the technique was changed to a fixed hammer, 7 of the burins formed were median. Only 3 were asymmetric, and there were no lateral burins made.

Then on an asymmetric preparation, using both moving and fixed hammers, median and lateral symmetries were sought. In 10 tries with the moving hammer 1 lateral and 3 median burins were accomplished, with the rest being asymmetrical. With a fixed hammer, being somewhat easier with pointed tools, 3 median burins resulted. No lateral burins resulted with the fixed hammer technique.

Lastly, on transversal preparations 8 of 10 tries using the moving hammer resulted in a lateral burin. The other two were asymmetric. A fixed hammer used on such preparations produced, with more difficulty than any other technique, 10 lateral burins.

For all these experiments it appeared that the techniques of preparation and burin blow determined the symmetry much as was expected. Median preparations determined median burins. Asymmetric burins evidenced the most variation, with more median and lateral burins achieved; and lateral preparations determined lateral burins.

Next, an experiment was performed in which one might control the angle of the biseau. Firstly, we must recognize that one does not readily or accurately conceive of stone tools with particular angles. When an effort was made to produce distinct angles it seemed awkward and time-consuming. Instead of flaking a simple burin, one had to consider the possibilities of controlling angles of the burin blow and the platform preparations. As mentioned above the contact between the artifact and hammer necessary to remove a spall is approximately 90 degrees. When angles of greater or less than about 90 degrees were attempted no removals occurred. Bringing the hammer down on the piece from directly above also failed to remove spalls.

When the established preparation techniques were used it was found to be equally impossible to control the burin angle. 8 of 10 angles on the dihedral preparation were in the range of angles from 55-75 degrees. On break platforms the angles clustered around 90 degrees. The largest range of variation came in the 10 tries on truncation platforms; their range of angles was from 55-95 degrees. This difference of 40 degrees among the truncation burins is more notable when compared to the standard deviation among burin angles. The standard deviation for the observed biseau angles was 14, and for the experimental burins it was 13. Thus the variability among biseau angles on truncation burins can be viewed as a measure of approximately three standard variations. Such a large amount of deviation emphasizes the unpredictable and uncontrollable nature of burin forms that were made to conform to particular dimensions.

After these two tests to control the biseau form one is largely convinced of the constraints of burin form imposed by the burin technique, or more precisely the mechanical contingencies of platform preparation and fixed-moving hammer. These two conceptual and procedural choices of the artisan will consistently produce burin forms that are predictable and almost always unavoidable.

Functional Results

Lastly, an experiment was attempted to investigate aspects of burins forms and/or techniques that might have any functional implications. Dihedral, truncation, and break burins were each used to splinter, incise, and shave various materials, including raw and cooked bones, dry and soaked antler, and pine wood. Nine burins in all were used, three in each technical type category. Two of the three burins representing each technical type were made of flint, the other being in obsidian. Of the nine total burins, one of each type had a bit 20 mm long, one 10 mm long, and the third 5 mm long. In this way the differences in raw material and biseau shape could be considered.

During the tests consideration was given to the type of burin being used, as well as the functional part of the tool: dihedral edge, trihedral point, or flank. The speed, precision, and results of each test were also considered.

To Split: it was found easiest to split raw and cooked bone, and the wood, using a median dihedral burin like a chisel (fig. 27a). With the bulb serving as a platform for the hammer, the dihedral edge at the tip was fitted into a notch or groove at one end of the material. The blow from the hammer easily sent the burin through the bone or wood. The effect of having two adjacent burin facets, as in a dihedral burin, is a reinforcement of the burin tip. In this way two plane surfaces (the facets) join to form a dihedral edge at the tip of the tool. In contrast, median or asymmetric truncation burins have an edge formed by only one facet, which is opposed by a truncated edge. The point of the truncation burin, in 10 attempts to split a bone, shattered 8 times. It then had to be resharpened to effectively produce a chisel-like tool.

Lateral truncation or break burins were essentially useless as chisels because of the orientation of the biseau with respect to the working axis. There is no axis aligning the bulb of the support with the biseau, and no platform upon which to strike it as a chisel.

To Incise: the easiest and most efficient tool for incising or grooving was the lateral truncation or break burin. Contact is made between the front dihedral edge of the burin (at the tip) and the working material, and the result is a groove formed at right angles to the biseau (fig. 27b). This is important, first because it is easiest to hold a burin for incising when the support is parallel--and the biseau perpendicular--to the groove. From this position the most pressure can be applied. Also, more of the biseau edge, which in this case is the whole dihedral edged tip, actively functions when making the incision. More shavings are taken off in less time. Lastly, one can also draw on one of the dihedral edges on the facet (fig. 27c), in addition to the dihedral tip, to scrape the side of the groove, simultaneously widening and deepening the groove.

Median or asymmetric burins on a truncation or dihedral edge are positioned at about a 45 degree angle with respect to the groove. At this angle only one of the trihedral points on the tip is functional. Normal usage of one of these burins reduces the amount of pressure that can be applied when engraving or incising. These burin types can be used with the entire dihedral tip, but the tool must be held perpendicular to the groove because of their biseau orientation. This position is more awkward than that used to hold lateral break burins.

Despite the various degrees of ease in manipulating the different burins all were found to be efficient incisors. All the different types could effectively trace and then incise a groove of several millimeters in just seconds. A more important difference than the burins was the material to be incised. Raw and cooked bone and dry antler were all extremely hard materials. Burins used on them, regardless of their technique of manufacture or biseau form, chipped or shattered frequently, and needed resharpening. The soaked antler and wood were softer materials and one could rapidly incise a notch in them.

The burins with the smallest bit projections, 5mm, were found to be the best burins for etching the initial groove. The small biseau was easier to guide, fitting neatly into the narrow grove that it was tracing. After having deepened the groove it was more efficient to use a longer, wider biseau.

To Shave: it was easiest to shave or smooth a bone tool using a dihedral or truncation burin with a median or asymmetrically-positioned bit (fig. 27d). Again, the relative ease was more dependent on how the tool was manipulated, rather than on its "true" function. With the above mentioned burins one could use either the dihedral facet or truncation as a rest for the index finger. The shaving occurs when one of the dihedral edges of a facet comes into contact with the working material. This burin function has been much discussed in recent years (Bordes 1965; Crabtree and Davis 1968; Rigaud 1972; Newcomer 1974), and the past experimental results were easily reconfirmed in these tests. The likelihood of the burin being used to smooth another tool seems highly probable after having observed the ease and efficiency of burins used this way.

Despite being more awkward than the other burins when shaving bone or wood, break burins functioned equally well in performing this task. The density of the shavings, as well as the smoothness of the bone surface, were identically produced by all three burin types. Since all three technical types possess at least one facet, which has two dihedral edges, they are equally useful for shaving. It appears that the only necessary attribute for this function is the dihedral edge. Because it is formed by two surfaces meeting at approximately 90 degrees it is much stronger than a smaller-angled edge, such as that found on raw flakes, retouched knives or end-scrapers.

To test the various tools in a series of different functions several bone tools were made. The first tool, a bone awl, was made on a raw bone (fig. 28a). The bone was splintered with a median dihedral burin. Then the bone flake was shaved using all nine burins. All were equally efficient for the task, except for the burins with the smallest bits, 5 mm. Because of the small biseau, they had less surface area that was needed when smoothing the length of the bone. Next the bone was incised, for ornamentation, using all the tools. As noted above, the break burins were the easiest to handle for the task; but all the burins were effective. The main difficulty in making the awl was not the burins, but the hardness of the bone. It was necessary to apply the burins with a large and steady force in order to remove the shavings. The awl was completed in 30 minutes.

Lastly two bone needles were made in splinters of cooked bone (fig. 28b,c). The bones were shaved again using all nine burins. For these smaller bone implements it was found easier in the last stages of smoothing to hold the burin steady and rub the needle against it. In this fashion the shavings were removed while protecting the fragile needle from breaking. The needle holes were started using the trihedral tips on several of the sharpest burins. These points were used to bore small holes on both sides of the tool. The holes were completed using burin spalls, which were easily controlled over the small, delicate working surface. The bone needles each required about one and one-half hours to complete.

Thus we see that the experimental tests confirmed the hypotheses about burin fabrication and utilization. The mechanical contingencies of manufacturing burins are primarily the technique used to prepare the striking platform for the *coup du burin,* and the choice of either a fixed or moving hammer. These two technical choices determine, almost without fail, the resulting biseau angle and symmetry. Functionally speaking, what we consider different technical burin forms all perform equally well in a variety of shaving and incising tasks. The primary differences that could be discerned among the forms was the easier manipulation of burins that possessed certain biseau orientations. The one notable functional difference was seen in the splitting experiments. In those tests the median dihedral burin, with a strong chisel-like point and a medially-placed hammer platform, proved to be superior to all other burin types. Otherwise, the functional experiments showed all the burins to be versatile tools that could have been used for numerous different tasks.

Lastly, it seems that functional tests such as those cited above are subject, like tool manufacture in prehistoric times, to the whims and biases of the artisan. The methods used here to fabricate or utilize burins may not necessarily coincide with those employed thousands of years ago. Nevertheless, these experiments demonstrated how a burin can be made and then used. Furthermore, they revealed a possible series of decisions and physical applications one logically considers in making a burin. From such understanding we can develop a more accurate picture of lithic technology as it relates to more complicated tool forms or artifact systems. We must remember that to assert with unflinching confidence how a burin was made or used must necessarily extend beyond the limits of scientific credibility. Instead, it is the role of the functional experiments to lend credence to our typological and numerical analyses, and to give us glimpses of the probable technological processes employed by prehistoric artisans.

VII. Conclusions

To summarize the results of the numerical and experimental analyses, and to illuminate the possible significant variations of burin morphology, let me return to the questions in Chapter I that provided the framework for this study.

It was first assumed that the prehistoric artisan, needing a tool for shaping bone or wood, chose to make and use a burin. Although only the burin was considered in this research, numerous other stone tools could have been used successfully to work softer materials like bone or wood. M. Newcomer demonstrated that burins, end-scrapers, and retouched blades, to name a few, all functioned efficiently and predictably in fabricating bone tools (1974).

Yet, if we consider the abundance of burins in the Upper Paleolithic, and then view them in light of the experimental work of Bordes (1965, 1972), Clark and Thompson (1954), Rigaud (1972), Tixier (1973), and Newcomer, they seem to be a likely, if not common, choice of the prehistoric craftsman for fabricating other tools.

By saying that the artisan decided to make a burin, it is meant that he chose to fabricate the generalized burin form to acquire one or several burin facets. His decision to make a burin can be regarded as a choice of a tool form intended for one or several functions. In this way we can view the burin as a unique tool form without defining any functional parameters.

In order to understand the process of burin fabrication we should consider first the technique-form relation influencing the craftsman's decisions and applications. The artisan could have chosen to use a fundamental burin technique: dihedral, truncation, or break, which in turn determined the burin form; or he could have chosen to make a detailed form demanding a particular technique. Because only the final burin form remains, without any explanation or record of the exact process by which it was made, burin morphology was first examined. Then, from the patterns of variation revealed in the attribute analysis it was possible to reconstruct a probable process employed in burin manufacture.

The possibility of the artisan choosing a specific form seems unlikely in light of the numerical results. First, it was demonstrated that simple, technical burins, when considered only in two dimensions, possessed few variables or patterns of significant morphological variation. Only the burin biseau angle and its symmetry (as seen in the frequency distributions and PCA) proved useful as variables.

Further numerical tests (crosstabulations and scattergrams) demonstrated the interdependency of the biseau angle and its symmetry. A scattergram correlating the two variables showed them to covary linearly: as the angle increases so does its asymmetry, or as the assymetry increases then so does the angle.

Lastly, the numerical tests showed both the biseau angle and symmetry to vary trimodally in association with the three burin techniques. Neither variable was significantly influenced by the support form, whereas they both exhibited distinct trimodal patterns when crosstabulated with dihedral, truncation, and break burins. The smallest angled, median burins were consistently found on dihedral facets, while the largest angled, lateral burins were made on breaks.

The limited morphological variation of simple burins, as seen in the statistical results, seems intimately related to the technique of manufacture. The results demonstrate the strong correlation between the specific techniques of manufacture and morphological variation, but it does not determine the causality of techniques or motivation of the artisan that determined those forms. The logical inference from such results, however, is that the technique was the artisan's principle choice. Tixier proffered a similar opinion about burin fabrication in 1958:

"The prehistoric worker did not seek a form, but utilized a technique that he applied to a flake or blade presenting an area appropriate for the application of this technique" (Tixier 1958:629).*

If the technical contingencies are the determining influences of burin form, then we should be able to predict with relatively accuracy the angles and symmetries that would result on experimental burins. To test this hypothesis, and determine the mechanical contingencies of burin manufacture, a number of burins were manufactured. The values for the biseau angles and symmetries of the experimental burins all closely resembled those same measures for the "study" burins. The angular form of the biseau was easily predicted using the manufacture technique as the criterion.

The mechanics of manufacturing burins showed that the craftsman's main choices concerned the preparation of the striking platform and the type of *coup du burin.* Because both the biseau angle and symmetry are interdependent aspects of the biseau, and of the burin technique, it seems improbable that an artisan initially chose to make a precise burin form without also recognizing the need to use a particular technique. In effect, his choice for a particular form would have been based on at least an intuitive understanding of the relationship between the technique and morphology. Yet in view of the strong correlation between form and technique, it hardly seems justifiable to speak of an artisan manufacturing burin types without also suggesting that he was aware of the importance of the manufacture technique as one of the main morphological determinants.

Experiments to control the shape of the biseau proved to be awkward and inefficient both in terms of the time required to make a burin and of the success in achieving the desired form. The difficulty of fabricating specific burin forms stresses the likelihood that the artisan did not choose to make a burin with precise morphological characteristics. More probable is that, as a flint knapper, he was aware of the most common burin shapes resulting from each technique. He then chose to make a general burin form from one of several possibilities, following a specific series of technical contingencies.

Functionally, all the different burin types were equally suitable for all the tasks. The only differences that appeared were how certain forms could be more easily manipulated than others, and the distinct function of median dihedral burins. The lateral break burin, for example, provided the best handle when it was used for grooving bone or wood. With the other burins it was necessary to hold the tool more firmly in the palm of the hand. Yet all the burins were equally efficient as incising, grooving, and smoothing tools. The median dihedral burin proved to be an extremely useful chisel for splitting bone and wood; the other burin forms were noticeably inferior because of their less sturdy point and their asymmetrically- placed platform.

The strong correlation of burin forms with their techniques also affirms the utility of the de Sonneville-Bordes and Perrot burin typology (1956). In their scheme simple, technical burins are initially grouped by their technique, being either dihedral, break, or truncation. This primary technical division suggests the importance of the technique as the main determinant of burin morphology. The subdivision of these burins by their biseau symmetry evidences, as well, the hierarchical significance of the biseau position. Yet this second class should not be overemphasized when using burins as cultural markers. Because the biseau form is determined essentially by the technique this subdivision is a redundant description of forms indicated by the dihedral, truncation, or break labels. In any case, their scheme still proves to be the most accurate and useful one, even after some 20 years of further lithic research.

In the final analysis it seems logical to regard the technical variations of burins as the most significant, and non-arbitrary variables. That the burin form evidences, in most cases, a specific mode of manufacture should be considered as one of the patterned, or deliberate,

*Author's translation of: "L'ouvrier préhistorique n'a pas cherché une forme, mais a utilisé une technique qu'il a appliquée à des produits de débitage présentant une zone adéquate á l'adaptation de cette technique."

choices of the artisan. He could have chosen to produce certain idiosyncratic forms (choices which we may call stylistic), or to use certain fabrication methods (technological choices), or both. Whatever his motivation, what appears certain is that there were deliberate and patterned decisions--stylistic and/or technological--to produce certain burin forms. The other possibility is that burin forms resulted opportunistically, or fortuitously. Some such cases may be of burins made on flakes or blades that were chosen because they already possessed platforms that lent themselves to the fabrication of a burin; or those that were made on supports originally truncated for other purposes; or on supports that were accidentally broken, the burins possibly being afterthoughts, or even accidents. In these cases the burin form would not be considered as the deliberate product of the artisan's efforts.

Unfortunately there are no methods for determining the artisan's motivation in making a burin. But examination of the archeological record reveals that particular burin forms were apparently preferred to others. The distribution of some types suggests that these tools were the deliberate stylistic-technological choices of the artisans fabricating them. The preponderance of dihedral burins in the Magdalenian IV and VI industries at La Madeleine demonstrates that it was the dihedral burin most often fabricated in those cultures (de Sonneville-Bordes 1966:18). Because of this distinct distribution we may assume that the dihedral burin was the culturally determined preference of those Magdalenian craftsmen. The pattern of dihedral burins sometimes outnumbering the other types by as much as 2 to 1 suggests that they are the products of the artisans' non-arbitrary choices for particular forms within the range of burin variability. Based on the predominance of one burin type over the others found in Magdalenian sites, we might refer to the peoples who lived in certain horizons as dihedral or truncation Magdalenians. In other words, we can view the frequencies of burin types in distinct horizons as markers indicating cultural priorities or traditions, much as we might describe the economy of a culture by the average size of its automobiles.

The choice of one technique over the others may be viewed as being similar to modern man's decision to use a 'Bic' pen instead of a 'Parker'. Functionally both pens are held similarly for the same tasks, but morphologically they can differ due to the materials used to make them, to the methods of manufacture, and to the designs of the manufacturer. Likewise, the simple, technical burins investigated here possess consistent differences in the features we consider diagnostic for burins, but these variables do not seem to hinder the function of any of the burin types; they all could have functioned equally well in performing any one of many possible tasks. The experimental results demonstrated that dihedral, truncation, and break burins all performed similarly in shaving and incising. The differences in burin angles, symmetry, or even technique, did not alter the function of any of the forms except for splitting.

Thus, we have seen by quantitative and experimental tests that the general burin forms are simple tools, technologically and morphologically, which were probably made by an artisan who followed a simple chain of decisions and actions. The burin was probably used, it likewise follows, for a variety of different tasks. That specific burin forms were used for specific chores seems unlikely given the morphological evidence and experimental results. Lastly, I have attempted to explore the intrinsic patterning of burins, using explicit, numeric and replicative methods, so as to make more apparent the complexity of the problems inherent in the questions we ask about the behavior of Paleolithic peoples and in our analyses of their stone craft traditions.

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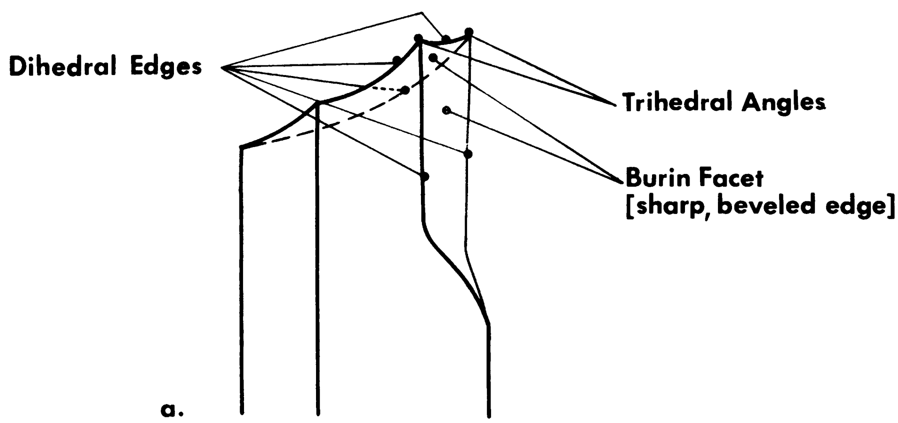
Acknowledgements

The author wishes to thank Drs. J.D. Clark and J. Sackett for providing access to their artifact collections, and for the suggestions and advice they offered. Appreciation and thanks are offered to Michael Schwartz, who wrote the Fortran program used for the factor analysis, and to Judith Ogden, who drew the figures. Lastly, Dr. G. Isaac must be specially thanked for his assistance, encouragement, and support throughout this project.

Figures and Tables



BASIC FEATURES OF THE 'TYPICAL' BURIN

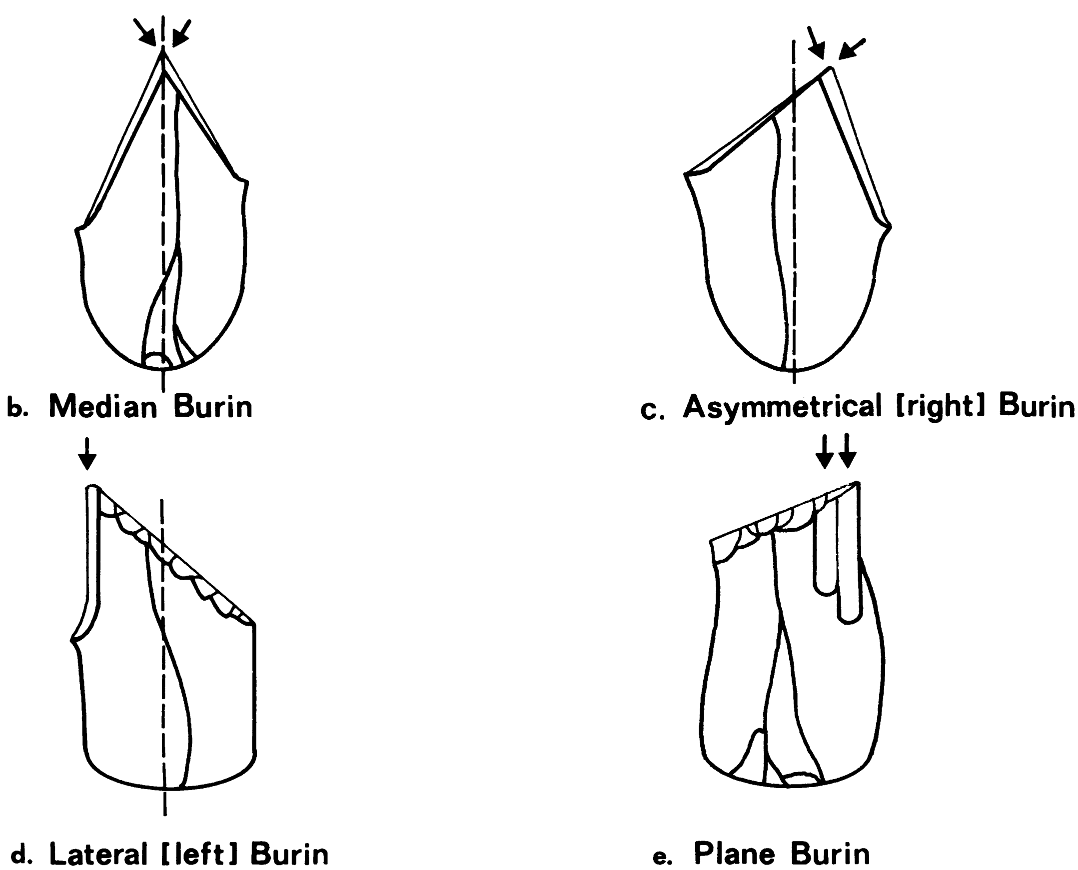


Figure 1 GENERAL BURIN TYPES

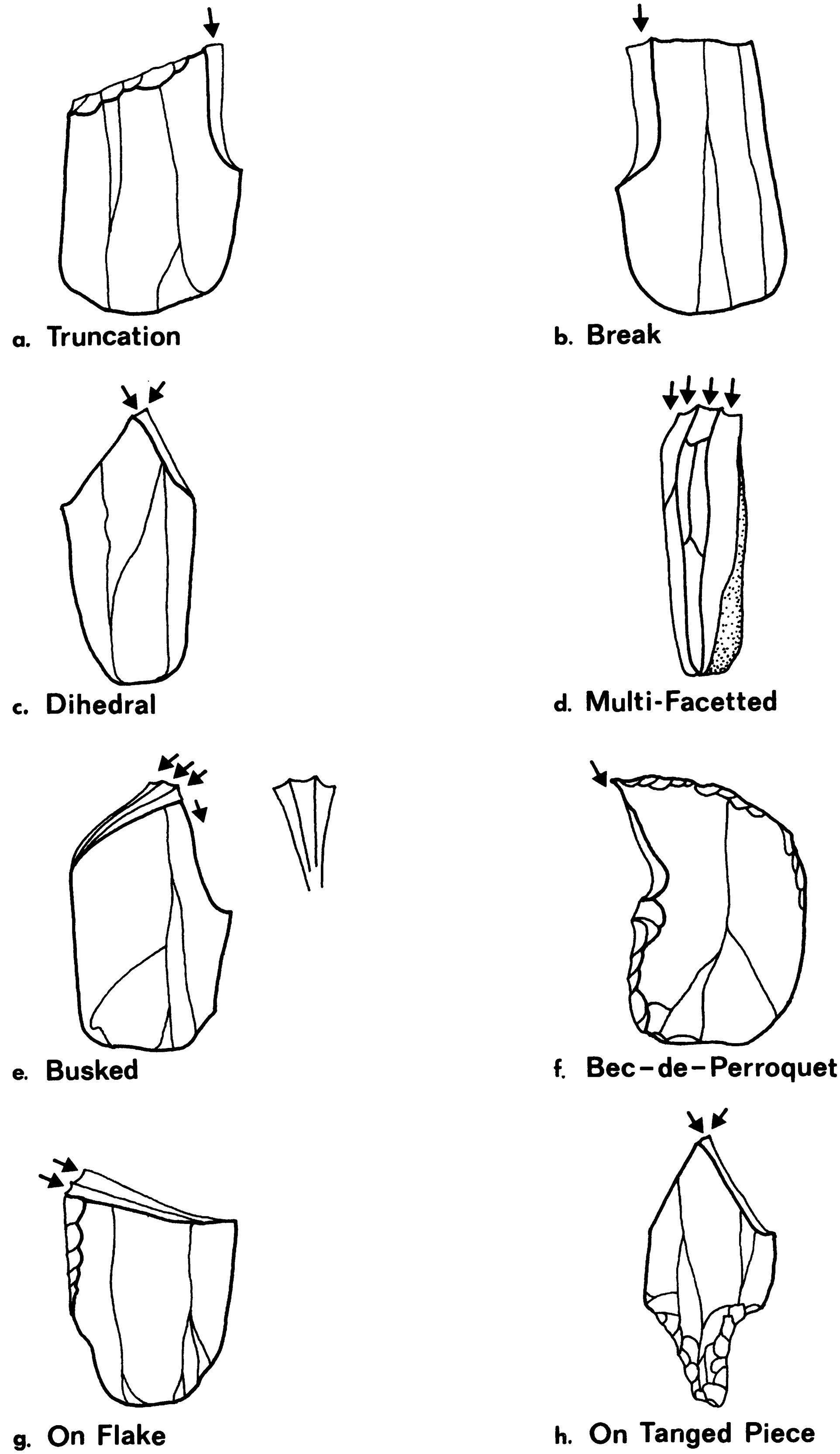
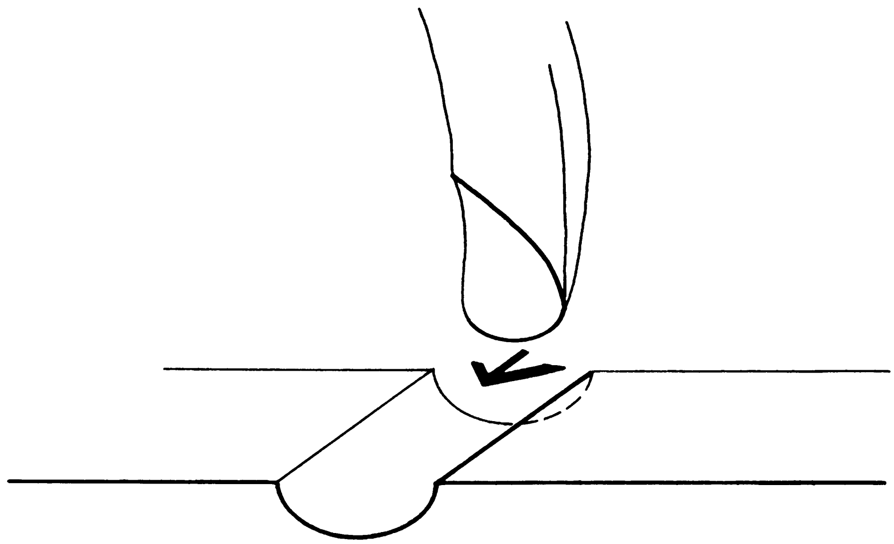
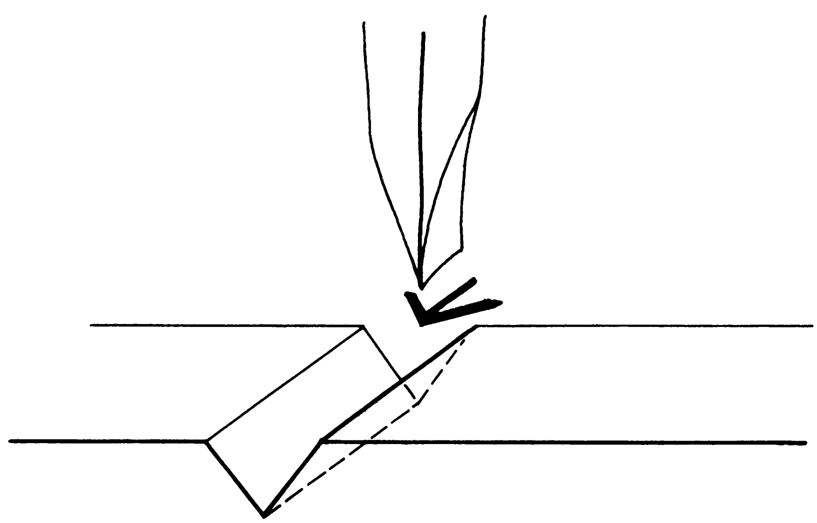


Figure 2 GENERAL BURIN TYPES

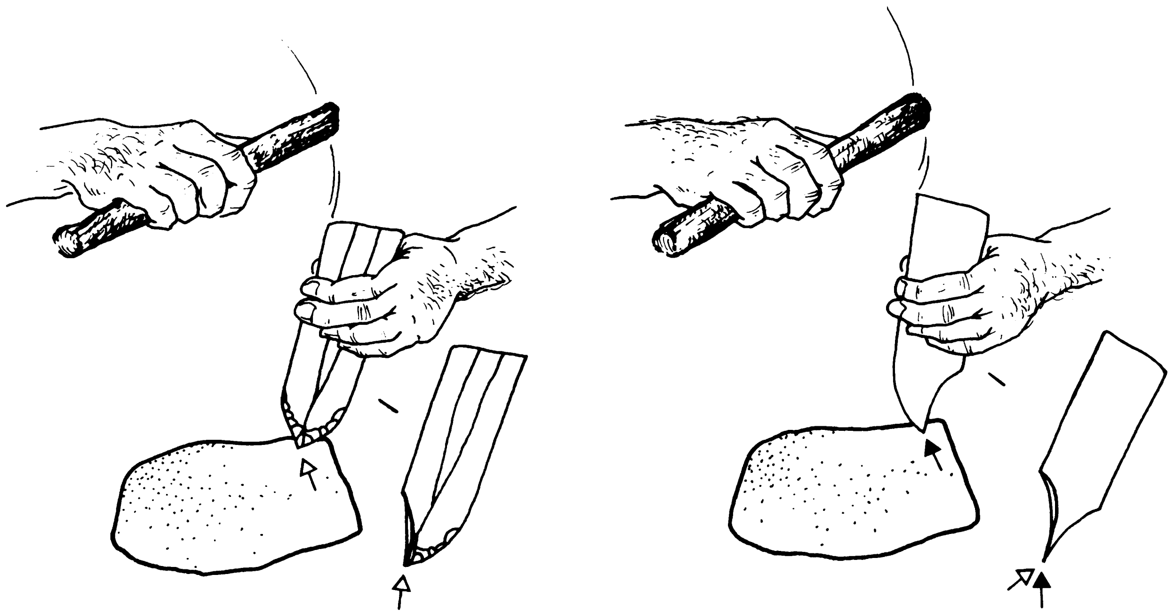


a. Polyhedric Burin for Grooving, Scraping

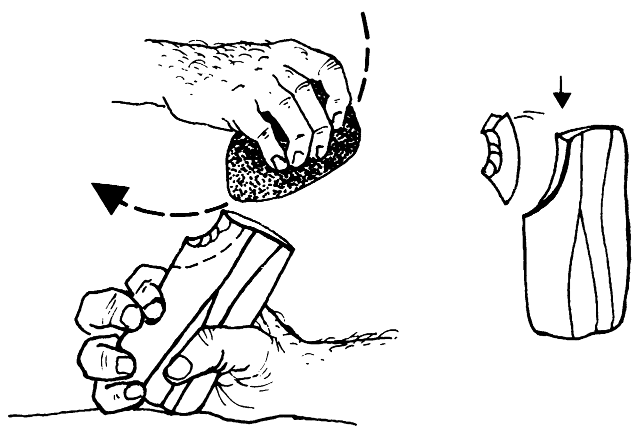


b. Rectilinear Burin for Incising

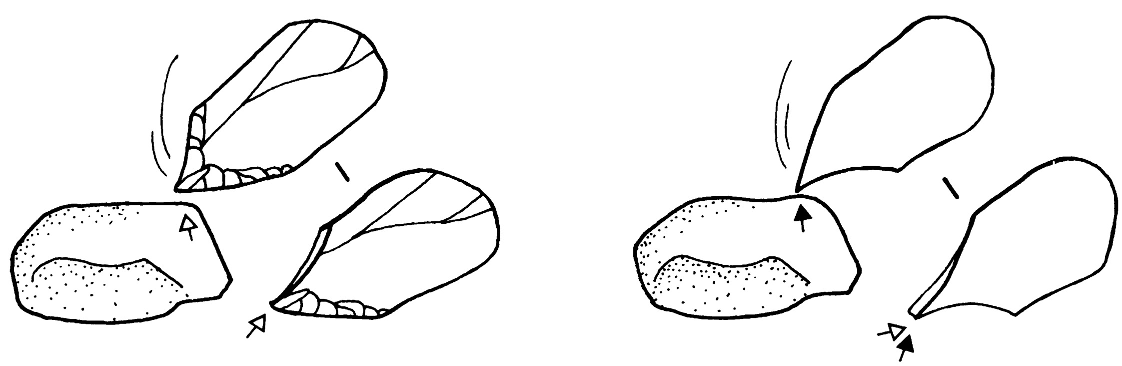
Figure 3 BURIN TYPOLOGY AND ASSOCIATED FUNCTIONS



a. ANVIL TECHNIQUE

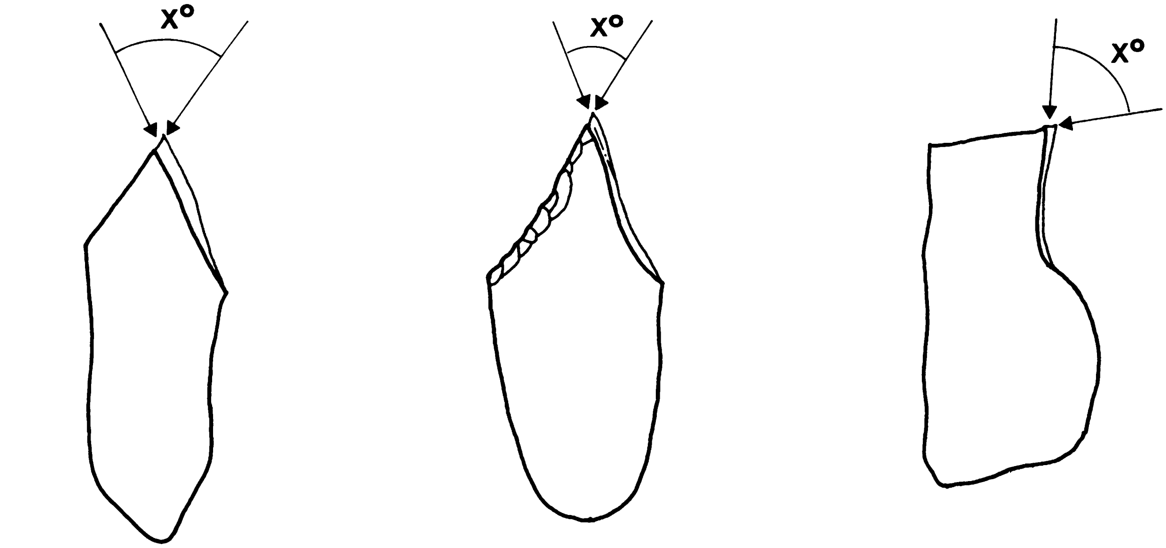


b. Hammer striking on fixed support [break]



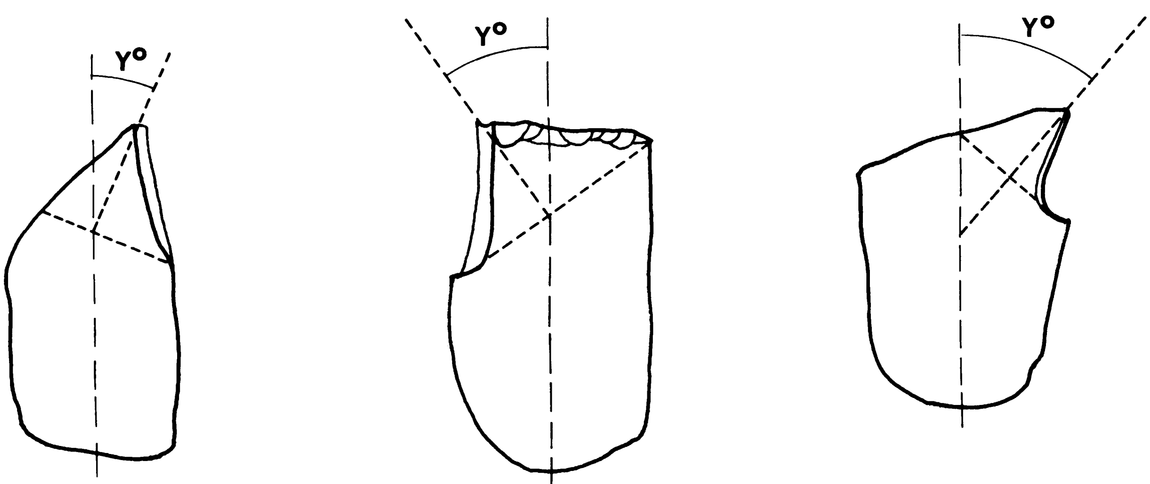
c. Striking burin support [truncation] on fixed hammerstone

Figure 4 TECHNIQUES OF MANUFACTURE



a. Dihedral   b. Truncation   c. Break

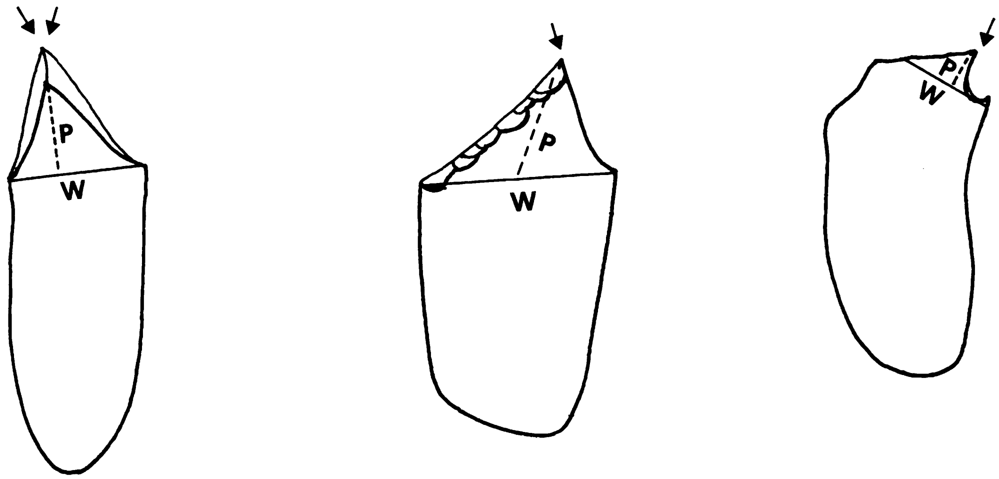
Burin Bit Angle = X Degrees



d.   e.   f.

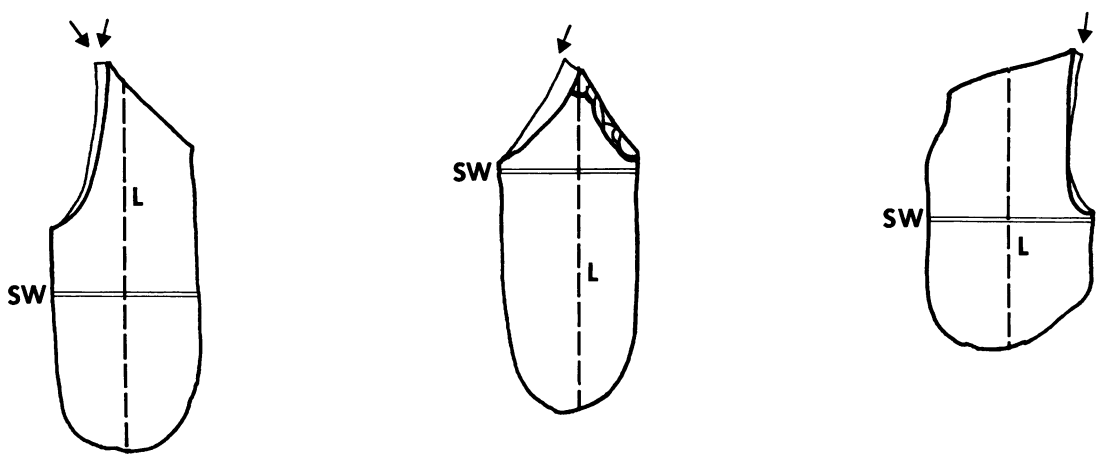
Burin Bit Symmetry = Y Degrees

Figure 5 BURIN DIMENSIONS in ATTRIBUTE ANALYSIS



a. Dihedral b. Truncation c. Break

Bit Projection Length = P mm -------
Bit Projection Width = W mm ———



d. e. f.

Support Length [working axis] = L mm – – – – –
Support Width = SW mm ═══

Figure 6 <u>BURIN DIMENSIONS in ATTRIBUTE ANALYSIS</u>

```
BITANGLE  BURIN BIT ANGLE X.

    CODE
              I
      35      *** (       1)
              I
              I
      40      *** (       1)
              I
              I
      45      ****** (       2)
              I
              I
      50      *********** (       4)
              I
              I
      55      *********** (       4)
              I
              I
      60      ****************** (       7)
              I
              I
      65      ******************************* (      12)
              I
              I
      70      **************** (       6)
              I
              I
      75      ************************** (      10)
              I
              I
      80      **************** (       6)
              I
              I
      85      ******** (       3)
              I
              I
      90      **************** (       6)
              I
              I
      95      ****** (       2)
              I
              I
              I.........I.........I.........I.........I.........I
              0         4         8        12        16        20
              FREQUENCY
```

MEAN	69.063	STD ERR	1.725	MEDIAN	69.667
MODE	65.000	STD DEV	13.798	VARIANCE	190.377
KURTOSIS	-.347	SKEWNESS	-.154	RANGE	60.000
MINIMUM	35.000	MAXIMUM	95.000	SUM	4420.000

Figure 7 FREQUENCY DISTRIBUTION of BIT ANGLE, LA MADELEINE SAMPLE

```
BITSYMM    BURIN BIT SYMMETRY Y.
     CODE
          I
     0    ************************************  (      7)
          I
          I
     3    ***********  (      2)
          I
          I
     6    ************************************  (      7)
          I
          I
     9    *****************************************  (      8)
          I
          I
    12    *******************************  (      6)
          I
          I
    15    ************************************  (      7)
          I
          I
    18    *******************************  (      6)
          I
          I
    21    *******************************  (      6)
          I
          I
    24    ****************  (      3)
          I
          I
    27    ******  (      1)
          I
          I
    30    ******  (      1)
          I
          I
    33    ****************  (      3)
          I
          I
    36    ***********  (      2)
          I
          I
    39    ***********  (      2)
          I
          I
    42    ******  (      1)
          I
          I
    45    ******  (      1)
          I
          I
    51    ******  (      1)
          I
          I
          I.........I.........I.........I.........I.........I
          0         2         4         6         8        10
          FREQUENCY
MEAN          16.359     STD ERR       1.532     MEDIAN        14.786
MODE           9.000     STD DEV      12.258     VARIANCE     150.266
KURTOSIS        .200     SKEWNESS       .826     RANGE         51.000
MINIMUM            0     MAXIMUM      51.000     SUM         1047.000
```

Figure 8 FREQUENCY DISTRIBUTION of BIT SYMMETRY, LA MADELEINE SAMPLE

BITANGLE

SUPPORT		COUNT / ROW PCT / COL PCT / TOT PCT	40	50	60	70	80	90	99	ROW TOTAL
	1	COUNT	2	6	8	17	13	8	2	56
BLADE		ROW PCT	3.6	10.7	14.3	30.4	23.2	14.3	3.6	87.5
		COL PCT	100.0	100.0	72.7	94.4	81.3	88.9	100.0	
		TOT PCT	3.1	9.4	12.5	26.6	20.3	12.5	3.1	
	2	COUNT	0	0	3	1	3	1	0	8
FLAKE		ROW PCT	0	0	37.5	12.5	37.5	12.5	0	12.5
		COL PCT	0	0	27.3	5.6	18.8	11.1	0	
		TOT PCT	0	0	4.7	1.6	4.7	1.6	0	
COLUMN TOTAL			2	6	11	18	16	9	2	64
			3.1	9.4	17.2	28.1	25.0	14.1	3.1	100.0

RAW CHI SQUARE = 5.00433 WITH 6 DEGREES OF FREEDOM. SIGNIFICANCE = .5433

BITANGLE

TECHNIC		COUNT / ROW PCT / COL PCT / TOT PCT	40	50	60	70	80	90	99	ROW TOTAL
	4	COUNT	1	4	8	14	11	4	1	43
DIHEDRAL		ROW PCT	2.3	9.3	18.6	32.6	25.6	9.3	2.3	67.2
		COL PCT	50.0	66.7	72.7	77.8	68.8	44.4	50.0	
		TOT PCT	1.6	6.3	12.5	21.9	17.2	6.3	1.6	
	5	COUNT	0	2	2	4	2	2	0	12
TRUNCATION		ROW PCT	0	16.7	16.7	33.3	16.7	16.7	0	18.8
		COL PCT	0	33.3	18.2	22.2	12.5	22.2	0	
		TOT PCT	0	3.1	3.1	6.3	3.1	3.1	0	
	6	COUNT	1	0	1	0	3	3	1	9
BREAK		ROW PCT	11.1	0	11.1	0	33.3	33.3	11.1	14.1
		COL PCT	50.0	0	9.1	0	18.8	33.3	50.0	
		TOT PCT	1.6	0	1.6	0	4.7	4.7	1.6	
COLUMN TOTAL			2	6	11	18	16	9	2	64
			3.1	9.4	17.2	28.1	25.0	14.1	3.1	100.0

RAW CHI SQUARE = 13.03359 WITH 12 DEGREES OF FREEDOM. SIGNIFICANCE = .3666

Figure 9 CROSSTABULATION of SUPPORT and BIT ANGLE, LA MADELEINE SAMPLE

CROSSTABULATION of TECHNIQUE and BIT ANGLE

BITSYMM

TECHNIC	COUNT / ROW PCT / COL PCT / TOT PCT	MEDIAN BURIN 1	ASSYMETRIC BURIN 2	LATERAL BURIN 3	ROW TOTAL
DIHEDRAL	4	30	10	3	43
		69.8	23.3	7.0	67.2
		81.1	55.6	33.3	
		46.9	15.6	4.7	
TRUNCATION	5	4	7	1	12
		33.3	58.3	8.3	18.8
		10.8	38.9	11.1	
		6.3	10.9	1.6	
BREAK	6	3	1	5	9
		33.3	11.1	55.6	14.1
		8.1	5.6	55.6	
		4.7	1.6	7.8	
COLUMN TOTAL		37	18	9	64
		57.8	28.1	14.1	100.0

RAW CHI SQUARE = 21.25605 WITH 4 DEGREES OF FREEDOM.
SIGNIFICANCE = .0003

CROSSTABULATION of TECHNIQUE and BIT SYMMETRY

BITSYMM

SUPPORT	COUNT / ROW PCT / COL PCT / TOT PCT	MEDIAN BURIN 1	ASSYMETRIC BURIN 2	LATERAL BURIN 3	ROW TOTAL
BLADE	1	31	16	9	56
		55.4	28.6	16.1	87.5
		83.8	88.9	100.0	
		48.4	25.0	14.1	
FLAKE	2	6	2	0	8
		75.0	25.0	0	12.5
		16.2	11.1	0	
		9.4	3.1	0	
COLUMN TOTAL		37	18	9	64
		57.8	28.1	14.1	100.0

RAW CHI SQUARE = 1.78464 WITH 2 DEGREES OF FREEDOM.
SIGNIFICANCE = .4097

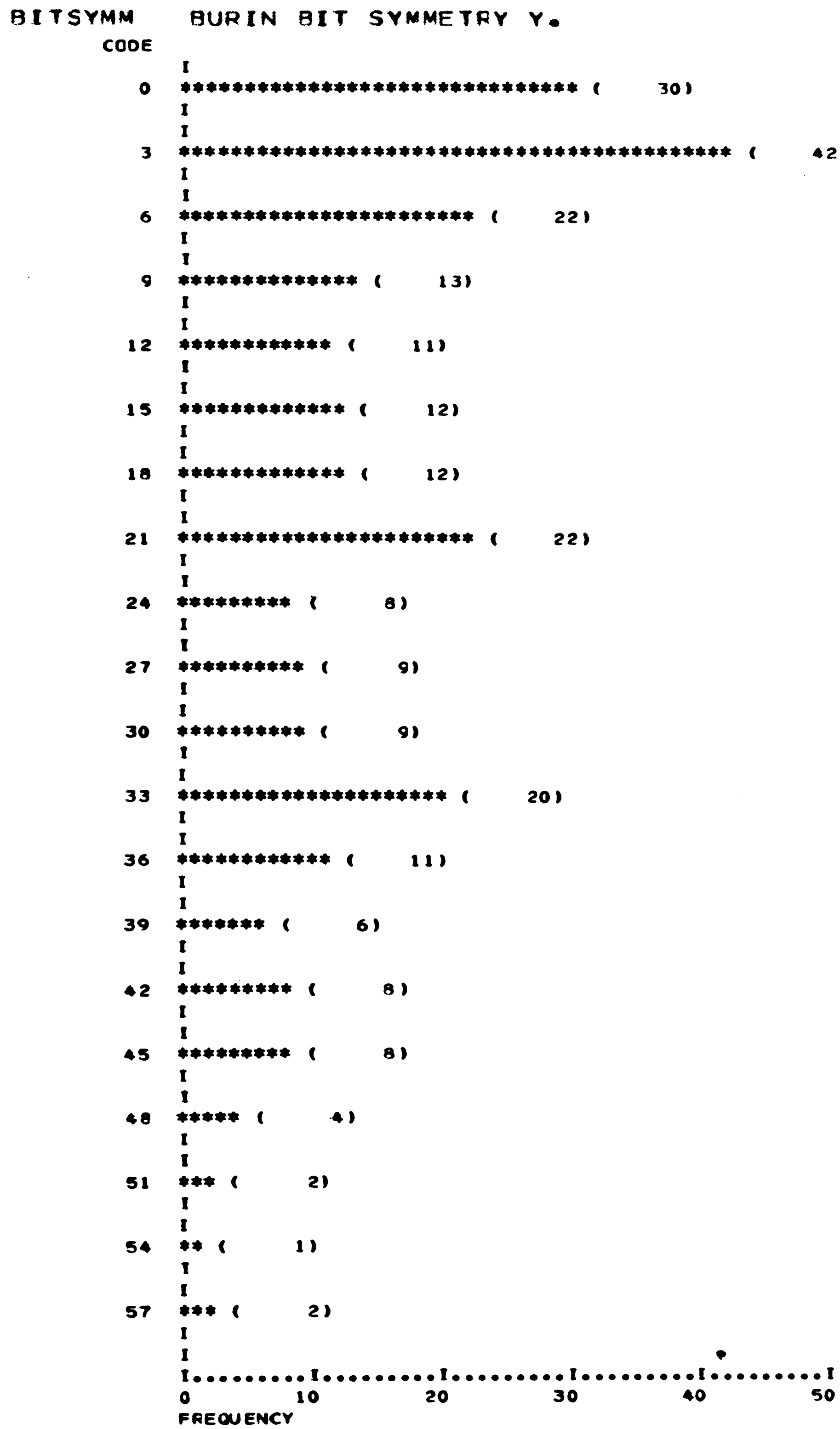
Figure 10 CROSSTABULATION of SUPPORT and BIT SYMMETRY, LA MADELEINE SAMPLE

```
BITANGLE  BURIN BIT ANGLE X.


    CODE
          I
    35    ** (        1)
          I
          I
    40    *** (        2)
          I
          I
    45    ********* (        8)
          I
          I
    50    ***************** (       16)
          I
          I
    55    ************************* (       24)
          I
          I
    60    ***************************** (       28)
          I
          I
    65    ************************************* (       36)
          I
          I
    70    ************************************ (       35)
          I
          I
    75    ********************************** (       33)
          I
          I
    80    *************************** (       26)
          I
          I
    85    ***************** (       16)
          I
          I
    90    ********** (        9)
          I
          I
    95    ******** (        7)
          I
          I
    99    ************ (       11)
          I
          I
          I.........I.........I.........I.........I.........I
          0        10        20        30        40        50
          FREQUENCY
```

MEAN	69.619	STD ERR	.869	MEDIAN	69.814
MODE	65.000	STD DEV	13.791	VARIANCE	190.197
KURTOSIS	-.384	SKEWNESS	.191	RANGE	64.000
MINIMUM	35.000	MAXIMUM	99.000	SUM	17544.000

Figure 11 FREQUENCY DISTRIBUTION of BIT ANGLE, "STUDY SAMPLE"



MEAN	17.929	STD ERR	.955	MEDIAN	15.16
MODE	3.000	STD DEV	15.158	VARIANCE	229.76
KURTOSIS	-.843	SKEWNESS	.542	RANGE	57.00
MINIMUM	0	MAXIMUM	57.000	SUM	4518.00

Figure 12 FREQUENCY DISTRIBUTION of BIT SYMMETRY, "STUDY SAMPLE"

```
BITPROJ    PROJECTION OF BURIN BIT P MM

    CODE
          I
       4  ****** (       5)
          I
          I
       6  ************* (      12)
          I
          I
       8  *********************** (      22)
          I
          I
      10  ******************************************** (      43)
          I
          I
      12  ************************************** (      37)
          I
          I
      14  ********************************* (      32)
          I
          I
      16  *************************** (      26)
          I
          I
      18  *********************** (      22)
          I
          I
      20  ******************* (      18)
          I
          I
      22  ********** (       9)
          I
          I
      24  ******* (       6)
          I
          I
      26  ******* (       6)
          I
          I
      28  ******** (       7)
          I
          I
      30  ****** (       5)
          I
          I
      34  ** (       1)
          I
          I
      38  ** (       1)
          I
          I
          I.........I.........I.........I.........I.........I
          0        10        20        30        40        50
          FREQUENCY
```

MEAN	14.595	STD ERR	.389	MEDIAN	13.719
MODE	10.000	STD DEV	6.178	VARIANCE	38.162
KURTOSIS	.702	SKEWNESS	.884	RANGE	34.000
MINIMUM	4.000	MAXIMUM	38.000	SUM	3678.000

Figure 13 FREQUENCY DISTRIBUTION of BIT LENGTH, "STUDY SAMPLE"

```
BITWIDTH   WIDTH OF BURIN BIT W MM

    CODE
             I
      6      **** (       6)
             I
             I
      9      ******* (      12)
             I
             I
     12      ************* (      24)
             I
             I
     15      ********************** (      41)
             I
             I
     18      **************************** (      53)
             I
             I
     21      ********************* (      40)
             I
             I
     24      ************* (      23)
             I
             I
     27      **************** (      30)
             I
             I
     30      ****** (      10)
             I
             I
     33      **** (       5)
             I
             I
     36      *** (       4)
             I
             I
     39      ** (       2)
             I
             I
     45      ** (       1)
             I
             I
  (WILD)     ** (       1)
             I
             I
             I.........I.........I.........I.........I.........I
             0        20        40        60        80       100
             FREQUENCY
```

MEAN	19.661	STD ERR	.427	MEDIAN	18.302
MODE	18.000	STD DEV	6.772	VARIANCE	45.865
KURTOSIS	.492	SKEWNESS	.518	RANGE	39.000
MINIMUM	6.000	MAXIMUM	45.000	SUM	4935.000

Figure 14 FREQUENCY DISTRIBUTION of BIT WIDTH, "STUDY SAMPLE"

```
SUPLNGTH   LENGTH OF WORKING AXIS L MM
     CODE
           I
      16   ** (       1)
           I
           I
      24   **** (       3)
           I
           I
      28   ****** (       5)
           I
           I
      32   ********** (       9)
           I
           I
      36   ******* (       6)
           I
           I
      40   ************* (      12)
           I
           I
      44   ************* (      12)
           I
           I
      48   ************************ (      23)
           I
           I
      52   ************************* (      24)
           I
           I
      56   ************************* (      24)
           I
           I
      60   ******************************* (      30)
           I
           I
      64   ***************************** (      28)
           I
           I
      68   **************** (      15)
           I
           I
      72   ************ (      11)
           I
           I
      76   ********** (       9)
           I
           I
      80   *********** (      10)
           I
           I
      84   *********** (      10)
           I
           I
      88   ****** (       5)
           I
           I
      92   **** (       3)
           I
           I
      96   *** (       2)
           I
           I
      99   *********** (      10)
           I
           I
           I.........I.........I.........I.........I.........I
           0        10        20        30        40        50
           FREQUENCY

MEAN          59.770    STD ERR      1.085    MEDIAN        59.733
MODE          60.000    STD DEV     17.216    VARIANCE     296.401
KURTOSIS       -.079    SKEWNESS      .284    RANGE         83.000
MINIMUM       16.000    MAXIMUM     99.000    SUM        15062.000
```

Figure 15 FREQUENCY DISTRIBUTION of SUPPORT LENGTH, "STUDY SAMPLE"

```
SUPWIDTH  SUPPORT WIDTH SW MM
    CODE
          I
    12    **** (      3)
          I
          I
    15    *** (      2)
          I
          I
    18    ****************** (     17)
          I
          I
    21    ************************* (     24)
          I
          I
    24    ********************************** (     33)
          I
          I
    27    ************************************ (     35)
          I
          I
    30    ***************************************** (     40)
          I
          I
    33    ******************************* (     30)
          I
          I
    36    ********************** (     21)
          I
          I
    39    ***************** (     16)
          I
          I
    42    ****************** (     17)
          I
          I
    45    ***** (      4)
          I
          I
    48    ******** (      7)
          I
          I
    51    ** (      1)
          I
          I
    54    ** (      1)
          I
          I
 (WILD)   ** (      1)
          I
          I
          I.........I.........I.........I.........I.........I
          0        10        20        30        40        50
          FREQUENCY
```

MEAN	29.952	STD ERR	.509	MEDIAN	29.788
MODE	30.000	STD DEV	8.068	VARIANCE	65.086
KURTOSIS	-.201	SKEWNESS	.360	RANGE	42.000
MINIMUM	12.000	MAXIMUM	54.000	SUM	7518.000

Figure 16 FREQUENCY DISTRIBUTION of SUPPORT WIDTH, "STUDY SAMPLE"

NUMBER OF VARIABLES = 6

NUMBER OF OBSERVATIONS = 252

VARIABLE	MEAN	STANDARD DEVIATION
1 BITANGLE	696.190476	137.911902
2 BITSYMM	193.333333	145.889894
3 BITPROJ	140.793651	61.832613
4 BITWIDTH	187.976190	69.793887
5 SUPLNGTH	584.166667	174.240812
6 SUPWIDTH	290.476190	82.701953

COVARIANCE MATRIX

1 BITANGLE	1.0000					
2 BITSYMM	.3818	1.0000				
3 BITPROJ	-.2709	-.1428E-01	1.0000			
4 BITWIDTH	.1478	.1693	.7668	1.0000		
5 SUPLNGTH	.3725E-01	.4903E-01	.3226	.3231	1.0000	
6 SUPWIDTH	.2670	.1063	.2845	.5120	.4544	1.0000

EIGENVALUES

2.386143	1.507750	.894363	.665826	.423369	.122549

PERCENT OF TOTAL CONTRIBUTION PER EIGENVALUE

39.769050	25.129168	14.906055	11.097096	7.056152	2.042479

EIGENVECTORS

	NUMBER 1	NUMBER 2	NUMBER 3	NUMBER 4	NUMBER 5	NUMBER 6
1 BITANGLE	.1093	-.7042	.0810	.3823	-.5125	.2771
2 BITSYMM	.1464	-.5549	-.5052	-.5759	.2892	.0089
3 BITPROJ	.4884	.4013	-.3740	.0024	-.1463	.6626
4 BITWIDTH	.5729	.0588	-.3217	.2747	-.1713	-.6783
5 SUPLNGTH	.4124	.0304	.5722	-.6068	-.3571	-.0760
6 SUPWIDTH	.4793	-.1752	.4091	.2801	.6896	.1349

Figure 17 PRINCIPAL COMPONENTS ANALYSIS on "STUDY SAMPLE"

BITANGLE

SUPPORT	COUNT / ROW PCT / COL PCT / TOT PCT	40	50	60	70	80	90	99	ROW TOTAL
BLADE	1	3	19	34	32	27	12	5	132
		2.3	14.4	25.8	24.2	20.5	9.1	3.8	52.4
		100.0	79.2	65.4	45.1	45.8	48.0	27.8	
		1.2	7.5	13.5	12.7	10.7	4.8	2.0	
FLAKE	2	0	5	18	39	32	13	13	120
		0	4.2	15.0	32.5	26.7	10.8	10.8	47.6
		0	20.8	34.6	54.9	54.2	52.0	72.2	
		0	2.0	7.1	15.5	12.7	5.2	5.2	
	COLUMN TOTAL	3	24	52	71	59	25	18	252
		1.2	9.5	20.6	28.2	23.4	9.9	7.1	100.0

RAW CHI SQUARE = 20.27371 WITH 6 DEGREES OF FREEDOM. SIGNIFICANCE = .0025

BITANGLE

TECHNIC	COUNT / ROW PCT / COL PCT / TOT PCT	40	50	60	70	80	90	99	ROW TOTAL
DIHEDRAL	4	2	20	44	43	24	3	0	136
		1.5	14.7	32.4	31.6	17.6	2.2	0	54.0
		66.7	83.3	84.6	60.6	40.7	12.0	0	
		.8	7.9	17.5	17.1	9.5	1.2	0	
TRUNCATION	5	1	3	6	25	26	16	17	94
		1.1	3.2	6.4	26.6	27.7	17.0	18.1	37.3
		33.3	12.5	11.5	35.2	44.1	64.0	94.4	
		.4	1.2	2.4	9.9	10.3	6.3	6.7	
BREAK	6	0	1	2	3	9	6	1	22
		0	4.5	9.1	13.6	40.9	27.3	4.5	8.7
		0	4.2	3.8	4.2	15.3	24.0	5.6	
		0	.4	.8	1.2	3.6	2.4	.4	
	COLUMN TOTAL	3	24	52	71	59	25	18	252
		1.2	9.5	20.6	28.2	23.4	9.9	7.1	100.0

RAW CHI SQUARE = 81.58255 WITH 12 DEGREES OF FREEDOM. SIGNIFICANCE = .0000

Figure 18 CROSSTABULATION of SUPPORT and BIT ANGLE, "STUDY SAMPLE"

CROSSTABULATION of TECHNIQUE and BIT ANGLE

BITSYMM

TECHNIC / COUNT / ROW PCT / COL PCT / TOT PCT		MEDIAN BURIN 1	ASSYMETRIC BURIN 2	LATERAL BURIN 3	ROW TOTAL
DIHEDRAL	4	85	37	14	136
		62.5	27.2	10.3	54.0
		65.4	54.4	25.9	
		33.7	14.7	5.6	
TRUNCATION	5	45	25	24	94
		47.9	26.6	25.5	37.3
		34.6	36.8	44.4	
		17.9	9.9	9.5	
BREAK	6	0	6	16	22
		0	27.3	72.7	8.7
		0	8.8	29.6	
		0	2.4	6.3	
COLUMN TOTAL		130	68	54	252
		51.6	27.0	21.4	100.0

RAW CHI SQUARE = 50.37286 WITH 4 DEGREES OF FREEDOM.
SIGNIFICANCE = .0000

CROSSTABULATION of TECHNIQUE and BIT SYMMETRY

BITSYMM

SUPPORT / COUNT / ROW PCT / COL PCT / TOT PCT		MEDIAN BURIN 1	ASSYMETRIC BURIN 2	LATERAL BURIN 3	ROW TOTAL
BLADE	1	74	36	22	132
		56.1	27.3	16.7	52.4
		56.9	52.9	40.7	
		29.4	14.3	8.7	
FLAKE	2	56	32	32	120
		46.7	26.7	26.7	47.6
		43.1	47.1	59.3	
		22.2	12.7	12.7	
COLUMN TOTAL		130	68	54	252
		51.6	27.0	21.4	100.0

RAW CHI SQUARE = 4.01713 WITH 2 DEGREES OF FREEDOM.
SIGNIFICANCE = .1342

Figure 19 CROSSTABULATION of SUPPORT and BIT SYMMETRY, "STUDY SAMPLE"

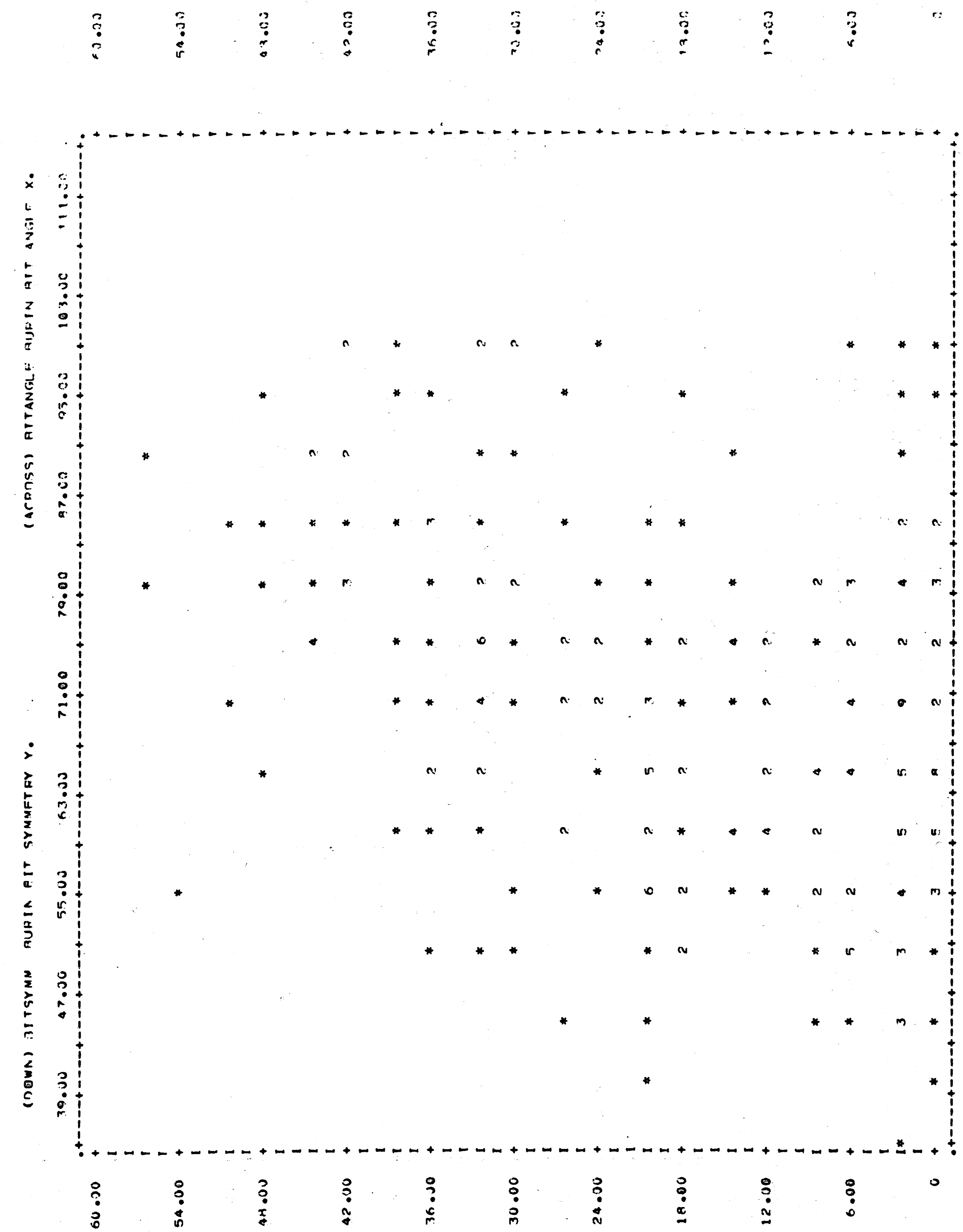


Figure 20 SCATTERGRAM of BIT SYMMETRY and BIT ANGLE, "STUDY SAMPLE"

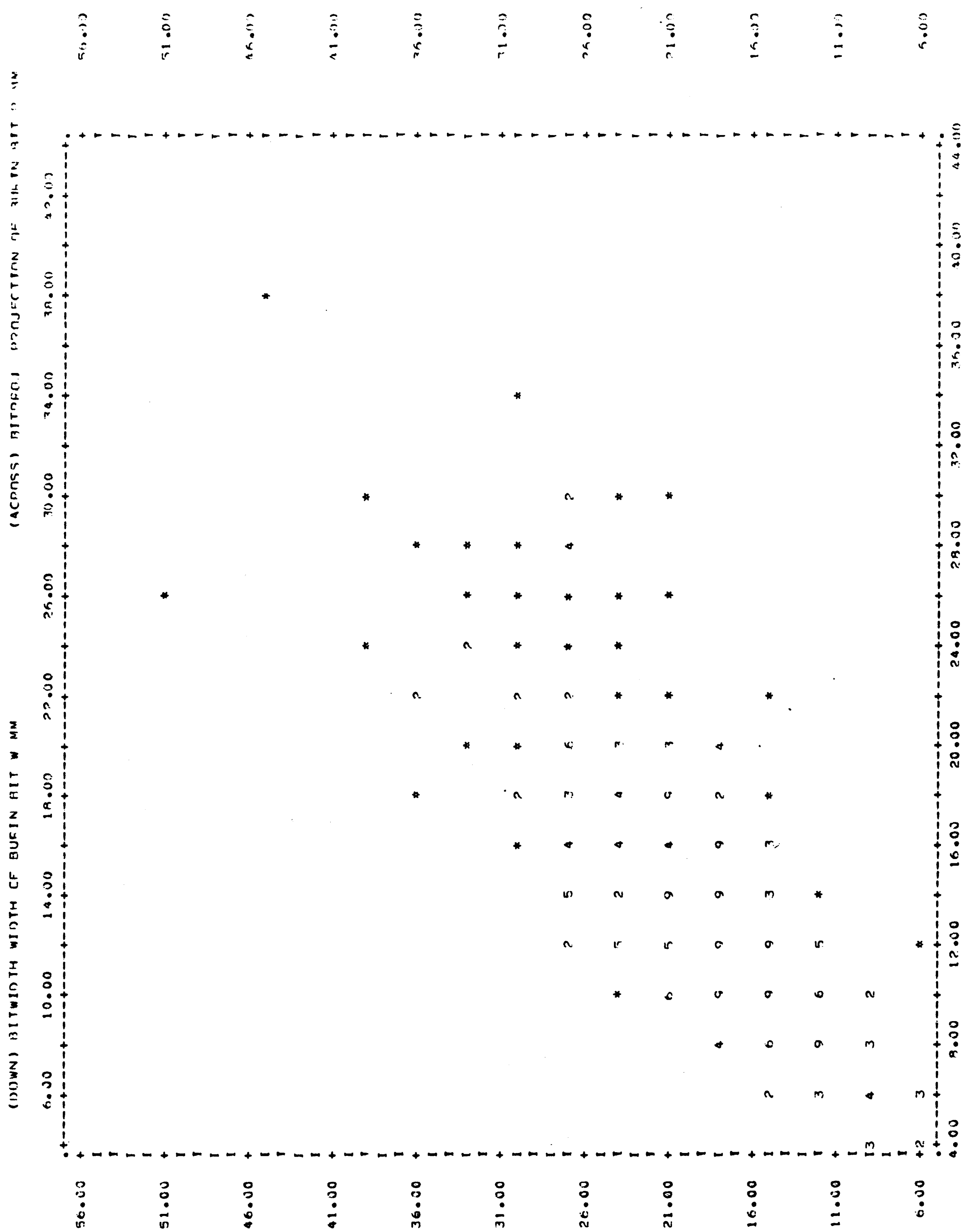


Figure 21 SCATTERGRAM of BIT WIDTH and BIT LENGTH, "STUDY SAMPLE"

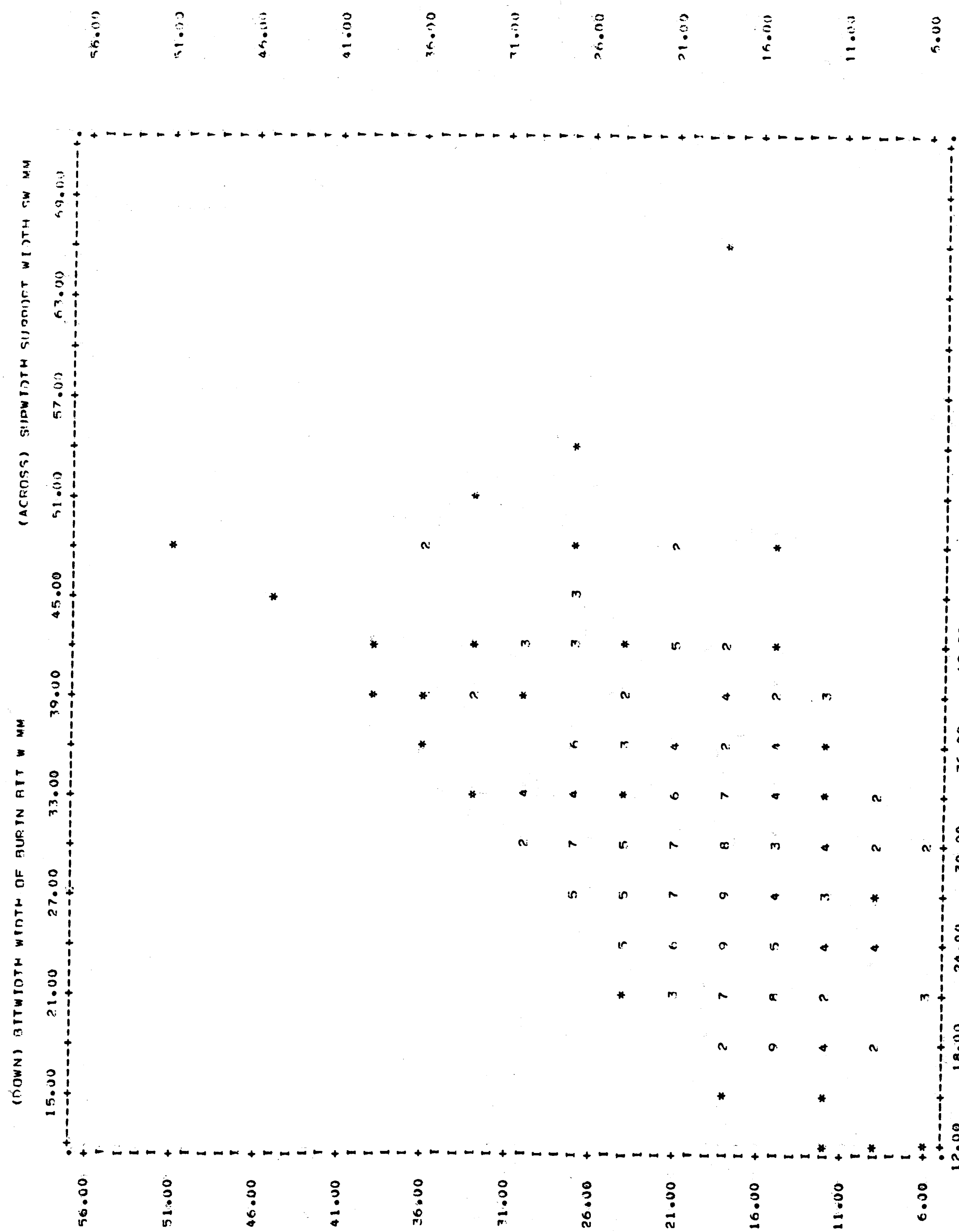


Figure 22 SCATTERGRAM of BIT WIDTH and SUPPORT WIDTH, "STUDY SAMPLE"

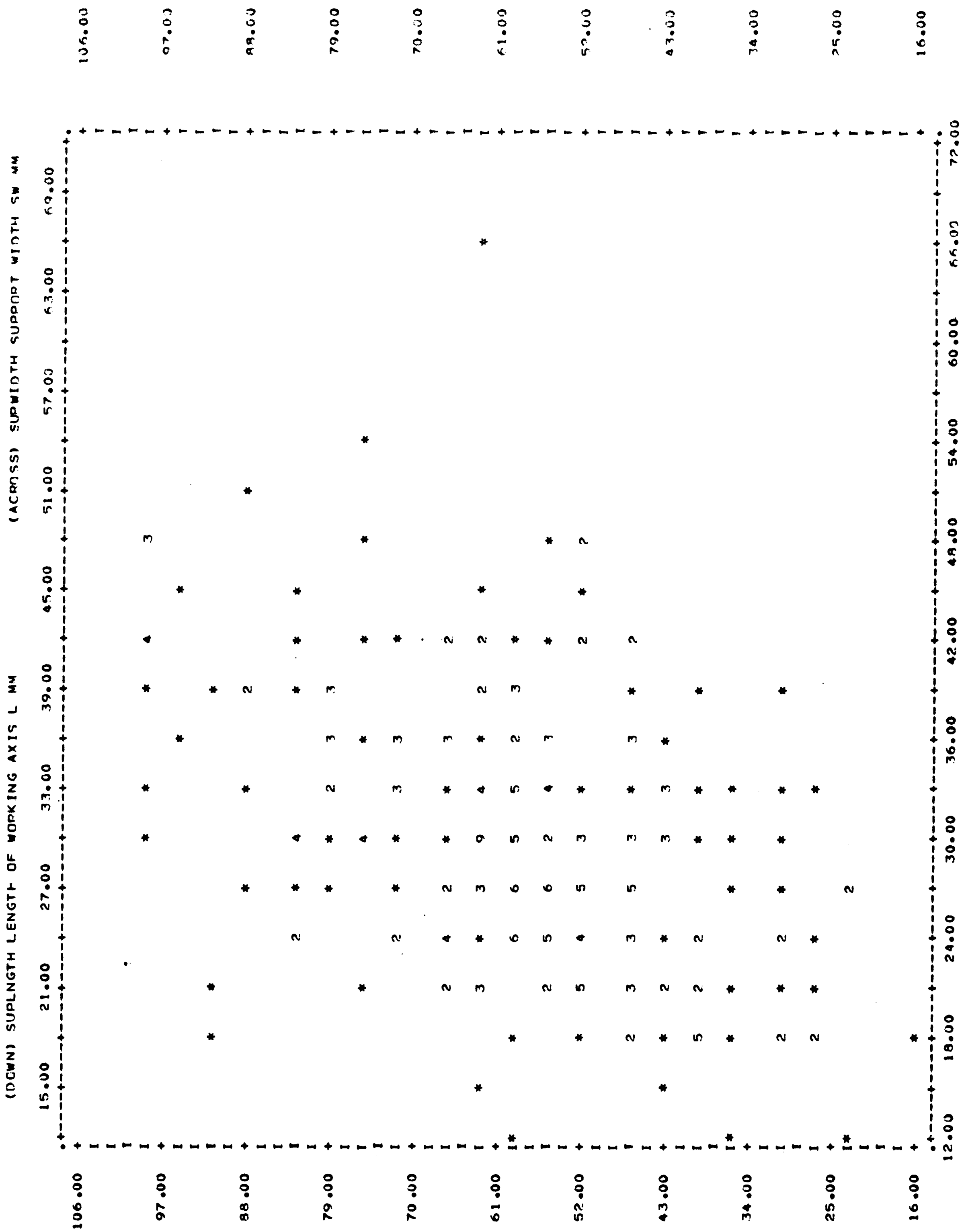


Figure 23 SCATTERGRAM of SUPPORT LENGTH and SUPPORT WIDTH, "STUDY SAMPLE"

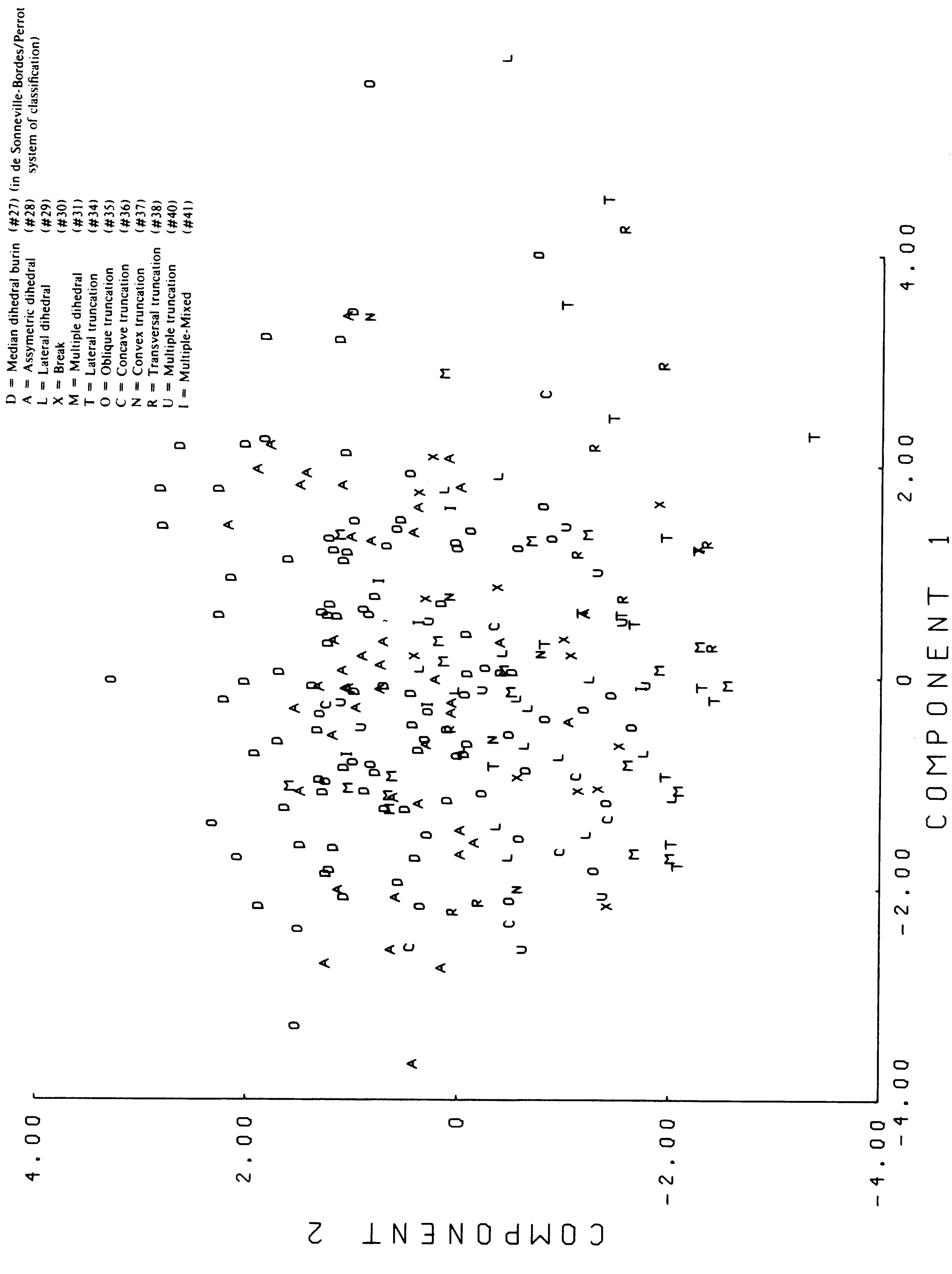


Figure 24 PLOT of "SAMPLE" BURINS on PRINCIPAL COMPONENTS MATRIX COMPONENTS 1 and 2

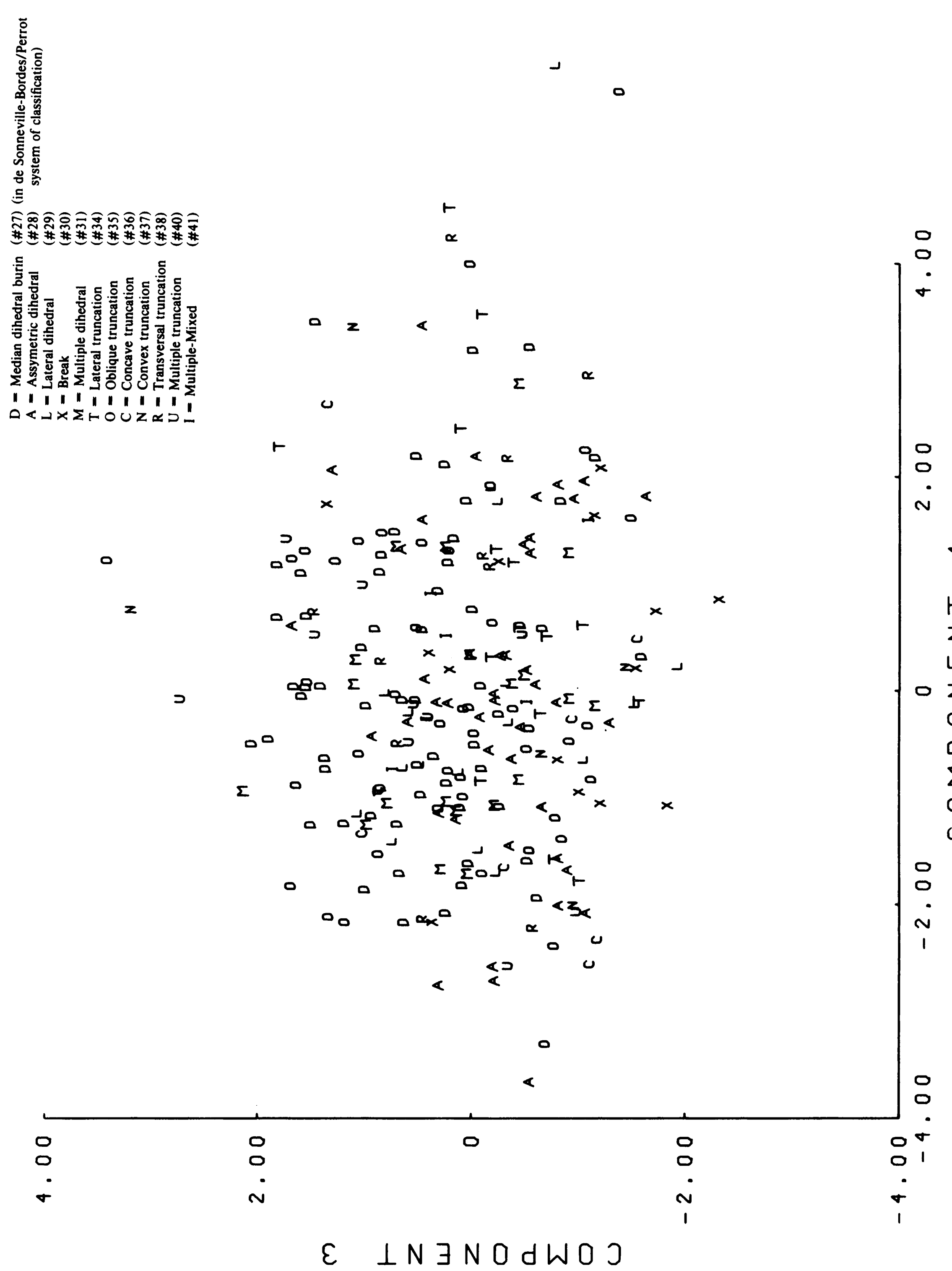


Figure 25 PLOT of "SAMPLE" BURINS on PRINCIPAL COMPONENTS MATRIX COMPONENTS 1 and 3

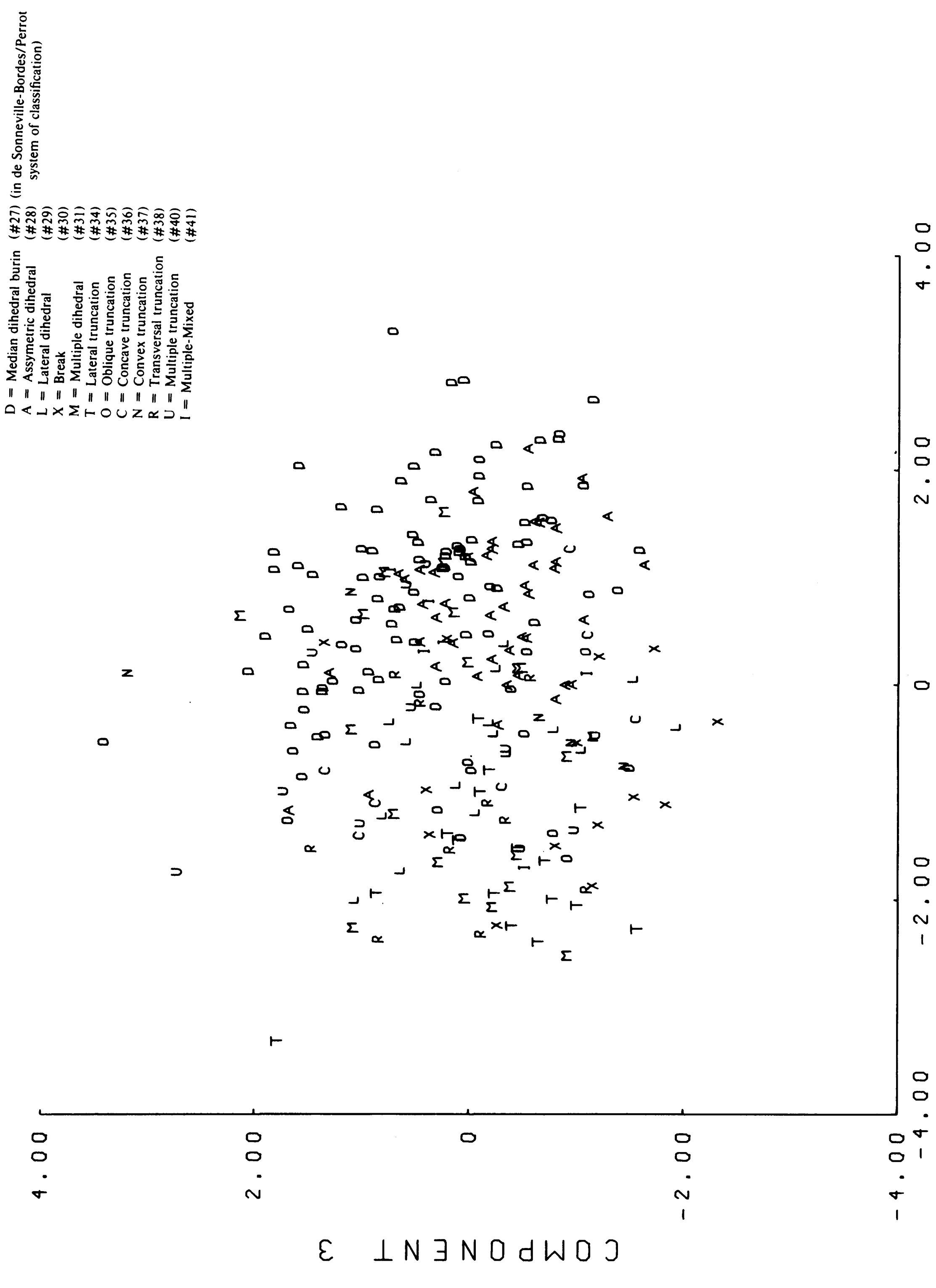


Figure 26 PLOT of "SAMPLE" BURINS on PRINCIPAL COMPONENTS MATRIX COMPONENTS 2 and 3

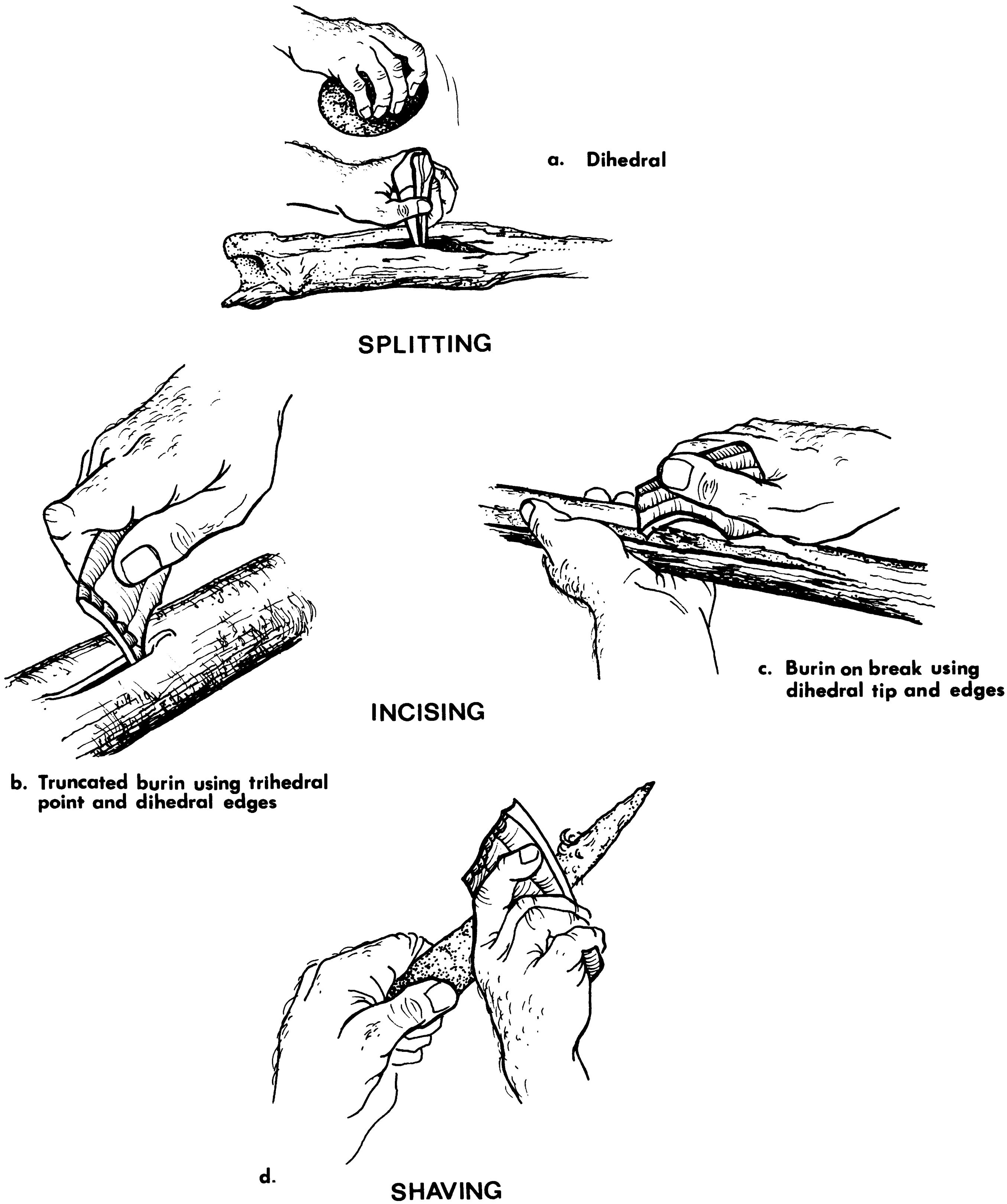


Figure 27 BURIN FUNCTIONS

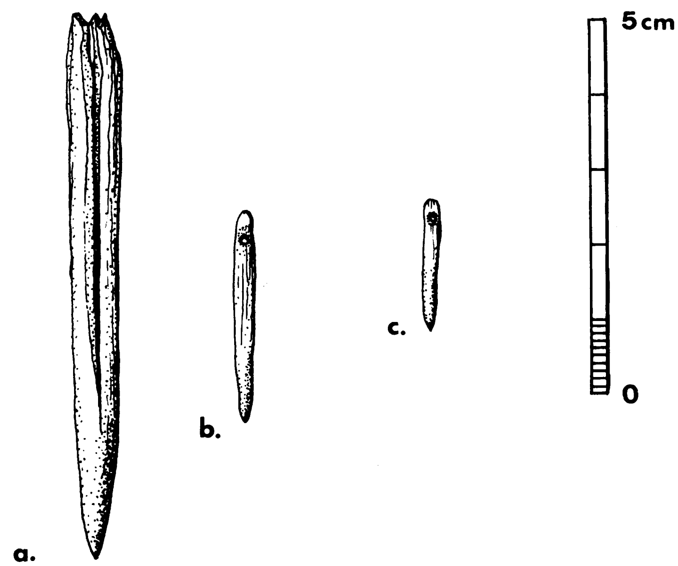


Figure 28 BONE AWL AND NEEDLES

TYPENO DE S-BORDES-PERROT TYPE NO.

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
	27	26	40.6	40.6	40.6
	28	6	9.4	9.4	50.0
	29	4	6.3	6.3	56.3
	30	5	7.8	7.8	64.1
	31	6	9.4	9.4	73.4
	33	1	1.6	1.6	75.0
	34	1	1.6	1.6	76.6
	35	5	7.8	7.8	84.4
	36	4	6.3	6.3	90.6
	41	6	9.4	9.4	100.0
	TOTAL	64	100.0	100.0	

SUPPORT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
BLADE	1	56	87.5	87.5	87.5
FLAKE	2	8	12.5	12.5	100.0
	TOTAL	64	100.0	100.0	

TECHNIC TECHNIQUE

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
DIHEDRAL	4	43	67.2	67.2	67.2
TRUNCATION	5	12	18.8	18.8	85.9
BREAK	6	9	14.1	14.1	100.0
	TOTAL	64	100.0	100.0	

Table 1 BURIN TYPES in LA MADELEINE SAMPLE

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
	27	60	23.8	23.8	23.8
	28	44	17.5	17.5	41.3
	29	17	6.7	6.7	48.0
	30	14	5.6	5.6	53.6
	31	20	7.9	7.9	61.5
	34	16	6.3	6.3	67.9
	35	42	16.7	16.7	84.5
	36	8	3.2	3.2	87.7
	37	5	2.0	2.0	89.7
	38	10	4.0	4.0	93.7
	40	10	4.0	4.0	97.6
	41	6	2.4	2.4	100.0
	TOTAL	252	100.0	100.0	

SUPPORT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
BLADE	1	132	52.4	52.4	52.4
FLAKE	2	120	47.6	47.6	100.0
	TOTAL	252	100.0	100.0	

TECHNIC TECHNIQUE

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
DIHEDRAL	4	136	54.0	54.0	54.0
TRUNCATION	5	94	37.3	37.3	91.3
BREAK	6	22	8.7	8.7	100.0
	TOTAL	252	100.0	100.0	

Table 2 BURIN TYPES in "STUDY SAMPLE"