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The Ohio State University, Ph.D., 1976
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A METHOD FOR THE ANALYSIS OF FLAKES IN ARCHAEOLOGICAL
ASSEMBLAGES: A PERUVIAN EXAMPLE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Carl James Phagan, B.S., M.S., M.A.

The Ohio State University
1976

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ACKNOWLEDGMENTS

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Lithic Technology
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I. INTRODUCTION

At least two million years ago people first learned that by applying force to a piece of stone in certain ways they could predict the fracture of the stone and produce a sharp edge or point which was more useful than the stone in its natural condition. Gradually through trial and error and through fortuitous accident they learned to control the variables involved in this fracture process until, by the end of the Paleolithic, they were able to make a wide range of varied and complex flaked stone implements.

Indications of the production and use of these flaked stone implements constitute most of the archaeological record of the Paleolithic period. Just what is this process of making implements by flaking stone? How do we learn about it? What are the variables that allow people to control this process? And how can the analysis of the archaeological record be organized to interpret and compare the process of making flaked stone implements? These are questions to which this study is addressed.

The attempt by prehistorians to understand past lifeways centers on the recognition and interpretation of patterned variability in the archaeological record. This pattern or organization in the archaeological record is assumed to result from organization in the original activity that produced it, and it is this original organized behavior that prehistorians seek to understand. They are constantly searching for more accurate and reliable methodologies and interpretive frameworks that will allow them to recognize and decipher patterned variability in the data they unearth.

Four kinds of variability are in the archaeological record: stylistic, functional, technological, and random (Binford and Binford 1966; Wilmsen 1970; Speth 1972). Of these, only the first three have cultural significance. Stylistic variability usually refers to variability attributable to different culturally imposed ideas about how an implement should "properly be." These attributes of propriety are normally recognized in morphological attributes such as size, shape, and decoration, and are made without reference to the function or production of the item. This stylistic variability in the archaeological record has been particularly useful in establishing chronological sequences and migration patterns of prehistoric peoples.

Functional variability in archaeological assemblages is the variability attributable to the actual or intended use of the implements. It is normally recognized in morphological attributes
such as size, shape, polish, or striations which are interpretable by analogy to the implements' functions. The increased dependence on analogic interpretation reduces the security of the conclusions, but carefully constructed functional analysis can be very useful in reconstructing probable lifeways of prehistoric peoples (Frison 1968; Wilmsen 1970).

Technological variability is considerably less well defined in the archaeological literature, but the term is most often used implicitly to indicate variability resulting from the differential application of distinct manufacturing techniques. This implicit definition will be further discussed later.

While each of these categories of artifact variability may provide fruitful analytic direction, the three are not theoretically equivalent classes, and should not be treated as such. Both stylistic expression and functional utility are achieved through technological activity. All variability, therefore, is first technological, and appropriate analytic questions are not so much "What variability is stylistic or functional or technological?", but "What technological variability also has stylistic or functional significance?", and "How can technological variability be interpreted in and of itself?".

Kleindienst recognizes this distinction between technological and other variability:

Technological classification involves asking how selected attributes were achieved; this is at least a first-order interpretation, even when grounded in experiment. A "functional" and/or "stylistic" analysis involves asking the purpose of or the intent directing the occurrence of particular technological-morphological attributes, and requires several further steps in testing and interpretation (Kleindienst 1975:383).

Anthony (1975), whose terminology is not quite parallel, nevertheless alludes to the same distinction between technological and other aspects of stone artifact assemblages. He further suggests the possibility of arriving at different levels of cultural patterning by recognizing these distinctions.

It seems possible that technological aspects of a stone assemblage represent long-enduring customs of a people of a possibly large area, whereas typological features may be more closely related to function, environment, and idiosyncrasies of a specific society more delimited in time and space (Anthony 1975:379).
The possibility of formulating and testing such basic cultural hypotheses by using specifically technological analysis is not novel except in its explicitness. In fact, of course, all three kinds of artifact variability need continual rigorous definition and explanation as complex, interdependent analytic systems. This study will develop such a treatment of technological variability in one segment of the archaeological record.

Technology is much more than manufacturing implements. Merrill (1968) suggests that, in its broader meaning, technology indicates the practical arts. Technological systems involve knowledge of the environment, especially with respect to human needs for water, food, shelter, and other basic necessities. These systems include complex sets of understandings and techniques for selecting implements or producing them from materials in the environment and for their use in serving human needs. "Technologies are the cultural traditions developed in human communities for dealing with the physical and biological environment" (Merrill 1968:576-7).

Anthropology has long been vitally concerned, along with other social sciences, with the impact of technology and effects of technological systems on other elements of social life. It is strange, therefore, that technological systems have come so slowly and haphazardly under careful study by archaeologists, whose data are particularly suited to the explication of such systems and their development in time and space.

Within the sphere of "technological systems," various sub-systems may be isolated and examined more closely, and it is the technological sub-system of the production of chipped stone implements that is the primary focus of this study. The term "production technology" will be used to indicate this particular portion of the total technological system. It implies basically the sequence of manipulative actions by an artisan in the production of chipped stone implements. Only occasionally has attention been specifically called to the importance of such studies.

It is indeed important to understand better these knapping techniques which have so long been employed. This ought to be possible through the investigation of the debitage which has been left behind. . . . it should be possible, through systematic investigation and experimentation, to reconstruct approximately or even exactly these primitive working techniques from the remains to be observed in the original discoveries. This would contribute to the better understanding of technological development and its regional differentiation -- an essential historically relevant procedure -- in prehistoric time (Kerkhof and Müller-Beck 1969:442).
Since tool production is a process, the techniques and motor habits of which vary stylistically and according to their relative efficiency, it should follow that variations in processes of tool manufacture are as important to our understanding of extinct cultural systems as the variations in the tools themselves. In addition to the patterned or normative factors which may be isolated through the analysis of chipped stone materials, we may discover that some of the steps in the manufacturing process were undertaken at different locations. Understanding of the manner in which manufacturing sequences were broken up and executed by different social units at different plates is of prime importance if we are to understand the operation of extinct cultural systems. For these reasons it is argued that as much analytical attention should be given to the artifacts that are the by-products of tool production as to the tools themselves (Binford and Quimby 1963:346-7).

Production technology, then, as well as other sub-systems of the total technological system, "constitute a major body of cultural phenomena in their own right" (Merrill 1968:582). As such, they deserve careful attention by archaeologists. Indeed, few situations in archaeology offer the opportunity to study unobserved behavior as accurately as does production technology. This is true because of the uniform operation through time of a constant noncultural framework in which prehistoric people functioned, which we can understand in much the same way they did, and within which we can confidently interpret their behavior.

Stone breaks now just as it did in prehistoric times, and the mechanical and physical constraints placed upon the modern stoneworker are precisely those with which his aboriginal counterpart was faced. Watson, LeBlanc, and Redman have stated this theoretical position appropriately.

Use of ethnographic analogy and of imitative experiments (knapping flint tools oneself, for instance, or making experimental pots) implies a uniformitarian view of the behavior of natural raw materials and of human beings. That is, one must believe that raw materials and -- at least so long as we are dealing with anatomically modern man -- human behavior in the past are directly comparable to those of the present. More specifically, with respect to human behavior, one must hold that the types of processes operating within and between human societies now are the same as those operative in the past. Hence, one can observe behavior in
the present (the manufacture of stone tools or of certain kinds of pottery, or the manner in which relationships between individual human beings or between human groups of various kinds are expressed in the nature and distribution of material remains made and used by them) and can discover and confirm general laws describing these relationships (Watson, LeBlanc, and Redman 1971:49-50).

The success of the modern craftsman in understanding and controlling lithic fracture and producing implements like those of prehistoric people provides an important perspective for interpreting the production technology of Paleolithic societies. When this perspective is combined with an understanding of lithic fracture mechanics, archaeologists have a powerful system for discovering and analyzing a basic part of prehistoric culture.
II. PROCESS OF LITHIC FRACTURE

Our knowledge of the lithic fracture process comes primarily from two sources, experimental replicators of stone implements, and specialists in the physics and mechanics of fracture in brittle solids. The most important recent contributions among experimentalists have been made by Bordes (1968), Bordes and Crabtree (1969), Muto (1971b), Bordaz (1970), Bucy (1971), Sheets (1975), Witthoft (1967), and others. Special mention should be made concerning the work of Mr. Don Crabtree of the Idaho State University Museum who, perhaps more than any other person, has been responsible for focusing archaeologist's attention on the value of experimental replication as a perspective from which to interpret chipped stone artifacts (Crabtree and Butler 1964; Crabtree 1966, 1967a, 1967b, 1968, 1969, 1970, 1972). The archaeological application of the principles of fracture mechanics in brittle solids is rather recent, and by far the most significant studies are those by Kerkhof and Müller-Beck (1969), Speth (1972), and Faulkner (1972).

A. Overview

It has been jokingly stated that "Making an arrowhead is easy. All you have to do is take a piece of rock and knock off everything that doesn't look like an arrowhead." The touchy part, of course, is knowing how to knock off only what you want. In other words, the crucial problem in understanding production technology is understanding the interrelated variables of lithic fracture. What are the factors over which the craftsman can exercise control and thereby successfully predict the shape of each flake removed from the raw material? How does he coordinate a sequence of such flake removals to produce, frequently within extremely narrow ranges of variation, implements which are both functionally and stylistically suitable to his tasks? And how can an understanding of this production technology be useful in recognizing similar technologies in archaeological assemblages? A first step toward answering these questions is a more detailed understanding of the fracture process itself.

In simplest terms, force is applied to a mass of stone and a piece of the stone is broken off. The mass of stone to which force is applied is commonly called the "core," and the piece removed is the "flake." The application of force may be in any of several ways, usually subdivided according to the relative duration of the force application into "pressure" and "percussion" techniques. Analysts sometimes refer to these as "static loading" and "dynamic loading,"
respectively, (Speth 1972:36, Faulkner 1972:102, 135) but the fracture process is essentially the same, regardless of which loading technique is employed. Force is applied to the core, normally by an intermediary device or flaking tool of some sort, such as a hammerstone or punch, in sufficient quantity to cause failure, or fracture, of the stone. The surface against which force is applied is the "striking platform," or often simply the "platform" (Figure 1, p. 8).

The applied force is transmitted into and through the stone as wave energy of two kinds, longitudinal and transverse. The longitudinal or "compression" wave tends to cause displacement of the individual particles of stone in the direction of the plane of fracture. Since fracture is caused by a tensile stress, or the pulling apart of the particles of stone at right angles to the plane of fracture (Speth 1972:37; Faulkner 1972:73-79; Kerkhof and Müller-Beck 1969:443), this longitudinal wave has little influence on the extension or propagation of the fracture. The transverse waves, however, do tend to produce tensile stress in the material at right angles to the plane of fracture and it is this transverse wave energy that has primary influence on the propagation of the fracture (Faulkner 1972:77).

When a sufficient amount of force is transmitted into the stone, fracture is initiated. The amount of force necessary to induce fracture varies with the area of the fracture surface and the resistance of the particular stone to molecular separation. If this critical force is confined to a very small contact area, called the "point of force application," fracture normally begins as a small circular crack, the "ring crack," which projects into the stone at a 90° angle to the surface against which force is applied (Faulkner 1972:98). This ring crack, which is slightly larger than the area of contact (Speth 1972:38), produces what is often called a "lip" on the ventral surface of the flake at its extreme proximal end (Figure 1, p. 8). As the fracture progresses, the ring crack quickly dissipates to form a cone-shaped fracture path, or a partial cone if the force is applied close to the edge of the core. This phenomenon is very similar to the cone-shaped fracture produced on the back side of a pane of glass when struck by a BB pellet. This cone-shaped fracture surface in turn rather quickly gives way to form an almost flat fracture plane; the position of which is determined by several factors, including the location of the point of force application and the proximity of the free surfaces of the core. The fracture process is a sequence of physical events that results from the application of force to a mass of stone. It begins with the formation of the ring crack, and concludes with the separation of the completed flake. The speed with which this process occurs varies with the characteristics of the particular raw material and with the amount and nature of the force application. It cannot occur faster than the speed with which force travels as wave energy through the stone. By very careful control of the amounts of force applied as static loading, the process may be slowed or stopped at any point (Faulkner 1972:75-79).
Figure 1. Platform Preparation: Blade Core
The prediction of the completed fracture path, and therefore the production of predetermined flake shapes, is dependent upon the control of several factors which will be mentioned in considerable detail in the following section. It is these factors, referred to below as "controllable variables", which prehistoric man learned to control in the production of flaked stone implements, and which modern analysts must likewise understand and control if they are to interpret adequately the remains left by their prehistoric ancestors.

B. Controllable Variables

With this brief overview of the fracture process serving as background information, attention may now be turned to the specific factors, controllable by the stoneworker, which allow the successful removal of flakes of predetermined shape. Again, this fracture process must be viewed as the basic element in the production technology system, for it is primarily with reference to this process that raw materials from the environment are evaluated as appropriate, and the sequence of individual flake removals necessary to produce a finished implement is determined. For example, flakes that produce the desired cross-section for an implement must normally precede flakes that produce its regular or symmetrical plan.

Variables that influence the fracture process and that are controllable by the stoneworker are interrelated rather than independent, and may be organized in several ways. Muto (1971b), whose concern is primarily with the percussion production of bifaces, uses variables of the objective piece or core, and variables of the percussor or flaking tool. Witthoft (1957) uses variables of the stone, of the workman, and of the intermediate tool. The organization suggested here incorporates input from both fracture theoreticians and experimental replicators. It is intended to provide a framework in which both flake and implement attributes may be evaluated as significant in revealing control of the fracture process.

The fracture process has been previously defined as the application of force to a core in order to remove a flake. It seems reasonable to organize the interrelated controllable fracture variables involved into major categories on the basis of (1) the object acted upon, or the core; (2) the force which produces the fracture; and (3) the interaction between the two.

1. Core Variables

a. Lithic Material
b. Platform Surface
c. Point of Force Application (PFA) Location
d. Point of Force Application (PFA) Size

e. Core Geometry

2. Force Variables

a. Angle
b. Amount
c. Duration

3. Interaction Variables

a. Relative Masses
b. Relative Hardnesses

In each of these controllable variables, considered below in detail, two questions will be important: First, how does the variable relate to the fracture process and the resultant flake morphology? Second, how and through what range can it be controlled by the craftsman?

1. Core Variables

a. Lithic Material

Some kinds of stone have properties that make them particularly suitable for producing implements by flaking. Others are virtually impossible to flake. Crabtree and Butler (1964) have summarized from the experimental replicator's perspective the characteristics of the raw materials that make them particularly good or bad for controlled flake production. Faulkner lists the characteristics that make stone suitable for flaking as "homogeneous, isotropic, hard, inert, elastic, brittle, and rigid" (Faulkner 1972:v). Each characteristic exists in lithic materials in varying degrees, and in controlling the fracture process considerable tolerance may be possible in any of them. But there are definite optimum ranges and most aboriginal stoneworkers must have been keenly aware of them. Good raw materials were a vital part of many aboriginal economies, and the quarrying, trading, and protection of such raw material sources were undoubtedly major concerns for many prehistoric peoples.

Control over the properties of the lithic materials is primarily limited to the initial selection of the more suitable raw materials available. The one exception to this limitation is the practice of "heat treating" certain flints, cherts, and chalcedonies in order to improve their flaking characteristics (Crabtree and Butler 1964; Purdy 1971; Bordes 1967). Faulkner states that heating these
materials may make them "more isotropic with respect to fracture. . . Concomitant with this improvement in isotropy is an effective 'weakening' of the material (Purdy 1971:90), making it easier to work . . . " (Faulkner 1972:8).

b. Platform Surface

The "platform" is the surface of the core against which force is applied in order to detach a flake. This core surface may be the natural surface of the stone, or cortex, it may be a surface produced by the prior removal of one or more flakes, or a surface produced by grinding or abrading. The cortex of suitable lithic material varies highly, from a thin coating not noticeably different from the material itself, to a thick, crumbly rind up to several inches thick. The critical factor in the suitability of the cortex as a platform surface for flake detachment is its effectiveness in transmitting applied force into the core. The harder, thinner types of cortex which transmit force effectively may be quite suitable as platform surfaces. Thicker, softer types almost always transmit force poorly and must be removed, frequently with considerable difficulty for exactly this reason. The soft cortex absorbs such a large proportion of the applied force that it becomes virtually impossible to apply adequate force amounts for reliable fracture. The process of cortex removal is frequently termed "decortication" (Muto 1971b:57).

A flaked platform, whether it is a single fracture surface or a series of small flake surfaces -- normally termed a "faceted" platform -- probably has little effect on the fracture process other than providing appropriate platform orientation (see Variable 2.c.). A platform that has been ground or abraded, however, does make considerable difference in the fracture process, particularly in the amount of force required to remove the flake (see Variable 2.b.). Both Speth (1972:38) and Faulkner (1972:67, 101) have specifically mentioned the potential importance of a ground or abraded platform. This importance stems from two factors. First, the presence of scratches or striations that result from grinding and abrading has a pronounced tendency to reduce the amount of stress needed to initiate the fracture process. This is undoubtedly one of the prime reasons that modern experimental replicators often refer to the grinding or abrading of a platform surface as "strengthening" it (Crabtree 1972; Muto 1971; Sheets 1973). Obviously one cannot "strengthen" stone, particularly by grinding or abrading it. What actually occurs is that, by reducing the amount of force necessary to remove a given flake, the result is the same as if the platform had been strengthened. For example, if a force of ten pounds is required to detach a desired flake and there is doubt that the platform is sufficiently strong to support the accumulation of that amount of force without crushing, the platform may be abraded so that the detaching
force is reduced to seven pounds, an amount within the platform's strength limits. The result — the production of the desired flake — is the same as if the platform had been "strengthened" to withstand the ten-pound force.

The second potential significance of an abraded platform is its effect in increasing the coefficient of friction between the platform and the flaking tool. When force is applied to the platform surface at approximately 90°, or "normal" to the platform, this coefficient of friction is of little consequence. However, if force is applied to the platform at some angle significantly different from normal, an increased coefficient of friction becomes a significant element in preventing the flaking tool from sliding on the platform surface. Successful flake removal requires the concentration of force within a small area on the platform (see Variable 1.d.), and it is vital that the flaking tool remain stationary on the platform. Faulkner suggests that a horizontal or "peeling" force component makes flake production much easier, and that an abraded platform is of considerable advantage in preventing slippage of the flaking tool as this horizontal component is applied (Faulkner 1972:121). Crabtree (1968:447) uses the term "outward" to designate this horizontal force vector. This outward force vector is particularly significant in producing flakes or blades by pressure techniques (see Variable 2.c.).

In addition to these two major effects of an abraded platform surface, there may also be a regularizing element in grinding or abrading a platform from which a series of flakes is to be removed. This would allow the craftsman to produce an entire series of quite similar flakes, since the individual points of force application had been regularized by the abrasion of the entire platform area. Such treatment of the platform might be especially significant in the production of highly stylized bifacial implements such as the Plano points from the North American Paleo-Indian tradition or various implements from the Arctic Small-Tool tradition.

The platform's angular orientation with respect to the core mass must be such as to allow sufficient force to be transmitted into the core mass to induce fracture along a suitable fracture plane. In practice this process is normally done in reverse order. A stoneworker first decides on a proper fracture path for the implement he needs to make. Then he determines the appropriate force angle to remove a flake along that fracture plane (see Variable 2.a.), and then the necessary platform orientation needed to deliver that force effectively. If the platform orientation is wrong the stoneworker may either create a platform with the proper orientation or he may alter the initial decision about the desired fracture plane.

The worker may control platform orientation in two ways. He may select an appropriately-placed surface, either the natural cortex
of the stone or a surface produced by an earlier fracture, or he may create such a surface by flaking or grinding.

c. PFA Location

The restricted area on the platform against which force is applied to detach a flake is called the "point of force application," or PFA. The position of the PFA relative to the core mass is of critical significance in determining the shape of the flake. It is at, or very close to, this point that maximum tensile stress occurs, and it is here that fracture originates (Faulkner 1972:112-115, 131-133). Controlling this location of fracture origination is absolutely essential to the reliable prediction of the fracture plane, and therefore of the flake shape.

The stoneworker's determination of the proper PFA location must include considering the "strength" of the platform at that point. This means that the PFA must be located on the platform so that it will not crush or collapse under accumulations of force which are inadequate to remove the intended flake (see Variable 2.b.). This normally means locating the PFA far enough away from the platform edge to avoid the "overhang" left by the removal of previous flakes (Figure 1, p. 8).

A further consideration in determining the location of the PFA is its position relative to the geometry of the core and the intended flake. Faulkner (1972:110-115) has clearly demonstrated that the PFA location with respect to the platform edge and the resulting proximity of the core face is a prime factor in determining flake thickness. He also indicates that the phenomenon called the outrepasse, in which the distal part of the fracture plane curves sharply inward and removes a large distal portion of the core (Figure 5c, p. 23), is caused by placement of the PFA rather far from the core edge.

Locating the PFA directly over and in line with a vertical ridge on the face of the core will result in the removal of that ridge in a long narrow "blade," a term given to any flake with roughly parallel edges and its length equal to two or more times its width. If the PFA is located directly over and in line with a relatively flat portion of the core face, a broad expanding flake will result. The principle involved is quite similar to slicing a cube of cheese, with the PFA being roughly equivalent to the point where the knife touches the cheese. Vertically slicing off the corner results in a long narrow piece of cheese with paralleled sides and a triangular cross-section. The next slice, removed just behind the first, results in a slightly wider piece of cheese, again longer than it is wide, but with a trapezoidal cross-section. The next slice will be still wider, and so on.
An additional consideration in determining the location of the PFA is the necessity of avoiding various inclusions and areas of naturally occurring stress or fracture in the material. These irregularities in the raw material have strong tendencies to produce corresponding irregularities in the fracture process.

Several techniques have been employed by both modern and aboriginal stoneworkers that help determine the location of the PFA and that improve the degree of control in applying force to it. These techniques are collectively referred to as "platform preparation," a term which includes the platform abrasion mentioned earlier. Perhaps the most important of these platform preparation techniques is the removal of a series of small flakes from the core face just below the edge of the platform. These flakes remove the "overhang" left on the platform edge from the detachment of prior flakes (Figure 1, p. 8), which assures that the PFA will be strong enough to support the necessary force accumulation without brushing. This locates the intended PFA on the very edge of the platform, making it considerably easier to strike accurately. Further, if by carefully removing the adjacent portions of the platform edge, the PFA can actually be isolated as a small projection or tip on the extreme edge of the platform surface, it is even more likely that the force will be applied precisely to that point. By using a flattened area of the hammerstone or billet, this projecting PFA will necessarily receive the initial impact, just as one's nose or stomach or whatever projects furthest receives the initial impact when running into a wall.

A special situation exists if the PFA is located on the margin of a thin bifacial core and has been prepared so that it is very "strong." In this case the area of maximum tensile stress may occur — and fracture originate — slightly away from the PFA rather than at it (Figure 2B, p. 15). This is probably due to the relatively thin cross-section of the core and the close proximity to the PFA of its opposite free face (Faulkner 1972:132-133). This phenomenon often results in distinctive flake characteristics, particularly at the proximal, or platform, end of the flake, which will be discussed in detail later.

d. PFA Size

Variation in the PFA size has questionable significance in its effect on the fracture process. There is some indication that if force is applied over a relatively larger area of the platform the resultant flakes tend to be somewhat thinner, especially at their proximal ends. A relatively smaller PFA may result in a slightly wider angle to the cone-shaped portion of the fracture path (the "bulb," or "bulb of force;" Figure 6, p. 39), thereby creating a more pronounced and thicker bulbar portion of the flake, and a correspondingly deeper concavity with more overhang at the proximal end of the
Figure 2. Special Flake Configurations
A smaller PFA may also result in a more acuminate cone-shaped portion of the fracture surface, with the apex located precisely at the PFA. In addition, a smaller PFA may result in a shallower ring crack, and therefore a less pronounced "lip" on the proximal end of the flake's ventral surface. Faulkner (1972:127) suggests that, at least in specified cases, the PFA is defined as "an area slightly smaller than the circumference of the ring crack which initiates fracture." This would indicate that as the PFA gets smaller the diameter of the ring crack becomes smaller and its depth might also be expected to decrease.

Control of this variable by the craftsman is limited to a rather small range. The basic technique for varying the size of the PFA is by varying the hardness of the force-delivering instrument (see Variable 3.b.). The PFA tends to be larger as the density of the flaking implement becomes relatively softer. As force is delivered, the softer material is distorted, conforming to the contours of the harder platform, and the transmitted force is effectively spread over a somewhat larger area. This will be discussed later in some detail, since it is closely involved in the possible distinctions between flakes made by "hard hammer" as opposed to those made by "soft hammer" techniques, a distinction which has long been significant in identifying certain archaeological complexes.

e. Core Geometry

This variable has infrequently been explicitly recognized as significant in controlling and predicting flake shape. Two references, however, indicate that core geometry is crucial. Faulkner (1972:131) states that "... ultimately the fracture path is determined by the geometry of the core." and Bucy (1971:24) suggests that "... the shape of the flake is largely determined by the shape of the face of the core from which the flake is removed."

Attention is again called to the example of slicing cheese. If the side of the cheese is irregularly shaped, then the outline of the slice will be correspondingly irregular. If the slice is removed from the side of a cheese cylinder with a narrow diameter, it will be a long, parallel-sided slice, rather thick for its width, and with a half-moon shaped cross-section. If a slice is removed from the side of a cylinder with a wider diameter, the slice will be parallel-sided, rather thin in proportion to its width, and with a much gentler curvature on its dorsal, or outer side. If a slice is removed from a sphere of cheese, the slice will be circular, and the larger the diameter of the sphere the gentler the curvature of its dorsal side.

This is simply slicing solid geometric figures, and once it is perceived as a principle for predicting flake shape it becomes a
major factor in decisions made by the stoneworker. If the flake shape is of importance to the stoneworker, then the shape of the core face prior to the flake's removal is of equal importance, and great care must be taken either to select or to construct an appropriate core face morphology. If, however, it is the shape of the core that is of prime importance, then the geometry of the core face prior to the flake's removal is of considerably less significance, and must be controlled only sufficiently to insure fracture completion on its intended path.

2. Force Variables

The amount of force necessary to detach a given flake, the angle of that force, and its duration are closely related variables of the fracture process. They are frequently controlled concurrently, and the phrase "techniques of force application" applies to this grouped control of force variables. If the amount of force required to detach an intended flake is not large, force variables can be quite successfully controlled by placing a flaking tool such as a sharpened piece of bone or antler precisely against the PFA and applying the force by pressure. While this technique allows extremely close control of the location of the PFA and the angle of force application, it does so at the expense of the amount of force which may be delivered, and is therefore limited to the production of relatively small flakes. The technique of indirect percussion, in which a short punch of wood, bone, or antler is placed directly against the PFA and then struck with a heavier object, overcomes to some extent the limitations on the amount of force deliverable precisely to the PFA.

In many flaking situations the force requirements are relatively large and it is necessary to deliver the force to the PFA by striking it directly with a hammerstone or with a bone or antler billet, and precise control of the PFA location and force angle become more difficult. It is possible, with a great deal of practice, to "hit exactly where you're looking," and very close control of this direct percussion technique may be achieved. Both the Brandon gun-flint manufacturers (Clarke 1935) and the Turkish manufacturers of flint blades for threshing sledges (Bordaz 1965:1969) have attained excellent control in striking the intended PFA precisely, and several modern replicators of aboriginal artifacts are also capable of such control. Despite the interrelated nature of these force variables, each is considered separately in this section because the large numbers of possible control combinations are even more confusing than definition or explanation of one variable in terms involving the others.
A great many prehistorians and experimenters have recognized the significance of this variable in controlling the stone-flaking process. Bordaz (1970:13) states that "the main consideration in holding the stone material is the angle at which the stone is held relative to the direction of the force." Ellis (1940:19,22) suggests that the force angle is important in predicting flake shape. Nuto (1971b:51-52) uses "errors of angle" as one fracture variable that may be controlled, and states that control of the force angle is basic to controlled flake production. Witthoft (1957:17) agrees that the direction of the blow is the most important factor in determining the nature of the flake. Wilmsen (1968b:985), Leakey (1954:129-30), Bordes and Crabtree (1969:4), Bordes (1967:11), Baden-Powell (1949:40), Bucy (1971:7,10,26), and others all call attention to the angle of the applied force in flake production.

The craftsman's control of this variable is simply the conscious alteration of the angle at which force is applied to the core. The core can be tilted, the punch can be slanted, the flaking tool or hammerstone can be pushed or swung in different directions, or any combination that results in force application at varying angles with respect to the core.

There are definite limitations to the angular range over which force can be transmitted into the core in sufficient amounts to produce the desired fracture. If the amount of force required for the intended fracture is relatively small, the range of angles over which that force may be effectively delivered is considerably greater than if the force requirements are rather large. This is due to the increased efficiency of energy transfer from the flaking tool to the core as the angle of force application approaches "normal," or 90° to the platform surface. In the following paragraphs three categories of force angle will be discussed. These categories cover the entire range of possible force angles for successful flake detachment, from approximately 75° to about 140° from the horizontal (Figure 3B, p. 19). While there is some overlapping of characteristics, these categories seem to cohere as definable technological units: (1) approximately 90°; (2) less than 90°; (3) more than 90°.

The first category may be considered basic and most efficient and the other categories are technological departures in either direction from it.

(1) If the force angle is between 85° and 95° to the platform surface, the efficiency of energy transfer from the flaking tool to the core is greatest. This situation is called "normal loading" (Faulkner 1972:119), or "downward" force (Crabtree 1968:464). In this basic fracture situation, the initial cone-shaped portion of the fracture path includes an angle of about 135° (Kerkhof and Muller-Beck 1969:444; Faulkner 1972:59). The plane of fracture,
Figure 3. Loading Angles: Blade Core
then, when force is applied normally to the platform near its edge, will be oriented at approximately half of 135°, or about 65° to the normal (Figure 3A, p. 19). The plane of fracture, as it progresses from the cone-shaped proximal portion of the fracture, first turns slightly back toward the normal and then, as it approaches the distal end of the core, curves slightly inward from the normal, giving the ventral surface of the completed flake a somewhat S-shaped longitudinal section. The average angle of this surface, when the angle of force application is normal to the platform, is probably about 65° from the normal (Figure 3B, p. 19).

(2) A second fracture situation is the application of force to the core at angles varying from 95° to about 140°. This type of force application is termed "oblique" loading (Speth 1972:38), "sliding" or "outward" force (Crabtree 1968:464), or "outward tangential loading" (Faulkner 1972:110). As the force angle varies in either direction from the normal, energy transmission from the flaking tool into the core becomes less efficient, since an increasing proportion is lost in the sliding or glancing elements of the force application. However, if the force application is angularly outward, a compensating effect tends to counteract this increasing inefficiency. Crabtree (1972, personal communication), Muto (1972, personal communication), and Faulkner (1973, personal communication) have all commented that less force is required to produce fracture when there is a significant outward component in the applied force. Speth states (1972:38) that "The overall effect of sliding or oblique impact is to reduce substantially the critical load necessary to produce cracking." The total energy required may actually be less than with normal loading, and the efficiency of flake production may therefore be greater. If stone-workers are concerned with the total efficiency of the process, this condition of an outward force component may be the most frequently occurring situation.

Another effect of an angular force component is in altering the entire cone-shaped portion of the fracture path in its orientation with the platform surface and the core mass. Figure 4, p. 21 illustrates how, as the force angle varies from normal, the orientation of the initial portion of the fracture is altered, producing varying flake morphologies. This is a complex phenomenon, and factors such as the proximity of the core face and distance of the PFA from the core edge are involved (See Faulkner 1972:110-115 for a more complete discussion). Speth, too, recognizes this effect on the definition and prominence of the cone or bulbar portion of the flake.
Figure 4. Loading Angles: Bifacial Core
In a general sense, therefore, flakes which are struck more obliquely ... should have steeper and less prominent cones and less salient bulbs of percussion (as in Figure 4A, p. 21 cjp) than flakes which are struck more steeply by the same hammer (as in Figure 4B, p. 21 cjp) (Speth 1972: 38).

In addition, the lip produced by the ring crack on the extreme proximal end of the flake tends to be less pronounced in outward loading situations. This is due to a diminished angular difference between the initial ring crack, which is always vertical to the platform surface, and the subsequent cone-shaped portion of the fracture (Figure 4, p. 21).

The overall effect of applying an outward force component, therefore, is to reduce the force amount required to detach the flake, to decrease the efficiency of energy transmission into the core (these two seem to act as offsetting factors), to reduce the prominence of the flake lip, and to reduce the prominence of the bulbar portion of the flake.

(3) A third situation with respect to force direction is the application of an "inward tangential loading" (Faulkner 1972:119-121), or force application more "into the piece" (Mehlennery 1957:33). This force angle of less than 90° produces noticeable effects in the fracture process, such as a considerably greater force requirement for flake detachment. Faulkner has demonstrated that an inward loading of 9° from the normal required approximately 2.5 times as much force to remove a flake from a standardized core as was required with normal loading (Faulkner 1972:121). He has also shown that this application of an inward force vector reduces the speed of fracture propagation substantially, and that by carefully controlling the amount of static force applied, the fracture process can be stopped completely at any stage from initiation to termination (Faulkner 1972:121). This agrees with the observations of modern experimental replicators.

It is quite likely this factor of increased force requirements with inward-directed force application that produces "hinge" and "step" fractures. These terms are applied to a range of phenomena, all of which involve the abrupt termination of the flake in an angular or sharply rounded distal end rather than in a gradual, smoothly tapered termination (Figure 5A, p. 23). If there is a significant inward force vector, the increased amount of force required to detach the intended flake may surpass the amount of force delivered. With the applied force thus less than that required for completion of the intended fracture, a hinge or step termination is the likely result.
A. step fracture termination

B. hinge fracture termination

C. core base removal

Figure 5. Step and Hinge Fracture Terminations
Mewhinney (1957:33), Leakey (1950:40), Bucy (1971:26), Muto (1971b:58), and the experience of other replicators (Crabtree 1971: personal communication; Bordes 1971: personal communication) attribute the production of these hinge or step fracture terminations to the application of inadequate force amounts, caused in part by an excessive inward-directed force vector. Such an inward force vector may also be partially responsible for producing the outrepasse phenomenon (see Variable 1.a. and Figure 2A, p. 15), particularly when the applied force is relatively great (Muto 1971b:58,62).

On the other hand, Faulkner has suggested that inward or outward loading does not affect the shape of the flake. He argues, with supporting experimental evidence, that this inward or outward loading affects only the speed of fracture propagation and the force required to produce that fracture (Faulkner 1972:105-121). This is a significantly different position from the experimenters mentioned above. While Faulkner's arguments are convincing, the angular variation in his experiments was restricted to a range of less than 10° from normal in either direction, and this may be inadequate to display a significantly altered fracture path. Nor can the experience of a great many skilled stoneworkers who indicate that the angle of the applied force does influence the flake shape be dismissed lightly. Perhaps further controlled experimentation is in order, modeled after Faulkner's work, but with angular variations approaching the 40° to 50° range. This might give information that could solve the problem.

It should be mentioned that the "apparent" force angle, or the angle at which the flaking tool intersects the platform, is not always the same as the "effective" or "actual" force angle, which is the sum of all the force vectors operating to produce fracture. This may be particularly significant when a billet or hammerstone describes an arc, producing a considerable lateral vector during impact. The effective force angle is tangent to the arc of the percussor at the PFA. The effective angle of force application may also be somewhat obscured during most pressure flaking techniques, including the production of Mesoamerican-type blades from polyhedral cores. In such static loading conditions of "downward and outward" force vectors (Crabtree 1968:446-478; Sheets and Muto 1972:632), the diagonal of a simple force parallelogram will reveal the effective angle of force application (Figure 3A, p. 19). It is in this context, also, that the coefficient of friction between the flaking tool and the platform surface is an important factor in preventing the flaking tool from slipping on the platform surface (Faulkner 1972:105; Speth 1972:38; see Variable 1.a.).

b. Amount

Several factors determine force requirements for removal of a given flake. Various lithic materials have differing properties of
internal cohesion. The molecular bonds that resist tensile stresses are much stronger in some types of rock than in others. In addition, force required for fracture along any intended fracture plane varies directly with the surface area of that plane. The total cohesive force holding the molecules of stone together along the intended fracture plane is therefore some coefficient of internal cohesion for the particular stone multiplied by the area of the fracture plane (Faulkner 1972:50). Obsidian is said to break more easily than flint because its coefficient of internal cohesion is less, thus requiring a smaller force to produce fracture along a given fracture surface area.

Two further elements previously discussed are involved in determining the force requirements for the removal of a given flake: the nature of the platform surface, particularly the presence of striations or scratches (see Variable 1.b.), and the angle at which the force is applied (see Variable 2.a.). These four elements -- the nature of the stone, the area of the intended fracture, the nature of the platform surface, and the angle of force application -- interact in determining the force required to produce fracture along a given fracture plane.

It may be helpful to view removal force as a continuum along which are insufficient, optimum, and excessive force ranges, each with its particular effects on the fracture process. Application of either insufficient or excessive amounts of force results in fracture characteristics that may readily be classed as irregular or problematic, and it is within the optimum range of force application that greatest control and predictability of flake detachment occurs. Optimum force is that force which is adequate to initiate fracture and to propagate it smoothly to a predictable termination without severely damaging either the core or the flake.

If the force applied is below this optimal range, or insufficient, one of several results can occur. In situations of severely inadequate force, fracture either will not be initiated or will progress only as far as the inadequate force permits and simply stop, leaving the flake still attached to the core. Another result of inadequate force may be the production of a "hinged" or "stepped" distal termination of the flake (see Variable 2.a.). The two are not different terms for the same phenomenon. Hinging is the abrupt but not angular alteration in direction of the fracture plane. The distal termination of a hinge fracture is abruptly rounded (Figure 5B, p. 23). Muto (1971b:58), Witthoft (1957:18), Mewhinney (1957:33), Faulkner (1972:123-4), and others have related this hinging phenomenon to the amount of force applied. A step fracture is probably the combination of two separate fracture processes: incomplete separation along the plane of fracture followed closely by the lateral
snapping off of the still-attached flake, perhaps as a result of a significant outward or horizontal component of the applied force (Figure 5A, p. 23).

Another phenomenon related to the application of insufficient force amounts is the undulation of the fracture plane, producing the commonly mentioned "ripple marks" on the fracture surface, which resemble the concentric ripples on the surface of a liquid. They have also been called "compression rings," "waves of compression," and the like. They are concave toward the PFA, and are produced by the action of transverse waves during the fracture process (Faulkner 1972:158). They often appear with greater amplitude toward the distal end of a flake which then terminates in a hinge (Figure 5B, p. 23), and it is this close connection which suggests that in at least some cases they are properly related to inadequate force amounts. Both hinging and step fracture flake terminations need considerably more experimental study.

The application of force amounts considerably in excess of that required to detach the flake may result in several characteristics. The area around the PFA, both on the flake and on the core, may be crushed, thus destroying the ring crack, any remnants of the platform surface that would otherwise have been left on the proximal end of the flake, and frequently the apex of the cone-shaped or bulbar area of the flake as well (Speth 1972:38; Faulkner 1972:131; Muto 1971b:58). In addition to this destruction of the area around the PFA, both Speth (1972:38) and Faulkner (1972:145-7) recognize a phenomenon associated with excessive force termed "hackling," or the presence, especially along the lateral margins and the bulbar area of the fracture surface, of many small cracks that form small sharp-angled ridges and valleys in the fracture plane. These frequently produce a "saw-toothed" appearance in the edge of the flake.

Crabtree (1971: personal communication) and Muto (1971b:62) suggest that excessive force also results in the inward curvature of the fracture plane at its distal end, causing the removal of the distal portion of the core, and including the phenomenon known as the outrepasse flake (Figure 2A, p. 15). This may be especially true when the excessive force is accompanied by an inward-directed force component. As noted earlier, however, Faulkner (1972:133) believes that this removal of the distal portion of the core is primarily the result of placement of the PFA relatively far in from the core edge.

Controlling the amount of force within optimum ranges is not difficult to perceive theoretically, but is often extremely difficult to achieve, and errors in force amount are among the most common mistakes noted in both aboriginal and modern stoneworking. With relatively small force amounts there is normally no real difficulty, but when the intended flake is larger and force requirements
correspondingly greater; the consistent application of optimum force while maintaining precise control of the PFA location and force angle can become a serious problem.

Options available to the stoneworker for applying varying force amounts are highly open to idiosyncratic and innovative choice. They are conveniently and somewhat arbitrarily divided into three major categories: pressure, percussion, and indirect percussion. While these categories of force application are discussed in this section on the relative amounts of force application, their significance in influencing both the angle (see Variable 2.a.) and the duration (see Variable 2.c.) of force application is clearly recognized. Practically speaking, these three variables of applied force interact quite closely, and choices regarding their application seldom occur without reference to all three.

Many researchers have recognized the significance of these differing force application techniques. Crabtree (1967b), Semenov (1964), Bordes (1969), Bordaz (1970), and many others divide the universe of flakes into pressure flakes and percussion flakes, or those produced by either static loading or by dynamic loading. In reality, the morphological difference between the two types of flakes is quite small, indicating that essentially the same force elements are interacting in similar ways. To date, no carefully controlled studies have defined or quantified distinguishing characteristics of the static—dynamic loading distinction.

Prime possibilities for such distinguishing characteristics lie in the relative size of the flakes produced, in attributes of platform preparation, and in the regularity in size and spacing of a series of flakes on an implement. These possible distinctions derive from the fact that in static loading conditions, more and smaller forces are more precisely controlled, and vice versa.

A further consideration in applying varying amounts of force is that each of these techniques allows the application of a range of force amounts, and these ranges overlap considerably. Flakes of a given size, for example, may require a detachment force of fourteen pounds, which may be delivered by rather forceful pressure, by indirect percussion, or by rather light direct percussion.

c. Duration

The duration of the applied force is seldom mentioned specifically as a distinct fracture process variable, probably because of its close interdependency with varying force amounts and with varying methods of applying that force. Faulkner states that the duration of force application ranges from only a few microseconds to a period of perhaps several seconds (Faulkner 1972:121-122).
rapidly-swung hammerstone is in contact with the core over slightly less time than one swung more slowly, and pressure may be applied either slowly or in a quick thrust. How this difference in duration of force application affects the fracture process is not adequately known, but its potential for doing so should be recognized. One practical involvement of this variable is its importance in the transmission of adequate force amounts into relatively small cores. This will be discussed in the following section.

3. Interaction Variables

Applying force to a piece of stone to produce a flake is a complex process of interaction between force and mass. As one is controlled or altered, the other is also affected, and predictable results require an understanding of this interaction.

a. Relative Masses

Of prime importance in controlled lithic fracture, from both theoretical and practical perspectives, is the relationship between the core mass, the fracture area of the intended flake, and, at least in situations of percussion force application, the mass of the flaking tool. Basic to this discussion is the recognition that, in the transmission of force from a flaking tool or percussor into a core, the effective force must be applied in or close to a particular direction, and it must be applied in adequate amounts to produce fracture. The necessary direction of the effective force requires that the core be stable during force application. If the flake removal force is less than that required physically to move the core, there is, of course, no problem in maintaining core stability. But in most implement production situations the core mass is relatively small in proportion to the flake removal force required, and core stability can become a serious problem. Inertia, or the tendency of a motionless object to remain motionless, is an important element in successfully dealing with this problem.

The inertia of an object is directly proportional to its mass, so that a larger mass has a greater tendency toward stability, and a larger force is therefore required to move it. If a core is relatively small, and its inertia correspondingly small, applied force requirements for detaching relatively large flakes simply overcome the core's inertia, displacing the core rather than being transmitted into it. Analogously, a slow-moving car can exert sufficient force to cause severe damage to a person only if the person is immobile: if he is not tied down, the slowly applied force simply shoves the person aside without causing damage.
Both modern and aboriginal stoneworkers have dealt with this problem in several ways. The size of the intended flake can be reduced, thus reducing the force requirements to levels which the core's inertia will tolerate. A series of smaller flakes may do the job of a single large one. This is actually an evasion of the problem rather than a solution. Assuming the area of the fracture surface to be a constant, force requirements cannot be reduced and real means to deal with the problem must be found.

One real solution is to effectively increase the core mass so that its greater inertia can withstand the required force. This may be accomplished in several ways, such as gripping the core tightly and holding it firmly, so that the effective mass becomes the mass of the core plus the mass of the hand plus the muscular energy exerted in holding the core firmly in place. Or the core may be wedged in a stump or log, or clamped in a vise or some other holding or supporting mechanism, but the result is to effectively add mass to the core and maintain its stability during force application.

Another way of dealing with this problem is to reverse the relative action of the two masses in what is often called the "anvil technique." The core becomes the mass in motion, and it is swung against a very large, stable mass or anvil. The flake is detached from the moving core mass as it strikes the anvil. This frequently occurs inadvertently when a hammerstone breaks against a large core. A very large boulder can be selected as the stable mass, and the speed with which the core must strike this anvil to produce a given flake-removal force is directly dependent. Problems in controlling this technique center primarily on maintaining appropriate force angle. Best success occurs when large core masses can be swung rather slowly, or in cases where precise force angle control is not critical, such as the production of burins, and smaller cores can be swung rapidly against an anvil stone.

Still another solution to the core displacement problem is to reduce the time over which force is applied in order to take maximum advantage of the small inertia the core does have. The displacement of a core, or overcoming its inertia, is actually a problem of its acceleration, which is dependent not only on its mass and the force exerted against it, but on the length of time over which that force is exerted. For a given mass and force, a shorter time results in less acceleration, or core movement. By swinging a given percussor faster, not only is more force delivered, but it is delivered over a shorter time. A fast-moving car does considerable damage to a person even if he is not tied down, largely because force is applied to the body faster than its inertia can be overcome. If a smaller percussor is utilized, it may be swung even faster and the amount of force delivered will remain the same, since force equals mass times speed. The primary advantage of the "baton technique" in flintworking is,
by increasing the leverage of the wrist, to increase the speed with which even a lighter percussor delivers force to a core. This reduces the time over which force is delivered and maximizes the core's inertia, while still delivering adequate force to produce fracture. This is perhaps not the most profound physics to be found, but it should serve to adequately illustrate the principle involved.

Virtually all prehistoric flaked stone artifacts involve the removal of sufficiently large flakes from sufficiently small cores to demand some kind of solution to the problem of core displacement. The problem is particularly critical in such situations as the fluting of Paleo-Indian projectile points, the production of large, thin bifaces, and the production of Mesoamerican blades from polyhedral cores (Phagan 1972). The dynamic relationships of the masses involved and the time over which they interact are critical in successful control of these fracture processes. Techniques of core support, holding devices (including the hand), different sized hammerstones, batons, billets, hammers, leverage devices — all are to be understood primarily as methods of delivering sufficient force to relatively small cores for removing rather large flakes.

b. Relative Hardnesses

A second area of interaction between the core and the flaking implement centers on the relative hardnesses of the two. A great many observers have recognized the potential significance of this variable in lithic fracture, and it is normally phrased in terms of a hard or soft percussor relative to the core hardness. Bordaz (1970:24-5) suggests the use of a "soft" flaking implement as one of two major distinguishing features of the Acheulian stoneworking tradition. He states that this "soft hammer technique" produces thinner or "shallower" flakes than does percussion with a hard hammer. Ellis uses soft and hard hammer techniques as a major subdivision of aboriginal stone technology, and suggests that a soft hammer produces "narrower, longer, and flatter flakes" (Ellis 1939:8-13). Bordes and Crabtree (1969:243) state that softer hammers produce shallower flakes, as does Leakey (1954:131-2). Prison (1970:36; 1968:149) uses flatness of the flake and prominence of a ventral lip to distinguish soft from hard hammer techniques of implement resharpening.

Mewhinney (1964) questioned the capacity of modern analysts to recognize the difference between flakes produced by soft hammer percussion as opposed to those produced by hard hammer techniques. He suggested that these preconceptions of most archaeologists were developed from the early statements of a few influential experimenters and simply accepted as fact. Largely as a result of Mewhinney's skepticism, Muto (1971b) developed a list of flake characteristics
that seem to have diagnostic potential in revealing this difference in production technique.

1) angle of platform remnant relative to dorsal flake surface
2) bulb of applied force: salient or diffuse
3) cone of applied force: acuminate or truncated
4) ripple marks: prominent or subdued, regular or irregular
5) amount, position, direction, and pattern of fissures (hackles)
6) crushing or collapsing of the platform
7) ventral lip at proximal end of flake

These must all be taken into consideration when attempting to discern the mode of manufacture. No one criterion is sufficient. Added to these somewhat partially developed criteria is the very subjective criterion composed of experience and termed "feel" (Muto 1971:114-115).

Muto then uses these criteria in evaluating a small sample of test flakes to distinguish, "at a rate of seven out of twelve," those produced by hard as opposed to soft hammer percussion (Muto 1971:108-120).

Speth has suggested, however, that bulbar prominence

... may be highly dependent on the angle of impact, the roughness of the platform, and the magnitude of the applied force. Great caution, therefore, should be used by prehistorians who rely heavily on bulbar prominence as a criterion for distinguishing between percussion by hardhammer (quartzite, basalt, or granite) and percussion by soft-hammer (bone, antler, or hard wood) (Speth 1972:39).

Bonnichsen and Morlan indicate that controlled experimental flake production "produced lips not only with a soft hammer, such as moose antler, but also with a hard quartzite impactor on glass, obsidian, and quartzite" (Bonnichsen and Morlan 1974:3).

The relative hardness of the flaking tool may also be significant in pressure application of force to the core, but no well-controlled experimental data are available with respect to the differential effects on the fracture process of relatively hard or soft pressers. Crabtree (1970:150-151) suggests that a softer tip which flexibly conforms somewhat to the contours of the core gives grip or "purchase" to the presser, preventing it from slipping on the PFA. He and other experimenters have successfully removed flakes using pressers as soft as hard wood (Crabtree 1970; Sheets and Muto 1972:632).
There is good indication that, in both pressure and percussion techniques, the applied force is spread over a slightly larger area by the use of a softer flaking tool, producing a larger PFA. As mentioned earlier (see Variable 1.d.), this larger PFA may result in a relatively thinner and flatter flake, with a more diffuse definition of the bulbar or proximal portion, and a less pronounced ventral lip produced by a shallower ring crack.
III. FLAKE ANALYSIS

The process of lithic fracture and its controllable variables outlined in the preceding chapters furnish a framework within which production technology may be analyzed. Such analysis may proceed, because of the nature of the fracture process, in two ways. As fracture occurs in stone, two new surfaces are simultaneously produced, either of which may be studied. One surface is on the ventral or inner side of the flake, and its correlate is the newly formed outer surface of the core, or core face. These two surfaces are almost mirror images, and what appears on one appears inverted on the other. The single feature of these fracture surfaces that is confined to the flake and does not appear on the core surface is the "eraillure" scar(s). Faulkner (1973) has given this phenomenon its most extensive treatment, but its precise cause, its range of expression, and its relationship to the fracture process are still not well understood. Its potential for further illuminating the fracture process is recognized, and it should remain a primary concern of experimentalists and theoreticians.

The two fracture surfaces suggest two approaches toward analyzing lithic fracture and its control: study the flakes, or study the cores. With respect to the fracture plane itself, it makes little difference whether one examines the core surfaces or the corresponding flake surfaces, and to examine them both is largely redundant. The fracture plane, however, divides the mass of stone into unequal portions, the remaining core and the flake, and, as masses of stone rather than as fracture surfaces, the technological information on the two pieces is not equivalent. A great deal more technological evidence is preserved on the flake than the core, and it is this fact that further focuses this study on flakes.

Among the technologically significant characteristics of flakes that have no corresponding expression on the core are: most of those dealing with the PFA, including its size, preparatory treatment, isolation, surface characteristics, and position with respect to the core face; those dealing with the shape, definition, and destruction of the bulbar area of the flake; and those dealing with the specific dimensions of the flake, particularly its thickness. Muto has recognized this fundamental importance of flake characteristics.
The objective piece with its various flake scars
is less than half of the diagnostic process. The thinning
and shaping flakes, the platform preparation flakes, and
. . . "non-diagnostic debitage" are the important parts
in reconstructing the manufacturing process. Only the
flakes removed, rather than the objective piece, show all
of the following: platform remnant, platform preparation,
platform crushing, dorsal and ventral surface morphology,
truncation or acumination of bulb of applied force, salient
or diffuse bulb of applied force, eraillures, fissures,
and compression rings (Muto 1971b:4-5).

Sheets also recognizes the significance of flakes, stating that
"Manufacturing behavior is recorded both on the finished artifact and
on the debitage" (Sheets 1975:372). The work of Skavlem and Pond,
early half a century ago, mentions the inadequacy of the implements
by themselves to reveal the "complete history of the manufacture of
. . . a finished implement" (Pond 1930:135). Their early recognition
of this principle was largely ignored, probably because there was
minimal concern with the explication of implement manufacturing
systems.

Technologically oriented analyses of stone implements have
recently received long-overdue attention. Sheets (1975), Bucy (1971),
Muto (1971b), Knudson (1973), and others are excellent sources for
such systems of implement analysis. But the other approach to techno­
logical analysis, flake studies, has continued to receive very little
organized or extensive treatment. This study of flakes is intended
to provide some basic organization and to elicit criticism.

When flakes have occasionally been studied in archaeological
assemblages, the focus of such studies has not been toward the dis­
covcry of technological behavior, but toward other ends. Collins
(1970), for example, uses three flake measurements to distinguish
between Acheulian and Clactonian assemblages. There is some suggestion
that these flake characteristics have production significance, but
his concern is basically a stylistic study using flake attributes
rather than implement attributes. Much of Wilmsen's study (1970) is
likewise the use of flake characteristics to distinguish stylistically
between various Paleo-Indian assemblages. He makes implicit assump­
tions about technology, and suggests that distinctions must be due in
some way to differential production of the flakes, but flake character­
istics are not specifically related to variable behavior. Cullberg
and Parsmar (1968) use five flake dimensions to differentiate
stylistically between several Swedish sites. Johansen (1971), in
the absence of more traditional time markers, uses variable pro­
portions of two flake characteristics to establish by seriation a
chronological sequence among eight Swedish sites. Frison, while his
prime concern is with interpretation of site utilization, nevertheless recognizes the importance of flakes in the assemblage. He distinguishes five morphological types of "retouch" or "resharpening" flakes in the Piny Creek assemblage.

At the Piny Creek site, as much or more information concerning activities performed there was derived from the retouch flakes as from the tools. . . . In other words, in this particular context, the tools themselves did not provide a basis for valid interpretation, which the retouch flakes did provide (Frison 1968:154).

Archaeologists have sometimes been forced into an examination of flakes because of a scarcity of implements in a potentially important archaeological assemblage. So, almost reluctantly and apologetically, they look at the flakes. No criticism of these studies is intended, but it should be recognized that flakes are real artifacts, and in some cases they are the best artifacts from which to discover prehistoric behavior patterns.

Without attempting to push a simple analogy too far, this entire matter of the importance of flakes in revealing production technology may be compared to a study of Colonial cabinetmaking. Hepplewhite tables and bow-fronted chests and ladder-back chairs were produced during certain times, used by certain people in certain combinations, and geographically diffused in certain patterns. Stylistic, functional, and distributional characteristics of these artifacts may reveal much cultural information about Colonial and later periods. But if our purpose is to understand the cabinetmaking trade, certainly a relevant and important part of Colonial culture, we are severely handicapped if our information is limited to the articles of furniture. Such an analysis of cabinetmaking from the pieces only is not impossible, of course, but it would be much easier and more secure if the entire cabinetmaker's workshop could be included in the analysis, including tools and floorsweepings.

In addition to the finished pieces of furniture, we must consider dove-tail joints, mortise joints, chisels, draw-knives, hammers, augers, and many other things as well. Especially to an experienced woodworker, the sawdust, plane or chisel shavings, lathe turnings, hammer marks, and scrap pile indicate production technology as surely as the chair itself. In fact, even a fairly astute observer may be unable to distinguish a carefully handcarved and finished table leg from a turned leg. Both are functionally and stylistically similar, but are produced by radically different techniques, and the introduction of the lathe is too important a technological innovation to overlook if it can be helped. Even a quick look at the scrap pile
and the shavings from its production, together with a practised evaluation of the leg itself, and the production technology is clear.

Just as the Colonial cabinetmaker learned to manipulate tools and raw materials to make long, thin shavings or short thick ones across the grain with chisels or draw-knives to produce dove-tail joints and bow-fronted chests, so during earlier periods flintworkers learned to manipulate tools and raw materials to make wide expanding flakes or long narrow ones with soft hammerstones or antler billets to produce flutes and Clovis points.

In a general way, an implicit technological framework has been present in much archaeological literature of the past several decades, even with respect to flakes. It was assumed that flakes were produced by human behavior, that differences in flakes must be produced by differences in behavior, and that measurements of flake differences must therefore somehow be measurements of behavioral differences. To a great extent this is true, but the nature of the observed variability and the differential behavior that may have produced it are in no way understood unless the variable characteristics can themselves be understood.

Any sizable assemblage of flaked stone material, implements and debitage, contains a potentially infinite number of attributes that can be measured and compared. Significant variation among two or more assemblages for any such attribute or combination of attributes may be observed and quantified, and relative differences in the assemblages may be confirmed. But unless the attributes themselves can be specifically related to a behavioral model of some sort, the cultural significance of those established differences remains unknown. Binford has stated that what is needed is "... a set of expectations as to relevance," so that significant selections "can be made from the infinity of characteristics potentially present in the body of empirical material being studied" (Binford 1972:249).

This study is designed to provide such a "set of expectations" or "behavioral model" or "theoretical framework" of lithic fracture control within which specific flake attributes can be seen to have specific behavioral relevance in production technology. Its purpose is not to expand the number of measurable attributes in a flake assemblage, but to reduce the attributes measured to those that can be behaviorally interpreted.
IV. FLAKE ATTRIBUTES

The twenty-eight flake attributes presented in this chapter have been selected for their potential in revealing differential control of one or more fracture variables from Chapter II. General research objectives in constructing this attribute list have been to devise an analytic method by which flake populations could be compared and used to describe specifically the differential flake-producing behavior represented by those populations. More specific research objectives and analytic procedures are included in Chapter V.

Continuous attributes, usually flake dimensions which can be measured against a standard scale, are recorded directly in angular or metric units in one or two computer-card columns per attribute. Discrete attributes, or those which are expressed in distinct, definable states, are coded as a series of up to ten such states and recorded in one computer-card column per attribute. Even with several columns reserved for identification and related specialized data, evaluation of a single flake is easily placed on a standard eighty-column computer card.

As it is listed, each attribute is defined and its relations to control of fracture variables is specified. Details of its measurement are given, and illustrations of these measurements are provided. Each state of discrete attributes is also defined and illustrated. Attributes are grouped according to their location on the flake, primarily to facilitate their observation, recording, and orderly presentation. Attributes 1-12 are attributes of the entire flake, either flake dimensions, indexes, or some evaluation involving the whole flake. Eight attributes, 13-20, are located on or immediately adjacent to the flake's proximal, or platform end, and one attribute, 21, is at the flake's distal end. Two attributes, 22 and 23, are located on the ventral or inner surface, and the final five attributes, 24-28, are on the dorsal surface.

A. Entire Flake Attributes

1. Raw Material

One or two computer card columns are used to code appropriate categories of lithic raw material. While this raw material attribute
is not itself a part of the fracture process, it is nevertheless critical to it and is a significant element in the larger technological process. Flake attributes resulting from similar stoneworking techniques may be quite different in different raw materials, and comparisons within and between such raw material types may be most revealing. The selection of the stone is among the initial decisions made in production technology, and the environmental or cultural constraints imposed upon that selection are crucial to an understanding of that technological system (see Variable 1.a.). Categories of raw material have their greatest archaeological significance as "natural" categories, readily definable by aboriginal craftsmen, rather than defined in technical petrologic terms. As with most discrete attributes, 0 is used to record cases in which no determination can be made. Suitable categories are selected and defined, such as:

1. = Basalt
2. = Obsidian
3. = Grey flint
4. = Etc., as needed

2. Flake Length

Two columns are used to record flake length to the nearest millimeter along the flake's bulbar axis, or axis of percussion (Figure 6, p. 39). If the flake length is greater than 99 mm., record as 99. If the measurement cannot be taken from the PFA to a natural flake termination (i.e., a hinged or a feathered termination), indicating a broken flake, 00 is recorded, thus eliminating the flake from determination of mean flake size, but allowing it to contribute in the later morphological attributes. Significance of this attribute is primarily related to fracture surface area and force amount required for flake detachment, and therefore indirectly to the technique of force application.

3. Flake Width

Two columns are used to record maximum flake width in millimeters, measured at right angles to the bulbar axis (Figure 6, p. 39). If the flake width is greater than 99 mm., record as 99. Again, if the flake appears to have unnatural lateral margins, indicating a broken flake, 00 is recorded. The primary significance of flake width is, like length, its relationship to fracture area, force required for detachment, and technique of force application.
Figure 6. Measurement of Flake Characteristics
4. Length X Width Index

Two columns are used to record an index generated by multiplying length times width to get an approximation of flake area. Since this index is proportional to the fracture surface area, it is primarily a statement of the force amount required for flake removal. Any significant variation from a normal distribution around the mean should be technologically significant with reference to force amounts.

5. Length / Width Index

Two columns are used to record an index generated by dividing flake length by flake width. This index is primarily an indication of flake proportion or shape, with lower values indicating short, wide flakes and higher values indicating long, thin flakes. When this index figure is 2 or above, the flake is arbitrarily termed a "blade." The consistent production of blades is possible only with very close and coordinated control of many variables, especially PFA location, direction of force application, and core face geometry. Significant proportions of this index value above 1.5 suggest such control, and values of 2 or above should occur only in well-controlled blade industries. Values below 1 indicate flakes wider than long, and significant proportions of values in this range suggest some unusual technological pattern, perhaps the initial shaping of large but relatively thin tabular raw material.

6. Maximum Width Location

Two columns are used to record the distance in millimeters along the bulbar axis from the PFA to the point of maximum width (Figure 6, p. 39). If the PFA is at the point of maximum width, record as 01. If the maximum width extends for some distance along the bulbar axis rather than being a specific point (as in very parallel-sided blades), the mid-point of that distance is recorded.

Relatively high values with respect to flake length indicate expanding flakes, normally removed from a flat core face without prominent ridges. These are frequently thinning flakes produced in the manufacture of bifaces (Muto 1971b), and relatively large proportions of such high values should indicate concern with implement section and good control of force application and direction, and PFA position.

7. Flake Thickness

Two columns are used to record maximum flake thickness in millimeters, measured perpendicular to the plane of the fracture surface
Flake thickness is dependent primarily on the PFA location relative to the core face, the geometry of that core face, and the direction of force application. Locating the PFA closer to the edge of the platform results in a thinner flake, and vice versa (Faulkner 1972:110-115). The direction of force application may also affect flake thickness and the relative position of maximum thickness. The primary interpretability of flake thickness lies in its affect on the flake index (attribute 9), and will be further considered there.

8. Maximum Thickness Location

Two columns are used to record the distance in millimeters from the PFA to the point of maximum thickness (Figure 6, p. 39). When correlated with flake length, this should indicate varying patterns of controlling the PFA location and direction of force application. Relatively high values should indicate an inward vector in the force application plus adequate to excessive force amounts. Faulkner's study indicates that such higher values imply location of the PFA further away from the core edge (see Variable 1.c.). Values at or very close to the PFA should indicate an outward component in the force application.

9. Flake Index

Two columns are used to record an index generated by dividing the Length X Width Index (attribute 4) by Flake Thickness (attribute 7), or flake length \times flake width. Technologically, there are no great flake thickness problems in producing either large thick flakes or small thin ones, but production of the large thin flakes necessary in the manufacture of most well-proportioned stone implements demonstrates careful control over many fracture variables. Relatively low values of this index indicate smaller thicker flakes, while higher values indicate larger thinner flakes requiring much more careful control of fracture variables. The primary interpretive value of this index is in providing a single, easily comparable, quantitative measure of general flake production control.

10. Longitudinal Cross-Section

One column is used to code as discrete data an evaluation of the flake's longitudinal cross-section, taken along the bulbar axis (Figure 6, p. 39). Placement into the following attribute states was governed primarily by the contour of the ventral profile and its orientation with the platform remnant at the flake's proximal end.
An area of slight ventral convexity near the proximal end, corresponding to the flake's bulb of applied force, is expected and discounted in evaluating flat and gently concave categories; 2, 3, and 6, below. In all discrete attributes, 0 is used to record flakes that are too fragmentary to make a determination for the attribute. In all section illustrations, ventral is down.

0 = indeterminate
1 =
2 =
3 =
4 =
5 =
6 =
7 =
8 =
9 = irregular, other

Relatively high frequencies of 2 and 3 suggest greater control of all critical fracture variables. High frequencies of 4 suggest a relatively hard percussor and inward-directed force application. High frequencies of 1 and 7 suggest somewhat inadequate force amounts. High frequencies of 6 indicate an inward-directed force component and adequate or excessive force amounts. High frequencies of 5 may indicate primarily shaping rather than thinning concerns, or attention to producing implement plan rather than section. States 5 and 6 of this attribute suggest rather low core mass, while 8 may be associated with the initiation of fracture away from the PFA, occurring most frequently in the thinning of bifaces (see Variable 1.1.c.).

11. Transverse Cross-section

One column is used to code an evaluation of the transverse cross-section of the flake, taken at right angles to the bulbar axis at the point of maximum width (Figure 6, p. 39). Primary consideration for placement in attribute states is given to the ventral profile of the section and its angle of conjunction with the dorsal surface, or "margin angle."
The steeper margin angles, as in 3, 7, and 8, are associated with strongly curved core faces, as in small diameter cores. Conversely, shallower margin angles, as in 4 and 6, suggest gently curved core faces, such as bifaces and larger flake and blade cores. Convex ventral profiles in 1, 2, and perhaps 3 are probably associated with inadequate or inward-directed force application, and 1 may indicate very short, thick-butted flakes with their maximum width near the proximal end.

12. Plan Outline

One column is used to code an evaluation of the generalized plan view of the flake.

0 = indeterminate
1 = squared (L = ±W)
2 = rectangular (L = <2W)
3 = distally expanding
4 = rounded
5 = oval
6 = parallel-sided (L = ≥2W)
7 = distally contracting
8 = wider than long
9 = irregular, other
Since flake outline is determined primarily by the geometry of the core face as it is intersected by the fracture plane, any very regular outline is indicative of a carefully prepared or selected core geometry, and relatively high frequencies of such flakes suggest consistency in controlling fracture and producing regular core face geometry. 3 and 4 are particularly suggestive of well-controlled biface thinning. High frequencies of 2 and 6 indicate good control, careful platform preparation, and the production of blades. 7 and 8 suggest shaping rather than thinning concerns, with less attention to platform preparation, as in the initial shaping of flake or blade cores, or the final shaping of bifaces, in which case the flakes are very small and short.

B. Proximal End Attributes

13. Platform Remnant Depth

One column is used to record the depth or thickness (dorsal-ventral) of the platform remnant on the extreme proximal end of the flake, measured to the nearest millimeter.

0 = indeterminate
1 = 1 mm or less
2 = 2 mm . . . similarly through
9 = 9 mm or greater

Generally, deeper platforms indicate less platform treatment such as isolation or surface preparation prior to force application, since platform treatment tends to reduce platform remnant size by locating the PFA closer to the core edge. More specifically, platform remnant depth is determined primarily by the distance of the PFA from the edge of the core, and reducing this distance is facilitated by most kinds of platform preparation.

14. Platform Remnant Width

One column is used to code the platform remnant width at the flake’s extreme proximal end. Measurements to the nearest millimeter are grouped as follows:
Reduced platform width is indicative of platform treatment prior to force application, and lower values can be interpreted as more careful attention to such platform preparation. The positioning and isolation of the PFA is particularly related to platform remnant width, since isolating the intended PFA as a small projection at the core edge severely reduces the amount of that edge removed with the flake. In some cases of careful PFA isolation and force application, flakes are produced on which the platform remnant is very little larger than the PFA itself. Such control is especially important in the production of regular blades and very thin bifaces.

15. Platform Remnant Shape

One column is used to code the shape of the platform remnant surface, using categories selected for their relationship to the fracture process and their frequent occurrence in lithic assemblages.

0 = indeterminate
1 = rectangular
2 = crescentic
3 = diamond-shaped
4 = lenticular
5 = triangular
6 = gull-winged
7 = rounded
8 = semi-circular
9 = irregular, other
High proportions of 0, or cases in which the platform remnant is too broken or crushed to evaluate, suggest force applications that are excessive, and relatively hard percussors. High proportions of 1, 3, and 5, or generally angular platform remnants, are indicative of little or no platform preparation, since preparatory treatment of the platform prior to flake removal tends to round the edges and corners. Such flake removals may suggest the rough initial shaping of cores. Force application close to a recessed portion of a core platform edge, generally rare except in cases of very short flakes, is suggested by 2.

Careful preparation of the intended PFA and good control of force application are indicated by higher proportions of 4 and 7, 7 being particularly indicative of platform isolation, and 4 of the removal of any overhang on the proximal portion of the core face (see Variable l.c., and Figure 1, p. 8). Even rather low proportions of 6 indicate the use of relatively soft, large, or flattened percussors and excessive force amounts, since this gull-winged platform remnant configuration is virtually always produced as the successive removal of two flakes (this being the second) with a single force application (Jelinek, Bradley, and Huckell, 1971). Immediately after a first flake is removed, the percussor continues its arc, applying force to the core platform immediately behind that flake and producing a second flake with this gull-winged platform remnant. As many as three or four of these flakes can be produced with a single force application.

The platform remnant represented in 8 is very indicative of an excessively strong platform, normally on the margin of a biface or relatively thin core, and adequate to excessive force spread effectively over a large area, perhaps by a relatively soft percussor. Fracture is initiated well away from the margin and PFA. The ring crack is exaggerated in depth and diameter, describing only an arc of a complete ring. The original core margin, including the well-prepared PFA, remains on the flake as the platform remnant (Figure 2B, p. 15). These flakes are normally quite suggestive of biface production, since their occurrence is restricted to removal from relatively thin cores.

16. Platform Remnant Surface

One column is used to code the nature of the platform surface remnant.
0 = indeterminate
1 = cortex, or natural surface of the stone
2 = a single flake scar
3 = two or three flake scars
4 = a series of smaller scars
5 = a mass of tiny crushed and hinged scars
6 = a ground surface

While these categories are somewhat arbitrary, they nevertheless represent definable stages in the technological continuum of platform surface treatment. Higher values represent generally greater concern with such surface preparation, presumably to provide greater control over those fracture variables associated with the PFA nature and location. A high proportion of cortex platforms is not necessarily technological "crudity," but may simply be technologically preliminary, or it may represent careful selection of appropriate platform surface and orientation rather than their production. Quarry activity should probably be characterized by rather low mean values for this flake attribute, whereas the final production of blades or bifaces would be characterized by rather high mean values.

17. Platform Angle

One column was used to code, in 10° units, the angle between the surface of the platform remnant and the average ventral flake surface (Figure 7, p. 48). Some observers, in recording this angle, have preferred to "measure stone" (Knudson 1973:174), rather than measuring the supplementary "air" angle (Wilmsen 1970:14-17). Three reasons for choosing to "measure air" were: to deal primarily with smaller figures; ease of reading the polar coordinate grid on which measurements were taken; and ease of comparability with a corresponding angular measurement between the core platform and the core face. Care should be taken in comparative situations to deal with equivalent angles.

0 = indeterminate
1 = greater than 90°
2 = 80-89°
3 = 70-79°
4 = 60-69°
5 = 50-59°
6 = 40-49°
7 = less than 40°
Figure 7. Platform Angle (Flake Angle)
Since the angle of the fracture plane with the platform is determined primarily by the angle of the applied force (see Variable 2.a.), this measurement is closely related to the direction of effective force application. The greater the outward force component, the greater the platform angle, and vice versa. The production of Meso-American blades from polyhedral cores (Crabtree 1968; Sheets and Muto 1972; Faulkner 1972; Sheets 1975) involves considerable outward force, and resulting platform angles approach 90°. Conversely, the platform angles of some biface thinning flakes, which may involve considerable inward-directed force components, are occasionally less than 40°. Clusters of values and their distribution around the mean may be highly suggestive of specialized or generalized production technologies.

18. Platform Preparation Scars

One column is used to code the presence and intensity of scars indicating the positioning and isolation of the intended PFA. These small scars are located on the extreme proximal end of the flake's dorsal surface, and their fracture originates from the platform surface (Figure 6, p. 39). They are produced by the removal of any overhang (Figure 1, p. 8) left on the core from prior flake removals.

0 = indeterminate
1 = no scars present
2 = 1-3 scars present
3 = 4-6 scars present
4 = 7 or more scars present

Higher values for this flake attribute indicate greater concern for the isolation, positioning, and preparation of the platform surface prior to flake removal.

19. Ventral Lip

One column was used to code the presence and prominence of a lip, or projection at the extreme proximal end of the ventral flake surface (Figure 1, p. 8). The frequent suggestion of this attribute as potentially significant in distinguishing soft from hard percussor techniques (see Variable 3.b.), indicates the need to quantify its prominence, despite obvious difficulties in measurement. The following system of evaluation is admittedly somewhat subjective and arbitrary, but is based on the fact that the ring crack which initiates fracture always occurs at right angles to the surface against which force is applied. Both the depth to which this crack penetrates and the subsequent angular alteration in its direction contribute to the prominence of the ventral lip.
0 = indeterminate
1 = no ventral lip
2 = slight ventral lip
3 = moderate ventral lip
4 = strong ventral lip

Definitions of the above attribute states are as follows:
'Slight' is difficult to see, but well enough defined to peel a fingernail shaving when the flake is held at a 45° angle against the nail and dragged lightly across it. "Moderate" lips are clearly visible, even though still small, and will easily catch under a fingernail. "Strong" implies an obvious, clearly visible state of the attribute.

Lower values for this attribute may indicate relatively harder force-applying implements, correspondingly smaller PFAs, and may also suggest angles of force application with strong outward components (see Variable 2.a.). Such control combinations might be expected in the initial shaping by percussion of various larger core types, or the production of rather large, thick, unspecialized flakes. Conversely, higher values may indicate relatively softer flaking tools, larger PFAs, and inward-directed force components such as might be produced in the removal of thinning flakes from bifaces.

Sufficient differences among observers in the interpretation of this attribute indicate the need for caution in applying such conclusions, particularly in the absence of other supporting evidence. However, if sample size is adequate and supplementary attributes are considered, this flake attribute may prove to be a sensitive technological indicator of flaking tool hardness or other variables.

20. Platform Destruction

One column is used to code the relative destruction or shattering of the platform remnant. Indication of such shattering or destruction varies from the irregular removal of the flake's entire proximal end to small irregular cracks extending from the platform area into the flake in almost any direction. Ranking this platform destruction as relatively severe or slight is somewhat arbitrary, but is made here on the basis of whether or not any of the platform surface remains on the flake.

0 = indeterminate
1 = no platform destruction, platform intact
2 = slight platform destruction
3 = severe platform destruction
This flake attribute is directly concerned with the amount of force delivered to remove the flake. Value 1 suggests optimum or inadequate force amounts, while 2 and 3 suggest increasingly excessive force applications, almost always by percussion. In addition, severe platform destruction may be closely related to the relative hardness of the percussor, with harder percussors producing greater platform destruction.

C. Distal End Attributes

21. Flake Termination

One column is used to code the nature of the flake's distal termination, since this characteristic is closely related to the amounts of force applied. Of particular importance are the hinge and step flake terminations (see Variable 2.b., Figure 5, p. 23).

0 = indeterminate
1 = tapered, sharp, or feathered
2 = squared or broken, stepped
3 = rounded or hinged
4 = other

Attribute state 1 is associated with optimum force amounts, while 3 is associated with inadequate force amounts. State 1 may indicate inadequate force amounts delivered with an outward component, resulting in a step termination, or it may indicate post-production breakage. State 4 is not interpretable, but serves to maintain the others as more securely defined categories.

D. Ventral Surface Attributes

22. Bulb of Force

One column is used to code combinations of two related characteristics of the cone or bulb of force. These features appear on the proximal portion of the ventral flake surface (Figure 6, p. 39). The truncated or acuminate appearance of this bulbar area and its pronounced or diffuse definition are combined as follows.
The terms "diffuse" and "pronounced" refer to both the rise of the bulbar area above the average ventral flake surface and the relative abruptness of that rise. "Truncated" and "acuminate" refer to the relative pointedness of the cone of force at its extreme proximal end. In both sets of terms, absolute definitions are probably impossible, and are not as important as consistently applied relative definition. Lower mean values suggest generally larger effective PFAs and softer flaking tools. Higher values, conversely, imply smaller PFAs and relatively harder flaking tools. Values 1 and 2 suggest the preparation of a rather large platform area of considerable strength, with force delivered by a relatively soft implement. Values 3 and 4 indicate greater attention to the precise location of the PFA, perhaps by pressure force application in the case of smaller flakes. Values 1 and 3 may indicate an outward-directed force component, while 2 and 4 may suggest greater inward-directed force application.

23. Ripple Marks

One column is used to code the intensity and location of ripple marks or compression rings on the flake's ventral surface.

0 = indeterminate
1 = truncated, diffuse
2 = truncated, pronounced
3 = acuminate, diffuse
4 = acuminate, pronounced

This undulation, or rippling of the fracture plane, however, is not well understood, and interpretations are tentative at best. Its apparent close connection with the hinging phenomenon (see Variable 2.b.) suggests that it is involved with the application of inadequate force amounts. MacDonald (1968) has suggested that pronounced rippling is also associated with bipolar percussion, in which the core base is supported firmly against a rock while the flake is removed.
The rather strong undulations supposedly produced on the fracture surface become a part of the definition of his "piece esquilles" implement type (MacDonald 1968:85-90).

Several phenomena that occur on the ventral surface of the flake are not included in this analysis because of the indefinite nature of their relationship to the fracture process and its control. They include eralllure scars on the bulbar surface (Faulkner 1973:4-12), gull-wings, striations or Wallner lines, and hackling (Faulkner 1972: 147-149).

E. Dorsal Surface Attributes

24. Cortex

One column is used to code the presence and relative amounts of cortex, or the natural surface of the stone, on the flake's dorsal side. The following categories are used to quantify the proportional area of cortex remaining on the flake.

0 = indeterminate
1 = no cortex
2 = less than 1/4 cortex
3 = 1/4 - 1/2 cortex
4 = 1/2 - 3/4 cortex
5 = more than 3/4 cortex
6 = all cortex

Since the dorsal surface of a flake is the same as the core face prior to the flake's removal, any characteristics of the dorsal flake surface can be considered characteristics of the core face. The removal, for example, of all traces of cortex from the core face prior to flake removal results in a flake with no traces of cortex on its dorsal side. An implicit assumption in assigning significance to this attribute is that cortex is normally not as desirable as freshly fractured material, either because of a difference in some quality of the stone itself or in the regularity of the two kinds of surfaces or edges (see Variable 1.b.).

The lower the mean value for this attribute, the greater the core preparation input prior to flake removal and vice versa. Larger percentages of flakes with high proportions of cortex suggest quarry sites at which primary shaping of cores or blanks is a major activity. Smaller, more regularly shaped flakes with smaller proportions of cortex suggest secondary shaping of blanks into preforms or finished implements. A correlation of this cortex attribute with flake size
and the presence of cortex on implements should suggest production technology and raw material utilization in a given situation.

25. Scar Number

One column is used to record the number of distinct flake scars on the dorsal side of the flake.

- 0 = none (dorsal is all cortex)
- 1 = 1 scar
- 2 = 2 scars
- 3 = 3 scars
- 4 = 4 scars
- 5 = 5 scars
- 6 = 6 scars
- 7 = 7 scars
- 8 = 8 scars
- 9 = 9 or more scars

Each scar on the flake's dorsal side corresponds to a flake removed from the core face prior to detachment of the study flake. A flake with six distinct scars on its dorsal side indicates at least six flake removal operations in preparing the core face for the detachment of this flake. Normally, then, the greater the mean value of this attribute the greater the technological input in preparation for flake removal. A readily recognizable exception to this rule is the production of blades, in which only a few very carefully patterned scars form the core face, and therefore the dorsal side of the removed flake (blade).

26. Scar Size

One column is used to code patterns in the size of scars on the flake's dorsal side.

- 0 = indeterminate
- 1 = predominantly small scars
- 2 = predominantly medium scars
- 3 = predominantly large scars
- 4 = small and medium scars
- 5 = small and large scars
- 6 = medium and large scars
- 7 = no pattern or regularity apparent
In making these determinations, "predominantly" means 2/3 or more, "small" is less than 3 mm. in maximum dimension, "medium" is 3-8 mm. in maximum dimension, and "large" is any scar over 8 mm. in maximum dimension. Any observable regularity in the size of the dorsal scars suggests a corresponding regularity of behavior in the preparation of the core face.

27. Scar Arrangement

One column is used to code readily observable patterns in the arrangement or orientation of scars on the flake's dorsal side.

0 = indeterminate
1 = patterned parallel with bulbar axis
2 = patterned perpendicular with bulbar axis
3 = patterned diagonally with bulbar axis
4 = patterned radially from margins
5 = no pattern obvious

The prime elements considered in this attribute are the regularity in placement of the PFAs and in the direction of the removal forces for the flakes that formed the core face, and subsequently the dorsal side of the removed flake. Value 1 indicates the removal of the study flake by a force applied in the same direction as those that prepared the core face: in other words, this flake is one in a series of flake removals, all by forces applied in the same direction. This suggests the careful preparation of a core with a rather large platform surface from which a whole series of flakes are subsequently removed, such as in the production of regular blades or large bifaces. Values 2 through 4 indicate that the study flake was removed by a force applied in a different direction from those that formed the core face, and indicate very careful planning and control. Such flakes might be expected in the preparation of cores, smaller bifaces, and Levallois flakes.

28. Scar Hinging

One column is used to code the occurrence and relative intensity of the hinged termination of the dorsal scars.
0 = indeterminate
1 = no dorsal scars hinged
2 = fewer than 25% hinged dorsal scars
3 = 25-75% hinged dorsal scars
4 = over 75% hinged dorsal scars

On the assumption that hinging is a technological goof, higher mean values for this attribute suggest relatively poorer control of critical force application variables. Conversely, lower mean values suggest better variable control (see Variables 2.a., b.).
V. ANALYTIC PROCEDURES

The preceding system of flake analysis was developed specifically within the context of the Ayacucho Archaeological-Botanical Project. In addition to this flake analysis, a forty attribute functional analysis and a thirty-five attribute technological analysis of the implements were developed for the Ayacucho material. Complete results of all three analyses will be included in the publication of the Ayacucho Project. A brief description of the archaeological and ecological elements of the Ayacucho valley is included here, along with the results of a limited application of the flake analysis. This was a test application of the flake analysis system, and demonstrates its usefulness by producing substantive and extremely interesting interpretations of the test material.

A. The Ayacucho Archaeological-Botanical Project

The Ayacucho Archaeological-Botanical Project was a large, multidisciplinary project under the direction of Dr. R. S. MacNeish of the Peabody Foundation for Archaeology, Andover, Massachusetts. It was funded by that foundation and by grants from the National Science Foundation. The project involved, in one capacity or another, well over a hundred students and scholars during a seven year period from 1966 to 1972. Preliminary reports of the project are available (MacNeish 1969;1970; MacNeish, Patterson, and Browman 1975). The goals of the project were to explore the cultural development of the area from its earliest evidences through the development of agriculture to its culmination in the Inca civilization.

B. The Ayacucho Valley

The research area was the entire Ayacucho valley, a roughly triangular Andean basin about 575 kilometers southeast of Lima, Peru (Figure 8, p. 58). The valley is approximately 100 kilometers on each side, located between 12°50' and 13°15' latitude, and between 74°05' and 74°25' longitude. It includes portions of the Pongor, Cachi, and Huarpa river drainages, which flow northward into the Mantaro river (Figure 9, p. 59). Lower elevations in the valley bottom are approximately 2000 meters while surrounding passes out of
Figure 8. Map of Peru with Ayacucho Valley Indicated
Figure 9. Ecologic Zones and Sites of the Ayacucho Valley
the valley are at elevations of 4400 meters or above, producing a wide climatic range of environments varying from quite warm and dry at lower altitudes to humid and cold at higher elevations. This environmental range has been subdivided into the following sequence of major ecologic zones, beginning with the lowest.

Mantaro Xerophytic; below 2500 meters, with a mean annual temperature of 21°C. and 125 millimeters of rainfall.

Thorn Forest Riverine; between 2500 and 2750 meters, with a mean annual temperature of 15°C. and rainfall of 375 millimeters. Temperatures seldom fall below freezing.

Thorn Forest Scrub; between 2750 and 3200 meters, with a mean annual temperature of 12°C. and rainfall of 500 millimeters. Rain falls only during the wet season from October to March, and there is occasional frost in the dry season.

Humid Woodlands; between 3200 and 4000 meters, with a mean annual temperature of 9°C. and rainfall of 750 millimeters. Rain is mostly limited to the wet season, and frost occurs regularly in the dry season.

Low Puna; between 4000 and 4500 meters, with a mean annual temperature of 3°C. and rainfall of 1000 millimeters. Frost occurs year-round.

High Puna; above 4500 meters, with a mean annual temperature of 0°C. and rainfall of 1500 meters. Frost occurs, with regular snows, even in the dry season (Vierra 1975:15-18; Palomino 1971:46).

C. The Archaeological Base

Between 1969 and 1972, ten preceramic sites were excavated, yielding a total of eighty-three stratigraphic components dated between 2000 B.C. and 20,000 B.C. Each component — used here only in the sense of stratigraphically associated archaeological units — has been assigned on the basis of distinctions in archaeological content to one of eight cultural phases. These phases are listed in Table 1, with their approximate dates and the numbers of archaeological sites and components from which they are known.

Early in the field season of 1971, a priorities list of components was drawn up for lithic analysis. This priorities list was made on the basis of the following criteria: first, to examine sites from a range of ecologic zones at several approximately contemporaneous time periods, providing synchronic comparisons across ecologic zones; second, to provide at least a limited perspective of lithic development
Table 1. Ayacucho Culture Phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>span</th>
<th>sites</th>
<th>components</th>
</tr>
</thead>
<tbody>
<tr>
<td>CACHI</td>
<td>1800-2800 B.C.</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>CHIHUA</td>
<td>2800-4500 B.C.</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>PIKI</td>
<td>4500-5900 B.C.</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>JAYWA</td>
<td>5900-7200 B.C.</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>PUENTE</td>
<td>7200-9000 B.C.</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>HUANTA</td>
<td>9000-11,000 B.C.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AYACUCHO</td>
<td>11,000-14,000 B.C.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PACAICASA</td>
<td>14,000-20,000 B.C.</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

(from MacNeish, Patterson and Brown 1975:22)

through time within several ecologic zones; and third, to examine at least one well-stratified site through its entire sequence, providing a good diachronic perspective at that site. Also of concern in arranging priorities for analysis of the components were good stratigraphic definitions, the availability of supplementary faunal and featural data, and the availability of reliable dates, preferably radiocarbon dates.

D. Sampling Procedures

After the priorities list of study components had been established, the problem of sampling was considered in some detail. All components on the priorities list had been excavated, most of them in their entirety, during previous seasons. Excavation was done in one-meter quadrants, and flakes had been counted and bagged by those one-meter quadrants within each stratigraphic component, thus providing convenient sampling units for a flake analysis.

At this time, too, rather severe time and personnel limitations were recognized. Only one laboratory assistant could be assigned, along with the author, to the flake analysis. The author was, in addition, involved in other field and analytic responsibilities. No archaeological material could be taken from Peru, and the field portion of the Ayacucho Project was rapidly drawing to a close. In short, it was recognized that some concessions were necessary in order to analyze as many of the study components as possible, without, however, sacrificing too severely the confidence levels of the data obtained.

The flakes were known to exist within all study components in strongly unequal distributions. Some quadrants contained several hundred flakes, while others in the same component contained very few. In some cases these large flake concentrations were spatially associated very closely with hearths, while others were unassociated
with hearths or other featural elements. This unequal distribution of flakes was presumed to reflect, at least potentially, spatial differential in their production. The examination of possible activity areas had a high priority within the general strategy of the Ayacucho Project, and it was therefore decided that the sampling strategy should recognize this distributional inequality within components. If concentrations of flakes represent concentrations of flaking activity, then the most convenient and reliable way of evaluating that activity is to sample from those flake concentrations.

In addition, the flake samples from several concentrations within a component could be combined to represent the flakes from the entire component, allowing such inter-component comparisons as evolutionary trends or differential site utilization. The exact degree to which such a combination sample represents the universe of flakes in each component is not statistically verifiable by random-based tests, but its representation of technological variability is certainly quite good.

With these analytic needs in mind, samples were taken from components in their order of study priority as follows. Areas of flake concentration were identified from quadrant maps of the component on which were plotted the locations of hearths and the numbers of flakes in each quadrant. Both relative density and size of these flake concentrations varied somewhat, but normally were no larger than four adjacent one-meter quadrants in which flake density was at least double that of surrounding quadrants. It was decided that the total sample size from each component should be 100 flakes (Cochran 1963: 23; Roscoe 1969:137), and that the sample should be taken in roughly equal proportions from three, four, or five quadrants, one from each selected area of flake concentration, depending on the number of flake concentrations present in the component. In other words, assuming that four areas of flake concentration were present in a component, 25% of the sample, or twenty-five flakes, would be taken from one quadrant in each of the areas of concentration, producing a total sample for the component of 100 flakes. This limited the expenditure of time by keeping the number of quadrant bags which must be processed to a maximum of five per component, and at the same time maintained the adequacy of the sample (minimum = 20%) from any single quadrant for intra-component comparisons.

Further, the sample from each component was selected from both those flake concentrations which were associated with hearths and those which were not. No more than two-thirds of a component's total sample was selected from either hearth or non-hearth associated quadrants.
Within those selected areas of flake concentration which were larger than a single quadrant, one quadrant was selected arbitrarily, or with no conscious bias for the selection of one over another. Flakes from the selected quadrants were then washed, recounted, and laid out for visual inspection. The appropriate number of flakes was then consciously selected to represent the range of variability in both size and raw material category within the quadrant, since these two flake characteristics were judged to be especially significant in interpreting technologically produced variation. The samples from all components analyzed were selected by the author in the same manner.

This sampling technique produces a representative cluster sample (Ragir 1967:185), the intent of which is not to guarantee in the sample by virtue of its randomness the proportional distribution of flakes in the components, but to provide an efficient, systematic, spatially stratified sample of flakes from a strongly heterogeneous known universe in such a way as to facilitate both intra- and inter-component comparisons. Mueller (1974:26-35) terms this cluster sampling technique "systematic stratified disproportional." He tested this and other sampling techniques as population predictors in an archaeological survey situation, and found that this technique produced valid conclusions at the 0.05 level of probability (Mueller 1974:49-50).

Samples were then analyzed by the author and one assistant, Mr. Sixto Alejandro Estrada, who was trained in the analytic procedures by the author. Regular replication checks were made throughout the analysis to insure maximum similarity of observation. Analysis was done in Peru during the 1971 field season on a total of 16 components. Table 2, p. 64 lists these sixteen components with their corresponding culture phases, ecologic zones, and dates.

The data were transferred to punch cards and processed at the computer center, the University of New Mexico, Albuquerque, New Mexico. The SPSS CODEBOOK program was used to collect statistics for each variable (Nie, Bent, and Hull 1970). In addition, indexes of various flake measurements were generated by a special program designed by Dr. R. K. Vierra, Northwestern University, the Ayacucho Project statistician.

E. Selection of example components for this study

For purposes of this study, a presentation of data from all 16 of the analyzed components was judged to be unnecessarily confusing as a demonstration of the analytic system's usefulness, and some further limiting framework was sought. A recent study by Vierra (1975), utilizing primarily faunal information from one of the Ayacucho sites, provides such structuring suggestions. That study will be reviewed and its conclusions used to organize the selection and presentation of examples of data from the flake analysis.
Table 2. Analyzed Components, Flake Analysis

Asterisk indicates components included in this study.

<table>
<thead>
<tr>
<th>SITE</th>
<th>COMPONENT</th>
<th>CULTURE PHASE</th>
<th>ECOLOGIC ZONE</th>
<th>DATE, B.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac100</td>
<td>f1</td>
<td>Jaywa</td>
<td>Thorn Forest Scrub</td>
<td>5600</td>
</tr>
<tr>
<td></td>
<td>f2</td>
<td>Jaywa</td>
<td></td>
<td>7000</td>
</tr>
<tr>
<td></td>
<td>h</td>
<td>Ayacucho</td>
<td></td>
<td>11,000</td>
</tr>
<tr>
<td>Ac102</td>
<td>VI</td>
<td>Chihua</td>
<td>Thorn Forest Scrub</td>
<td>3600</td>
</tr>
<tr>
<td></td>
<td>VII *</td>
<td>Piki</td>
<td></td>
<td>5200</td>
</tr>
<tr>
<td></td>
<td>VIII *</td>
<td>Puente</td>
<td></td>
<td>7200</td>
</tr>
<tr>
<td>Ac158</td>
<td>If1 *</td>
<td>Chihua</td>
<td>Thorn Forest Rivering</td>
<td>3200</td>
</tr>
<tr>
<td></td>
<td>IV *</td>
<td>Piki</td>
<td></td>
<td>4800</td>
</tr>
<tr>
<td></td>
<td>VII *</td>
<td>Piki</td>
<td></td>
<td>5200</td>
</tr>
<tr>
<td></td>
<td>XI *</td>
<td>Jaywa</td>
<td></td>
<td>5800</td>
</tr>
<tr>
<td></td>
<td>XII *</td>
<td>Jaywa</td>
<td></td>
<td>6400</td>
</tr>
<tr>
<td></td>
<td>XIII *</td>
<td>Jaywa</td>
<td></td>
<td>7000</td>
</tr>
<tr>
<td>Ac300</td>
<td>C *</td>
<td>Jaywa</td>
<td>Low Puna</td>
<td>6200</td>
</tr>
<tr>
<td>Ac335</td>
<td>C *</td>
<td>Jaywa</td>
<td>Humid Woodlands</td>
<td>6000</td>
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<td></td>
<td>H</td>
<td>Puente-Jaywa</td>
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<td>7200</td>
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<td></td>
<td>J1</td>
<td>Puente</td>
<td></td>
<td>7800</td>
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</table>
Vierra has analyzed in some detail eleven components of the Puente (Ac158) site. He first demonstrates that differences between the eleven components are, on the basis of relative percentages of major implement categories, statistically insignificant (Vierra 1975:28-30). A factor analysis using eighty-four perceramic archaeological components from the Ayacucho valley, including the eleven Ac158 components, and 127 specific implement types as cases reduced the eighty-four variables to twenty factors, with all eleven Ac158 components (and only those components) forming factor one (Vierra 1975:30-31). This confirms the structural, and presumably the cultural, homogeneity of the eleven Ac158 components, based on specific implement types.

He then demonstrates that the faunal remains from the eleven components do not show the same homogeneity, but are characterized by high levels of variability. On the assumption that faunal remains reflect basic resource procurement strategies, he combines the eleven Ac158 components with sixty-four Nunamiut Eskimo assemblages of known subsistence activity and thirty well-documented archaeological assemblages from Mexico and North America in a factor analysis. By constructing increasingly inclusive matrixes utilizing these 105 assemblages and thirty-one categories of skeletal parts, and subjecting them to both Q-mode and R-mode factor analyses and to a discriminant analysis, he reduces the variability in the Ac158 components to six factors. Each factor represents a resource procurement strategy on the basis of interpretation from the known and well-documented assemblages (Vierra 1975:85-96).

(1) Ac158III is a probable hunting station characterized by short occupations, highly selected deer and camelid parts, some domesticated seeds, high proportions of smashed bone fragments, and low lithic content (Vierra 1975:105-110).

(2) Ac158IV represents probable intensive plant collecting and harvesting with supplemental hunting, primarily in summer; less intensive use of animals, with only choice "high muscle mass" elements present; low bone debris with no apparent concentration; and bone weaving tools and a child burial suggest family activity (Vierra 1975:110-112).

(3) Ac158V, VII, and VIIA are characterized by the probable processing of whole animals, with choice elements carried away from the site; high proportions of low-yield elements are present, such as toe bones. Hearths are few and small, with indication of spatial partitioning for task specific activities (Vierra 1975:112-115).
(4) Acl58VI is recognized as problematic, with probable short varied occupations. Low artifact and debris densities indicate least intensive occupation of the eleven components, and a single small hearth and an adolescent burial are present (Vierra 1975: 115-117).

(5) Acl58VIII represents probable generalized hunting and trapping activity, with broad spectrum procurement strategies; manos and milling stones suggest plant processing or incipient cultivation, and these, as well as bone weaving tools and two infant burials, suggest family activities; there is strong clustering of deer remains along the rockshelter wall, with guinea pig remains clustered around one of the hearths. This factor may represent a transition from primary hunting activities to later trapping activities (Vierra 1975: 122-124).

(6) Acl58IX, X, XI, XII are all similar and probably represent the systematic trapping of guinea pig, with supplemental hunting of deer and guanaco. Very high proportions of guinea pig remains and more lithic artifacts suggest intensive occupation, as do more and larger hearths and two adult burials. Clustering of bone debris to the north side of the site may indicate clean-up activities of extended occupations, and six post-holes in XII also suggest longer-term occupations (Vierra 1975:117-122).

From this Vierra concludes that the homogeneity initially observed in the similar proportions of stone artifact classes in the eleven components is misleading, and that a careful analysis of the faunal and featural data more accurately reveals considerable variability in systems of environmental exploitation at the site. His findings are convincing, and it is difficult to avoid their implications of behavioral and organizational differential. How can this discrepancy be explained? Why did the initial lithic analysis miss such variability? Does this suggested resource procurement variability occur within a single lithic context? Could lithic analysis be refined to detect such behavioral differences, and if so, how? Could it be that the initial lithic analysis revealed no significant variability because it was conducted at an inappropriate scale or level (Dunnell 1971:159)? Were some critical aspects of the lithic assemblages overlooked, resulting in an analytic system which was not adequately sensitive to reveal such variability? More specifically, could a study of flakes, in which the scale of the analytic unit is reduced to attribute of discrete object, increase the sensitivity of the lithic analysis in detecting such variability? Plog, in discussing the archaeological applications of general systems theory, confirms this need for greater sensitivity to artifact variability in analytic systems (Plog 1975:208,211).
With these questions forming a set of research problems, flake analysis data from four Acl58 components are presented. All four of these components, Acl58IV, VII, XI, and XII, are included in Vierra's study. In addition, data from three components of other Ayacucho sites, Acl02VII, Ac300C, and Ac335C, are included for comparison and to help establish ranges of significance and observed variability. Brief descriptions of each site are included, and a summary chart of sampling information from the seven example components is given in Table 3, p. 68.

The Puente site, Acl58

This site is located approximately four kilometers north of the present village of Ayacucho (Figure 9, p. 59), near a small bridge. It is a rock-shelter, now collapsed, situated on a steep slope overlooking a small stream. Elevation at the site is 2600 meters, placing it in the Thorn Forest Riverine ecologic zone. A maximum occupation area of eighty-nine square meters, constituting 95% of the site, was excavated in 1969 and 1970 (Figure 10, p. 69). The site is characterized by an unusually clear sequence of thirty-five stratigraphic components, (Figure 11, p. 70) both sterile strata and strata indicating heavy occupation, and a good sequence of eleven radiocarbon dates range from approximately 7000 B.C. to 1700 B.C. Four cultural phases are included; Jaywa, Piki, Chihua, and Cachi (Vierra 1975: 22-25; MacNeish 1969:24;17-23).

The Ayamachay site, Acl02

This site is a small cave, six meters by eight meters, located approximately sixteen kilometers north of Ayacucho near the small village of Pacalcasa (Figure 9, p. 59). Its elevation is 2900 meters, in the Thorn Forest Scrub ecologic zone. It was excavated completely in 1969, and revealed seventy centimeters of refuse with seven stratigraphic components, the lower three of which are preceramic. They range from 7200 B.C. to 3600 B.C., and are assigned to Puente, Piki, and Chihua cultural phases (MacNeish 1969:26-30).

The Tambo Cave site, Ac300

This site is located near the pass eastward from the Ayacucho valley on the Tambo road about twenty-four kilometers north of Ayacucho (Figure 9, p. 59). Its elevation is 4000 meters, in the Low Puna ecologic zone. It is a small cave literally beneath a huge boulder on a steep slope. The single preceramic component is assigned to the Jaywa culture phase, dated at 6200 B.C. (MacNeish 1970:28,32).
Table 3. Sample Information From Test Components

Asterisk indicates components sampled prior to decision N=100

<table>
<thead>
<tr>
<th>SITE</th>
<th>COMPONENT</th>
<th>NO. OF M² EXCAVATED</th>
<th>NO. OF FLAKES EXCAVATED</th>
<th>NO. OF M² SAMPLED</th>
<th>NO. OF FLAKES SAMPLED</th>
<th>% OF EXCAVATED FLAKES IN SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac158</td>
<td>IV</td>
<td>55</td>
<td>3662</td>
<td>5</td>
<td>100</td>
<td>2.7</td>
</tr>
<tr>
<td>Ac158</td>
<td>VII</td>
<td>71</td>
<td>4079</td>
<td>4</td>
<td>107*</td>
<td>2.6</td>
</tr>
<tr>
<td>Ac158</td>
<td>XI</td>
<td>69</td>
<td>5142</td>
<td>5</td>
<td>182*</td>
<td>3.5</td>
</tr>
<tr>
<td>Ac158</td>
<td>XII</td>
<td>52</td>
<td>3042</td>
<td>3</td>
<td>100</td>
<td>3.3</td>
</tr>
<tr>
<td>Ac102</td>
<td>VII</td>
<td>43</td>
<td>2820</td>
<td>4</td>
<td>100</td>
<td>3.5</td>
</tr>
<tr>
<td>Ac300</td>
<td>C</td>
<td>18</td>
<td>525</td>
<td>5</td>
<td>100</td>
<td>19.0</td>
</tr>
<tr>
<td>Ac335</td>
<td>C</td>
<td>42</td>
<td>3943</td>
<td>4</td>
<td>100</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23,213</td>
<td>789</td>
</tr>
</tbody>
</table>
Figure 10. Puente Site, Ac158; Floor Plan

KEY

- - - - Edge of former overhang

1 meter contour interval

Present rock cliff

Rock wall of former cave

1969

Area excavated

1970

1 meter

Cross section
Cross section B - A

Zones | C14 dates | Cultural Complexes
---|---|---
Ia | | Chachí
Ib | | 
Ic | 2045 B.C. | 
Id | | 
Ie | | 
U | | 
II | | 
Ig, Ib and Id not shown
Ih | 4340 B.C. | Chihua
IIb | | 
Ij | 4320 B.C. | 
II | 4410 B.C. | 
IIAb | | 
IIa | 4680 B.C. | 
IIb | | 
IIb and IC | | 
III | 4610 B.C. | Piki
IVA | | 
V | 4720 B.C. | 
VIIA | | 
VII | | 
VIIA | | 
VIII | 5210 B.C. | Jaywa
IX | | 
IXA | 5470 B.C. | 
X | | 
XI | | 
XII | | 
XIIA | 6910 B.C. | 
XIII | | 

Figure 11. Puente Site Stratigraphy
The Jaywamachay site, Ac335

This site is a long narrow rockshelter twenty-five meters long by only five or six meters deep. It is located on the main Ayacucho-Pisco highway about twenty kilometers southwest of Ayacucho on the banks of the Cachi river (Figure 9, p. 59). Elevation at the site is 3400 meters, in the Humid Woodlands ecologic zone. It was excavated in 1969 and 1970, revealing twelve clearly-defined preceramic strata dated from 9000 B.C. to 6000 B.C., with Jaywa, Puente, and Huanta culture phases represented (MacNeish 1969:26; 1970:23-28).
VI. DATA

The following data are from the application of the flake attribute system to the seven sample components in the Ayacucho Valley sequence. They are presented as charts of summary statistics for each of the twenty-eight flake attributes. On each chart, statistics for each of the seven sample components appear in columns. Their presentation in this way is to facilitate their interpretation, if possible, as indicative of inter-component variability corresponding to that discovered in Vierra's analysis. In addition, inter-component variability in the attribute data may be compared and interpreted directly as differential control of the fracture process and implement production technology. For explanation of attribute state abbreviations in Tables 4 through 32, reference should be made to the description of that attribute in Chapter IV.

Several generalizations are used in interpreting the collected attribute statistics. The mean value, or the statistical average, is most important in continuous attributes and those discrete attributes in which individual states are ranked according to some scale of behavior, such as number of scars on the flake's dorsal surface. This mean may be interpreted as a sort of behavioral average with respect to the attribute, but it indicates nothing about the distribution of cases around that mean. Thus, while differences in mean values are probably indicative of behavioral differences, similarities in mean value may not indicate behavioral similarity.

The statistical mode, or the most frequently occurring value, the median, or the fiftieth percentile (the point at which equal numbers of values fall on either side), and the standard deviation, or a sort of average of the deviations from the mean, are included as descriptions of the values around the mean (Technically, standard deviation is the square root of the variance, and variance is the mean of the squared deviations from the mean. Both characterize the spread of the observations around the mean, and standard deviation has the advantage of being expressed in the same units as the original measures.). They are especially useful in revealing variability obscured within similar means, such as a bimodal distribution that suggests the production of both large and small flakes, with few medium-sized flakes.

Minimum, or the smallest value, maximum, or the largest value, and range, or the difference between the two, are useful in suggesting relative specialization of flake production. Smaller ranges suggest
greater specialization and, conversely, larger ranges imply a more 
generalized pattern of fracture variable control.

The precise determination of significance is recognized as some- 
what problematic at this stage in the development of the flake attri-
bute system. How different do two values have to be before that dif-
ference becomes important in behavioral terms? The problem may be 
approached from three perspectives: statistical, experimental, and 
comparative. Since cluster sampling techniques such as that used in 
this study are poorly suited to such statistical tests of signifi-
cance as Chi-square without the application of specialized correction 
factors (Mueller 1974:48), and since this study is focused on arch-
aeological rather than experimental data, a comparative determination 
of significance is used. This is the primary reason for including in 
the analysis the three components from sites other than Acl58. Be-
cause of its frequent specific definition within statistics, the term 
"significant" has been avoided, and words such as "important" or 
"relevant" have been used in the interpretive remarks.

The flake analysis data are presented below, and interpretive 
comments for each attribute are organized with reference to the follow-
ing specific questions. First, over what fracture variables does this 
attribute indicate varying control? Second, does the variability ex-
pressed for the attribute suggest trends or development in fracture 
control and production technology within the Acl58 components? Third, 
does the variability expressed for the attribute tend to support or 
confirm Vierra's conclusions regarding the differential site activity 
at the Acl58 site? And fourth, does the variability expressed for 
the attribute suggest differences between the Acl58 components and the 
components from other example sites which might be the result of dif-
ferential site activity?

After the data have been presented and interpretive comments made 
for each attribute, a more coordinated summary will be included in the 
final chapter.

A. Entire Flake Attributes

1. Raw Material

An evaluation of the raw material for both flakes and implements 
was made only on the basis of three major categories; basalt, obsidian, 
and other siliceous materials. This was recognized as perhaps in-
adequately discriminating to evaluate the selection of certain lithic 
materials for given flake or implement types, but this system was al-
ready in operation and a decision was made not to alter it.
Basalts were light grey to black, with occasional dark red specimens. Fracture surfaces varied from quite rough and grainy to extremely smooth, indicating a range of crystalline structure. While close petrologic examination was not made, one particular type of very black, extremely fine-grained basalt occurred with sufficient frequency in Acl58 and other lower-elevation sites to suggest a quarry source. However, three seasons of searching and asking failed to locate such a source. Basalts in considerable variety are readily found today throughout the Ayacucho valley in alluvial deposits and river beds, especially at lower elevations.

Obsidian from the Ayacucho valley sites was quite heterogeneous, certainly suggesting no single or even predominant quarry source. It is easily discernable by the smooth glassy nature of the fracture surfaces and the absence of any crystalline structure. Color normally varied from grey to black, with occasional dark red or brown specimens. Inclusions such as phenocrysts varied greatly, as did the relative opaqueness of the material. Again, no sources of obsidian were located, despite rather extensive efforts. Many local inhabitants immediately recognized the obsidian samples, many had heard of sources high in the tundra, but none could specifically locate a source. The occurrence of obsidian varies strongly with altitude, making up over eighty percent of the flakes in some tundra components while being virtually absent from some components at lowest elevations.

The category "other siliceous materials" includes a wide range of flints, cherts, and chalcedonies of extremely varied color and texture, all demonstrating some degree of conchoidal fracture and a very fine or microcrystalline structure. These materials, while not as common as basalts, are still rather readily available today in river gravels and alluvial deposits.

Table 4 shows the percentages of flakes in each raw material category for the seven test components. The relative homogeneity of the percentage profiles in the Acl58 components indicates that variability in other flake attributes for these components is not due to their differential expression in the raw material categories, but

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt</td>
<td>1</td>
<td>46.0</td>
<td>53.3</td>
<td>53.6</td>
<td>44.4</td>
<td>36.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Obsidian</td>
<td>2</td>
<td>9.0</td>
<td>2.8</td>
<td>3.3</td>
<td>8.1</td>
<td>4.0</td>
<td>79.0</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>45.0</td>
<td>43.9</td>
<td>43.2</td>
<td>47.5</td>
<td>60.0</td>
<td>11.0</td>
</tr>
</tbody>
</table>
to other technological factors. However, differences between the Acl58 components and others, particularly Ac300C, may well be largely due to such differential expression of attributes in the raw material categories. The rather brittle nature of obsidian may result, for example, in the excessive destruction of the platform area on obsidian flakes, whereas identically produced flakes in flint or basalt may retain the platform area. Observed differences in platform attributes between two such components, therefore, may be largely due to the nature of the raw materials rather than to differential production technology. In each of the following attributes, cases in which this raw material factor is considered important will be specifically noted.

Control is exercised for this attribute by selection of one type of raw material over another from those available locally, or by trade or other procurement of non-local materials. The pattern of similarity among the Acl58 components, with quite distinct profiles in each of the other components, suggests that the raw material procurement systems for all components were dominated by local availability, with possible trade of secondary importance.

Within the Acl58 components, greatest similarities are demonstrated between IV and XII, and between VII and XI. While this is not viewed as particularly strong evidence, it fails to confirm Vierra's hypothesis of similarity between XI and XII. Differences between Acl58 components and others are viewed as reflecting differential availability of raw materials locally, particularly with reference to site elevation. The possible exception is Acl02VII, in which the rather high percentage of other siliceous materials may be a conscious selection of these materials over more readily available basalts.

2. Flake Length

Table 5 presents summary statistics for flake length. This attribute is dependent upon several variables, such as force amount, force angle, and the core's shape and size, all of which are

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>14.4</td>
<td>14.5</td>
<td>15.3</td>
<td>16.1</td>
<td>15.3</td>
<td>14.0</td>
<td>18.8</td>
</tr>
<tr>
<td>Mode</td>
<td>8.0</td>
<td>10.0</td>
<td>8.0</td>
<td>11.0</td>
<td>10.0</td>
<td>10.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Median</td>
<td>12.5</td>
<td>12.8</td>
<td>13.0</td>
<td>14.3</td>
<td>14.3</td>
<td>12.3</td>
<td>16.7</td>
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<tr>
<td>Minimum</td>
<td>4.0</td>
<td>5.0</td>
<td>6.0</td>
<td>6.0</td>
<td>5.0</td>
<td>5.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>44.0</td>
<td>45.0</td>
<td>46.0</td>
<td>36.0</td>
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<td>50.0</td>
</tr>
<tr>
<td>Range</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>30.0</td>
<td>33.0</td>
<td>51.0</td>
<td>43.0</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>7.7</td>
<td>7.5</td>
<td>7.4</td>
<td>6.9</td>
<td>7.0</td>
<td>7.4</td>
<td>9.3</td>
</tr>
</tbody>
</table>
controllable by the stoneworker. Differential control of these variables is discussed in detail under attributes 4, 5, and 9, since such attributes as flake length, width, and thickness are technologically more revealing when combined as various indexes rather than as absolute measurements in themselves. In other words, flake proportions are more revealing than flake dimensions.

Within the Acl58 components there is some trend toward longer flakes in the older components, though this is not strong. Greatest similarity is between IV and VII, while greatest mean differences exist between VII and XI, and between XI and XII. This is interpreted as a failure to confirm Vierra's proposed similarity between XI and XII. In addition, dissimilarities in mode, median, maximum, range, and standard deviation between XI and XII further question Vierra's conclusion. The lower maximum value for XII, along with a correspondingly lower range, a smaller standard deviation from a higher mean, and higher mode and median values all suggest the specialized production of longer flakes in that component.

For other components, Acl02VII is very similar to Acl58XII, and Ac300C is similar to the later Acl58 components with both the shortest flakes and the greatest range, suggesting a lack of specialization. Ac300C is the component with nearly eighty percent obsidian flakes. The fracture qualities of obsidian are such that longer flakes are normally expected, and since this component has the lowest mean value for flake length, this may indicate the scarcity of large raw material nodules or some similar factor. Ac335C, with high values in all statistics, probably suggests distinct technological patterns that produce significantly longer flakes.

3. Flake Width

Summary statistics for flake width are presented in Table 6. Flake width, like length, is dependent upon and controlled by several variables such as PFA placement, force angle, and core shape. Also

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>15.3</td>
<td>14.7</td>
<td>14.6</td>
<td>15.3</td>
<td>15.0</td>
<td>12.5</td>
<td>16.1</td>
</tr>
<tr>
<td>Mode</td>
<td>12.0</td>
<td>9.0</td>
<td>10.0</td>
<td>19.0</td>
<td>11.0</td>
<td>10.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Median</td>
<td>13.5</td>
<td>13.3</td>
<td>13.4</td>
<td>14.4</td>
<td>13.2</td>
<td>10.4</td>
<td>13.1</td>
</tr>
<tr>
<td>Minimum</td>
<td>5.0</td>
<td>6.0</td>
<td>4.0</td>
<td>6.0</td>
<td>5.0</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>41.0</td>
<td>37.0</td>
<td>33.0</td>
<td>43.0</td>
<td>60.0</td>
<td>50.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Range</td>
<td>36.0</td>
<td>31.0</td>
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<td>37.0</td>
<td>55.0</td>
<td>46.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>7.2</td>
<td>6.7</td>
<td>5.9</td>
<td>6.4</td>
<td>7.6</td>
<td>7.5</td>
<td>8.9</td>
</tr>
</tbody>
</table>
like flake length, it is technologically most significant when considered in relationship to other flake dimensions and will be discussed more fully in those relationships.

Within the Ac158 components, mean flake widths are not radically different. In fact, with the exception of an unusually high modal value in Ac158XII and slightly high values for median, maximum, and range in this component, all Ac158 components appear fairly homogeneous. Lowest mean, minimum, maximum, range, and standard deviation in Ac158XI suggest a somewhat more specialized activity of producing slightly narrower flakes. Within Ac158 components, maximum variation occurs between XI and XII, failing to confirm Vierra's hypothesis of structural-functional similarity between those two components.

Among other components, the large maximum and range values in Ac102VII imply the rather generalized production of a wider range of flakes, perhaps from larger-diameter cores. Ac300C, with rather large maximum and range values but a noticeably smaller mean suggests the production of higher proportions of narrow flakes along with a few rather wide ones. Such a pattern might be expected in producing bifaces from blanks; some wider thinning flakes and many narrower and smaller shaping flakes. The high proportion of obsidian in Ac300C may also be a factor contributing to the production of narrower flakes in that component. Ac335C, with a noticeably larger mean, highest standard deviation, and rather low maximum and range values suggests the specialized production of only a moderately wide range of flakes; i.e., few very narrow and no very wide flakes, but considerable variability, tending toward large, in the mid-width range.

4. Length X Width Index

Flake dimensions of length and width have technological significance when considered independently, as above. However, these attributes have even greater importance when considered in relationship to each other, as proportional rather than absolute statements. A long narrow flake, for example, has quite different technological significance than a long wide flake. The two represent distinct patterns of variable control which are not obvious from a consideration of either dimension independently. In order to consider these proportional implications of flake dimensions, several indexes have been generated as quantitative statements of basic flake morphology.

Table 7 presents statistics for an index generated by multiplying the flake's length times its width for an approximation of the fracture surface area. This area is proportional to the force required for detachment of the flake, and its greatest significance is with reference to these force amounts.
Table 7. Length X Width Index

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>252.3</td>
<td>245.4</td>
<td>247.1</td>
<td>267.4</td>
<td>265.1</td>
<td>215.8</td>
<td>351.1</td>
</tr>
<tr>
<td>Mode</td>
<td>70.0</td>
<td>56.0</td>
<td>72.0</td>
<td>130.0</td>
<td>180.0</td>
<td>80.0</td>
<td>120.0</td>
</tr>
<tr>
<td>Median</td>
<td>162.5</td>
<td>154.0</td>
<td>178.3</td>
<td>185.8</td>
<td>176.0</td>
<td>130.2</td>
<td>230.5</td>
</tr>
<tr>
<td>Minimum</td>
<td>44.0</td>
<td>40.0</td>
<td>50.0</td>
<td>48.0</td>
<td>35.0</td>
<td>30.0</td>
<td>49.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>1482.0</td>
<td>1395.0</td>
<td>1518.0</td>
<td>1085.0</td>
<td>2100.0</td>
<td>2800.0</td>
<td>1800.0</td>
</tr>
<tr>
<td>Range</td>
<td>1438.0</td>
<td>1355.0</td>
<td>1468.0</td>
<td>1037.0</td>
<td>2065.0</td>
<td>2770.0</td>
<td>1751.0</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>252.7</td>
<td>250.3</td>
<td>214.7</td>
<td>210.8</td>
<td>276.2</td>
<td>319.3</td>
<td>369.7</td>
</tr>
</tbody>
</table>

Within the Ac158 components, general similarity exists between IV, VII, and XI, with XII demonstrating a noticeably distinct profile. The larger mean and small maximum, range, and standard deviation values in XII strongly suggest the regular and more specialized production of flakes with larger fracture surfaces, or flakes requiring the application of consistently greater amounts of force. This evidence fails to confirm Vierra's conclusions of similarity between Ac158XI and XII.

For other components, Ac102VII has considerably greater maximum, range, and standard deviation values, as well as a low minimum, and implies a more generalized production of varied flake sizes. Ac300C, with the smallest mean and minimum, but the greatest maximum and range, indicates the production of many small flakes with a few very large ones, perhaps due in part to high proportions of smaller obsidian nodules as basic raw material. When this small mean is considered along with the relatively lower force requirements for fracture in obsidian, the smaller force amounts in Ac300C become obvious. This may indicate the extensive use of pressure force application techniques. Ac335C, with considerably greater mean and median values and moderate values for maximum and range, suggests the regular production of large flakes, but without extremely large ones. This regular application of rather large amounts of force probably indicates considerable percussion flaking in the component. These greater force requirements also imply potentially greater difficulty in controlling other fracture variables, such as the PFA location and force angle.

5. Length / Width Index

Table 8 presents statistics for an index generated by dividing flake length by flake width. This produces a two-dimensional quantitative statement of flake shape. Round or square flakes have a value of 1. Values of less than 1 indicate flakes wider than long, and vice versa. Flakes with their length equal to or greater than twice their width, or those with values of 2 or more, are called
Table 8. Length / Width Index

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.02</td>
<td>1.05</td>
<td>1.12</td>
<td>1.14</td>
<td>1.09</td>
<td>1.25</td>
<td>1.33</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.34</td>
<td>0.33</td>
<td>0.37</td>
<td>0.32</td>
<td>0.40</td>
<td>0.36</td>
<td>0.44</td>
</tr>
<tr>
<td>Maximum</td>
<td>3.00</td>
<td>3.50</td>
<td>3.25</td>
<td>2.67</td>
<td>2.25</td>
<td>2.75</td>
<td>3.83</td>
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<td>Range</td>
<td>2.66</td>
<td>3.17</td>
<td>2.88</td>
<td>2.35</td>
<td>1.85</td>
<td>2.39</td>
<td>3.40</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.48</td>
<td>0.51</td>
<td>0.50</td>
<td>0.47</td>
<td>0.41</td>
<td>0.49</td>
<td>0.65</td>
</tr>
</tbody>
</table>

"blades." In general, flakes with regularly higher values for this index require more precise control over fracture variables such as PFA location, core geometry, and force angle.

Within the Ac158 components there is a slight trend toward shorter, wider flakes through time from older to more recent. Ac158VII, with large maximum and range values, suggests greater variability in flake production, while Ac158XII, with smaller maximum and range values conversely suggests greater specialization in the production of somewhat longer, narrower flakes. Similarities between Ac158XI and XII are considered sufficient to confirm Vierra's hypothesis of similarity.

For other components, the small maximum and range values for Ac102VII suggest a rather specialized production of flake shape, which is not inconsistent with its apparent generalized production of flake size (see Attribute 4). Ac102VII therefore suggests production of a range of flake sizes of rather more standard shape, perhaps from similarly shaped cores such as lenticular-sectioned bifaces. Ac335C demonstrates higher values for all statistics, implying the regular production of elongated flakes, including substantial numbers of blades. When this is combined with the larger force requirements indicated by Attribute 4, Ac335C demonstrates the regular well-controlled production of large blade-like flakes, and is technologically quite distinct from other components.

6. Maximum Width Location

Table 9 presents summary statistics for a measurement of the distance from the PFA to the point of maximum width (Figure 6, p. 39). This measurement indicates the expanding or contracting configuration of the flake's shape, as well as its proportional distribution of mass. Higher mean values suggest distally expanding flakes and, conversely, lower values suggest distally contracting flakes. In biface production, the former are associated primarily with thinning the core, or the formation of its section, while the latter are associated with shaping the piece, or forming its plan outline.
Table 9. Maximum Width Location

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>7.3</td>
<td>7.6</td>
<td>8.3</td>
<td>8.6</td>
<td>8.4</td>
<td>7.9</td>
<td>10.8</td>
</tr>
<tr>
<td>Mode</td>
<td>4.0</td>
<td>6.0</td>
<td>5.0</td>
<td>7.0</td>
<td>6.0</td>
<td>6.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Median</td>
<td>6.1</td>
<td>6.4</td>
<td>7.0</td>
<td>7.4</td>
<td>6.9</td>
<td>6.8</td>
<td>9.3</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>28.0</td>
<td>31.0</td>
<td>36.0</td>
<td>19.0</td>
<td>31.0</td>
<td>29.0</td>
<td>31.0</td>
</tr>
<tr>
<td>Range</td>
<td>27.0</td>
<td>30.0</td>
<td>35.0</td>
<td>18.0</td>
<td>30.0</td>
<td>27.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>5.2</td>
<td>5.4</td>
<td>5.6</td>
<td>4.5</td>
<td>5.7</td>
<td>4.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>

The PFA location and the force angle with respect to core geometry are the fracture variables primarily responsible for variability in this attribute.

Within the Ac158 components, there is a slight trend toward the production of flakes with their widest point closer to the PFA, from oldest to most recent (XII to IV). This may imply a slightly increased concern with implement plan over section, possibly produced by an increasingly more outward-directed force application. The smaller values for maximum, range, and standard deviation in Ac158XII imply greater specialization of flake production, while larger values for these same statistics in XI conversely suggest less specialization. This fails to confirm Vierra's conclusion of similarity between the two components.

Both the Acl02VII and Ac300C profiles for this attribute fall within the range of the Ac158 components, and do not suggest particular technological patterns. However, the profile for Ac335C is quite different from all other components, strongly implying unique flake removal techniques. The noticeably greater-mean value without increased maximum and range values indicate a high proportion of flakes with their maximum width, and presumably the flakes' center of mass also, located well away from the PFA. This suggests more inward-directed force, an increased concern with core section, and good control of other fracture variables. This is quite consistent with other attributes of flake size and shape for this component.

7. Flake Thickness

Table 10 presents summary statistics for a measurement of flake thickness, which is determined primarily by the PFA location with respect to the core edge and force direction. The Ac158 components present a closely homogeneous profile with the exception of unusually high maximum and range values in XI and somewhat low values for those
Table 10. Flake Thickness

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3.1</td>
<td>3.2</td>
<td>3.2</td>
<td>3.2</td>
<td>3.3</td>
<td>2.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Mode</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Median</td>
<td>2.3</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>2.8</td>
<td>2.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>11.0</td>
<td>12.0</td>
<td>17.0</td>
<td>9.0</td>
<td>16.0</td>
<td>12.0</td>
<td>21.0</td>
</tr>
<tr>
<td>Range</td>
<td>10.0</td>
<td>11.0</td>
<td>16.0</td>
<td>8.0</td>
<td>15.0</td>
<td>11.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>2.2</td>
<td>2.1</td>
<td>2.1</td>
<td>1.8</td>
<td>2.2</td>
<td>2.1</td>
<td>2.9</td>
</tr>
</tbody>
</table>

statistics in XII. This suggests the more generalized production of a wider range of flake thickness in XI and a more specialized production of flakes with respect to thickness in XII. This fails to substantiate Vierra's hypothesis of similarity between the two components.

Ac102VII is generally similar to the Ac158 components, particularly to Ac158XI. Ac300C is considerably lowest in mean value with moderate maximum and range values, suggesting production of many rather thin flakes. This is probably due in large part to the high proportions of obsidian in the component, and corresponds well with the small length X width index for the component (see Attribute 4). Ac335C again presents a unique profile, with predictably the thickest flakes, though the mean is not excessive. However, this component also has the highest values for maximum, range, and standard deviation, suggesting flakes somewhat less specialized for thickness.

8. Maximum Thickness Location

Table 11 presents summary statistics of a measurement of the distance from the PFA to the point of maximum thickness (Figure 6, p. 39), an attribute closely related to the distance from the PFA to the point of maximum width (see Attribute 6). Profiles of the two attributes generally confirm that close relationship. This attribute is controlled by PFA location, core shape, and force direction.

Within the Ac158 components there is a slight trend from oldest to most recent (XII to IV) toward the production of flakes with their thickest point closer to the PFA, suggesting an increasing concern with implement plan rather than section. An increasingly more outward-directed force application may effect such a trend. Ac158IV, with lower mean and higher maximum and range values, suggests the rather inconsistent production of a wide range of flake thickness location, but with a concentration of those thicker toward the PFA.
Table 11. Maximum Thickness Location

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>4.5</td>
<td>5.1</td>
<td>5.1</td>
<td>5.9</td>
<td>5.5</td>
<td>6.3</td>
<td>6.6</td>
</tr>
<tr>
<td><strong>Mode</strong></td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>3.5</td>
<td>3.0</td>
<td>4.8</td>
<td>3.8</td>
<td>4.3</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>33.0</td>
<td>25.0</td>
<td>27.0</td>
<td>27.0</td>
<td>45.0</td>
<td>44.0</td>
<td>44.0</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>32.0</td>
<td>24.0</td>
<td>26.0</td>
<td>26.0</td>
<td>44.0</td>
<td>43.0</td>
<td></td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td>5.6</td>
<td>5.0</td>
<td>5.5</td>
<td>5.2</td>
<td>5.0</td>
<td>6.3</td>
<td>7.4</td>
</tr>
</tbody>
</table>

The somewhat higher mean value for Acl58XII is perhaps significant of more inward-directed force application, location of the PFA further from the core edge, and increased concern with implement section. Evidence from this attribute fails to confirm Vierra's conclusion of similarity between Acl58XI and XII.

For other components, Acl02VII is again well within the range of the Acl58 components and does not indicate unique technological patterns. Ac300C and Ac335C both demonstrate larger mean values, as well as maximum and range values, suggesting the production of flakes with their maximum thickness further from the PFA. This may indicate placement of the PFA further from the core edge, a greater inward force vector, or a combination of the two. The production of flakes with their greatest thickness and center of mass well distal to the PFA is important in the removal of irregularities from the core face and the production of implements with thin, regular cross-sections.

9. Flake Index

This index was generated by dividing an approximation of the fracture surface area, length X width, by flake thickness. The result is a generalized three-dimensional numerical statement of total flake shape, and is broadly indicative of combined control of fracture variables. As the length or width increases (the numerator), the fracture surface increases, force requirements increase, control of all fracture variables become more important, and numerical value for flake index increases. Similarly, as flake thickness decreases (the denominator), the PFA is located closer to the core edge, control of fracture variables such as direction of force application become more critical, chances for failure are greater, and numerical value for flake index increases. For example, flakes of equal fracture surface area (length X width) will have higher flake index values as their thickness decreases, and flakes of a given thickness will have higher flake index values as their length, width, or both increases.
Large thin flakes, therefore, have higher values than large thick ones, and large thin or thick flakes have higher values than small thin or thick ones. The higher values indicate generally greater control of fracture variables, and a simple ranking of the mean values from lowest to highest should approximate a statement of increasing total control of those variables.

Table 12 presents statistical data for flake index values. For unexplained reasons, values for minimum, maximum, range, and standard deviation were missing from the computer print-out for Ac158XII. Within the Ac158 components, a ranking of the means from lowest to highest produces the following sequence: VII, XI, IV, XII. The smallest difference, suggesting the greatest similarity, occurs between XI and IV, and the largest difference, suggesting least similarity, occurs between IV and XII. The difference between XI and XII fails to confirm Vierra's hypotheses of similarity between the two.

For other components, Ac300C shows the lowest mean values of all components, Ac102VII is intermediate, and Ac335C demonstrates the highest mean flake index value by a considerable margin. The low mean value in Ac300C is primarily due to a great many small obsidian flakes with low fracture surface area which, even though they are rather thin, do not demonstrate a high degree of variable control.

A ranking of the flake-index means for all seven test components gives the following sequence of increasing control of fracture variables: Ac300C, Ac158VII, Ac158XI, Ac102VII, Ac158IV, Ac158XII, and Ac335C.

Table 12. Flake Index

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>79.2</td>
<td>73.2</td>
<td>77.2</td>
<td>87.5</td>
<td>77.9</td>
<td>72.5</td>
<td>98.7</td>
</tr>
<tr>
<td>Mode</td>
<td>44.0</td>
<td>40.0</td>
<td>72.0</td>
<td>72.0</td>
<td>60.0</td>
<td>40.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Median</td>
<td>69.8</td>
<td>65.4</td>
<td>71.8</td>
<td>72.4</td>
<td>71.9</td>
<td>64.6</td>
<td>79.0</td>
</tr>
<tr>
<td>Minimum</td>
<td>24.0</td>
<td>22.5</td>
<td>19.2</td>
<td></td>
<td>17.5</td>
<td>15.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>191.3</td>
<td>233.3</td>
<td>227.3</td>
<td>190.0</td>
<td>233.3</td>
<td>329.7</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>167.3</td>
<td>210.8</td>
<td>208.1</td>
<td>177.5</td>
<td>218.3</td>
<td>305.7</td>
<td></td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>38.1</td>
<td>37.5</td>
<td>36.6</td>
<td>38.9</td>
<td>38.5</td>
<td>63.4</td>
<td></td>
</tr>
</tbody>
</table>
10. Longitudinal Cross-Section

Table 13 presents summary percentages for placement of flakes into 10 categories or states on the basis of their longitudinal cross-section. States 1 and 7 suggest inadequate force amounts, states 5 and 8 suggest shaping implement plan or other activity that removes proportionally large amounts of core edge and small amounts of stone. State 6, and to some extent states 4, 5, and 8, suggest rather flexible core support. State 6 also suggests excessive force, PFA placement rather far in from the core edge, and perhaps a large inward-directed force vector. States 2, 3, and 4 demonstrate most consistent variable control, with 2 indicating possible softer flaking tool or rigid core support, 4 indicating possible harder flaking tool or more flexible core support, and 3 indicating an optimum cross-section for balanced control of all variables and consistent flake production.

Within Ac158 components, VII and XI contain greater percentages of flakes in problem categories, such as those suggesting inadequate force, excessive or poorly directed force, inadequate core support, or extremely irregular flakes. Conversely, IV and XII contain greater percentages of flakes in states 2, 3, and 4, suggesting more regular

<table>
<thead>
<tr>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0 0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1</td>
<td>2.0</td>
<td>0.0</td>
<td>3.3</td>
<td>2.0</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>2</td>
<td>6.0</td>
<td>11.2</td>
<td>9.8</td>
<td>22.2</td>
<td>15.0</td>
<td>10.0</td>
</tr>
<tr>
<td>3</td>
<td>33.0</td>
<td>27.1</td>
<td>26.2</td>
<td>31.3</td>
<td>34.0</td>
<td>32.0</td>
</tr>
<tr>
<td>4</td>
<td>24.0</td>
<td>14.0</td>
<td>17.5</td>
<td>12.1</td>
<td>16.0</td>
<td>18.0</td>
</tr>
<tr>
<td>5</td>
<td>22.0</td>
<td>18.7</td>
<td>20.2</td>
<td>17.2</td>
<td>20.0</td>
<td>22.0</td>
</tr>
<tr>
<td>6</td>
<td>2.0</td>
<td>0.9</td>
<td>4.4</td>
<td>0.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>7</td>
<td>9.0</td>
<td>19.6</td>
<td>8.7</td>
<td>11.1</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>8</td>
<td>1.0</td>
<td>3.7</td>
<td>3.8</td>
<td>3.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Irreg.</td>
<td>9 1.0</td>
<td>4.7</td>
<td>6.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
variable control. The high values of state 2 in Ac158XII may indicate either the use of a softer flaking tool or more rigid core support. Ac158XI and XII differences fail to confirm Vierra's hypothesis of similarity.

Within other components, Ac300C suggests some problems, especially with inadequate force application as indicated by higher values of states 1 and 7. Ac102VII is intermediate and generally quite similar to Ac158IV. Ac335C contains higher percentages in the optimum configuration categories, especially state 3. Its rather high percentage in state 5 may well represent the short shaping flakes which produce the final symmetrical plan of implement edges.

11. Transverse Cross-Section

Table 14 presents summary percentages for placement of flakes into 10 categories or states on the basis of their transverse cross-section. State 1 is probably associated with harder percussors, placement of the PFA rather far from the core edge, a larger inward-directed force vector, and perhaps with inadequate force. States 2 and 3 may also indicate a rather hard percussor and significant inward-directed force. States 3, 5, and 8 are indicative of rather narrow

<table>
<thead>
<tr>
<th>Table 14. Transverse Cross-Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>158IV</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Ind.</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>Irreg.</td>
</tr>
</tbody>
</table>


cores or initial shaping flakes from larger cores. States 4, 6, and 7 suggest larger cores and the regular removal of thin flakes, perhaps with softer flaking tools.

Within Ac158 components there seems to be a pattern of narrower cores as suggested by consistently higher percentages of states 3, 5, and 8. Ac158IV, VII, and XI indicate by higher percentages in states 1, 2, and 3 the use of harder percussors and perhaps a more inward-directed force vector. Ac158XII has lower percentages for these states, and also displays considerably higher percentages in states 4, 6, and 7, suggesting greater use of softer flaking tools and perhaps larger cores. The differences between Ac158XI and XII fail to support Vierra's hypothesis of similarity between the two.

For other components, there is little indication of small or narrow cores, suggested by low percentages of states 3, 5, and 8 in all three components. Ac102VII is most similar to Ac158IV. Ac300C demonstrates a reduced percentage of state 1, suggesting a reduced use of hard flaking tools. Ac335C shows a profile quite similar to Ac158XII, in which low percentages of states 1 and 2, as well as high percentages of states 6 and 7, suggest greater use of softer flaking tools.

12. Plan Outline

Table 15 presents summary percentages for placement of flakes into 10 categories or states on the basis of their plan outline. States 3, 4, 5, and 6 should be associated with patterns of consistent control of fracture variables and regularly shaped cores. States 1 and 2 should suggest more angular short and medium-length cores and

<table>
<thead>
<tr>
<th>State</th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Squared</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.9</td>
<td>0.0</td>
<td>1.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Rectang.</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>4.7</td>
<td>0.0</td>
<td>4.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Dist. Exp.</td>
<td>3.0</td>
<td>2.0</td>
<td>2.0</td>
<td>11.2</td>
<td>2.0</td>
<td>11.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Rounded</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>8.7</td>
<td>4.0</td>
<td>8.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Oval</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>6.6</td>
<td>5.0</td>
<td>6.6</td>
<td>7.0</td>
</tr>
<tr>
<td>11-Sided</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>10.4</td>
<td>6.0</td>
<td>10.4</td>
<td>11.0</td>
</tr>
<tr>
<td>Dist. Contr.</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>1.9</td>
<td>7.0</td>
<td>1.9</td>
<td>2.0</td>
</tr>
<tr>
<td>Wider Than</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>13.7</td>
<td>8.0</td>
<td>13.7</td>
<td>11.0</td>
</tr>
<tr>
<td>Long</td>
<td>9.0</td>
<td>9.0</td>
<td>9.0</td>
<td>15.0</td>
<td>9.0</td>
<td>15.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Irreg.</td>
<td>65.0</td>
<td>58.9</td>
<td>47.5</td>
<td>55.6</td>
<td>64.0</td>
<td>68.0</td>
<td>72.0</td>
</tr>
</tbody>
</table>
consistent control of force direction. Results of this attribute are difficult to interpret. The very high percentages in all test components for state 9, or irregular, is unexplained, other than the general suggestion that the production of irregularly-shaped flakes is normally indicative of irregularly-shaped cores. Concern with shaping those irregular cores produces irregular flakes, but such core-shaping activity is usually done either at the quarry site or in some very early stage of blank production, an interpretation difficult to support for the test components. Particularly puzzling is the fact that the highest value for irregular flakes occurs in Ac335C, which consistently demonstrates greater regularity of variable control, and which should result in flakes with a regular plan outline.

Within the Ac158 components, XII appears somewhat different from the other three, with higher percentages in states 3, 4, 5, and 6. The higher percentages in state 8 for Ac158IV, VII, and XI suggest the possibility of rather short, wide cores, and perhaps a greater concern for producing implement plan rather than section. The profile for XII among the Ac158 components fails to confirm Vierra's hypothesis of similarity between XI and XII.

Among other components, only the higher values for state 6 are noteworthy, suggesting for all three components an element of consistent control of force direction and core face morphology.

B. Proximal End Attributes

13. Platform Remnant Depth

Table 16 presents summary statistics of a measurement of the depth of the flake's platform remnant. This is a rather direct indication of the distance of the PFA from the edge of the core or platform. Since the 10 states of the attribute correspond to a continuous linear measurement, the mean for each component is also included.

Within the Ac158 components there is a rather consistent profile for IV and XII, except that the indeterminant or 0 value for XII is quite high. With this, and with all other attributes of the flake's proximal or platform end, it is important to consider the meaning of 0 values and their effect on the profiles of individual components. Since placement in the indeterminant category is normally made on the basis of destruction of the flake's proximal end, components with many thin, fragil flakes may be overrepresented in state 0 and consequently underrepresented in states which would otherwise be more characteristic of the component. This may be particularly true if force is delivered with a rather hard flaking tool. Or, if the PFA is normally
Table 16. Platform Remnant Depth

<table>
<thead>
<tr>
<th>Ind.</th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16.0</td>
<td>28.0</td>
<td>21.3</td>
<td>44.4</td>
<td>22.0</td>
<td>49.0</td>
<td>35.0</td>
</tr>
<tr>
<td>1mm or less</td>
<td>14.0</td>
<td>8.4</td>
<td>12.6</td>
<td>17.0</td>
<td>13.0</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>2mm</td>
<td>24.0</td>
<td>28.0</td>
<td>31.1</td>
<td>16.2</td>
<td>35.0</td>
<td>21.0</td>
<td>18.0</td>
</tr>
<tr>
<td>3mm</td>
<td>22.0</td>
<td>15.0</td>
<td>21.3</td>
<td>16.2</td>
<td>12.0</td>
<td>10.0</td>
<td>16.0</td>
</tr>
<tr>
<td>4mm</td>
<td>10.0</td>
<td>12.1</td>
<td>6.6</td>
<td>7.1</td>
<td>5.0</td>
<td>1.0</td>
<td>8.0</td>
</tr>
<tr>
<td>5mm</td>
<td>8.0</td>
<td>3.7</td>
<td>1.6</td>
<td>4.0</td>
<td>5.0</td>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td>6mm</td>
<td>4.0</td>
<td>1.9</td>
<td>2.7</td>
<td>2.0</td>
<td>2.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7mm</td>
<td>1.0</td>
<td>1.9</td>
<td>1.1</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8mm</td>
<td>0.0</td>
<td>0.9</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>9mm or more</td>
<td>1.0</td>
<td>0.0</td>
<td>1.6</td>
<td>1.0</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>mean</td>
<td>3.0</td>
<td>2.9</td>
<td>2.7</td>
<td>3.1</td>
<td>2.5</td>
<td>2.4</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Located at the extreme edge of a small core with low inertia and force is applied rapidly, even by a bone or antler billet, the proximal portion of the flake may be quite likely to shatter during removal, particularly in obsidian or other very brittle raw material. The high value for state 0 in Ac158XII may suggest just such flake removal techniques. Ac158IV and XII show similar distributions of values for states 1, 2, 3, and 4, while VII and XI show similar distributions characterized by a strong peak at state 2. This evidence fails to confirm Vierra's hypothesis of similarity for Ac158XI and XII.

For other components, both Ac102VII and Ac300C show a peak at state 2 similar to that in Ac158VII and XI, while Ac335C shows a distribution for states 1 through 4 which is similar to Ac158IV and XII. In addition, Ac300C, and to a lesser extent Ac335C, demonstrate high state 0 values, probably as a result of high proportions of obsidian in the two components. Lowest mean value for platform remnant depth is in Ac300C, which corresponds well with that component's high proportion of small, thin flakes. Higher mean values for this attribute occur in Ac158IV, XII, and Ac335C, which are the three components most similar in distribution for this attribute, as well as the components which demonstrate highest flake index value (see Attribute 9).

14. Platform Remnant Width

Table 17 presents summary statistics for groupings of platform remnant width measurements. Mean values are included since the 10 attributes states correspond to grouped linear measurements. The same statistics appear in all components for state 0 as appeared in Table 16 for platform remnant depth, and explanatory comments made there apply here equally.
Table 17. Platform Remnant Width

<table>
<thead>
<tr>
<th>Ind.</th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1mm or less</td>
<td>16.0</td>
<td>28.0</td>
<td>20.8</td>
<td>44.4</td>
<td>22.0</td>
<td>49.0</td>
<td>35.0</td>
</tr>
<tr>
<td>2 mm</td>
<td>6.0</td>
<td>6.5</td>
<td>11.5</td>
<td>5.1</td>
<td>15.0</td>
<td>11.0</td>
<td>15.0</td>
</tr>
<tr>
<td>3-4 mm</td>
<td>10.0</td>
<td>16.8</td>
<td>19.1</td>
<td>11.1</td>
<td>11.1</td>
<td>15.0</td>
<td>10.0</td>
</tr>
<tr>
<td>5-7 mm</td>
<td>29.0</td>
<td>20.6</td>
<td>20.2</td>
<td>16.2</td>
<td>25.0</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>8-10 mm</td>
<td>19.0</td>
<td>11.2</td>
<td>14.2</td>
<td>11.1</td>
<td>12.0</td>
<td>5.0</td>
<td>12.0</td>
</tr>
<tr>
<td>11-13 mm</td>
<td>6.0</td>
<td>8.4</td>
<td>8.2</td>
<td>6.1</td>
<td>6.0</td>
<td>3.0</td>
<td>7.0</td>
</tr>
<tr>
<td>14-17 mm</td>
<td>8.0</td>
<td>3.7</td>
<td>4.4</td>
<td>3.0</td>
<td>4.0</td>
<td>0.0</td>
<td>4.0</td>
</tr>
<tr>
<td>18-21 mm</td>
<td>3.0</td>
<td>0.9</td>
<td>0.5</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>22 or more</td>
<td>3.0</td>
<td>1.9</td>
<td>0.5</td>
<td>2.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>mean</td>
<td>4.7</td>
<td>4.2</td>
<td>4.1</td>
<td>4.5</td>
<td>4.0</td>
<td>3.6</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Within the Ac158 components, platform remnant widths demonstrate profiles similar to those for platform remnant depth. Ac158IV shows a pronounced peak at state 4, with considerably more representation in states 5 through 9 than other components. In addition, Ac158IV has the greatest mean value for platform remnant width. The wide platforms in this component suggest either very little preparation or isolation of the PFAs; short, wide flakes from large-diameter cores; or the initiation of fracture away from the PFA, as on a well-prepared biface margin. Ac158XII has a less pronounced peak at state 4 and considerably fewer wide platforms in states 5 through 9. Ac158VII and XI also have few wide platforms, but the peak at state 4 is not pronounced. Greatest similarity among Ac158 components is between VII and XI, and XII is noticeably different from XI, failing to confirm Vierra's hypothesis.

For other components, Ac300C demonstrates the lowest mean value with very few wide platform remnants in states 5 through 9, and is clearly unique with respect to this attribute, implying either considerable isolation and preparation of the PFAs or small, narrow cores. Ac102VII has considerably more wide platform remnants in states 5 through 9 and a pronounced peak at state 4, similar to Ac158IV, and suggests some element of standardization in flake production. Ac102VII also has a rather high value for state 2, perhaps indicative of a second element of production specialization. Ac335C has considerable proportions of wide platform remnants in states 5 through 9, which corresponds with its high proportion of large flakes. However, the most frequently occurring value is state 2, suggesting much preparation and isolation of the PFAs prior to flake removal, particularly since the Ac335C flakes are largest of all components.
15. Platform Remnant Shape

Table 18 presents summary percentages for placement of flakes into 10 categories or states of platform remnant shape. Those states characterized by well-defined angularity, such as 1, 3, and 5, indicate less platform preparation prior to flake removal, since such preparation tends to round the sharper corners of the platform area. States 4 and 7 suggest maximum platform preparation, particularly the isolation of the PFA as a projection on the core edge. States 2 and 6 suggest the use of rather soft, large, or flattened flaking tools and the removal of multiple flakes with a single force application. State 8 indicates considerable platform preparation, softer flaking tools, larger force amounts, and rather thin cores, such as bifaces.

Evaluation of this attribute is quite problematic, demonstrating little internal consistency other than anticipated highest values for state 4 in all components. In addition, consistency with plausible interpretations of other attributes is very poor, and this attribute must therefore be considered inadequately or inappropriately discriminating.

<table>
<thead>
<tr>
<th>Table 18. Platform Remnant Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>158IV</td>
</tr>
<tr>
<td>Ind.</td>
</tr>
<tr>
<td>Rectangle</td>
</tr>
<tr>
<td>Crescent</td>
</tr>
<tr>
<td>Diamond</td>
</tr>
<tr>
<td>Lenticular</td>
</tr>
<tr>
<td>Triangle</td>
</tr>
<tr>
<td>Gull-Wing</td>
</tr>
<tr>
<td>Rounded</td>
</tr>
<tr>
<td>Semi-Circ.</td>
</tr>
<tr>
<td>Irreg.</td>
</tr>
</tbody>
</table>

16. Platform Remnant Surface

Table 19 presents summary percentages for placement of flakes into 7 categories or states on the basis of the nature of the platform remnant surface. States are graduated from no platform surface preparation in state 1 to maximum preparation in state 6. This continuum should not be equated with increasing technological sophistication, but only with an increasing number of operations in the preparation of platform surfaces. A single-flake platform, for example, may be technologically as difficult to produce as a ground platform. In addition,
Table 19. Platform Remnant Surface

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0</td>
<td>15.0</td>
<td>21.3</td>
<td>46.5</td>
<td>23.0</td>
<td>49.0</td>
<td>36.0</td>
</tr>
<tr>
<td>Cortex</td>
<td>1</td>
<td>29.0</td>
<td>17.5</td>
<td>7.1</td>
<td>36.0</td>
<td>4.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Single Scar</td>
<td>2</td>
<td>34.0</td>
<td>32.2</td>
<td>26.3</td>
<td>19.0</td>
<td>17.0</td>
<td>10.0</td>
</tr>
<tr>
<td>2-3 Scars</td>
<td>3</td>
<td>10.0</td>
<td>8.7</td>
<td>4.0</td>
<td>10.0</td>
<td>8.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Series, small</td>
<td>4</td>
<td>0.0</td>
<td>1.9</td>
<td>6.1</td>
<td>4.0</td>
<td>5.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Mass, small</td>
<td>5</td>
<td>0.0</td>
<td>0.5</td>
<td>2.0</td>
<td>0.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Ground</td>
<td>6</td>
<td>6.0</td>
<td>12.6</td>
<td>8.1</td>
<td>8.0</td>
<td>14.0</td>
<td>19.0</td>
</tr>
</tbody>
</table>

Assumptions should not be extended from the flake's platform remnant surface to the entire platform surface of the core, since preparation of the platform surface may be limited to an area only slightly larger than the PFA of the intended flake. States 5 and 6, therefore, are not necessarily suggestive of some specialized grinding of the entire platform surface of a core, but may indicate only the abrasive preparation of a limited area on the platform surface.

Within the Ac158 components, the high 0 value in XII indicates a distinct pattern of flake production characterized by the destruction of the platform area in a high proportion of cases. However, XII does not demonstrate patterns of flake thickness, raw material, platform remnant depth, or other attributes which readily account for this high proportion of 0 values. Since many flake attributes in Ac158XII demonstrate apparently greater control of fracture variables than other Ac158 components, this high proportion of 0 values should be accounted for by factors consistent with that degree of control. At least one possibility is the regular preparation or selection of minimally strong platforms, or those that, even though they are crushed during flake removal, are nevertheless just strong enough to effect predictable fracture. This may be termed, a "critical balance" of fracture variables.

There is a noticeably high acceptance of cortex as a suitable platform surface in Ac158IV. The consistently high proportion of single-flake platforms in all Ac158 components is indicative of a basic system of platform preparation throughout the sequence. The high proportion of ground platforms in Ac158VII is somewhat problematic, but suggests an element of careful platform preparation within a component otherwise demonstrating far less concern with platform preparation or other control of fracture variables. Ac158XII is sufficiently different from XI to question Vierra's hypothesis of similarity.
For other components, Acl02VII is unusual only in the very high proportion of cortex platforms, which may be related to its suitability in the predominantly flint-chert raw material of the component. The Ac300C profile is dominated by the extremely high proportion of crushed and indeterminate platform remnants, almost certainly related to the brittle nature of the component's largely obsidian raw material. Ac335 is also characterized by a rather high value for state 0, which may be due in part to the obsidian in the component, and in part to the critical balance of fracture variables mentioned above. The high proportion of ground platforms in Ac335C indicates an element of quite careful platform preparation.

17. Platform Angle

Table 20 presents summary percentages for 10° groupings of successively smaller platform angles (Figure 7, p. 48). Platform angle is largely determined by force direction. Within Acl58 components, VII and XI similarly suggest considerable outward force vectors by their high values for state 1 and modes of 2. Acl58IV and XII demonstrate modal values of 3, indicating the regular application of more inward-directed force. Somewhat higher values in XI for state 6 may imply an element of even greater inward-directed force. Differences between Acl58XI and XII, particularly in states 0, 1, and 2, tend to disconfirm Vierra's hypothesis of similarity.

For other components, Acl02VII demonstrates a solid block of values between 60° and 89°, while in Ac300C a similar block of values ranges between 70° and greater than 90°, suggesting slightly different generalized patterns of force angles. Ac335C shows a rather strong modal peak value at 70° to 79° with decreasing values on either side, which suggests a narrower, more specialized range of force angles.

Table 20. Platform Angle

<table>
<thead>
<tr>
<th>Ind.</th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>90°</td>
<td>0</td>
<td>31.0</td>
<td>29.0</td>
<td>25.7</td>
<td>48.5</td>
<td>34.0</td>
<td>56.0</td>
</tr>
<tr>
<td>80-89°</td>
<td>1</td>
<td>1.0</td>
<td>7.5</td>
<td>6.6</td>
<td>0.0</td>
<td>3.0</td>
<td>9.0</td>
</tr>
<tr>
<td>70-79°</td>
<td>2</td>
<td>21.0</td>
<td>22.4</td>
<td>19.1</td>
<td>11.1</td>
<td>21.0</td>
<td>15.0</td>
</tr>
<tr>
<td>60-69°</td>
<td>3</td>
<td>29.0</td>
<td>21.5</td>
<td>16.4</td>
<td>17.2</td>
<td>20.0</td>
<td>15.0</td>
</tr>
<tr>
<td>50-59°</td>
<td>4</td>
<td>14.0</td>
<td>10.3</td>
<td>15.3</td>
<td>13.1</td>
<td>13.0</td>
<td>2.0</td>
</tr>
<tr>
<td>40-49°</td>
<td>5</td>
<td>3.0</td>
<td>5.6</td>
<td>8.7</td>
<td>6.1</td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td>40°</td>
<td>6</td>
<td>1.0</td>
<td>2.8</td>
<td>6.0</td>
<td>1.0</td>
<td>4.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.0</td>
<td>0.9</td>
<td>2.2</td>
<td>3.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
18. Platform Preparation Scars

Table 21 lists summary percentages for placement of flakes into 5 categories or states on the basis of the number of platform preparation scars (Figure 6, p. 39). The location of these scars on the dorsal side of the flake's proximal end makes them far less susceptible to damage during flake removal than other proximal characteristics. Consequently, values for state 0 are much smaller, and indicate cases of rather severe damage to the flake's proximal or platform end. In this regard, slightly higher 0 values for Ac158VII and XII may be due either to the previously mentioned critical balance of variables, to the application of excessive force amounts, or to the use of relatively hard flaking tools. The most noticeable aspect among the Ac158 components is the unique pattern in IV which reveals larger numbers of flakes without preparation scars and considerably smaller numbers with seven or more such scars. This is strong indication of a technological pattern involving far less platform preparation or PFA isolation. Other Ac158 components are quite consistent, including XI and XII, which tends to confirm Vierra's hypothesis of similarity.

Among other components, both Ac102VII and Ac300C are quite similar to Ac158VII, XI, and XII, indicating roughly equivalent attention to platform preparation. Ac335C, however, demonstrates noticeably greater amounts of such platform preparation in having both the lowest value for state 1 and the highest value for state 4.

Table 21. Platform Preparation Scars

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0</td>
<td>6.0</td>
<td>11.2</td>
<td>3.3</td>
<td>9.1</td>
<td>2.0</td>
<td>5.0</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>40.0</td>
<td>27.1</td>
<td>27.9</td>
<td>29.3</td>
<td>30.9</td>
<td>32.0</td>
</tr>
<tr>
<td>1-3</td>
<td>2</td>
<td>10.0</td>
<td>6.5</td>
<td>11.0</td>
<td>5.0</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>4-6</td>
<td>3</td>
<td>7.0</td>
<td>0.9</td>
<td>3.8</td>
<td>4.0</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>7 or more</td>
<td>4</td>
<td>37.0</td>
<td>54.2</td>
<td>54.1</td>
<td>52.5</td>
<td>55.0</td>
<td>49.0</td>
</tr>
</tbody>
</table>

19. Ventral Lip

Table 22 lists summary percentages for placement of flakes into 5 categories or states on the basis of the presence and relative prominence of a lip on the extreme proximal end of the flake's ventral surface (Figure 6, p. 39). The presence of these lips may indicate the flake's removal with a relatively softer flaking tool or with an increased outward force vector.
Table 22. Ventral Lip

\[
\begin{array}{cccccccc}
\text{Ind.} & 158\text{IV} & 158\text{VII} & 158\text{XI} & 158\text{XII} & 102\text{VII} & 300\text{C} & 335\text{C} \\
0 & 0.0 & 1.9 & 4.4 & 1.0 & 2.0 & 4.0 & 0.0 \\
1 & 47.0 & 55.1 & 50.3 & 75.8 & 56.0 & 75.0 & 58.0 \\
2 & 35.0 & 26.2 & 27.3 & 13.1 & 28.0 & 15.0 & 27.0 \\
3 & 9.0 & 7.5 & 10.9 & 3.0 & 8.0 & 3.0 & 10.0 \\
4 & 9.0 & 9.3 & 7.1 & 7.1 & 6.0 & 3.0 & 5.0 \\
\end{array}
\]

Within the Acl58 components, IV, VII, and XI demonstrate a generally similar pattern, with IV showing a slightly higher value for state 2, or the presence of slight lips. Acl58XII, however, demonstrates considerably fewer lips, suggesting a quite different flake removal pattern, perhaps characterized by softer flaking tools and greater outward-directed force vectors. This evidence fails to confirm Vierra's hypothesis of similarity between Acl58XI and XII.

For other components, Acl02VII and Ac335C are quite similar to Acl5BVII and XI, while Ac300C is similar to Acl58XII. The slightly lower proportion of strong lips in Ac300C may be due to its high proportion of obsidian.

20. Platform Destruction

Table 23 presents summary percentages for placement of flakes into 4 categories or states on the basis of the relative destruction of the flake's platform remnant. It is, in effect, a more specific statement concerning those flakes which appear as 0 or indeterminate for most other attributes of the proximal end. Greater platform destruction is anticipated with brittle types of raw material such as obsidian, with the application of excessive force amounts, and with the use of relatively harder flaking tools.

Within the Acl58 components, IV, VII, and XI present a generally similar pattern, with a slight progression from less platform destruction in IV to slightly greater such destruction in XI. Acl58XII, while demonstrating the same proportion of flakes without platform destruction, nevertheless demonstrates a noticeably different pattern in the relative severity of that destruction. Its higher proportions of severe platform destruction suggest either the application of greater force amounts, the use of relatively harder flaking tools, or the preparation of considerably weaker platforms. In any case, this fails to confirm Vierra's hypothesis of similarity between Acl58XI and XII.
Table 23. Platform Destruction

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0</td>
<td>1.0</td>
<td>0.9</td>
<td>0.0</td>
<td>1.0</td>
<td>5.0</td>
<td>8.0</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>74.0</td>
<td>71.9</td>
<td>67.2</td>
<td>67.7</td>
<td>64.0</td>
<td>31.0</td>
</tr>
<tr>
<td>Slight</td>
<td>2</td>
<td>10.0</td>
<td>8.3</td>
<td>13.6</td>
<td>7.1</td>
<td>10.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Severe</td>
<td>3</td>
<td>15.0</td>
<td>18.7</td>
<td>19.1</td>
<td>24.3</td>
<td>21.0</td>
<td>43.0</td>
</tr>
</tbody>
</table>

For other components, the patterns of relatively greater platform destruction are most easily viewed as resulting from correspondingly greater proportions of more brittle raw materials such as flint, chalcedony, or obsidian, though greater force amounts, harder flaking tools, or a critical balance factor may also be involved.

C. Distal End Attributes

21. Flake Termination

Table 24 presents summary percentages for placement of flakes into 5 categories or states on the basis of their distal termination. This attribute is indicative of the relative amounts and directions of flake removal forces.

Within Ac158 components, IV demonstrates the highest proportion of feathered terminations and the lowest proportion of hinged terminations, both of which suggest maximum well-controlled force application. Ac158VII suggests less control of these variables by its low proportion of feathered terminations and high proportion of broken terminations. These broken terminations imply either post-production breakage or step fracture terminations produced by application of inadequate force amounts with outward-directed force vectors. The Ac158XI and XII profiles are similar to IV, with the exception of slightly increased proportions of hinged terminations and reduced proportions of feathered terminations, implying a slightly less consistent application of force amount and direction in XI and XII. The similarity of these two components confirms Vierra's hypothesis.

In other components the profile for Ac102VII is quite similar to the generalized Ac158 pattern. Ac300C, however, is noticeably different in its high percentage of broken terminations and correspondingly low percentage of feathered terminations. In all probability this is the result of both the high incidence of obsidian and the much thinner flakes in that component. Both factors may contribute to increased post-production damage and higher values for state 2.
Table 24. Flake Termination

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0.0</td>
<td>0.0</td>
<td>0.5</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Feathered</td>
<td>67.0</td>
<td>54.2</td>
<td>60.7</td>
<td>61.6</td>
<td>62.0</td>
<td>51.0</td>
<td>73.0</td>
</tr>
<tr>
<td>Broken</td>
<td>28.0</td>
<td>38.3</td>
<td>26.2</td>
<td>28.3</td>
<td>30.0</td>
<td>43.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Hinged</td>
<td>3.0</td>
<td>4.6</td>
<td>6.0</td>
<td>9.1</td>
<td>7.0</td>
<td>5.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Other</td>
<td>2.0</td>
<td>2.8</td>
<td>6.6</td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Ac335C demonstrates the lowest proportion of broken terminations as well as the highest proportion of both feathered and hinged terminations. This pattern is quite different from other components, and appears somewhat problematic. The high percentage of feathered terminations and the low percentage of broken terminations strongly indicate optimum control of force application, an interpretation consistent with indications of good control in most other flake attributes. Highest proportions of hinged terminations, however, contradict this interpretation, since they normally indicate inadequate force amounts or excessive inward-directed force vectors. In fact, both components which normally demonstrate best control of fracture variables, Ac158XII and Ac335C, here have the highest proportions of hinged terminations. One possible explanation is closely related to the critical balance of fracture variables mentioned above in the discussion of several attributes of the proximal end. As flakes become wider, longer, and thinner, the ranges within which variables must be controlled are sharply reduced, thus increasing the difficulty of their consistent control and the occurrence of obvious failures as these critical tolerances are exceeded. "When she was good, she was very, very good; but when she was bad, she was horrid!" seems an appropriate description of the phenomenon.

D. Ventral Surface Attributes

22. Bulb of Force

Table 25 presents summary percentages for placement of flakes into 5 categories or states on the basis of the relative definition and appearance of the bulb of force on the flake's ventral surface. The PFA size, the relative hardness of the flaking tool, and the force direction may affect the expression of this flake attribute.
Table 25. Bulb of Force

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0</td>
<td>1.9</td>
<td>2.7</td>
<td>2.0</td>
<td>11.0</td>
<td>22.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Trun., diff. 1</td>
<td>57.0</td>
<td>39.2</td>
<td>41.5</td>
<td>55.6</td>
<td>66.0</td>
<td>31.0</td>
<td>52.0</td>
</tr>
<tr>
<td>Trun., pron. 2</td>
<td>16.0</td>
<td>18.7</td>
<td>19.1</td>
<td>10.1</td>
<td>7.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Acum., diff. 3</td>
<td>19.0</td>
<td>26.1</td>
<td>24.6</td>
<td>25.1</td>
<td>10.0</td>
<td>33.0</td>
<td>28.0</td>
</tr>
<tr>
<td>Acum., pron. 4</td>
<td>8.0</td>
<td>14.0</td>
<td>12.0</td>
<td>7.2</td>
<td>6.0</td>
<td>9.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Within Ac158 components, highest values for state 1 in IV and XII suggest larger PFAs, greatest use of softer flaking tools, and greater outward-directed force vectors. Low values for state 2 in XII, for state 3 in IV, and for state 4 in both IV and XII are generally consistent with this suggestion. Ac158VII and XI appear quite similar and suggest somewhat harder flaking tools, smaller PFAs, and more inward-directed forces. This fails to confirm Vierra's hypothesis of similarity for Ac158XI and XII.

For other components, Ac102VII suggests greatest use of softer flaking tools and outward-directed force vectors by a very high value for state 1 and low values for all other states. Ac300C indicates by its much lower value for state 1 and higher value for state 3 the use of harder flaking tools; still with outward-directed force vectors. Ac335C presents a mixed profile, but with continued outward-directed force vectors.

Since states of this attribute consist of varying combinations of two bulbar characteristics, its interpretation is difficult, and may be clarified by a recombination in different order. Combining states 1 and 2 results in a value for all occurrences of truncated bulbs of force, while a combination of states 3 and 4 produces a value for all occurrences of acuminate bulbs. Similarly, combining states 1 and 3 results in a total for diffuse bulbs, while 2 and 4 gives a total for pronounced bulbs. Table 26 presents these accumulated totals for all test components.

Truncated bulbs are associated with larger PFAs and softer flaking tools, and conversely, acuminate bulbs are associated with smaller PFAs and harder flaking tools. Diffuse bulbs may indicate more outward-directed force vectors and softer flaking tools, while pronounced bulbs suggest more inward-directed forces and harder flaking tools. Ac158IV and XII are similar in displaying rather high values for truncated and diffuse bulbs, while Ac158VII and XI similarly display lower values for diffuse, and higher values for acuminate and pronounced bulbs.
For other components, Ac102VII shows very high truncated, high diffuse, and low pronounced and acuminate values, suggesting softer flaking tools and outward force vectors. Ac300C shows low values for all states except acuminate, implying the use of somewhat harder flaking tools. Ac335C demonstrates moderate values for both truncated and acuminate, suggesting no consistent trend in PFA size or flaking tool hardness. However, its very high value for diffuse and correspondingly low value for pronounced bulbs indicate consistently outwardly-directed force vectors and perhaps softer flaking tools. These indications are generally consistent with those from Table 25.

23. Ripple Marks

Table 27 presents summary percentages for placement of flakes into 6 categories or states on the basis of the location and intensity of ripple marks on the flake's ventral surface. These ripple marks may be associated with the application of inadequate force or with rigid core support, as in certain bipolar or anvil percussion techniques.

In all Ac158 components the only possibly important statistic is the slightly high value in XI for state 2, suggesting slightly less control of force amounts in that component. Ac158XI and XII are quite similar, confirming Vierra's hypothesis of similarity between the two.
For other components, Acl02VII demonstrates slightly less rippling than any component, suggesting the application of consistently adequate force amounts. Ac300C and Ac335C both show marked increases of slight rippling over the entire ventral surface, state 2. The implication is for either significantly reduced control of force amounts or the strongly differential display of this attribute in obsidian. Almost certainly the latter is the case, since other indications of force control are not consistent with the former interpretation, and since the relative proportions of obsidian and rippling correspond closely in the two components.

E. Dorsal Surface Attributes

24. Cortex

Table 28 presents summary percentages for placement of flakes into 7 categories or states on the basis of the relative proportions of cortex present on the flake's dorsal side. This flake attribute is an indication of the attention given to the core face prior to flake removal. For all components, the high proportions of state 1, or the lack of any cortex on the dorsal side, suggests that in none of them is there significant production of blanks or preforms from raw material. This was apparently done elsewhere, probably at the site of raw material acquisition, and flake production at these cave sites was restricted to the final production or reworking of implements.

All Acl58 components are similar except for a slightly high value for state 6 in component IV, suggesting some limited initial shaping or reduction of raw material, perhaps only a single nodule. The similarity of Acl58XI and XII confirms Vierra's hypothesis.

Table 28. Cortex

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>83.0</td>
<td>85.0</td>
<td>82.5</td>
<td>79.8</td>
<td>91.0</td>
<td>79.0</td>
</tr>
<tr>
<td>1/4</td>
<td>2</td>
<td>5.0</td>
<td>2.8</td>
<td>7.7</td>
<td>7.1</td>
<td>3.0</td>
<td>11.0</td>
</tr>
<tr>
<td>1/4-1/2</td>
<td>3</td>
<td>4.0</td>
<td>5.6</td>
<td>6.0</td>
<td>6.1</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>1/2-3/4</td>
<td>4</td>
<td>1.0</td>
<td>1.9</td>
<td>3.3</td>
<td>3.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>3/4</td>
<td>5</td>
<td>1.0</td>
<td>2.8</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>all</td>
<td>6</td>
<td>6.0</td>
<td>1.9</td>
<td>0.5</td>
<td>3.0</td>
<td>1.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>
For other components, Acl02VII shows highest values for state 1, implying the highest level of core pre-treatment. Ac300C is lowest for state 1, possible indicating somewhat smaller or scarcer raw material with more cortex-bearing pieces brought to the site.

25. Scar Number

Table 29 presents summary percentages for placement of flakes into 10 categories or states on the basis of the number of distinct flake scars on their dorsal surfaces. Since each scar on a flake's dorsal surface represents a flake removed from the core face prior to detachment of the study flake, higher numbers of such scars indicate greater attention to core preparation. 0 values correspond with flakes having completely cortex dorsal surfaces.

For Acl58 components, IV, VII, and XI demonstrate basically similar profiles with noticeable peak values at state 3. Acl58VII, however, does have a rather high value for state 1, suggesting relatively less core preparation. Component XI has a rather low value for state 9, perhaps indicating the relative scarcity of flakes from maximally prepared cores such as bifaces. The Acl58XII profile is noticeably distinct, with a large block of values between states 1 and 5, and without a conspicuous peak value. This may suggest less specialized core preparation or the acceptability of a wider range of core shapes. In any case, it is sufficiently different from Acl58XI to question Vierra's hypothesis of similarity.

For other components, both Acl02VII and Ac300C are quite similar to the Acl58IV, VII, and XI pattern, particularly to XI. This close similarity between Acl02VII and Ac300C is somewhat surprising in view of the extreme difference in raw material composition. Ac335C has a high proportion of values between states 6 and 9, suggesting considerable core preparation.

Table 29. Scar Number

<table>
<thead>
<tr>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0.0</td>
<td>6.0</td>
<td>1.9</td>
<td>0.5</td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td>1 scar</td>
<td>1.0</td>
<td>9.0</td>
<td>17.8</td>
<td>13.1</td>
<td>11.1</td>
<td>11.0</td>
</tr>
<tr>
<td>2 scars</td>
<td>2.0</td>
<td>13.1</td>
<td>16.8</td>
<td>15.8</td>
<td>11.1</td>
<td>17.0</td>
</tr>
<tr>
<td>3 scars</td>
<td>3.0</td>
<td>19.7</td>
<td>14.1</td>
<td>15.0</td>
<td>14.1</td>
<td>23.0</td>
</tr>
<tr>
<td>4 scars</td>
<td>4.0</td>
<td>16.4</td>
<td>14.1</td>
<td>17.7</td>
<td>14.1</td>
<td>23.0</td>
</tr>
<tr>
<td>5 scars</td>
<td>5.0</td>
<td>8.4</td>
<td>12.1</td>
<td>12.6</td>
<td>12.1</td>
<td>6.0</td>
</tr>
<tr>
<td>6 scars</td>
<td>6.0</td>
<td>9.3</td>
<td>9.8</td>
<td>8.1</td>
<td>7.0</td>
<td>12.0</td>
</tr>
<tr>
<td>7 scars</td>
<td>7.0</td>
<td>5.0</td>
<td>4.7</td>
<td>2.7</td>
<td>7.1</td>
<td>5.0</td>
</tr>
<tr>
<td>8 scars</td>
<td>8.0</td>
<td>1.0</td>
<td>0.0</td>
<td>2.2</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>9 or more</td>
<td>9.0</td>
<td>16.0</td>
<td>16.8</td>
<td>12.0</td>
<td>16.2</td>
<td>11.0</td>
</tr>
</tbody>
</table>
26. Scar Size

Table 30 presents summary percentages for placement of flakes into 8 categories or states on the basis of the relative size of their dorsal scars. Varying patterns in core preparation may reflect different stages in production technology, such as blanks, preforms, or finished product in biface manufacture. In this case, each successive stage should demonstrate successively smaller, more regular scars on the dorsal surfaces of flakes removed.

Within Ac158 components there is considerable variation. Ac158IV has a noticeable peak at state 3, or predominantly large scars, and a high value for state 7, or flakes with no apparent size regularity. This bimodal distribution implies two distinct patterns of core preparation, or perhaps stages within a larger pattern. Ac158VII shows a rather strong concentration of large or medium dorsal scars, which may result from a core shaping technique in which very close tolerances in core section are not important. Ac158XI shows a very pronounced preference for predominantly large dorsal scars, indicating a more specialized core preparation pattern, but again without rigid cross-section restrictions. Ac158XII demonstrates a similar but somewhat reduced preference for large dorsal scars, which confirms Vierra's hypothesis of similarity between XI and XII.

For other components, Ac102VII is quite similar to Ac158XII, and Ac335C is quite similar to Ac158IV. Ac300C demonstrates a somewhat distinct pattern of attribute states, with greater occurrence of predominantly small dorsal scars along with some medium and large. This may be related to the high proportions of obsidian in the component or to its generally smaller flakes, but the impression is one of greater importance of core shape.

### Table 30. Scar Size

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0</td>
<td>6.0</td>
<td>0.0</td>
<td>1.1</td>
<td>3.0</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Pre. Small</td>
<td>1</td>
<td>4.0</td>
<td>8.4</td>
<td>7.1</td>
<td>9.1</td>
<td>6.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Pre. Med.</td>
<td>2</td>
<td>13.0</td>
<td>39.3</td>
<td>18.0</td>
<td>21.2</td>
<td>21.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Pre. Large</td>
<td>3</td>
<td>34.0</td>
<td>48.6</td>
<td>55.7</td>
<td>44.4</td>
<td>42.0</td>
<td>37.0</td>
</tr>
<tr>
<td>Small+Med.</td>
<td>4</td>
<td>9.0</td>
<td>0.0</td>
<td>3.8</td>
<td>6.1</td>
<td>6.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Small+Large</td>
<td>5</td>
<td>9.0</td>
<td>0.0</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Med.+Large</td>
<td>6</td>
<td>3.0</td>
<td>0.9</td>
<td>5.5</td>
<td>5.1</td>
<td>11.0</td>
<td>8.0</td>
</tr>
<tr>
<td>No Pattern</td>
<td>7</td>
<td>22.0</td>
<td>1.9</td>
<td>8.2</td>
<td>10.1</td>
<td>12.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>
27. Scar Arrangement

Table 31 presents summary percentages for placement of flakes into 6 categories or states on the basis of apparent patterning in the arrangement of dorsal scars. Regularity in PFA placement and in force direction are relevant variables. As anticipated, all components demonstrated rather high proportions of flakes in which no pattern in spacing or direction was obvious.

For Ac158 components, the lack of pattern is noticeably greater than in other components, suggesting a basically similar technology at the Ac158 site, with some internal variability. Ac158IV shows the highest value for state 5, indicating least specialization in core preparation. Ac158VII demonstrates the lowest value for state 1 and the highest value for state 4, perhaps implying more smaller cores on which preparation flakes are removed from all edges by forces directed toward the core's center. Ac158XI and XII are similar, confirming Vierra's hypothesis and indicating a generalized core preparation pattern with some tendency toward the removal of core preparation flakes in the same direction as the force which removes the study flake.

For other components there is generally greater regularity or patterning in core preparation than in the Ac158 components, producing lower state 5 values and higher state 1 values. Ac102VII shows lowest radial and highest parallel patterning, suggesting larger cores with more flakes removed by forces applied parallel to each other and in the same direction as that removing the study flake. In other words, the study flake is one in a series of flakes removed by parallel forces from a single margin or platform area of the core, as in the production of large bifaces or regular blades. Ac300C and Ac335C continue this same pattern, but with both demonstrating higher values for state 4 as well, suggesting the removal of flakes from the edges of smaller bifaces by forces directed toward the core's center.

Table 31. Scar Arrangement

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0</td>
<td>6.0</td>
<td>0.0</td>
<td>0.5</td>
<td>2.0</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Parallel</td>
<td>1</td>
<td>22.0</td>
<td>18.7</td>
<td>25.7</td>
<td>30.3</td>
<td>48.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Perpendicular</td>
<td>2</td>
<td>4.0</td>
<td>2.8</td>
<td>5.4</td>
<td>2.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Diagonal</td>
<td>3</td>
<td>6.0</td>
<td>5.6</td>
<td>8.7</td>
<td>4.0</td>
<td>7.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Radial</td>
<td>4</td>
<td>9.0</td>
<td>29.9</td>
<td>18.0</td>
<td>18.2</td>
<td>6.0</td>
<td>22.0</td>
</tr>
<tr>
<td>No Pattern</td>
<td>5</td>
<td>52.0</td>
<td>43.0</td>
<td>41.5</td>
<td>43.4</td>
<td>37.0</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
28. Scar Hinging

Table 32 presents summary percentages for placement of flakes into 5 categories or states on the basis of the proportion of dorsal scars terminating at their distal ends in hinges. Interpretation of this attribute is quite similar to that for attribute 21, Flake Termination, except that control of the amounts and directions of applied force here relates to the prior removal of core preparation flakes rather than removal of the study flakes themselves.

All Ac158 components are similar, but with VII showing slightly more flakes without hinging, XI showing slightly higher values for state 2, and IV and XII demonstrating slightly higher values for state 3, suggesting slightly different patterns of force application control. Vierra's hypothesis of similarity between Ac158XI and XII is confirmed by this evidence.

For other components, Ac102VII demonstrates noticeably least hinging of all components, suggesting better control of force amounts and direction, and perhaps more concern with core preparation. Ac300C is very close in profile to Ac158VII, while Ac335C demonstrates most hinging of all components, particularly in its high value for state 3. This may be related to the critical balance of variable control within closely restricted tolerances, as proposed for this component in several other attributes.

Table 32. Scar Hinging

<table>
<thead>
<tr>
<th></th>
<th>158IV</th>
<th>158VII</th>
<th>158XI</th>
<th>158XII</th>
<th>102VII</th>
<th>300C</th>
<th>335C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind.</td>
<td>0</td>
<td>6.0</td>
<td>0.0</td>
<td>0.5</td>
<td>3.0</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>56.0</td>
<td>63.6</td>
<td>56.8</td>
<td>55.6</td>
<td>71.0</td>
<td>62.0</td>
</tr>
<tr>
<td>25%</td>
<td>2</td>
<td>10.0</td>
<td>13.1</td>
<td>21.9</td>
<td>14.1</td>
<td>11.0</td>
<td>11.0</td>
</tr>
<tr>
<td>25-75%</td>
<td>3</td>
<td>27.0</td>
<td>22.5</td>
<td>19.1</td>
<td>26.3</td>
<td>17.0</td>
<td>24.0</td>
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<tr>
<td>75%</td>
<td>4</td>
<td>1.0</td>
<td>0.9</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
VII. SUMMARY AND CONCLUSIONS

A. Summary

This study defines within a broad technological framework the more specific cultural system of stone implement production. A review of the literature of both experimental replication of stone implements and the archaeological application of fracture mechanics identifies the production of stone implements to be a series of flake-producing fractures in the lithic raw material which is controllable in varying degrees by the stoneworker. Further, this varying control of the fracture process is seen to result from the control of specific variables which are defined and explained, and which are most apparent in their expression on the flakes produced in the fracture process. These fracture variables are used to construct, as a series of 28 flake attributes, an analytic system sufficiently sensitive to reveal differential patterns of control over the fracture process in the production of stone implements.

As a test of the attribute system's sensitivity and usefulness it is applied to flake samples from sixteen archaeological components from the Ayacucho valley, Peru. Statistics for each of the 28 flake attributes are collected for each archaeological component by a standard computer analysis. An intensive study by Vierra (1975), based primarily on faunal remains from several of the same archaeological components in the Ayacucho valley, is reviewed and used as a basis for the selection of flake analysis data. Four components from a single site, Ac158, are included in both Vierra's study and the flake analysis, and these components form the basis for comparison and testing of the flake analysis system. In addition, three components from different ecologic zones in the Ayacucho valley are included for comparison with the Ac158 data. The flake analysis data for these seven sample components is presented as tables of summary statistics for each flake attribute. Interpretation of the flake data is organized according to four specific research questions: (1) Over what fracture variables does this attribute indicate control? (2) What trends or patterns in control of the fracture process are indicated within the four Ac158 components? (3) To what extent do these patterns of fracture control in the Ac158 components confirm Vierra's conclusions for those components? (4) What differences or similarities in patterns of fracture control exist between the Ac158 components and the three components from other sites?
B. Conclusions

1. Acl58 Components

Four components from the Puente site in the Ayacucho Valley, Acl58IV, VII, XI, and XII, demonstrate considerable similarity in their proportions of raw material categories, their range of flake dimensions, and in core preparation techniques. Greatest differences among these components are in patterns of platform preparation and force application, and three distinct profiles are evident. Components VII and XI are quite similar and represent a single generalized pattern of flake production and fracture variable control. Components IV and XII, however, are clearly separate from each other and from the other two. Each represents a definable and more specialized pattern of variable control and flake production.

2. Acl58IV

Control of the fracture process in this component is toward the production of generally shorter, wider, and thinner flakes, probably from consistently short, large-diameter cores. More cortex remains on both the core face (the dorsal surfaces of removed flakes) and the platform remnant. There is indication of less preparation of the platform area and less isolation of the PFA at the core edge. Force amounts and directions are well controlled within rather narrow ranges, suggesting some degree of specialization in producing these flakes. Ranges of variation in the expression of most attributes are not wide.

Vierra indicates that this component is characterized by plant collecting and processing, with only supplemental hunting of choice animals such as deer, and that it was probably a longer-term occupation of the site by family units. The flake analysis may reasonably support this interpretation of site utilization. Supplemental hunting and its attendant implement requirements maintain a continuity in the basic Acl58 pattern of flake production, but production and maintenance of the larger core-type implements likely involved in plant collecting and processing may explain the short, rather specialized and well-controlled flakes from larger-diameter cores.

3. Acl58VII and XI

The flake data from these two components suggest much less specialized control of fracture variables, with most attributes expressed over consistently greater ranges of variation. Flakes are thicker, shorter, and generally smaller, probably from rather short or shallow cores. In addition, flakes are consistently thicker and
wider at their proximal end, suggesting the removal of more stone material from the core edge than from the center, and indicating greater concern for core/implement plan than for section.

Vierra characterizes the Acl58VII component as a series of short-term occupations, such as temporary hunting camps, in which whole animals are secured and processed. Low-yield elements are numerous and high-yield portions rather scarce, probably indicating that the better portions of the animals were taken away from the site. Here, too, the flake data may coincide well with Vierra's hypothesis of site activity. Presumably these small groups of hunters with prepared toolkits largely limited their flintworking activity to repair and re-edging their hunting and processing implements. This accounts for the shorter, thicker flakes and the apparent emphasis on core plan rather than section. Vierra's conclusions for Acl58XI are considered below.

4. Acl58XII

Among Acl58 components, flakes from XII consistently demonstrate more reliable control of most fracture variables, and the expression of most attributes over noticeably narrower ranges of variation. The implication is for a more specialized production technology in this component. Flakes are longer, wider, and thinner than in other Acl58 components, almost certainly from longer or deeper cores. There is evidence for the use of somewhat softer flaking tools, greater amounts of platform preparation and PFA isolation, greater inward-directed force vectors, and apparently increased concern with thinning or shaping the core's section. Greatest similarity with other Acl58 components is in core preparation, and greatest differences are in force angle, force amount, flaking tool hardness, and flake dimensions. Higher proportions of hinging, rippling, and damage to the platform area indicate a critically balanced control of force variables within narrow ranges, and the application of adequate to excessive force amounts, perhaps with bone or antler billets.

Vierra interprets this component as intensive, long-term occupation by family groups engaged in guinea pig trapping and supplemental large game hunting. Such a dual focus of resource procurement is not reflected in the flake data as bimodal distributions of attribute states. In fact, Acl58XII frequently demonstrates noticeably narrower ranges of variability and higher modal values, suggesting a single specialized pattern of flake production. However, this need not be seen as a contradiction of Vierra's conclusions. It may simply be that the lithic element of the assemblage was not involved in the procurement of guinea pigs. Trapping was not an activity that required specialized stone tools. Vierra mentions the occurrence together of guinea pig remains and small worked and polished bone triangles.
This evidence tends to support the reasonable assumption of the non-
lithic nature of any specialized implements associated with guinea pig
procurement, and encourages acceptance of both a dual focus in re-
source procurement strategies and a single specialized pattern of
flake production.

This specialized nature of flake production in Ac158XII is
viewed as more closely related to group composition and length of
occupation than to resource procurement activity. Both Ac158 compon-
ents which indicate most specialized flake production, IV and XII,
are interpreted by Vierra as long-term occupations by larger social
units. It is highly likely that more relaxed situations in such
longer-duration occupations were those in which raw materials were
converted from blanks into needed implements. This seems particularly
likely in view of the more tedious and time-consuming production of
basic implement section. Platform preparation is more critical, more
inward force is required, flakes are wider and thinner, and their
centers of mass tend to be further from the flake's proximal end; all
of which indicate greater attention to core section, and all of which
characterize the Ac158IV and XII components. Flintworking activity
associated with shorter occupations by smaller task-specific groups,
on the other hand, might be restricted to the hurried restoration of
worn or broken implements to functional status, producing shorter,
thicker flakes.

5. Agreement of Flake Analysis with Vierra's Conclusions

With more specific reference to Vierra's interpretations of site
utilization for the four Ac158 components, the flake analysis pro-
vides mixed support. On the one hand, three patterns of flake-pro-
ducing behavior correspond to Vierra's three patterns of resource
procurement at the site, and in each case the production technology
suggested by the flake data can reasonably be envisioned within the
proposed procurement system. Both the flake analysis and Vierra's
faunal data recognize the unique character of component IV.

On the other hand, however, the two analytic systems produce a
contradictory placement of Ac158XI. In Vierra's analysis, XI is
placed with XII, and the two are interpreted as a unit. In the
flake analysis, XI is quite different from XII, and instead is very
similar to VII. Eleven of twelve entire-flake attributes; seven of
eight proximal-end attributes; and two of eight distal-end, ventral
side, and dorsal side attributes tend to confirm the difference be-
tween XI and XII. They are simply two distinct patterns of flake
removal. Even those eight attributes which do support Vierra's
conclusion of similarity between XI and XII also fail to distinguish
consistently between those two and other components; and four of
these are attributes of the dorsal surface, which fail to make
distinctions between any Ac158 components. No explanation for this discrepancy is proposed, but a critical evaluation of the functional and technological analysis of the stone implements may distinguish which, if either, identity is correct for Ac158XI.

6. Comparison of Ac158 Components with Other Sample Components

Three components from other sites in the Ayacucho valley were included in the flake analysis to extend the basis of comparison beyond the Ac158 components and to test further the sensitivity of the analytic system. Ac102VII, Ac300C, and Ac335C were selected because they were within the time range of the Ac158 components, and because each was from a different ecologic zone in the valley (Table 2, p. 64). If a similar pattern of flake attributes is found to occur across all seven sampled components, its source could well be in the nature of the attribute system or in some regularity of lithic fracture, rather than in a culturally-based differential of fracture control. However, if different patterns of flake attribute expression occur in some components, as might be anticipated if those components represent strongly differing ecological situations, then both differences and similarities of flake production may be attributed to culturally-induced adaptive mechanisms.

Patterns of flake attributes reveal one of these comparative components, Ac102VII, to be well within the range of attribute expression of the Ac158 components, and two, Ac300C and Ac335C, which differ noticeably from the Ac158 range. The distinct patterns of raw material content for each of the three components and their differences from the Ac158 pattern emphasize the local acquisition of raw material in all components, and imply little inter-zone transport of this commodity. These distinct raw material profiles quite likely introduce an interpretive variable not involved in the Ac158 components; the differential expression of attributes in various raw materials.

7. Ac102VII

Among the three components from other sites, the one most similar to Ac158 components is Ac102VII. flakes from this component demonstrate a rather mixed and generalized pattern of fracture control. There is mixed evidence for the hardness of flaking tools, core preparation, and flake dimensions. The range of expression for most attributes is rather wide, and mean values usually fall well within those of the Ac158 components. There is some indication for inward-directed force vectors, slightly less platform preparation, and wider platform remnants, some of which have cortex surfaces. Adequate force amounts and firm core support, along with the consistent location
of the PFA well away from the core edge complete the rather generalized profile of Ac102VII flake production.

Interpretation of these three comparative components in very precise behavioral terms is difficult in the absence of additional data, but it appears that Ac102VII, with its more generalized and inconsistent patterns of flake attributes, may indicate shorter-term, more task-specific occupations of that site by smaller groups.

8. Ac300C

Flakes from this component are unique, particularly for those attributes most affected by the nature of obsidian raw material. Most noticeable is the high proportion of small, thin flakes requiring much less force, and predictably highest proportions of damaged flakes. Nearly eighty percent of the flakes are obsidian. Cores were generally small and short, and there are strongly mixed indications for core preparation regularity and for flaking tool hardness. This mixed pattern of attribute expression extends to force amounts and angles as well, with indications of both large and small force amounts, inward- and outward-directed force vectors, and harder and softer flaking tools. Only in platform preparation and PFA isolation is there consistent control of fracture variables.

The Ac300C is quite distinct and difficult to interpret. The high proportions of damaged platforms may tend to obscure some element of specialized flake production. Implications are for a slightly longer-term occupation, perhaps seasonal, in which smaller groups engaged in a range of procurement activities.

9. Ac355C

Of all components analyzed, Ac355C regularly presents the most consistent and specialized pattern of flake attributes. This component demonstrates greatest concerns with platform preparation, isolation of the PFA close to the core edge, grinding or abrading the platform surface, and a closely controlled force angle. Flakes are longer, wider, and slightly thicker than in all other components, with considerable numbers of blades. Force requirements are high, but control is consistently good, with indication of an emphasis on thinning larger cores, inward-directed force vectors, and the possible use of relatively softer flaking tools. The implications are strongly for long-term or permanent occupation of that site by larger social units, perhaps as a base camp in which the production of large thin implements from raw material blanks was an important activity.
10. Utility of the Analytic System

These interpretations confirm the utility of the proposed flake analysis system in several respects. It is useful in generating hypotheses and explanations regarding prehistoric behavior patterns in both comparative and descriptive contexts, and in either synchronic or diachronic perspectives. It is useful as an independent body of data to verify hypotheses otherwise generated. It is considerably more sensitive to variation in lithic assemblages than traditional implement typologies. It expands the range of useful analytic procedures available to archaeologists, either as a supplementary lithic analysis or as a basic analytic system in situations of high flake proportions. And finally, it converts the lowly, often-discarded "waste flake" into a "real artifact."
BIBLIOGRAPHY

Anthony, B. W.

Baden-Powell, D. F. W.

Binford, L. R.

Binford, L. R. and S. R. Binford

Binford, L. R. and G. Quimby

Bonnichsen, R. and R. E. Morlan

Bordaz, J.


Bordes, F.

Bordes, F. and D. Crabtree  
1969 The corbicula blade technique and other experiments.  

Bucy, D. R.  

Clarke, D. L.  

Clarke, R.  

Cochran, W. G.  

Collins, D.  

Crabtree, D. E.  


1967b Notes on experiments in flintknapping, 4: tools used for making flaked stone artifacts. Tebiwa 10:1.


Crabtree, D. E. and B. R. Butler  
Cullberg, C. and T. Parsmar  

Dunnell, R. C.  

Ellis, H. H.  
1940 Flint-working techniques of the American Indians: an experimental study. Ohio Historical Society, Columbus.

Faulkner, A.  


Frison, G. C.  


Jelinek, A. J., B. Bradley, and B. Huckell  

Johansen, A.  

Kerkhof, F. and H. Müller-Beck  

Kleindienst, M. R.  

Knudson, R.  
Leakey, L. S. B.


MacDonald, G. F.

MacNeish, R. S.

MacNeish, R. S., A. Nelkin-Terner, and A. G. Cook

MacNeish, R. S., T. C. Patterson, and D. L. Browman

Merrill, R. S.

Mewhinney, H.


Mueller, J. W.

Muto, G. R.


Nie, N., D. H. Bent, and C. H. Hull

Palomino, J. R.
1971 Geografía general de Ayacucho. Universidad Nacional de San Cristóbal de Huamanga, Ayacucho, Peru.

Phagan, C. J.
1972a Technological change in highland Peru: 8000 to 3000 B.C. Paper presented at the 38th annual meeting of the Society for American Archaeology, San Francisco.

1972b Variables in lithic technology and the problem of fluting. Paper presented to the 30th annual Plains Conference, Lincoln, Nebraska.

Phagan, C. J. and R. K. Vierra

Pond, A. W.

Purdy, B. A.

Purdy, B. A. and H. K. Brooks
Ragir, S.

Roscoe, J. T.

Semenov, S. A.

Sheets, P. D.

Sheets, P. D. and G. R. Muto

Speth, J. D.

Tsirk, A.

Watanabe, H.

Watson, P. J., S. A. LeBlanc, and C. R. Redman

Wilmsen, E. N.

Witthoft, J.