Bipolar Technology and Pebble Stone Artifacts:

Experimentation in Stone Tool Manufacture

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ABSTRACT

There is a general lack of research concerning the technological aspect of pebble stone artifacts throughout the Northern Plains. As a result, little is known about the manufacture of these materials except that it is generally accepted that bipolar technology was the predominant manufacturing technique used because of the small size of the pebbles. However, research regarding bipolar technology has also been limited. Furthermore, many researchers have indicated that this technique is crude, poorly controlled, and that it only supplies a marginal product.

The research outlined within this thesis examines the manufacture and archaeological significance of pebble stone materials. The ultimate aim of this is to provide some clarification regarding the use of the bipolar method in relation to pebble stone materials. Therefore, the mode of manufacture of pebble stone artifacts will be, in part, accomplished by an examination of experimentally replicated split pebbles using the bipolar technique.

As a final point, considering the obvious wide geographic distribution and frequency of use of bipolar technology and pebble stone materials it is unlikely that this technique was thought of so unfavorably by pre-contact groups or that pebble materials were considered marginal or used only when superior quality raw material was not available.

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LIST OF ABBREVIATIONS

SSP	Silicified siltstone pebble stone
Qtz-ite	Quartzite
Gen Mat	Genetic Material
NSKR	North Saskatchewan River, Saskatchewan
GIL	Grassy Island Lake, Alberta
FR	Fresno Reservoir, Montana
V	Ventral
D	Dorsal
L	Left
R	Right
Lth	Length
W	Width
T	Thickness
X	Longitudinal axis
Y	Transverse axis
Z	Axis through pebble thickness (perpendicular to Y axis)
Af	Applied force
Rf	Rebound force
x_1	Proximal point of impact
x_2	Point of anvil contact
x	Visible in hand specimen
n	Not visible in hand specimen
is	Irregular shear surface
d	Diffuse

pr	Pronounced
i	Negative Inverted
sh	Sheared
s	Slight damage/barely visible
h	Hackles
PIC	Proximal impact crushing
DIC	Distal crushing
PLED	Percussion lines extending distally
PBP	Proximal bulb of percussion
DBP	Distal bulb of percussion
dc	Distal crushing
dft	Distal flake termination
dfr	Distal flake removed
pfr	Proximal flake removed
rlfr	Right lateral flake removed
llfr	Left lateral flake removed
dfr/p	Dorsal flake removed/proximally
dfr/d	Dorsal flake removed/distally
vfr/d	Ventral flake removed/distally
vfr/p	Ventral flake removed/proximally
dvfr/d	Dorsal and ventral flake removed/distally
vfr/dp	Ventral flake removed distally and proximally
dfr/pd	Dorsal flake removed/proximally and distally
fr/d	Flake removed/distally
vdfr/d	Ventral and dorsal flake removed/distally
mm	Millimeters
cm	Centimeters

B.P.	Relates to time in number of years prior to 1950
VAM	vise-anvil-maul
BC	Bipolar core
dI	Intermediate pebble diameter
dL	Longest pebble diameter
dS	Shortest pebble diameter

1. INTRODUCTION

1.1 Introduction

Research concerning bipolar technology and the technological aspect of pebble stone artifacts throughout the Northern Plains has been limited in the past. Furthermore, research that has been conducted regarding the bipolar technique has classified it as a crude and poorly controlled method that supplies only a marginal product and, therefore, not likely a method favored by pre-contact groups (Binford and Quimby 1963; Boksenbaum 1980; Hardaker 1979; Haynes 1977; Honea 1965; Knudson 1978; Shafer 1976; Sollberger and Patterson 1976; Weir 1976; White 1977). Consequently, there has been little real understanding regarding the manufacture of artifacts from pebble stone materials except that it has been generally accepted that bipolar technology was the predominant manufacturing technique used largely because of the small size of these materials.

The pebble stone artifacts that I refer to bear no resemblance to the Paleolithic Oldowan Pebble-Tool tradition as defined by researchers such as Oakley (1967), Leakey (1971) and Bordes (1973). Oldowan tools are crudely manufactured all-purpose generalized chopping tools produced from large water worn pebbles that are large enough to be held firmly in the hand.

They are produced by striking several flakes off an end or side of a large pebble using straight percussion with a hammerstone (as illustrated by Waldorf 1984: 21). In contrast, the pebble tools from the Northern Plains are usually quite small and finely manufactured and bipolar technology is the predominate mode of their manufacture.

The research conducted here was largely initiated because I did not agree with previous interpretations that the bipolar technique is a crude method of stone tool manufacture supplying only a marginal product. As I alluded above, many bipolar pebble stone artifacts are very finely crafted implements. A case in point is illustrated in Figure 1.1., which is a replicated projectile point crafted by Eldon Johnson of Saskatoon, Saskatchewan. This point is manufactured from a split silicified siltstone pebble (Johnson 1986) that is only about 2.5 cm. long and 1.2 cm. wide, that clearly and incontrovertibly illustrates the degree and quality of tools that can be achieved from split pebble stone materials. In addition, I felt that given the obvious wide geographic distribution of bipolar technology, and its frequency of use, it is unlikely that this technique was thought of so unfavorably by pre-contact groups.

A number of factors have previously been identified that can be used to assist in determining the presence of the bipolar technique within an assemblage. One body of suggestive evidence is the occurrence of bipolar cores; of course, this is a reasonable supposition.

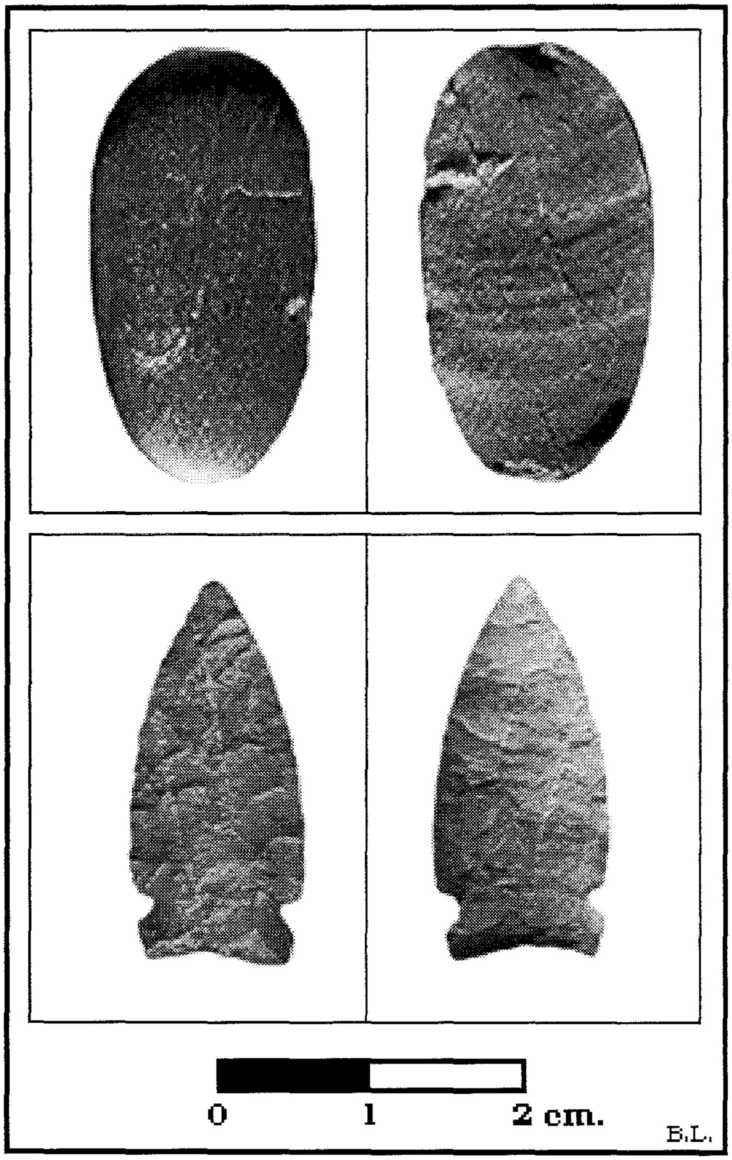

Figure 1.1. Replicated projectile point made by Eldon Johnson, Saskatoon, from a split silicified siltstone pebble.

A second indicator of bipolar technology is the presence of flakes exhibiting a major bulb of percussion on the proximal end and a minor bulb of percussion on the distal end of the specimen, although this characteristic (two bulbs of force on the same flake) has been previously recorded as a rare occurrence. Flakes with two bulbs of percussion can only be produced through the bipolar technique when direct primary mechanical force from the hammerstone and indirect secondary rebounding mechanical force from the stone anvil is exerted simultaneously on both ends of a core.

The third indicator of bipolar technology is association of bipolar materials with stone anvils. Anvils used in the bipolar manufacture of lithic material are generally flat pieces of stone large enough to accommodate the article being worked; although, references are also occasionally made regarding the use of other items as anvils such as large pieces of bone.

The above factors do not exclusively confirm the presence of the bipolar technique within an archaeological assemblage, however, they appear to be the only predominantly recurring elements that have been associated by previous researchers with bipolar reduction found in the archaeological record.

In order to interpret, adequately describe, and accurately classify artifact attributes it seems reasonable to assume that knowing how they were formed should be a fundamental step in their classification. It is suggested here that if research goals concern artifacts derived by a specific manufacturing technique, for example the bipolar splitting of pebble stones, then it is necessary to look beyond the completed specimens. This statement does not mean that completed pebble stone artifacts, or for that matter any other bipolar materials, should not be studied for their own sake, which would be inconceivable. Rather, I suggest that to identify the possible function of an artifact it is also necessary to investigate the process of manufacture of a given specimen. With bipolar archaeological materials this has not generally been done other than to indicate that the bipolar technique employed in their manufacture requires a hammer and an anvil. Actually, there is even considerable confusion over what exactly constitutes the method of bipolar reduction although it seems rational that the use of this technique should be a clear and straight-forward concept.

This thesis attempts to bring some cohesiveness and clarification to the bipolar question along with an examination of the Northern Plains pebble stone technology. Given the obvious controversial nature of bipolar reduction techniques, and the present lack of replicative research regarding this method within North American archaeology, it appeared that what was needed was to seriously examine the bipolar question at this time. In particular, I felt that there was a need to expand on a body of research that examined not only the bipolar method, but classified the resultant artifacts and discernible attributes produced by this technology. It is on this basis that the analysis conducted here was executed. Therefore, research within this thesis concentrated, in particular, on providing a classification of bipolar technology, the mode of manufacture of pebble stone artifacts derived through replicative/experimental studies with non-archaeological materials, and an analysis of the debris created during the bipolar reduction of pebble materials. The resultant interpretations derived through the experimental replicative analysis conducted in this thesis provide a number of significant conclusions within this much needed area of study.

2. RESEARCH PARAMETERS AND THEORETICAL FRAMEWORK

2.1 Research Goals and Operationalization

The investigations conducted within this thesis concentrate, in particular, on four archaeological problems regarding bipolar technology used to produce pebble stone artifacts, as outlined below.

2.1.1 Problem 1. The first phase was to conduct an assessment of what constitutes bipolar technology since, although it has been generally established as a very specific and crude technique of working lithic material, many authors differ in their opinion regarding the implementation of this technology.

Although it would seem that the use of the bipolar technique should be clear and straight forward, as frequently transpires within archaeological literature, just the opposite is true. For example, there are those who feel that the archaeological use of the term bipolar should be dropped entirely. However, much of the argument concerning this issue appears to be circular. Some of the bipolar debate is even irrelevant and unnecessarily argumentative. Chapter 3 of this research reviews the technique of bipolar reduction and examines the controversy surrounding this technique in an attempt to provide some clarification regarding the issue and to assist in the determination of what exactly constitutes the bipolar method of stone tool manufacture.

2.1.2 Problem 2. A major dilemma of lithic researchers is the recognition of bipolar materials within the archaeological record. Although current archaeological literature does indicate that bipolar technology is predominantly used with most pebble materials. Additionally, several typologies do currently exist for bipolar cores, for example Binford and Quimby (1963). There is, however, still much debate within the archaeological literature concerning what exactly does constitute a bipolar core as opposed to other items (Goodyear 1993; Hardaker 1979; Hayden 1980; LeBlanc 1992; Patterson 1979a, Rondeau 1979; Shott 1989; Sollberger and Patterson 1976).

In order to adequately understand this technique, and to aptly apply it to pebble stone artifacts, a serious examination of bipolar stone working technology (what classifies it, its implementation and what products result from this stone working process) was undertaken by conducting extensive experimental replications. In particular, these investigations concentrated on the potential of pebble stone working techniques. To assist in this investigation select metric attributes were recorded and a multivariate attribute analysis was conducted on the resultant by-products created during the experimental replications.

Experimental research is favored by many lithic researchers. For example, in an evaluation of debitage technology, Prentiss and Romanski (1989: 96) noted that controlled experimentation was necessary before generalizations could be demonstrated.

Additionally, Magne (1989: 16) stated that lithic experimentation can assist in legitimizing descriptions. The goal of the analysis conducted here was to determine if experimentally replicated split pebble stone materials displayed a series of universal attributes and whether bipolar specimens displayed attributes distinct from non-bipolar debitage. This examination provided useful information concerning attributes of pebble stone debris created through bipolar technology.

2.1.3 Problem 3. There is a definite need to distinguish pebble stone materials and bipolar technology, therefore, a comparison of pebble artifacts from several archaeological collections and the experimentally-replicated materials was conducted. This analysis provided useful introductory information regarding the temporal and spatial extent of pebble stone artifacts across the Northern Plains. Because of the time and labor involved in this type of analysis, this portion of the research was restricted to a general preliminary statement only.

2.1.4 Problem 4. A final set of concerns relates to the geographic extent, the temporal time frame, and the number of distinct divisions of bipolar technology. Consequently, a preliminary analysis of the archaeological literature was undertaken relating to two main points. One, to assess the possible overall geographical extent of pebble stone artifacts within the Northern Plains. Initial information indicates that the Early Middle Prehistoric period (7500-5000 B. P., as defined by Reeves 1973) had a distinctive pebble stone (artifact) component separate from other pebble stone materials found on the Northern

Plains. It should, therefore, be possible to link a distinct pebble stone component from the Northern Plains with the Early Middle Prehistoric period.

Second, to determine whether a separate and major pebble stone component can be defined in the Early Middle Prehistoric period. Therefore, data were analyzed to see if a temporal pattern emerged regarding pebble stone artifacts. This research clearly demonstrates, however, that there are actually several temporally separated bipolar industries.

2.2 Theoretical framework

The theoretical and interpretative basis that I followed within this thesis was inductive/deductive research methods associated with the cultural historical approach. I believe this provided the best framework upon which to base my interpretations.

The realization of this research was achieved mainly through three phases. First, experimental parameters were derived from the analysis of archaeological pebble stone artifacts. Second, data were accumulated through the experimental replication of pebble stone tools and cores from non-archaeological materials. Finally, accumulated data from the replicated materials were compared to archaeological artifacts. I believe that the interpretations derived through the interplay between replicated items and actual artifacts will lead to a better understanding of the making and functioning of pebble tools. This point has been previously noted by Amick, *et al* (1989:1) who stated that "the most effective way of relating experimental results to the archaeological record is interactively." The synthesis of these data was used for the development of general descriptive and classification models used throughout this thesis regarding bipolar technology on the Northern Plains.

3.
THE TECHNIQUE AND CONTROVERSY OF BIPOLAR TECHNOLOGY

3.1 Technique

The use of the bipolar technique has a long history. For example, Semenov (1964) describes mammoth bone dating to Mousterian times that bear the proportions and traces of wear indicative of their being used as anvils for stone knapping. Although a large bone, block of hardwood, the ground, the padded thigh or even the palm of the stone worker's hand may be employed as an anvil, the most commonly used material is stone (Honea 1965).

Binford and Quimby (1963) provided the first description of bipolar technology in North America as part of an analysis of several archaeological sites in Northern Michigan. They described the bipolar flaking technique as a method that produces distinctive flakes by special use of a hammer and anvil (Binford and Quimby 1963). Subsequent researchers maintained this basic description (Crabtree 1972; Honea 1965; Kobayashi 1975; Leaf 1979a).

The standard bipolar method is to hold with one hand the objective piece of material to be manipulated (such as a pebble core) on a hard, flattish stationary anvil-stone so that the distal end is in contact with the anvil. This technique is illustrated in Figure 3.1. Then it is struck on the proximal end with a hammerstone that is held in the other hand. When percussion is applied at the proximal end of the specimen a force rebounds from the anvil, and a primary force at the point of impact also occurs. The applied pressure, therefore, produces force from both the anvil and the percussor. When applied force is in direct opposition to the rebound force the material will exceed its elastic limit and the objective piece of material will shatter or shear.

Herbort (1988: 35-37) has provided four methods of bipolar reduction, as illustrated in Figure 3.2. These include: one person-one hand; one person-two hand, two person-two hand, and VAM (vise-anvil maul). The one person-one hand method is the standard method described above. With the one person-two hand method the core is supported on the anvil, usually with a medium such as sand, so that the hammerstone can be held with two hands allowing the application of more applied force when needed. The two person-two hand is similar to the previous method except that the core is actually held by another person. I am assuming this would be an extremely trusting individual, although I would not recommend this procedure. The VAM (vise-anvil-maul) method involves the core being braced between two branches in a vise-like manner and the hammerstone being hafted to a handle. This method would allow for highly forceful applications of pressure and would be used to break down only the hardest of materials.

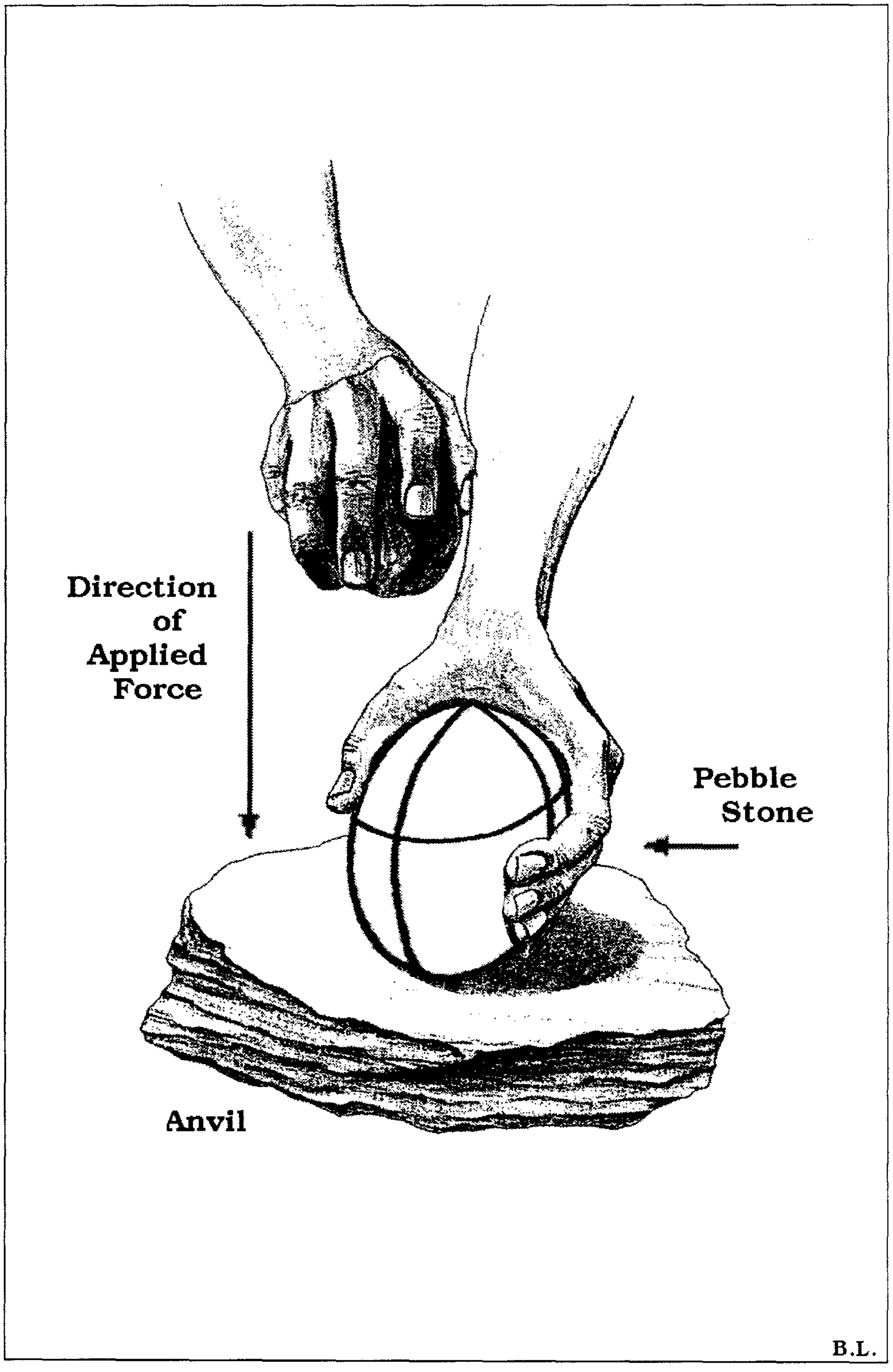

Figure 3.1. The bipolar method (based on Crabtree 1972).

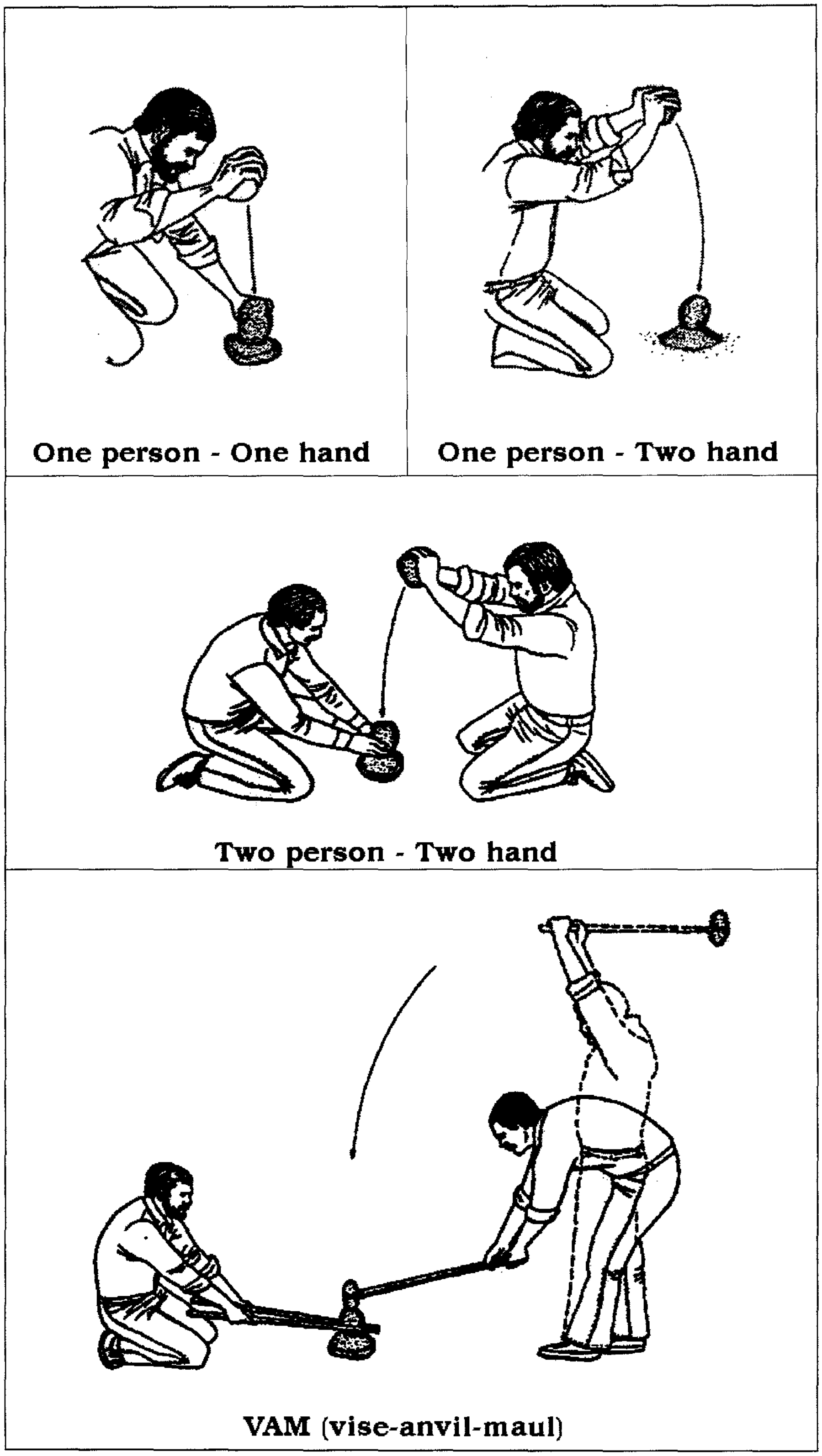

Figure 3.2. Methods of bipolar reduction (from Herbort 1988: 36, 37).

Obviously, flakes struck off using the bipolar reduction technique are called bipolar flakes and accordingly cores used in this process are referred to as bipolar cores. Although, as will be discussed within subsequent sections of this study, bipolar flakes and cores can and do vary highly.

3.2 Controversy

Most researchers have noted that the bipolar technique is used whenever the lithic resources are predominantly small, because these materials have to be used more efficiently (for example, Binford and Quimby 1963; Crabtree 1972; Honea 1965; Kobayashi 1975; Knudson 1978; Leaf 1979a; Sollberger and Patterson 1976). As a result, the bipolar technique is constantly reported to be widespread in those parts of the world where the main sources of flaking materials are theorized to be small, such as pebble stones. The bipolar technique is quite widespread throughout the Northern Plains and although small pebble materials under 5 centimeters in length do occur in abundance within this region (Ball 1987; Low 1994; Quigg 1977, 1978; Reeves 1972; Walker 1980, 1984, 1992) they certainly are not a monopoly over other available lithic resources. Many materials such as Swan River chert are also available throughout the Northern Plains region (Low 1994, 1995a-d). Additionally, larger cobbles may (and are) also frequently fractured using this technique (Herbort 1988). Therefore, it is not reasonable to assume that material size alone determines the types of technology employed.

In the past, archaeological researchers, such as Honea (1965) and Kobayashi (1975) indicated that blades made by the bipolar technique often produced a bulb of force on the ventral surface at both ends of the detached piece. Other researchers (Crabtree 1972; Sollberger and Patterson 1976) have contradicted this theory. For example, Crabtree (1972) believed that this technique sometimes leaves a positive or negative inverted bulb of force scar on either end, but very rarely on both ends of the same flake or blade; a point concurred with by Sollberger and Patterson (1976). Moreover, Sollberger and Patterson (1976) state that though true bipolar flakes could be produced with two force bulbs on opposite ends of a flake there is no technical advantage for doing so. They note that bulbs of percussion at both ends would result in less available total cutting edge if used as an unretouched flake and if a true bipolar flake was used as a tool blank, shaping and retouch flaking would be made at least twice as difficult by the presence of two bulbs of percussion. First, I do not believe that a double bulb of percussion was the ultimate technological feature being sought. Second, considering the generally small size of bipolar bulbs it is unlikely that shaping or retouching a specimen was made twice as difficult. (Bipolar attributes are discussed in Chapter 6).

According to Crabtree (1972) the ideal bipolar fracture is made by directing one of the forces slightly off-center which will split or shear the core. Shearing radiates the force waves from one end or the other, usually from the end having the least contact with the percussor or anvil. He notes that this method usually does produce only one bulb at the proximal end of a blade or flake (Binford and Quimby 1963; Crabtree 1972; Hardaker 1979; Honea 1965; Kobayashi 1975; Leaf 1979a; Sollberger and Patterson 1976). Additionally, he states that although a true bulb of force does not occur on the distal end there is sometimes evidence of force or damage at the distal end of the flake removed (Crabtree 1972; Sollberger and Patterson 1976).

Several researchers (Carter 1978; Crabtree 1972; Sollberger and Patterson 1976) contend that anvil-supported cores used to produce flakes and blades must have the distal working edge of the core's base free of contact with the anvil, which prohibits a bulb of force at both ends. Also, they note that when manufacturing blades the force must be directed tangentially rather than perpendicularly to the face of the core. As a result the detached blade will have one bulb of force at the proximal end. These same researchers further state that anvil-supported cores produce flatter blades than those that are hand held or placed on a yielding support and if the so called "true bipolar technique" is used for blade making, the force is in direct opposition between anvil and percussor and the blade will collapse and there will not be bulbs of percussion on both ends. Therefore, they believe that although the anvil is useful in many techniques the force is normally not applied in direct opposition to the anvil (Carter 1978; Crabtree 1972; Sollberger and Patterson 1976)..

Vanderwal (1977) found that mean length and width of usable bipolar flakes exceed the similar properties of residual bipolar cores, largely because cores can be reduced while in use to a point where they are no longer serviceable. Shott (1989) notes that the small size of archaeologically recovered bipolar artifacts does not necessarily reflect the size at which they were valued, merely the size they had reached when discarded after extensive reduction. Goodyear (1993) adds that bipolar reduction would actually signal the last possible effort to procure usable flakes from a nearly exhausted tool kit. Regarding this point, Goodyear (1979) states that where no other comparable raw material is nearby, such a practice of intensive recycling is an effective and rational way of dealing with a tool replacement problem. Honea (1965) and Shafer (1976) also describe the bipolar technique as being particularly suited for small pebbles, which would be difficult to produce flakes with by other techniques. Furthermore, Goodyear (1993) suggests that bipolar cores reflect a low potential raw material supply at a given site and that they represent a strategy of intensive raw material curation based on recycling of increasingly scarce portable artifacts.

I have stated previously that size availability of raw material need not completely limit types of flaking techniques employed. Although the size of raw material to be worked would certainly be considered in the selection of particular knapping techniques, the type of lithic material can also greatly influence the quality of knapping results even more than limitations in size of raw material. Given the widespread use of bipolar technology, however, I do not believe that this technique can be considered as a final effort to attain usable materials or was employed because no other lithic materials were available.

Ingbar (1994: 54) notes that it is the stone tool technology that needs to be considered not the source. "In essence, we need to determine how technology "flows through" adaptive behavior" (Ingbar 1994: 54). In other words, if a group had no particular use for a raw material then its proximity to it would be inconsequential (Ingbar 1994: 54). Therefore, it is important to keep in mind that lithic manufacturing techniques can be linked to archaeological assemblages without the confirmation of raw materials source areas (Andrefsky 1994: 21).

As this research will display, the bipolar technique can be a very efficient method of working stone. This belief is contrary to the views of lithic researchers such as Sollberger and Patterson (1976). Although, others such as Root (1992) also consider the bipolar method to be a effective technique of stone working.

Hardaker (1979) states that bipolar technology is a lithic manufacturing tradition and because of the peculiar nature regarding the mechanics of this technique, he can see no other recourse for the researcher to understand it than that of replicative studies, a view that has also been presented by Crabtree (1975: 105). Rondeau (1979) counters that Hardaker's (1979) statement is an interpretation of the archaeological record that does not logically follow from any results that can be produced by experimental replication. Rondeau's (1979) statement is remarkable given that analogy and experimentation are really the only means that archaeologists have with which to make inferences. Rondeau's (1979) argument largely appears to be somewhat circular. At one point he states, "replication techniques . . . may not actually replicate the prehistoric situation" and then in the same paragraph he adds, that "replication experiments by this author [Rondeau] support the contention that useful flake forms can be repeatedly produced with reasonable efficacy" (Rondeau 1979: 18).

Rondeau (1979) summarizes four points that he states must be considered when developing interpretations regarding prehistoric lithic collections. These are:

A. to consider the existing archaeological literature concerning both the previous interpretations of such collections as well as previous replication studies;

B. to consider the logic in developing those interpretations;

C. to consider the factors that must be controlled during the replication study;

D. to consider the archaeology that produced the collection under study.

He further notes that without the careful consideration of these elements no amount of lithic replication will aid in correctly interpreting archaeological collections.

Weir (1976) also argues against the possibility of a bipolar tradition. He concludes that bipolar flakes in some cases may be the result of a "generalized" use of anvil stones. This statement is within the gray realm concerning what does or does not constitute bipolar technology within the archaeological literature. In other words, many archaeologists debate whether the simple use of an anvil constitutes bipolar technology. According to Weir (1976) it does not and this position is strongly concurred with by others, for example, Sollberger and Patterson (1976).

Carter (1978) states that the use of the term “hard anvil technique” would be preferable to the use of the term bipolar. Patterson (1979a: 22) and Sollberger and Patterson (1976) also states that the "simple use of a hard anvil to obtain simultaneous flake detachments should . . . be given a separate classification, distinct from true bipolar fracture techniques." Patterson (1979a: 22) adds that "only cases involving true bipolar fractures should be classified as bipolar flaking." Patterson (1979a) and Sollberger and Patterson (1976) argues that the use of an anvil does not necessarily produce bipolar fractures. To them true bipolar fracture involves initiation of fracture at the proximal end of the core, where force is applied, and at the distal end of the core resting on a hard anvil and not simply a detachment of separate flakes on the striking platform and anvil ends of the core. I do not believe there is a real distinction here, although, they state that the latter situation should be termed 'simultaneous flake detachment' to avoid confusion with technology involving "true bipolar fracture." The differentiation they present does not, however, lessen the confusion but rather it adds to the bewilderment of this technique already in the literature.

Hayden (1980) does not agree with the analysis presented by Patterson (1979a) and Sollberger and Patterson (1976). He also notes that they have unfortunately added to the confusion concerning the identification of bipolar cores and that their interpretation seems to be improbable. Hayden believes that Patterson (1979a) and Sollberger and Patterson (1976) have ignored the standard definition of the bipolar core and bipolar technique and that they have attempted to invent new terminology. This does appear to be the situation. The attempt to do this comes from the feeling by Patterson (1979a) and Sollberger and Patterson (1976) that it is difficult to control material using the bipolar technique, which leads them to the conclusion that it cannot be a real technique. However, it is unjustifiable that we should discount a technique even if it has been previously classified as being crude solely by modern standards.

According to Hayden (1980), individuals using bipolar techniques were minimally concerned with control of the medium and primarily concerned with simply obtaining usable pieces of stone for a specific task at hand; a goal that he notes has surprisingly few constraints. Although I agree with Hayden regarding the classification of the bipolar technique, I disagree with him on the point that control of the medium was not a concern. As far as I have been able to discern, the control of the material being worked in knapping is of paramount concern to the flintknapper. It is quite evident within the archaeological literature that there are many artifact types that could be and were produced by using the bipolar technique and it is unlikely that these occurred by chance.

Patterson (1979a) adds the names of Crabtree (1972) and Kobayashi (1975) to his and Sollberger's (Sollberger and Patterson 1976; Patterson and Sollberger 1977) as those who restrict themselves to the use of the term bipolar flaking to those instances where true bipolar fractures occur. As previously noted, however, Crabtree (1972) clearly defines bipolar reduction technology quite simply and broadly, that is, as a technique of resting a core or lithic implement on an anvil and striking the core with a percussor. By this definition bipolar reduction can produce many flakes of widely varying size and form (Shott 1989). Goodyear's (1993) description of bipolar reduction is similar to Crabtree's (1972); bipolar cores are produced from materials that have been placed on a stone anvil and struck repeatedly with a hammerstone for the derivation of flakes. On the other hand, Kobayashi (1975) does maintain that a core must be struck vertically (at right angles) to the striking platform to produce bipolar flakes. This view is also held by Jeske and Lurie (1983) who state that bipolar reduction produces flakes by placing a core on a stone anvil and striking the core with a stone hammer at a 90^0 angle (straight down) producing two opposing points of impact, one on either end of the core.

Haynes (1977) notes that the bipolar technique may simply involve holding a core against an anvil and pounding it until it shatters or releases more than one or two flakes. Honea (1965) and Shafer (1976) believe that the occurrence of some bipolar flakes may simply be due to random errors within the more general framework of using a hard anvil. Boksenbaum (1980) notes that bipolar technology may be a variant of smash flaking, which produces an anomalous class of flakes having resulted from smashing. Knudson (1978: 45) has expressed the view that the bipolar technique is often "an accompaniment to more stylized and complicated technologies within a single cultural system." Sollberger and Patterson (1976) argue that true bipolar flaking simply represents errors, accidents, or an unskilled technique by individual craftworkers. Given the wide geographical range of the use of this technique and, as I have noted, the diversity and range of bipolar by-products, these interpretations are extremely unlikely.

Sollberger and Patterson (1976) further conclude that the true bipolar flaking technique is not technically advantageous and probably does not form the basis for specific chipped stone industries. Their position is often noted within the literature by many researchers who concur with this interpretation. However, as the research presented here will demonstrate this interpretation is also not valid.

Haynes (1977) and White (1977), however, both note that bipolar flaking, while not a sophisticated knapping technique, may be the main or only knapping technique found in some Old and New World assemblages. Sollberger and Patterson (1976), however, contend that true bipolar techniques may have no relation to specific cultural traditions. To these researchers the use of a hard anvil can offer a mechanical advantage by preventing deflection of the core during percussion giving more efficient use of applied energy; however, they state that it is hardly the basis for a distinct chipped stone industry. As noted above, they describe true bipolar flaking as the lack of skill in flintknapping, rather than as an alternate desirable technique. Honea (1965) adds that the firm support of a core on an anvil can be used with a variety of knapping techniques, such as pressure flaking, not only bipolar reduction. Sollberger and Patterson (1976) emphasized that the presence of bipolar flaking characteristics does not imply a consistent bipolar technique and that if true bipolar flaking is done, there is some loss of flaking control on any size core when compared with direct percussion. Therefore, they note that when the bipolar technique is not employed use of a hard anvil can produce uniform results.

Carter (1978) suggests the possibility of several bipolar industries and that one involved the longitudinal splitting of cobbles between hammer and anvil. He (Carter 1978: 15) notes that many of the cores produced in this manner have been "split down to sub-cylindrical nuclei of relatively small diameter." Flenniken (1981, 1983) provides a further example of a separate and distinct bipolar industry that he identifies as the Systematic Bipolar Microlith Technology at the Northwest Coast Hoko River site, in northern Washington. Flenniken's (1981, 1983) definition of microliths is that they are not blades but rather small specialized flakes that are quite short and have at least one margin that is sharp. He selected the name Systematic Bipolar Microlith Technology because he feels it involves the systematic bipolar reduction of the lithic material. That is, rather than merely striking the anvil supported cobbles with a percussor and retrieving the usable remains the flintknapper systematically selected how and where to strike a core to achieve particular end products. The likelihood of there being several bipolar industries seems reasonable given the diverse types of bipolar artifacts observed within the archaeological record.

It is quite evident from the above discussion that there is indeed much controversy regarding what constitutes bipolar technology, how the technique is put to use, what lithic materials are favoured and what by-products result from the application of this unique method of working stone. A great deal of the mis-interpretation with this technology originates from there not being any in-depth studies regarding the above, or of a synthesis of the bipolar material already in the literature. Therefore, given the controversial nature of the bipolar technique, and the lack of replicative research regarding this method, I felt that research needed to be carried out that describes and classified this technology, its resultant artifacts and the attributes produced by this technique. It is on this basis that the following analysis was executed.

4. METHODOLOGICAL PROCEDURES OF DATA COLLECTION

4.1 Application

A noted concern within the archaeological literature regarding the bipolar splitting of pebble stones exists that has fundamental implications regarding the study of these materials. That is, how are pebble stones split using the bipolar technique without crushing them into useless pieces of shatter? McPherron (1967), for example, has described this variable outcome of the bipolar shearing of small pebbles. He has noted that often the pebble shatters completely, leaving only fragments that may show percussion wave scars on their cleavage faces. Alternatively, the pebble may fracture internally, leaving a split pebble with irregular, angulated cleavage faces. This characteristic is related to factors such as tool selection, the quality of the material, and the body form of a pebble. How, then, was the bipolar method used to produce the abundance of pebble materials evident within the archaeological record?

Researchers such as Hardaker (1979) have noted that there are a number of variables that largely control the bipolar technique. These include the material of the core, the weight of the percussor relative to the shape and size of the core, and the intensity of force that is generated by the flintknapper.

Furthermore, it is consistently suggested that the derived elements from a bipolar core have to be studied closely to clarify and determine the practical limits of this technique. Replicative experimentation is one method that can assist in the interpretation of bipolar reduction techniques within the archaeological record.

My primary goals during the experimental stage of this project were the rudimentary factors that would influence the shearing of a pebble stone through the application of the bipolar technique. For example, what caused one pebble to shear cleanly into two halves while another, apparently similar pebble, shattered into largely unusable debitage? Additionally, what ambient factors accounted for the apparent wide range of variation between these two extremes? Therefore, the initial experimentation involved assessing not only the bipolar method, but also the tools that produced the most optimum results in this procedure that are outlined below. Additionally, the actual shearing and fracture properties involved in the bipolar process of pebble splitting was observed and recorded.

Pebble materials used during the initial assessment of the tools were discarded and are not included in the analysis of the experimental data. In part I felt that this was a learning process. More importantly, the major focus at this stage was to assess the tools and not the pebble materials. Moreover, including these materials would unacceptably skew the results of the experimental data.

Once the appropriate hammer and anvil were selected each replication was conducted in as uniform a manner as possible.

First, the dimensions of the pebble were recorded on a numbered index card. Then, gripping the pebble to be fractured between my thumb and forefinger of my left hand, I then rested my hand on the anvil and placed the pebble's distal end in contact with the anvil (in a vertical position). Gripping the hammerstone in my right hand I then lightly tapped the top of the pebble. By doing this I could hear and feel the resonance within the pebble change.

During the initial experimentation an interesting observation was made. I noted that after some practice I began to feel the change in resonance being generated within the pebble stone as it was held on an anvil and lightly tapped with a precussor on the proximal end. I also began to notice a change in the tone of resonance generated within the pebble stone during this process. That is, that as a pebble was held on an anvil and gently tapped, while rocking the pebble slowly from side to side (as well as altering the angle that the percussor was being held), it was possible to feel the resonance and hear the tone change within the specimen indicating the optimum point at which a pebble should be struck so that it will more frequently shear, rather than shatter (Low 1996b).

Once I determined that the pebble was in an optimum position I then applied a controlled amount of force to the proximal end of the specimen. Some researchers still note (for example, Kuijt, *et al* 1995:118) that it is necessary to apply a massive blow to the objective piece when using a bipolar technique. However, to do so would render the material useless. As I note, it is necessary to control the amount of force being applied so as not to shatter the material completely. The smaller the objective piece being worked the more control must be used with applying the force.

The debitage resulting from the aforementioned activity was collected into a small plastic bag with the index card. Specimens were set aside before the next replication for later analysis. All replicated specimens where examined using both a hand lens (10X) and a standard binocular microscope (40X - 100X). The microscope helped to verify the attributes observed by the hand lens. The results of this analysis will be discussed later in Section 6 of this thesis.

To accurately identify and differentiate between irregular pebble shears and those through the width and thickness of a pebble a model of an ellipsoid, with standard X, Y and Z axes, was used (Figure 4.1), with the X axis extending down from proximal to distal end, the Y axis extends through the width, and the Z axis through the thickness of the pebble. Additionally, to differentiate between the shear face and the pebble axes the letters (A, B and C) were assigned for the main ventral faces of the split pebble (Figure 4.1). A pebble face of AB was sheared along the widest section of the pebble parallel to the Y axis and down the X axis. A pebble face of AC was sheared along the thinnest (relatively speaking) section of the pebble parallel to the Z axis and down the X axis. Several irregular fractures occur and will be dealt with independently throughout Section 6 except for several pieces that are referred to as citrus-sections (due to their similarity to orange wedges). The pebble faces of these specimens are referred to as

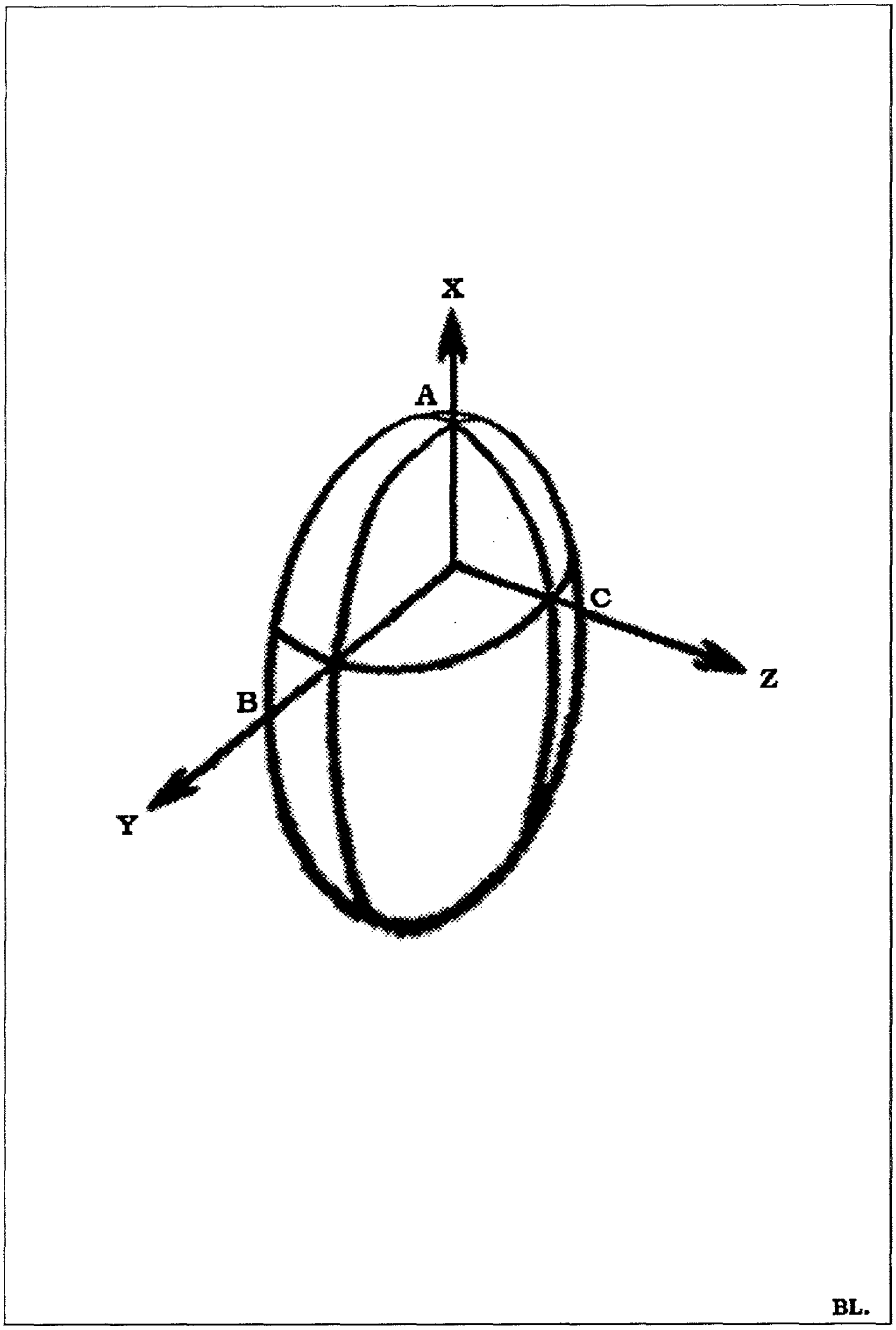

Figure 4.1. Model for stress definition in three dimensions (modified from Pursh 1995: 137).

BC, that is, they extend down the X axis but run irregularly, and at various angles to the Y and Z axes creating a wedge-shaped section.

Figure 4.2. outlines the pebble stone orientation terminology that was used regarding a specimen's ventral, surface, dorsal surface, proximal end, distal end and longitudinal axis. Figure 4.3. illustrates the major types of flake termination. Of main concern here are the feather and axial terminations. In particular, axial terminations occur on the bulk of the experimentally replicated materials.

According to the geologic Udden-Wentworth scale that is used almost universally by sedimentologists for the classification of lithic debris (Boggs 1987: 107), pebbles range from 4 to 64 mm. in length. Stones that form individual particles larger than 64 mm (but less than 256 mm) are classified as cobbles. However, the application of this classification to pebble stone artifacts, rather than to individual particles, is unusable for this study. This determination is based on several factors. First, it is highly unlikely that split pebble stone artifacts would be found as small as 4 mm in diameter that had been produced by bipolar reduction. Second, the use of this classification treats artifacts between 4 mm and 64 mm as being equivalent in relation to their size. In actual fact, a preliminary examination of pebble stone artifacts indicates that there is a wide range of variation in pebble stone artifacts that this size classification does not take into account. Therefore, the use of the Udden-Wentworth scale will not be used to classify pebble stone artifacts for this research. An arbitrary size

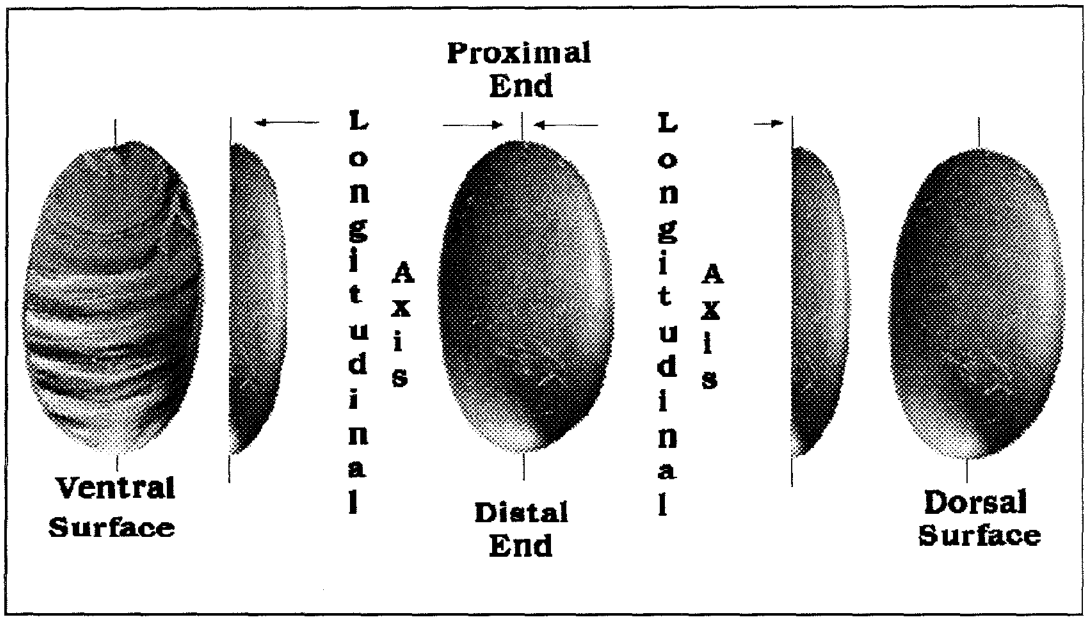

Figure 4.2. Pebble Stone orientation terminology.

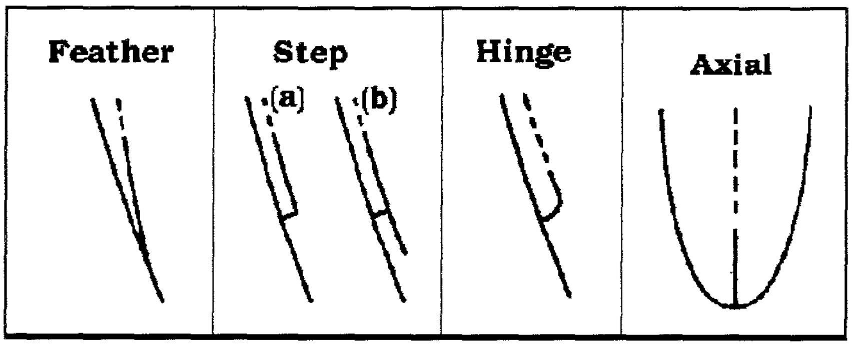

Figure 4.3. Flake terminations (modified from Cotterell and Kamminga 1987: 684).

classification that will be used in this thesis is as follows: small, <3 cm; medium, >3 cm/<6 cm; large, >6 cm. This division should adequately separate the artifacts that will be examined for classification and analysis within this thesis.

As a final point, one method for splitting pebble stones has been previously suggested by Johnson (1991). He suggests that one pebble be placed on an anvil and another pebble held on top of the first (Figure 4.4). Then the upper pebble is struck with a hammerstone driving the top one through the lower pebble. Thus the upper pebble acts as a wedge to force the lower one to split. Although Johnson (1991) claims to have a reasonably high level of success in splitting these pebbles in this manner he does admit that his method requires a bit of manual dexterity.

During the initial stage of the analysis I rejected this method largely because of the deftness of this technique. For one thing, it is quite difficult to perfectly align two pebbles, one on top of the other, so that one of these can be split. The overwhelming result, using this method, was that one of the pebbles can slip during percussion resulting in a small chip(s) being broken off near the touching faces of the two specimens, rather than shearing the pebbles into halves (Low 1996b). As a result the frequency of successful pebble splitting was markedly low. The highest frequency of successful attempts during the bipolar splitting of pebble stones resulted using single specimens resting upon an anvil; therefore, that is the method I ultimately used during the experimental replications.

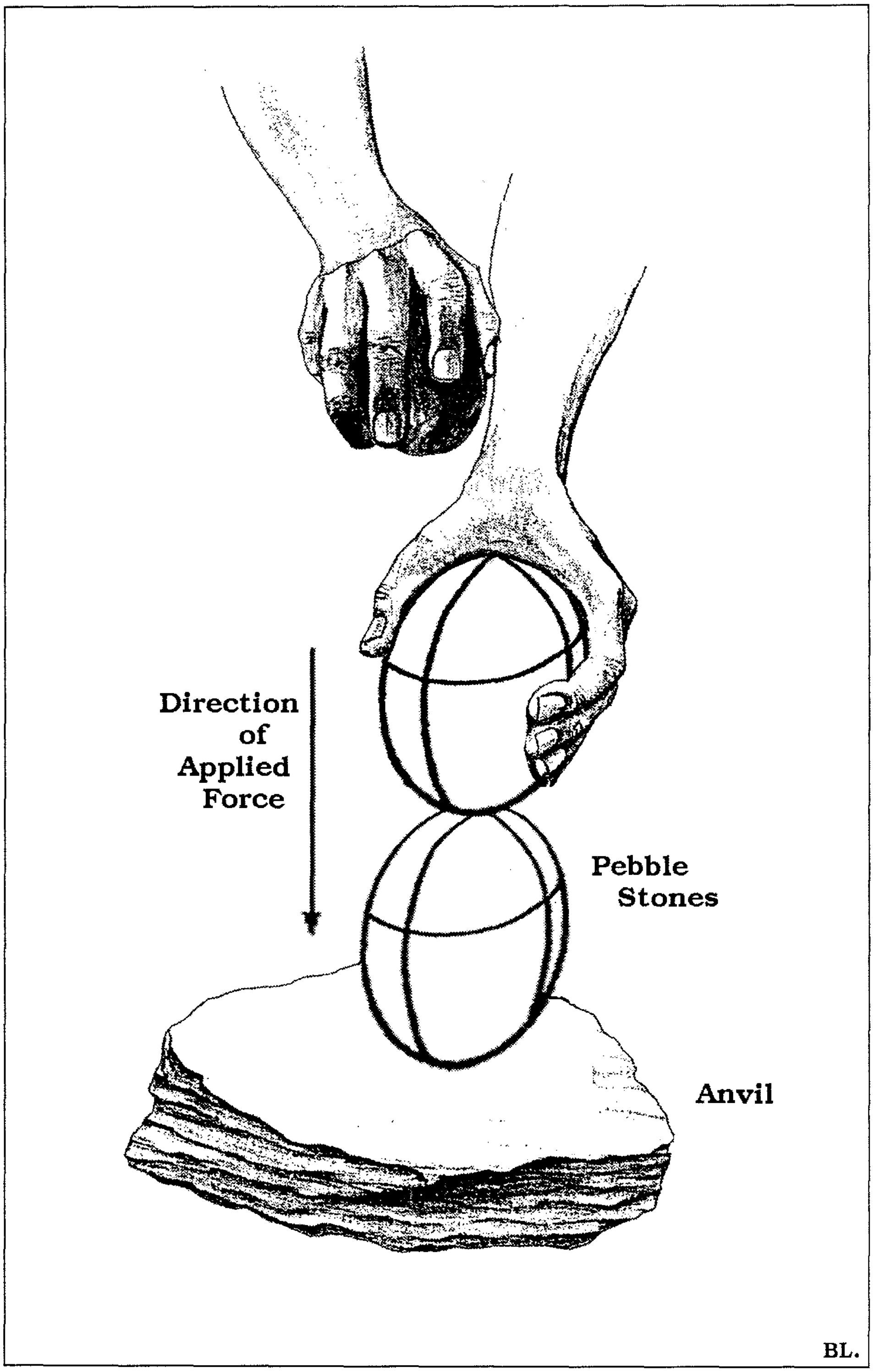

Figure 4.4. Eldon Johnson pebble splitting method (based on Crabtree 1972).

4.2 Tool Selection

A number of knapping tools were first tested that produced unsatisfactory results, including a variety of hammerstones of various sizes, shapes and weights followed by a wide range of anvils. This process allowed me to eliminate a number of undesirable variables. This materials selected and the logic involved in their selection are discussed below.

A major consideration, that appears to have the most fundamental effect regarding bipolar pebble splitting, is the type and grade of anvil used (Low 1996b). It was concluded during the initial testing of tools that the amount of rebound force was not only related to the amount of pressure applied to the top of the pebble from the hammerstone, but that it is directly proportional to the size and density of the anvil as well. Furthermore, it was discovered that the overall weight of the hammerstone is not as crucial when compared to the role of the anvil. It was quite evident during the initial material testing that the anvil obviously stored a certain amount of the applied force before it rebounded back into the pebble stone. During experimentation I discovered that while a small relatively thin anvil would store only small amounts of energy, a larger anvil with more densely concentrated and compacted sediments would store considerably higher rates. This characteristic allows the applied pressure to disperse through a small anvil and very little to be rebounded.

The relationship of stored energy within an anvil to the frequency of successful pebble splitting attempts is an essential link connecting success rate to ratio of effort expended. For example, it was determined that because a relatively small anvil could only store a small amount of energy it required an extensive amount of downward force from a precussor to attempt the shearing of a pebble in two halves. Because more downward force was applied to a pebble and less energy returned from the anvil the usual result was the crushing or shattering of the specimen into numerous pieces. In this instance, a great amount of control of the experimental replication was lost and the shearing of the pebble materials was left largely to chance. Moreover, with a small anvil, pebble materials that should have split into two sections were most often crushed into numerous pieces of shatter.

Alternatively, when a large anvil was used only a moderate amount of downward force was needed to be applied to a pebble stone to shear it as more energy was being rebounded back from the anvil. The result is that using a large dense anvil with a moderate amount of applied force results in a very high success ratio during the bipolar shearing of pebble stone materials (Low 1996b). With a large anvil stone it was discovered that a great amount of control (to the amount of pressure applied to a pebble stone) could be attained. As well, a much smaller hammerstone could be used, and in fact, when used in conjunction with a large anvil provided much superior results to the larger hammerstones and smaller anvils.

The materials used for tools during the experimental replications include a granite hammerstone (L-16.95 cm x W-6.6 cm x T-5.1 cm), and a quartzite anvil (L-25.25 cm x W-17.0 cm x

T-10.45 cm), (Figure 4.5 and 4.6, respectively). This tool combination proved to be more than adequate for the experimental portion of this thesis.

The pecking that is visible on both the hammerstone and the anvil, as illustrated in Figures 4.5 and 4.6, developed as the replications proceeded and is a typical outcome of bipolar stone tool manufacture.

Although it was necessary for the hammerstone to have sufficient density to perform adequately, the hammerstone was not selected for weight, but rather because of its ease in handling and its wide broad striking face. The anvil, on the other hand, was selected mainly for its density because of the amount of energy it would store from an applied force. The anvil selected possessed sufficient density for the experimental replications conducted yet remained small enough to be portable. The above tool combination allowed for the maximum amount of control during the experimental replications.

4.3 Pebble Selection

The nature of raw lithic material available in a given area is likely a prime factor determining not only the practice of certain stone flaking techniques but also the technological development of pre-contact cultures. As well, the practice of certain flaking techniques may be characteristically associated with given stages in the development of a lithic complex. The occurrence of bipolar technology on the Plains is an obvious example of the influence of

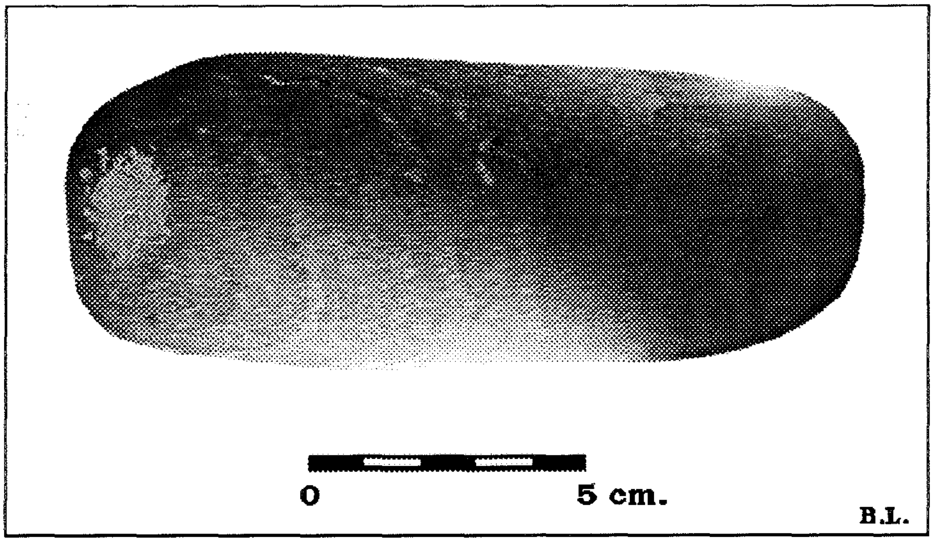

Figure 4.5. Stone hammer used during experimental replications (L-14.95 cm. x W-6.6 cm. x T-5.1 cm.).

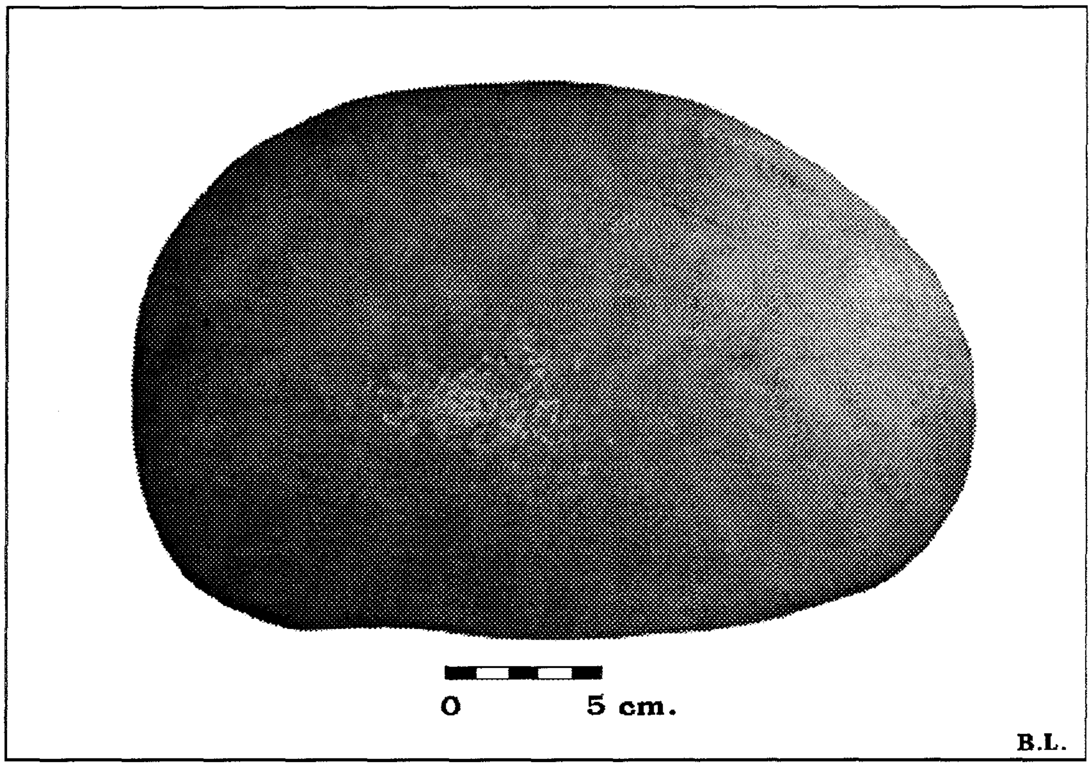

Figure 4.6. Quartzite anvil used during experimental replications.

the size and form of locally available lithic material used within a specialized flaking technique. In consideration of the above, numerous pebble stone materials that included a range of size and form were tested including quartz, quartzite, a variety of cherts, some miscellaneous generic materials, and silicified siltstone pebble stones as defined by Johnson (1986), which are often referred to as black chert pebbles. While all of these materials could be split using the bipolar method several factors led to the selection of the silicified siltstone pebble materials that were ultimately used as the major material during the experimental data analysis (although a variety of raw materials were used and analyzed including chert and quartzite).

First, the form and not the size of the pebble appears to be the primary factor controlling the shear or shatter tendencies of the material. This factor was observed during the initial material testing but was not quantified until the completion of the experimental replications. It should be noted here that silicified siltstone pebbles are generally flatter in form while other materials such as quartzite tends to be rounder in appearance. To assist in the differentiation of pebble form Zingg indices as outlined in Blatt, *et al*, (1980: 80-81) and McLane (1995: 24-26) were calculated to determine the oblate (disk), equant, bladed and prolate (roller) characteristics of the specimens. A specimen that is oblate in form, also identified as a disk, is thin, flat, narrow, semi-circular and flattened at the poles, whereas an equant pebble is round and circular. Bladed materials are generally flattened narrow and irregular in shape. A prolate or roller form is spheroidal and lengthened in the direction of the poles. It was essential for this study to make quantitative comparisons regarding the form of pebbles since this characteristic appeared to be fundamental to the shearing properties of these materials.

In order to classify the shape of a pebble Zingg indices are first calculated (d_L=longest diameter, d_I=intermediate diameter, d_S= shortest diameter). Once the indices are recorded then the ratios of d_I/d_L and d_S/d_I are plotted on a chart to determine the form of the specimen. This classification system accurately determines the overall size and roundness of a pebble as illustrated in Figure 4.7. Pebble form will be discussed more fully in Section 8.

Second, the quality of the material is another fundamental trait regarding the shear/shatter frequency of a pebble stone. That is, the finer more evenly grained the knappable material the high the grade and the better it can be manipulated, thus, the finer the final product. A poor grade lithic material, one containing flaws, for example tiny fractures or inclusions of foreign elements, is very hard to control during the knapping process.

The pebbles that I selected for this study consisted of fine grained materials that would clearly display surface features (such as ventral flake attributes). Quartzite pebbles, for example, split nicely using the bipolar method but virtually no surface attributes can be identified even with the aid of a microscope. Silicified siltstone pebbles, however, also split very well and they have the additional benefit of being very fine grained. Thus, these

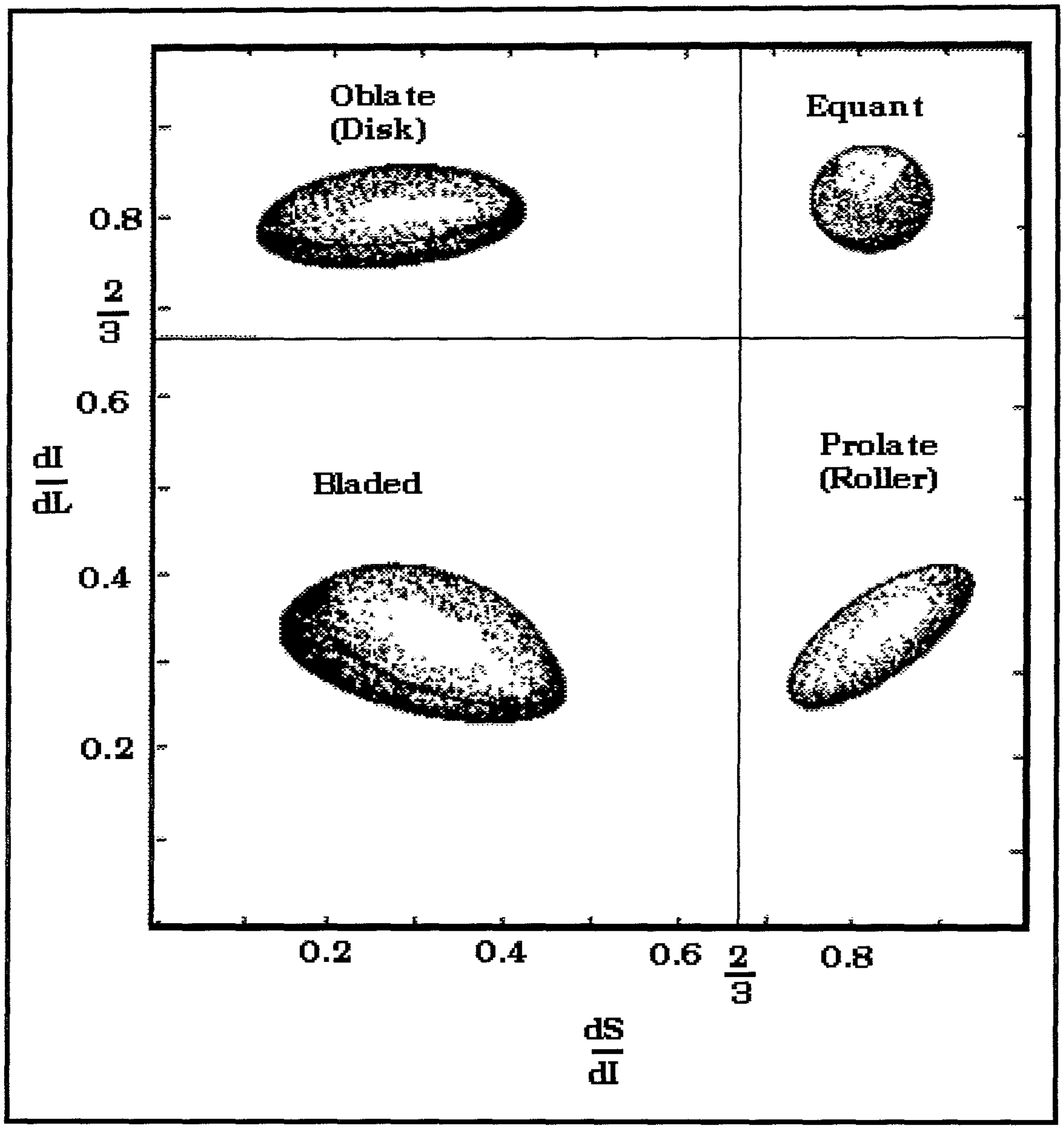

Figure 4.7. Classification of pebble shapes (after Zingg, 1935 in Blatt, *et al*, 1980: 80).

materials often (but not always) displayed fracture and surface attributes such as percussion lines that could be identified.

The third major consideration in the selection of silicified siltstone pebbles over other pebble materials was their relative abundance. Although some of the fine grained miscellaneous pebble cherts also clearly displayed features such as bulbs of percussion, the silicified siltstone pebbles occur in much greater frequency and, therefore, were more frequent and easily collected. This will be discussed more completely in Section 10. This allowed me to conduct an extensive amount of initial testing before the actual experiments began. Several miscellaneous materials were also recorded, however, so that a comparison could be formed between a variety of lithic types, including the silicified siltstone specimens. The locales and collection of materials will be discussed subsequently in Section 9.

One problem in the examination of the replicated specimens was that the small size of the materials combined with their dark surfaces meant that all materials had to be analyzed using both a hand lens and a microscope. This, in itself, was not a problem in analysis, but creating adequate illustrations from these materials using standard photographic equipment did not produce satisfactory results. Additionally, using only microscopic photographs would have been prohibitively costly. This dilemma was overcome in part by video scanning, and in part by having photographic images of specimens placed on a photo-CD. These illustrations could then be enlarged within Photoshop 3.0. This allowed the attributes to be clearly illustrated.

5. BASIC PRINCIPLES OF ROCK FRACTURE AND FRACTURE MECHANICS

5.1 Preliminary statement

During the process of splitting a pebble stone using the bipolar technique it was observed that the type of fracture that would most frequently occur related to the overall body shape of the specimen. Thin pebbles of a fairly uniform thickness (relative to the width of the pebble), even ones with an inferior general condition that contained flaws, would shear more frequently than thicker materials (Low 1996b). This is especially true for pebbles that are quite round, as they have a general tendency to shatter rather than shear. This occurs because the body shape of the pebble determines the shear/shatter tendencies in regard to the processes that occur within the pebble relative to the applied and rebound forces.

To understand the process of pebble fracturing more clearly a discussion of fracture mechanics and the basic principles of spherical wave motion are essential at this point. To begin with, the variation in the shearing or shattering of a pebble stone is commensurate with the processes involved in the physics of stress waves and the fracturing of stone following impact. Cotterell and Kamminga (1979: 97) note that classical fracture mechanics can therefore be used in lithic studies because flaking is just a specialized form of fracture.

A brief outline of the physics of fracture mechanics based on the previous work of several researchers (Cotterell and Kamminga 1979, 1987; Konopinski 1969; Moffat 1981; Pande, Beer, Williams 1990: Pusch 1995: Rinehart 1960; Shott 1994; Speth 1972; Wittke 1990) as it relates to rock stresses, the effects of body shape and the changes in the shape of a stress wave caused through impacts is provided here. As noted previously, an awareness of these processes is necessary to more clearly illustrate why some pebbles shear cleanly in two halves while other specimens shatter into numerous highly variable pieces. Discussion will largely be limited to spherical bodies and stress waves and how the former is affected by the latter.

5.2 Fracture Mechanics

Flaking or fracturing occurs when a force is applied to a solid body (Cotterell and Kamminga (1979: 99). Material stability is largely related to the rate at which force increases or decreases (Cotterell and Kamminga 1979:98) and the maximum stress differential acting on the fracture surfaces (Cotterell and Kamminga (1979: 102). The characteristics of force and stress that are pertinent to this study are separated here between the primary directions of force and the secondary or peripheral stresses that ultimately modify the original specimen.

Figure 5.1 outlines the model used to define the primary directions of force relevant to this study. First, the initiation of the force applied through impact (Af) occurs at point X_1. For this study, this occurred when the hammerstone struck the proximal end of a pebble stone at point X_1. This application of pressure creates a main direction of force that extends down the X axis from points X_1 to X_2. Second, because this study deals with bipolar technology there will, therefore, be a second direction of force referred to as the rebound force (Rf), which is initiated at point X_2. Rebound force (Rf) will occur when the applied force (Af) emanating down the X axis strikes another object, such as the anvil upon which the pebble stone was in contact, rebounding some of the force back along the X axis from points X_2 to X_1.

The above implies that the processes described refer to a straight linear longitudinal line of force from the point of impact on the proximal end of the pebble stone to the point of contact where the specimen rests on the anvil and back again. This is in fact, far from the actual processes that take place as the above applies only to the primary direction of force. Other factors that control the shearing of a pebble stone are the secondary wave fronts or stress waves in relation to the specimen's overall dimensions (the ratio of a pebble's width along its Y axis to its thickness along the Z axis and its length along the X axis).

Speth (1972: 36-37) notes that stress waves will transmit a disturbance that is analogous to dropping a pebble on a water surface. As one would expect, longitudinal waves emanate from the point of impact in the direction of the wave front (Figure 5.2.).

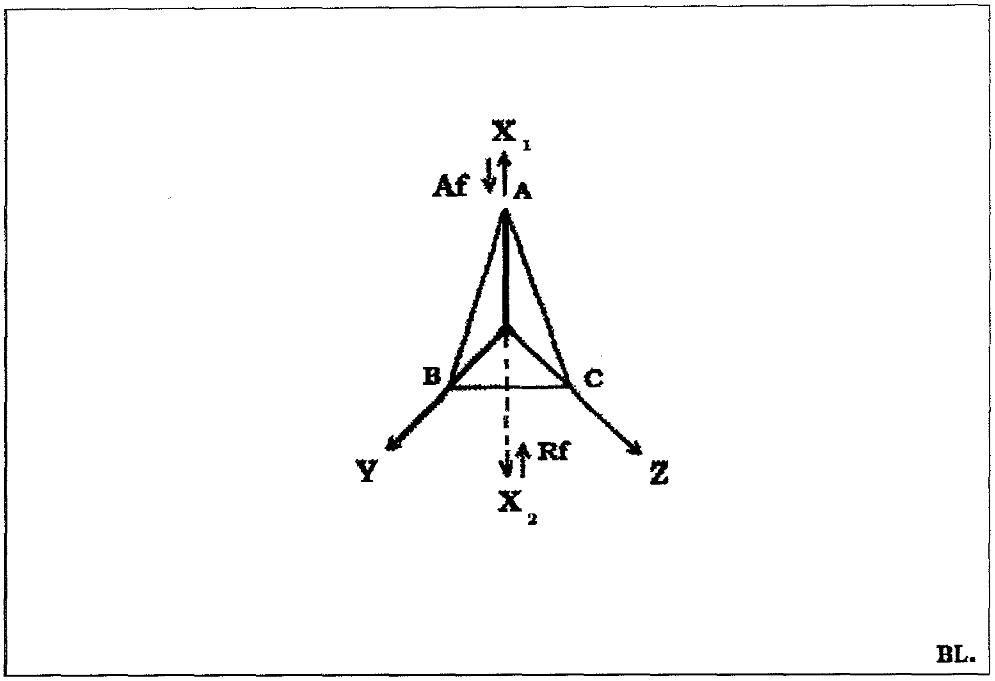

Figure 5.1. Direction of applied and rebound force (modified from Pursh 1995: 137).

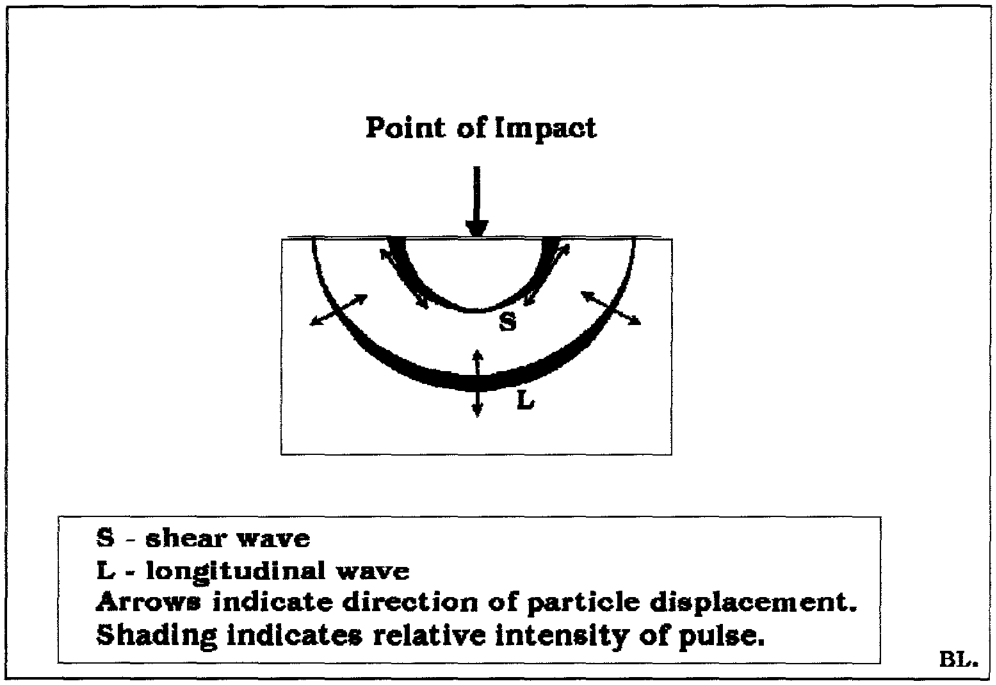

Figure 5.2. Propogation of spherical longitudinal and shear waves into an elastic solid (modified from Speth 1972:35).

Longitudinal waves cause the displacement of particles in a direction parallel to the wave front. Speth (1972: 36) states that "the maximum intensity of stress in the longitudinal wave is directly along the line of impact."

Alternatively, shear waves travel out from the point of impact causing the displacement of individual particles within the specimen perpendicular to the direction of the wave front (Speth 1972: 37). Therefore, "the maximum intensity of the stress in the shear wave lies along a line perpendicular to the axis of maximum intensity of the longitudinal wave" (Figure 5.2.). This process has varying affects, between the cylindrical symmetry around the Y and Z axis of a pebble and the fracture or shear properties of a specimen. The rounder or more symmetrical the specimen the more frequently it will likely shatter, whereas, a more asymmetrical pebble will more frequently shear transversely into two sections longitudinally down the X axis and parallel to the Y axis.

Cotterell and Kamminga (1987: 698-699) have also described the above phenomenon in relation to pebble stones. They state that a form of wedging occurs when a nucleus is subjected to end-loaded compression (Cotterell and Kamminga 1987: 688). In this instance, wedging refers to the surface area that deforms plastically, or penetrates the specimen, at the point of impact by a hammerstone creating an indentation, or wedging action, into the material (Figure 5.3). They state, as illustrated in Figure 5.4, that "compression-controlled crack propagation occurs in bipolar flaking and . . . the nucleus is usually split into two or

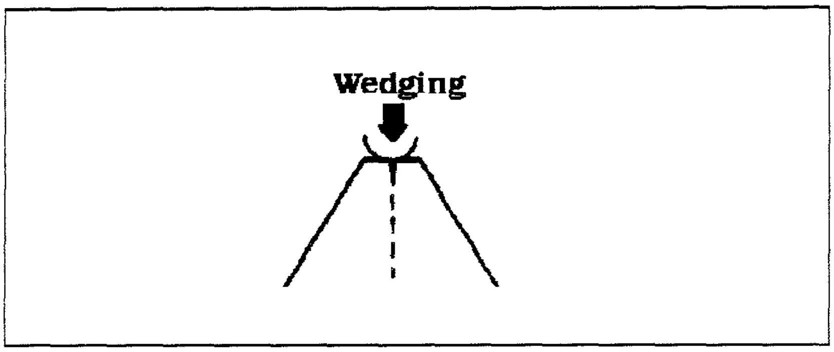

Figure 5.3. Wedging initiation at point of impact (from Cotterell and Kamminga 1987: 684).

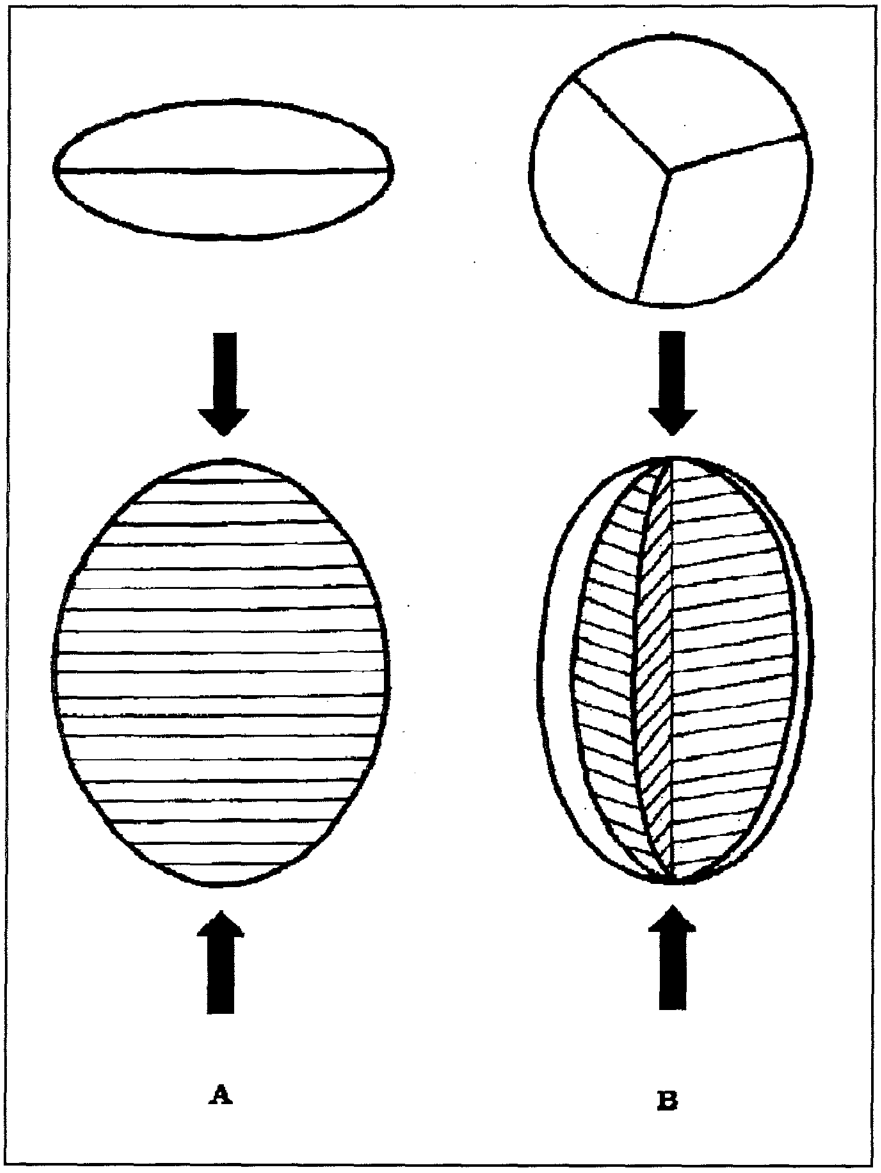

Figure 5.4. Pebble stone compression fractures (from Cotterell and Kamminga 1987: 699).

three fragments of roughly equal size" ending in an axial termination (Cotterell and Kamminga 1987: 698). In this instance the flat pebble illustrated in Figure 5.4:A has sheared longitudinally and transversely ending in an axial termination. The ellipsoid pebble illustrated in Figure 5.4:B displays linear longitudinal citrus-section fractures (these will be addressed in Section 6). The third alternative is for the specimen to shatter. Cotterell and Kamminga (1987: 699-700) further note that the bipolar technique is one of the rare circumstances were compression-controlled propagation can occur and that axial terminations are common.

If we study the process involved in this more closely we can see, as illustrated in Figure 5.1, that an impact on the top of a pebble sends a primary line of force longitudinally through the material along its X axis. However, spherical waves also emanate from the point of impact extending away from the point of disturbance in wave fronts (Konopinski 1969: 439; Rinehart 1960). Figure 5.2 and 5.5 illustrate the planar and spherical flow of the wave fronts as they move away from the point of impact. These wave fronts are in the form of transverse stress waves that move along a linear line away from the source of disturbance and longitudinal waves that form a curvature as they emanate from the point of impact. Additionally, these waves do not remain static, but rather pulse or oscillate as illustrated in Figure 5.6. As outlined, although the general movement of force away from the point of impact may be in a generally linear direction the force waves emanating from that point are anything but static.

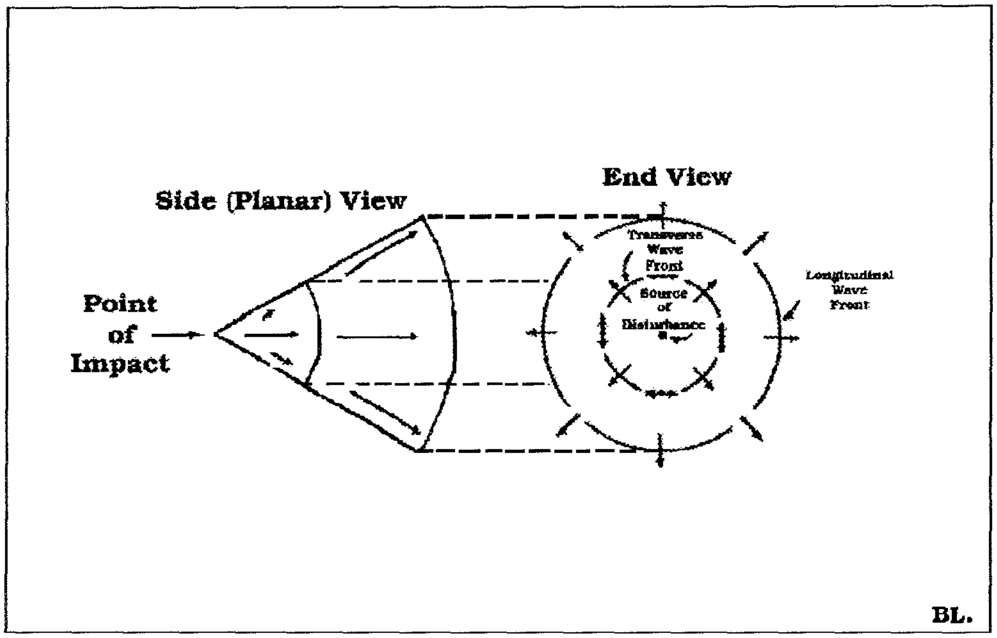

Figure 5.5. Divergence of spherical wave fronts (modified from Rinehart 1960:4, 177).

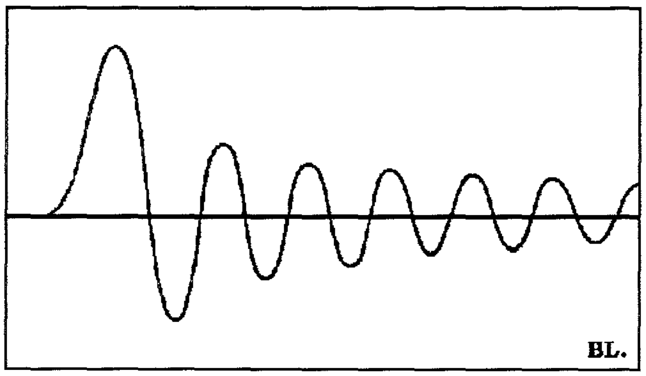

Figure 5.6. Pulse wave front (modified from Konopinski 1969: 482).

The affects of the spherical nature of these wave fronts as they emanate through the specimen will have a variable outcome that is dependent on the overall body shape of the material. It has been noted that with regard to pebbles this outcome would vary depending on whether the pebble was thin compared to its width, having a more flattened shape, or if the specimen was quite round and circular being shaped more like an ellipsoid. If we observe the first example in more detail, as illustrated in Figure 5.7:A-D, we can see that the major reflection of the spherical wave front expands across the Y axis, emanating down from the point of disturbance, and reaching its maximum extent at the mid-section of the pebble. To this point, side reflections even across the Y axis are small with little peripheral disturbance, however, once the spherical wave passes through the mid section of the pebble the frontal portion of the wave decreases in size as it is compressed into the lower end of the pebble and the rear area of the wave is reflected back into the specimen (Figure 5.7: E-F). Side reflections across the Y axis now intensify.

If the above processes are applied to pebble splitting using the bipolar technique, it was noted that as the head-on force exited the bottom of the pebble it entered the anvil upon which the pebble rested, also creating a compression at the point where the pebble contacted the anvil. This compression is created by the energy collected within the anvil being rebounded back into the specimen. With pebbles of a flattened shape the tendency is for them to shear longitudinally down the X axis and transversely across the Y axis (Figure 5.4:A and 5.7:G). This occurs because,

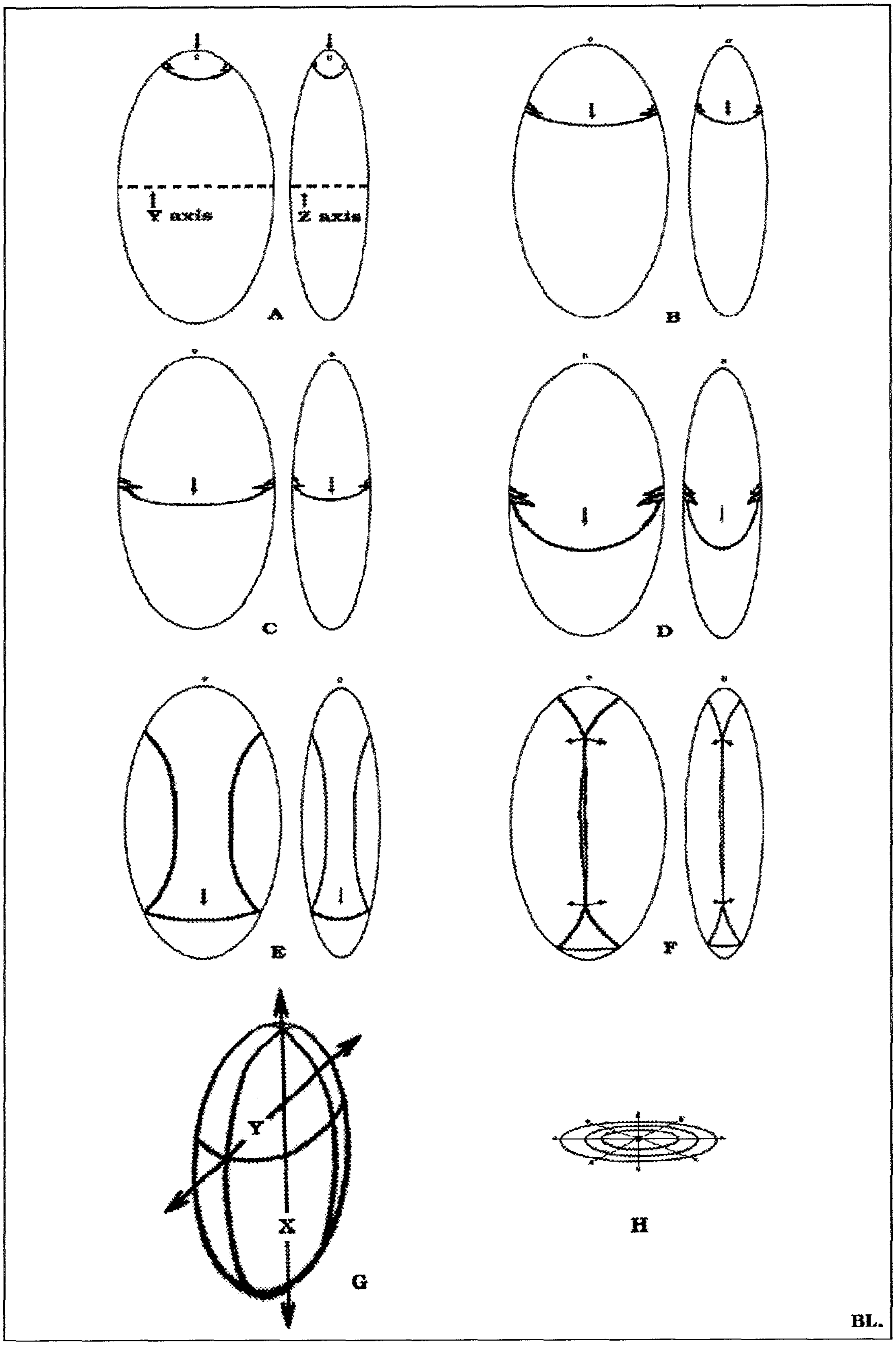

Figure 5.7. Spherical wave movement in an oval shaped body (modified from Pursh 1995:137 & Rinehart 1960: 4, 113, 114).

although force is being applied to all points of the pebble (Figure 5.7:H), most of the wave movement and the major application of force being exerted is transversely across the Y axis and thus the pebble will shear in this direction.

With a circular, ellipsoid body the force wave is initially reflected down through the specimen in much the same manner as the previous examples illustrated in Figure 5.7. However, the major difference is that the spherical waves are allowed to pass through a larger portion of the material (Figure 5.8:C) before the side reflections create the lower compressional waves that are reflected back into the material (Figure 5.8:D-E). With this body shape this tends to create a highly variable area of central pressure within the material (Figure 5.8: C and F) as the force waves emanate away from the point of contact and compressional waves are reflected back into the pebble. The areas of compression where the pebble contacts the anvil and the rebound force are also dispersed back into the pebble. When the force being applied exerts an irregular amount of pressure within the material, as it does when the pebble is a circular ellipsoid, then the specimen will tend to shatter in random, highly variable pieces or, occasionally, fracture into several linear citrus-sections (Figure 5.4:B).

It should be noted here that the force processes outlined above relate only with materials that have pressure applied while the specimens are in contact with an anvil. If an anvil is not used during the knapping operation, such as direct percussion with hand held materials, then the applied force just dissipates

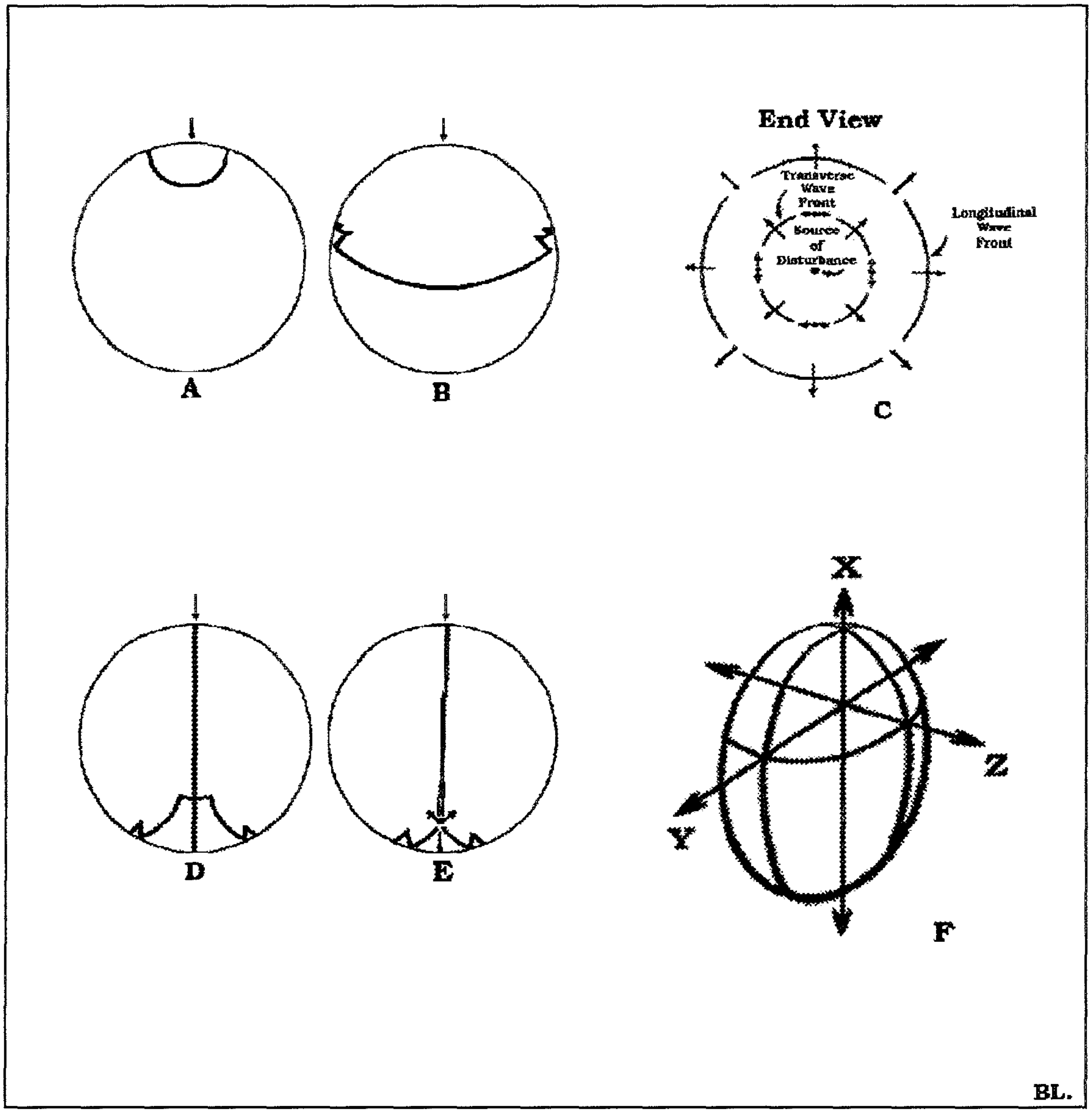

Figure 5.8. Spherical wave movement in a circular shaped body (modified from Pursh 1995: 137 & Rinehart 1960: 4, 112).

departing out the distal end of the specimen. Additionally, these processes apply to materials that remain intact while the force waves pass through the specimen. Occasionally, small proximal and distal flakes will detach following an impact that alters the shape of the pebble and thus changes the dispersal pattern of the applied and rebound force waves.

6. ANALYSIS: EXPERIMENTAL REPLICATION

6.1 Analysis of Replicative data

The data base used here for the experimental portion of this thesis consists of 521 bipolar replications with pebble stones. Variables recorded include: the original pebble dimensions (length [X axis], width [Y axis], thickness [Z axis]) and ten technological classes (identified below).

Multivariate attributes recorded for classes 1-5 include: proximal impact crushing (PIC), distal impact crushing (DIC), percussion lines extending distally (PLED), proximal bulb of percussion (PBP), distal bulb of percussion (DBP) and other miscellaneous flake scars. Proximal and distal impact crushing was noted as readily visible (x), slight damage barely visible (s) or not visible (n) through a hand lens. Percussion lines were recorded as pronounced (pr), diffuse (d) or not visible (n). Bulbs of percussion are identified as being sheared (sh), pronounced (pr), negative inverted (i) or not visible (n).

Other attributes recorded include irregular sheared surfaces (is) and flake scars identified by their position (for example, vfr/d = ventral flake removed/dorsally). Classes 6-10 include shattered specimens and those that sheared incompletely or fractured irregularly.

6.1.1 Analysis of identifiable multivariate attributes produced during experimental bipolar reduction.

The attributes were selected based on several criteria. One, I selected those attributes that I felt would occur most frequently. Two, they needed to be in such combinations as to be able to differentiate between bipolar and non-bipolar materials. Three, the list needed to be of manageable proportions, that is, easily used and interpreted. I believe the attributes used meet the above criteria. Furthermore, within the attribute tables I have listed the specimen's number, material type and source (area of collection). Material types were listed during the experimental replications so that differences between them could be identified. The only observable difference I noted was that the silicified siltstone and generic cherts were fine grained enough to display various ventral attributes, whereas, the generic, quartzite and quartz materials were so hard and coarse grained that surface attributes rarely occurred. I previously noted this characteristic as the primary reason for mainly selecting the silicified siltstone materials for the actual experimental replications. Source areas were noted as I was not sure before the replications if, for example, silicified siltstone pebbles collected from the North Saskatchewan River, Saskatchewan, or from Grassy Island Lake, Alberta, would react differently. As it turns out, materials of analogous composition exhibited the same attributes and fracture habits regardless of its source of collection.

It was decided that pebble dimensions should be included when it was observed that body form appeared to play a significant role in the final product when attempting to split a pebble using the bipolar technique. Therefore, length, width and thickness were recorded and assigned the designations of X axis (length), Y axis (width) and Z axis (thickness). These data could be used with future research to determine if there is an optimum ratio of length, width and thickness at which a pebble will shear, or for that matter at what ratio the pebble will shatter.

The following characteristics all relate to the ventral surface attributes of the split pebble stone materials following the experimental replication. These attributes are recorded for all complete split pebble sections (for example, within Class 2 these attributes are recorded for both the left and right split pebble sections of the specimen). Illustrations of these attributes are not provided here as the figures in the next section, which discuss the technological classes, will also illustrate and address these features.

6.1.1.1 Proximal impact crushing (PIC) occurs when the hammerstone strikes the top of the pebble driving the force down into the specimen. Even with a controlled strike the impact of the hammer against the pebble is sufficient to crush a small amount of the material at the point of impact. Even if no other attributes are visible this attribute will indicate the point at which the initial impact occurred. In only a few rare instances was this attribute not visible through a hand lens.

6.1.1.2 Distal impact crushing (DIC) occurs when the force of striking the pebble with a hammerstone drives the specimen into the anvil upon which it rests. The initial force being applied to the pebble results in a small area of the material being crushed at its point of contact with the anvil. This attribute occurs almost as frequently as does PIC. When DIC is present, especially in association with PIC on one specimen, it can be concluded that the piece in question is a bipolar by-product. This can be stated because DIC can only occur from a specimen that has been struck on the proximal end while the distal end was in contact with an anvil.

6.1.1.3 Percussion lines extending distally (PLED) were noted as such so that there would be no confusion that these force lines extended down from the point of impact at the proximal end of the pebble and not up from the anvil's rebound force. Originally I had expected that I would need a category for percussion lines that extended towards the proximal end, but this characteristic was identified in only three specimens. Those pieces fractured irregularly and will be discussed in the next section. Pronounced percussion lines occurred often, although diffuse force lines did occur more frequently. Regarding the 259 pebbles that had at least one complete surface, pronounced percussion lines were identified in 48, and diffuse force lines in 71, specimens. One hundred and forty of the replicated specimens displayed no visible percussion lines.

6.1.1.4 Proximal bulbs of percussion (PBP) occur on the ventral surfaces of some split pebbles below the point of impact of the applied force. In a replicative study of lithic percussion techniques by Herbort (1988: 36) he noted that force bulbs characteristic of direct percussion do not exist on bipolar materials. Percussion bulbs are positive conchoidal bulges caused by impact on many siliceous stones. However, the experimental replicative materials outlined here clearly illustrate that not only do they form on bipolar materials, but they tended to vary considerably as well.

Only three specimens with pronounced positive bulbs of percussion were identified among all the materials experimentally replicated here. It is likely that the controlled impact I was using to apply pressure to split the pebbles was insufficient to produce this attribute. With straight percussion knapping a considerable amount of force is applied to a piece of raw material. If that amount of force was applied to a pebble stone in contact with an anvil the specimen would be crushed into numerous pieces of shatter.

Diffuse positive proximal bulbs of percussion were recorded on 43 specimens. Additionally, 108 of the specimens (with at least one complete section) displayed no visible (n) proximal bulbs of percussion.

Proximal bulbs of percussion generally can not be used to distinguish bipolar from straight percussion materials with one exception. That is, sheared (sh) proximal bulbs of percussion are distinctly bipolar. This is essentially what Crabtree (1972: 41) identifies as a split cone. With a sheared bulb of percussion the tightly compressed percussion lines forming the bulb can be readily identified but the distinguishing positive bulge is not present. Rather, the bulb area is flat having been sheared straight through the feature. Furthermore, sheared bulbs occurred only on the proximal ends of the specimens analyzed here and when it was identified on one section of a split pebble it was usually recorded on the other accompanying half. As noted, this attribute appears to be uniquely a bipolar feature. Sheared bulbs occurred on 13 of the experimentally replicated materials.

Another attribute that appears quite frequently among the experimental materials analyzed is a negative inverted bulb of percussion. With negative inverted bulbs of percussion the typical positive bulge that would extend out from the ventral surface of a flake in a small convex mound is concave, or inverted, fading into the ventral surface of the flake (or in this case the split pebble half). A negative inverted bulb of percussion frequently occurred in association with an opposing diffuse positive bulb on the contrasting section of the opposite split pebble half.

6.1.1.5 Distal bulbs of percussion (DBP) incontrovertibly identify specimens as being derived from bipolar technology. This is because a distal bulb of percussion can only be derived from a force opposite to, or opposing, the applied force, such as the rebound force emanating back into a pebble stone that is in contact with an anvil and has had pressure applied to its proximal end. Only by having opposing waves of force at both ends of the material can a distal bulb occur. Distal bulbs of percussion generally truncate the distally extending percussion lines in an opposing direction. That is, the distal bulb of percussion extends into the percussion lines truncating them. If this situation occurs then it is certain that a bulb of percussion is located on the distal end of the specimen and, in fact, this characteristic occurred in 21 specimens. It is also noteworthy that in 16 of these cases a positive distal bulb occurred on one half and a negative inverted bulb on the other. No positive pronounced or sheared bulbs were present on the distal end of any of the specimens analyzed.

6.1.1.6 An "other" category was used so that the numerous miscellaneous flake scars that occurred during the experimental replications could be identified. These flakes are all outlined in Table 6.1, which is a summary of the abbreviations that I used within the other tables. The detachment of flakes during experimentation was recorded, as noted in Table 6.1, but since they were subsidiary to the actual analysis I was undertaking they were given no further consideration other than noting their location of detachment. For example, vfr/d refers to a ventral flake that was removed from the dorsal end of the specimen during the experimental replication and rlfr refers to the removal of a flake from the right lateral edge of the pebble stone.

6.1.2 Analysis of experimental bipolar reduction

During the definitive analysis of the 521 experimentally replicated materials I identified and recorded ten technological classes (these are identified below).

6.1.2.1 *Class 1:* Class 1 specimens (Table 6.2) consist of pebbles that are split longitudinally into two halves down the X axis and relative to the Z axis (thickness plane) with a ventral surface of AC (refer to Figure 4.1) and end in an axial termination. Both lateral halves are complete, although they are not generally of equal proportions. In fact, one half of the split pebble tends to

Table 6.1. Abbreviations used in Tables 6.2-6.11.

SSP	Silicified siltstone pebble stone
Qtz-ite	Quartzite
Gen Mat	Generic Material
NSKR	North Saskatchewan River, Saskatchewan
GIL	Grassy Island Lake, Alberta
FR	Fresno Reservoir, Montana
V	Ventral
D	Dorsal
L	Left
R	Right
L(X)	Length (X axis)
W(Y)	Width (Y axis)
T(Z)	Thickness (Z axis)
x	Visible through a hand lens
n	Not visible in hand specimen
is	Irregular shear surface
d	Diffuse
pr	Pronounced
i	Negative Inverted
sh	Sheared
s	Slight damage/barely visible
h	Hackles
PIC	Proximal impact crushing
DIC	Distal crushing
PLED	Percussion lines extending distally
PBP	Proximal bulb of percussion
DBP	Distal bulb of percussion
dft	Distal flake termination
dfr	Distal flake removed
pfr	Proximal flake removed
rlfr	Right lateral flake removed
llfr	Left lateral flake removed
dfr/p	Dorsal flake removed/proximally
dfr/d	Dorsal flake removed/distally
vfr/d	Ventral flake removed/distally
vfr/p	Ventral flake removed/proximally
dvfr/d	Dorsal and ventral flake removed/distally
vfr/dp	Ventral flake removed distally and proximally
dfr/pd	Dorsal flake removed/proximally and distally
fr/d	Flake removed/distally
vdfr/d	Ventral and dorsal flake removed/distally
dI	Intermidiate pebble diameter
dL	Longest pebble diameter
dS	Shortest pebble diameter

Table 6.2. Class 1 specimens split into two halves parallel to Z axis (thickness)

SP #	Mat. Type	Source	Dimensions (cm's)						PIC		DIC		PLED		PBP		DBP		Other		Style
			Original			(means)			L	R	L	R	L	R	L	R	L	R	L	R	
			L(X)	*W(Y)*	*T(Z)*	*L(X)*	*W(Y)*	*T(Z)*													
....**1**	SSP	NSKR	2.16	1.24	0.82				x	x	n	x	n	n	d	i	n	n			4
....**2**	SSP	NSKR	2.57	2	0.78				x	x	s	s	d	d	d	i	n	n			2
....**3**	SSP	NSKR	3.11	1.76	1.2				s	s	s	s	pr	pr	d	n	i	d	dfr/d/p	dfr/p	2
....**4**	SSP	NSKR	2.4	1.62	1.05				x	x	x	x	d	d	n	n	n	n	dfr/p		1
....**5**	SSP	NSKR	5.86	3.31	2.1				x	x	x	x	d	d	n	n	n	n	llfr	dfr/p	3
....**6**	SSP	NSKR	3.73	2.31	1.41				x	x	x	x	n	n	n	n	n	n	dfr/p	llfr	4
....**7**	SSP	NSKR	2.7	1.53	0.96				x	x	x	x	n	n	n	n	n	n			4
252	SSP	NSKR	2.21	1.56	1.21				x	x	x	x	n	n	n	n	n	n		dfr/d	1
253	SSP	NSKR	2.25	1.38	0.84				x	x	x	x	n	n	n	n	n	n	is	is	3
254	SSP	NSKR	2.6	1.8	0.97				x	x	x	x	n	n	i	d	n	n			1
....**8**	SSP	GIL	2.99	1.98	1.01				x	x	x	x	n	n	n	n	n	n		llfr	3
....**9**	SSP	GIL	3.23	1.7	0.77				x	x	x	x	n	n	n	n	n	n	vfr/p	vfr/p	3
..**10**	SSP	GIL	2.81	2	0.57				x	x	n	x	d	d	n	n	n	n			3
..**11**	SSP	GIL	2.13	1.85	1.02				x	x	n	n	d	d	n	n	n	n			1
..**12**	SSP	GIL	3.24	2.01	1.14				x	x	n	n	d	d	n	n	n	n	dfr/p		2
..**13**	SSP	GIL	3.66	2.12	1.31	Silicified			x	x	n	n	n	n	n	n	n	n	dfr/p		3
..**14**	SSP	GIL	3.15	2.13	1.16	Siltstone			x	x	x	x	n	n	n	n	n	n			3
..**56**	SSP	NSKR	4.72	3.49	1.13	Pebbles			x	x	s	s	pr	pr	n	n	n	n			3
..**60**	SSP	NSKR	2.35	1.9	0.85	**2.3**	**1.6**	**0.8**	x	x	n	n	pr	pr	n	n	n	n	dfr/p	dfr/p	1
..**15**	Qtz-ite	NSKR	2.8	1.66	0.86				x	x	x	x	n	n	n	n	n	n			4
..**16**	Qtz-ite	NSKR	3.14	2.25	0.71	Quartzite			x	x	n	x	n	n	n	n	n	n	dfr/p	dfr/pd	2
..**17**	Qtz-ite	NSKR	3.2	2.12	1.05	**3**	**1.9**	**1**	x	x	x	x	n	n	n	n	n	n	drf/d	dfr/d	1
..**18**	Gen Mat	FR	3.56	2.02	1.07				x	x	x	x	n	n	n	n	n	n	dfr/p		1
..**19**	Gen Mat	FR	4.07	2.75	1.26	Generic Mat.			x	x	n	n	n	n	n	n	n	n			3
..**20**	Gen mat	NSKR	3.55	1.85	0.89	**3.6**	**1.9**	**1**	x	x	x	x	n	n	n	n	n	n	dfr/d		3
																			vfr/p		

Table 6.2. Class 1 specimens split into two halves parallel to Z axis (thickness)

..22	Gen chert	GIL	2.65	1.79	1.08				x	x	s	s	n	n	n	n	n	n			3
..23	Gen chert	GIL	3.65	1.67	0.87				x	x	x	x	n	n	n	n	n	n			4
..21	Gen chert	NSKR	3.01	1.4	1.17				x	x	n	x	d	d	n	n	n	n	dfr/p	dfr	1
136	Gen chert	NSKR	2.3	1.7	0.99	Generic chert			x	x	x	x	pr	pr	n	d	n	n			3
137	Gen chert	NSKR	3.18	2.16	1.33	**2.9**	**2**	**1.2**	x	x	n	n	pr	pr	d	n	n	n			2
Grand Total (means)			2.67	1.7	1.08																

be proportionately larger than the other.

There are several factors largely responsible for this class of fracture. One determinant relates to impurities or irregularities within the material that produce a weak bond. This characteristic would allow the specimen to fracture prematurely along the weakly bonded area. Another factor relates to the irregular shape of the pebbles within this category, that is one that was not symmetrical in form. Therefore, rather that sitting squarely and evenly on an anvil a pebble with an irregular shaped end may have more pressure applied to a lateral edge rather than the center of the specimen. Many specimens within this class display several combined traits such as impurities and irregular shaped ends.

The 30 specimens from this class outlined in Table 6.2 include: 19 silicified siltstone, three quartzite, three genetic material and five genetic chert pebbles. Additionally, as outlined in Table 6.2, it can be seen that all materials exhibit proximal impact crushing and all but four specimens display distal impact crushing. Only one specimen, number 3 (Figure 6.1) displays pronounced percussion lines, seven others exhibit diffuse percussion lines and the remainder show no evidence of percussion.

Specimens 1 (Figure 6.2), 2 (Figure 6.3), 3 (Figure 6.1), and 254 exhibit diffuse or negative inverted proximal bulbs of percussion and specimen 3 (Figure 6.1) also displays a diffuse positive distal bulb of percussion on one half and a negative inverted distal bulb of percussion on the other. (All specimens are

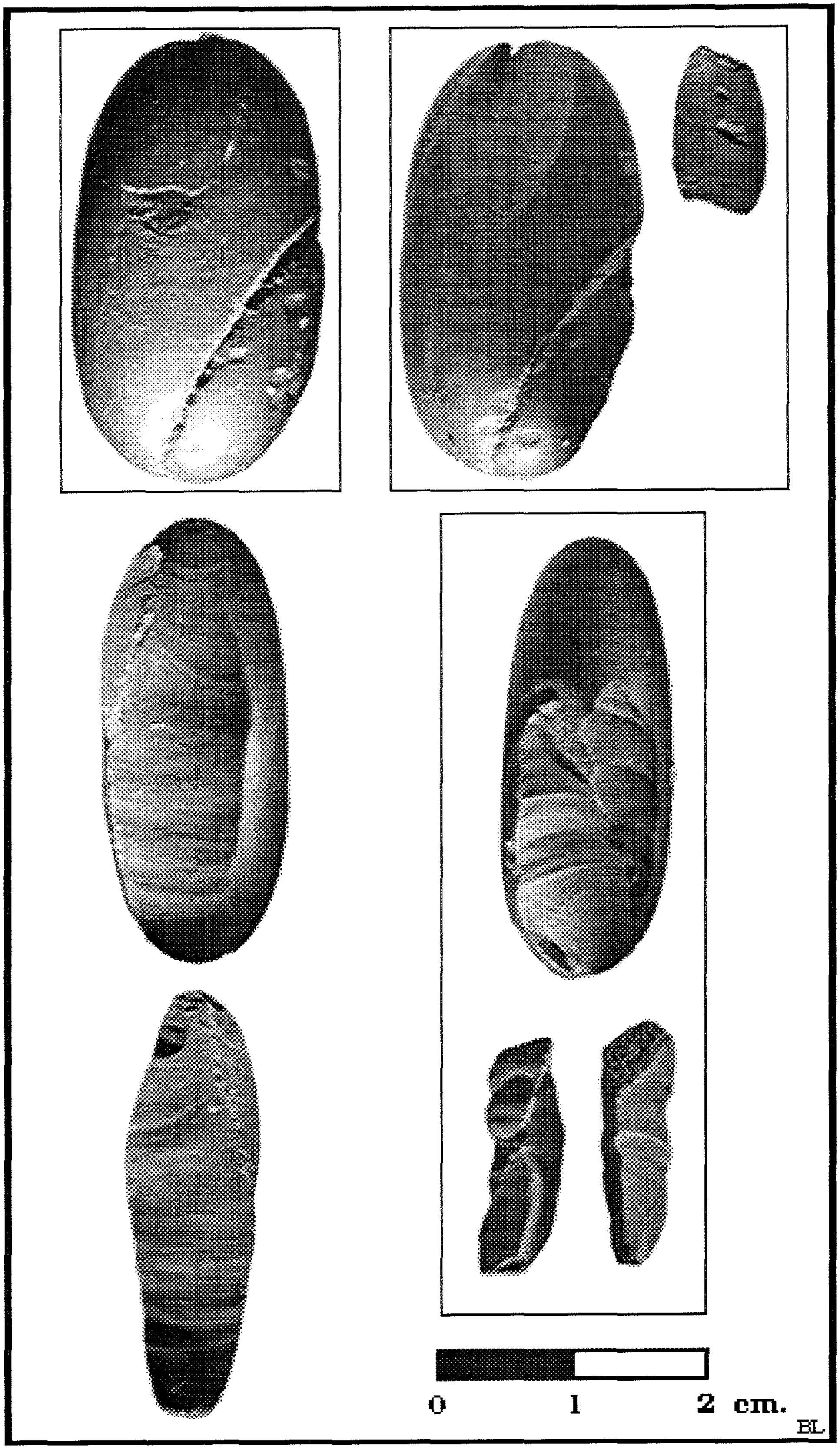

Figure 6.1. Class 1 silicified siltstone pebble - split parallel to the Z axis - Style 2 (specimen 3).

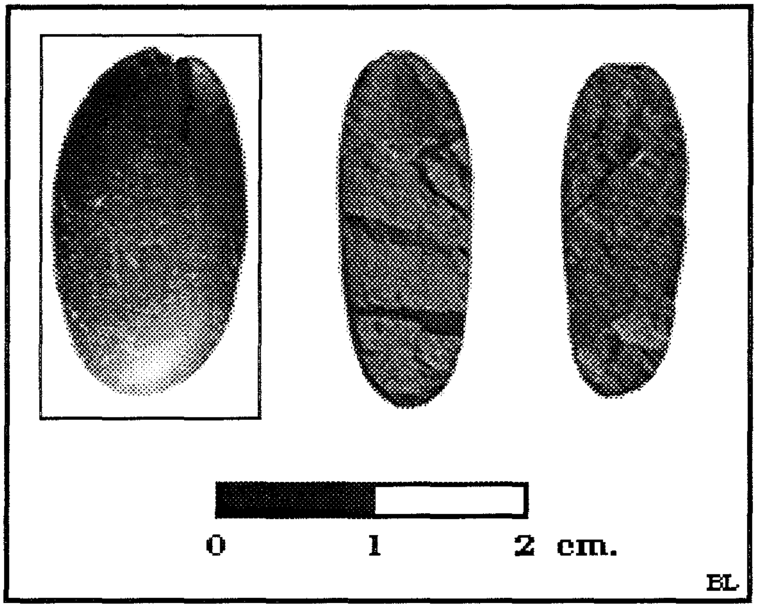

Figure 6.2. Class 1 silicified siltstone pebble - split parallel to the Z axis - Style 4 (specimen 1).

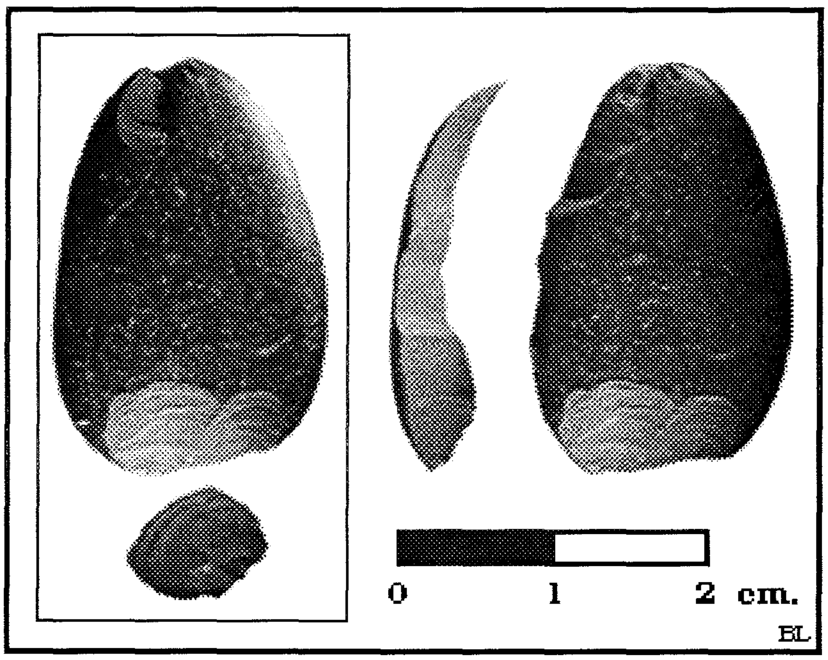

Figure 6.3. Class 1 silicified siltstone pebble - split parallel to the Z axis - Style 1 (specimen 2).

displayed with the proximal end up).

Additionally, numerous small flakes were detached from the ventral and/or dorsal surfaces on several specimens during the experimental replications.

Although the general trend within this category is for the pebble to shear transversely across the Y axis there are actually four styles of breakage pattern in this class. The first occurs in specimens that are relatively thin in relation to their width and have small impurities present. With style 1 specimens the main body of the pebble remains generally intact with a thin curved flake being removed from one outer lateral edge. Figures 6.3 and 6.4 exhibit this style. This is an unusual characteristic of bipolar materials as flakes usually tend to be flat ventrally, an observation also recorded by Herbort (1988: 36) who noted that bipolar flakes tended to be flat in cross-section and not curvate.

With the specimen in Figure 6.3 the impurities along the distal end caused several dorsal flakes to be removed. This permitted the applied force to be transferred to the lateral edge of the pebble, thus dislocating the small curved flake from the body of the specimen.

With regard to the specimen in Figure 6.4 a similar situation occurred except that the impurities caused the dorsal flakes to be removed from the proximal end of the pebble. It is believed that this caused the same transference of the applied pressure to the outer edge of the pebble, and therefore, shearing the small curved flake from the body of the specimen.

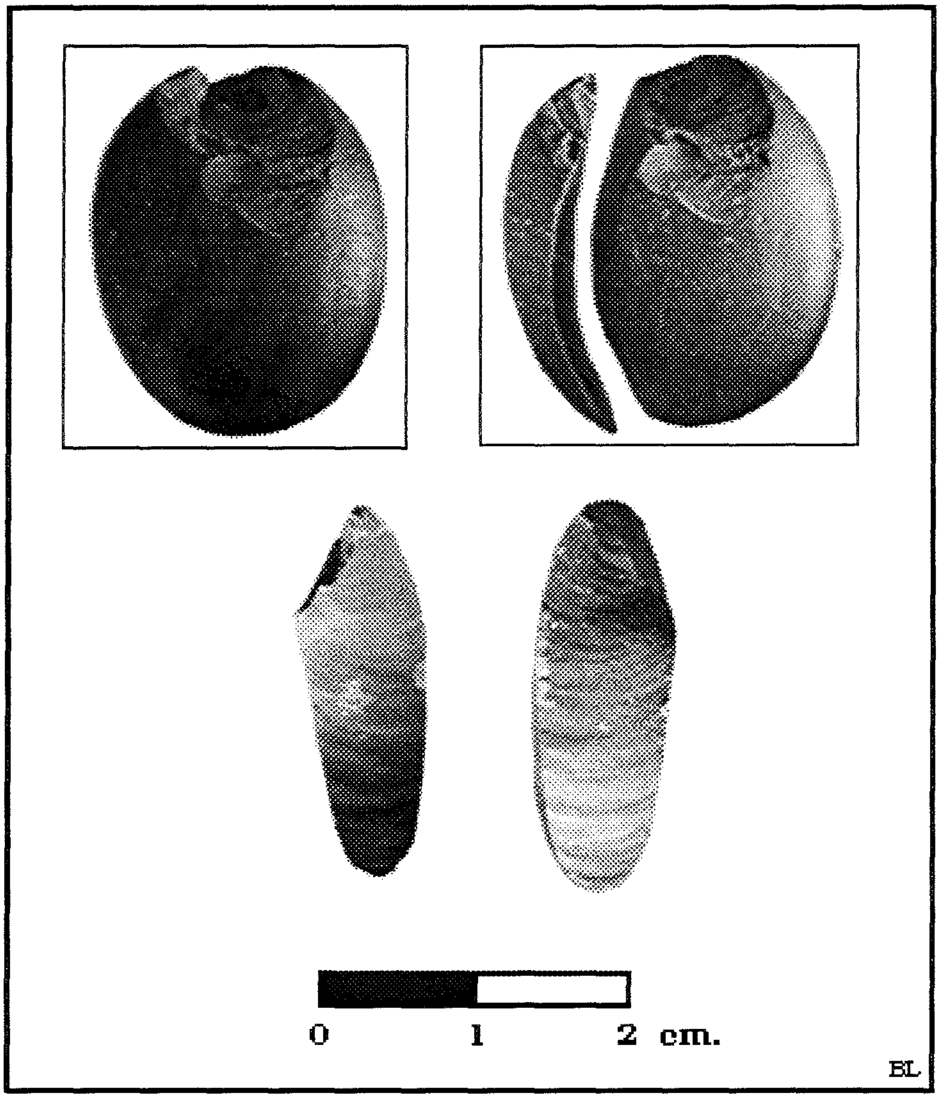

Figure 6.4. Class 1 silicified siltstone pebble - split parallel to the Z axis - Style 1 (specimen 60).

Style 2 specimens also have flakes removed from a lateral edge but rather than being curved they are quite linear in form and flat ventrally. As noted above this is the standard form of cross-section present among the bipolar materials represented here. Figure 6.1 illustrates one of these that has a number of visible impurities in the pebble. One long flake was removed from the lateral edge and several small dorsal flakes removed distally and proximally. Figure 6.5 is another illustration of one of these specimens. In this case it is likely the irregular shaped bottom that allowed the majority of the applied pressure to pass down the one lateral edge of the pebble removing one long linear flake from that side of the specimen.

The next style of shear in Class 1 appears to be caused primarily from material impurities although these specimens also have irregularly shaped ends. Style 3 specimens all shear longitudinally, but across the pebble at a slightly diagonal angle to the Z axis. In all cases represented among the materials here there is an irregular sheared surface on the ventral faces of the split pebble halves. This is likely a consequence of the impurities in the material. Figures 6.6, 6.7 and 6.8 illustrate this shear style.

The final specimens in this class display shears parallel to the Z axis. Style 4 specimens split the pebble into nearly equal halves parallel to the Z axis in long straight linear flakes. Figures 6.2 and 6.9 illustrate two of these specimens. It can be seen that the ventral flake surfaces have sheared irregularly, but relatively straight through the pebble.

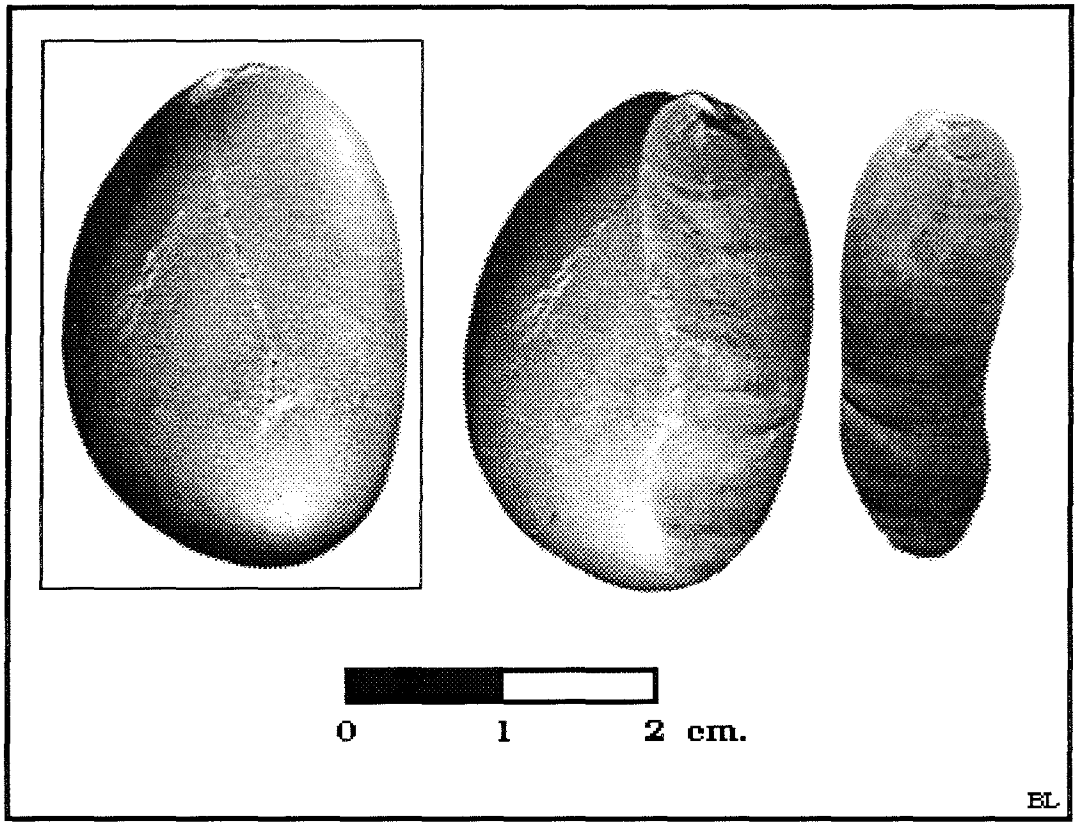

Figure 6.5. Class 1 generic chert pebble - split parallel to the Z axis - Style 2 (specimen 137).

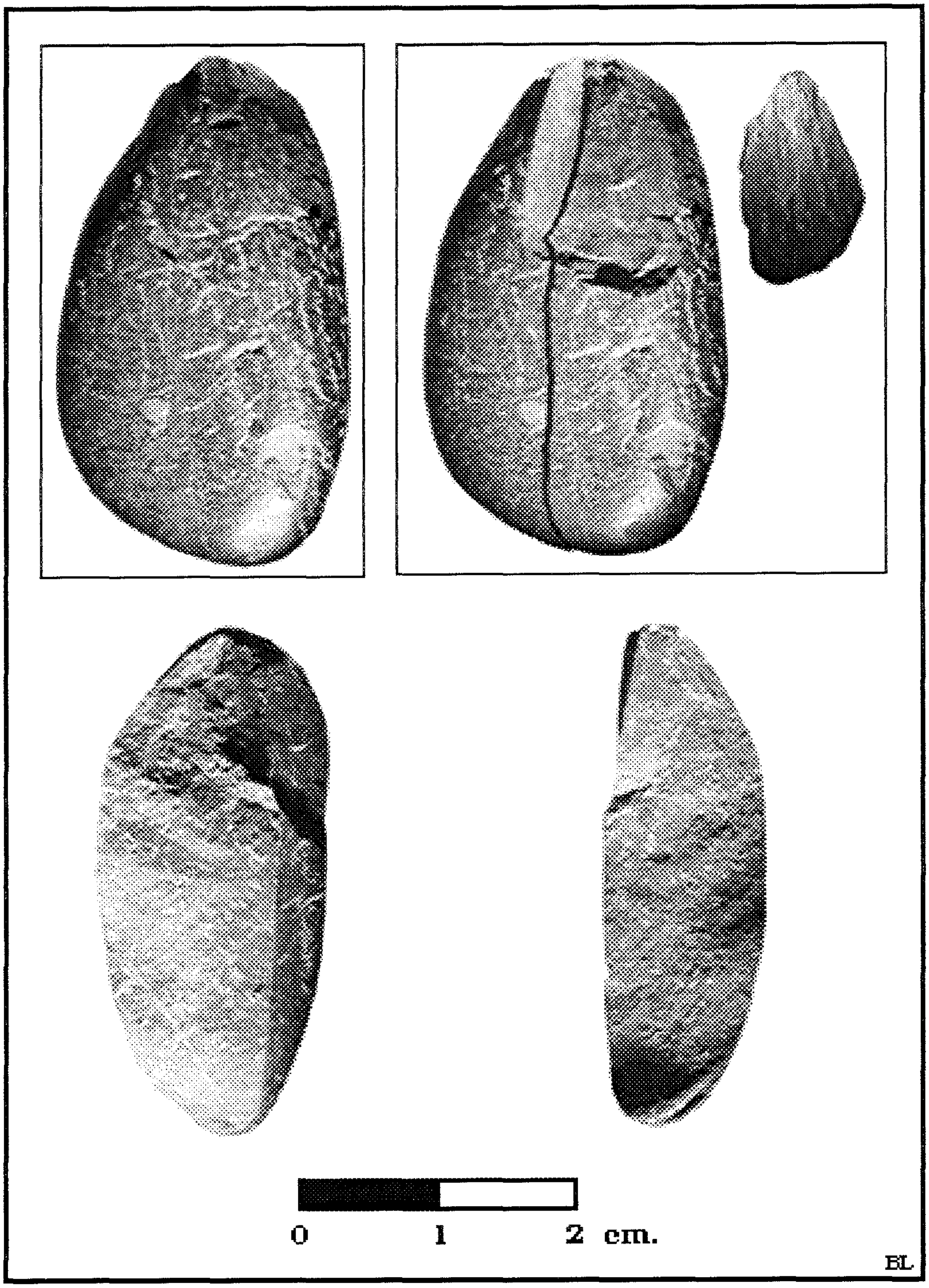

Figure 6.6. Class 1 silicified siltstone pebble - split parallel to the Z axis - Style 3 (specimen 13).

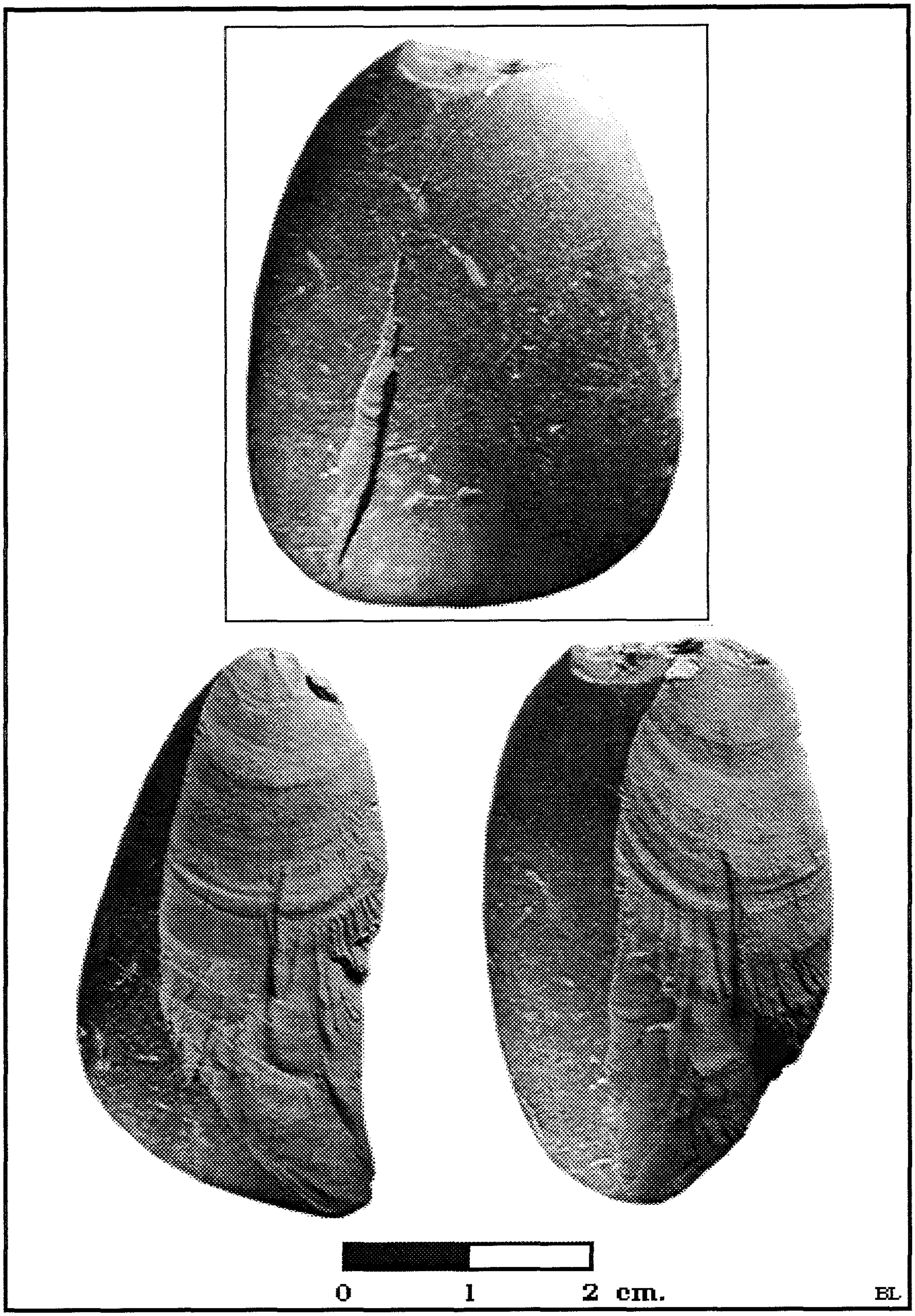

Figure 6.7. Class 1 silicified siltstone pebble - split parallel to the Z axis - Style 3 (specimen 56).

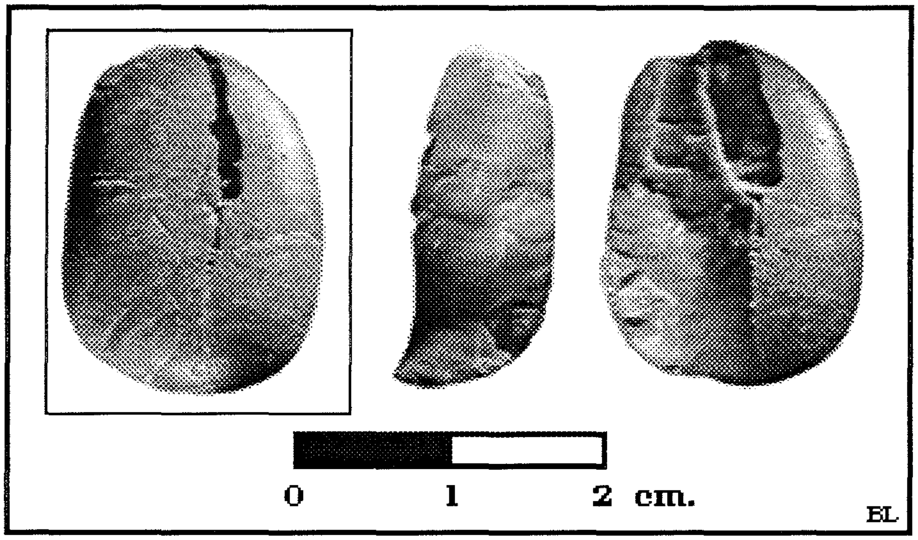

Figure 6.8. Class 1 generic chert pebble - split parallel to the Z axis - Style 3 (specimen 136).

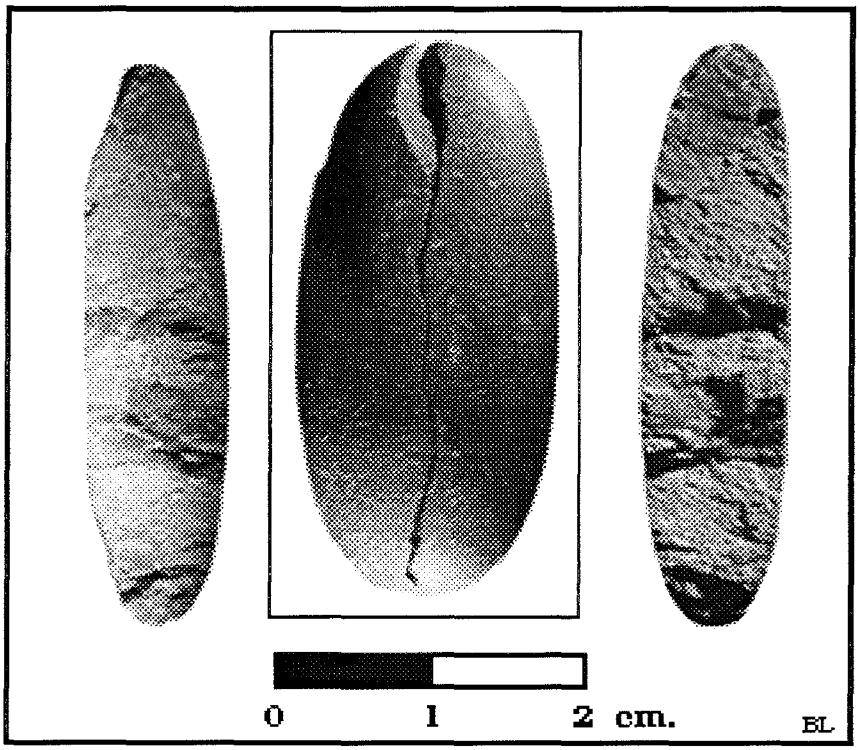

Figure 6.9. Class 1 generic chert pebble - split parallel to the Z axis - Style 4 (specimen 23).

The ratio of thickness to the width is a little larger with these specimens and it is believed that this has allowed for slightly more applied force to be dispersed through the Z axis. The extra force emanating across the Z axis combined with the impurities caused the pebble to shear in this manner. Class 1 specimens comprised 5.8% of the total experimental data set.

6.1.2.2 *Class 2* materials (Table 6.3) include pebbles that are split into two halves longitudinally down the X axis and transversely across the Y axis, ending in an axial termination, with both halves of the specimen complete. There are a total of 162 specimens in this class consisting of: 96 silicified siltstone, 37 generic chert, 15 generic material, 10 quartzite and 4 quartz pebbles. All Class 2 specimens display some proximal and distal impact crushing. Seventy-one (43.6%) of the Class 2 specimens exhibit percussion lines with 24 (14.8%) of those displaying pronounced lines of force. Three types of percussion bulbs were identified among the Class 2 materials: sheared, positive diffuse, and negative inverted. Strongly pronounced positive bulbs of force did not occur among the Class 2 materials and, in fact, this trait occurred among only three of the replications analyzed here.

A frequent attribute occurrence among the Class 2 materials are two bulbs of percussion on the same section. This characteristic has been noted by previous researchers as a rarely occurring bipolar trait, however, with the experimental replications that I conducted using pebble stone materials this characteristic occurred on 9.4% of at least one split half of the overall data set and on 29.6% of the Class 2 materials. It can be

Table 6.3. Class 2 specimens split into two halves parallel to the Y axis (width)

SP #	Mat. Type	Source	Dimensions (cm's)						PIC		DIC		PLED		PBP		DBP		Other	
			Original			(Means)			L	R	L	R	L	R	L	R	L	R	L	R
			L(X)	*W(Y)*	*T(Z)*	*L(X)*	*W(Y)*	*T(Z)*												
..24	SSP	NSKR	2.6	2	0.88				x	x	x	x	n	n	n	n	n	n	h	h
..25	SSP	NSKR	2.5	1.6	0.76				x	x	s	n	n	n	i	d	i	d		
..26	SSP	NSKR	4.31	2.8	1.55				x	x	n	n	pr	pr	i	d	i	d		
..27	SSP	NSKR	3.32	2.1	1.13				x	x	s	s	pr	pr	i	sh	i	d		
..28	SSP	NSKR	3.15	2.17	0.75				x	s	x	x	pr	pr	i	d	n	n	h	h
..29	SSP	NSKR	2.53	1.87	0.7				x	x	s	s	d	d	n	i	i	d		
..30	SSP	NSKR	2.57	2	0.78				x	x	s	s	d	d	d	i	n	n		
..31	SSP	NSKR	4.1	3.44	1.4				x	x	n	n	d	d	n	n	i	d		
..32	SSP	NSKR	3.2	2.06	1.46				x	x	x	x	n	n	n	n	n	n		
..33	SSP	NSKR	2.8	2.4	1.7				x	x	s	x	n	n	d	i	i	d		
..34	SSP	NSKR	2.85	2.18	1.5				x	x	x	x	n	n	n	n	n	n		
..35	SSP	NSKR	2.35	2.06	0.87				x	x	n	x	d	d	n	n	n	n		
..36	SSP	NSKR	2.3	1.85	1.25				x	x	n	n	d	d	n	n	n	n		
..37	SSP	NSKR	2.51	1.7	0.8				x	x	n	n	pr	pr	i	d	n	n		
..38	SSP	NSKR	3.24	1.96	1.4				x	x	x	x	n	n	n	n	n	n	is	is
..39	SSP	NSKR	2.4	2.22	1.3				x	x	x	x	d	d	sh	sh	n	n	is	is
..40	SSP	NSKR	2.86	2.19	1.06				x	x	x	x	d	d	n	d	n	n		sf/d
..41	SSP	NSKR	2.06	1.99	1				x	x	x	x	n	n	n	n	n	n	dfr/p	
..42	SSP	NSKR	3.02	2.4	1.2				x	x	x	x	d	d	n	d	n	n	dfr/p	
..43	SSP	NSKR	2.36	1.8	0.9				x	x	x	x	n	n	n	n	n	n		dfr/d
..44	SSP	NSKR	2.6	2.3	0.89				x	x	x	x	d	d	n	n	n	n	is	is
..45	SSP	NSKR	3.26	1.56	1.3				x	x	x	x	n	n	n	n	n	n	is	is
..46	SSP	NSKR	3.51	2.7	1.31				x	x	x	x	n	n	n	n	n	n	dfr/d	

Table 6.3. Class 2 specimens split into two halves parallel to the Y axis (width)

..47	SSP	NSKR	2.6	1.85	0.87		s	s	n	n	d	d	i	d	n	n		dfr
..48	SSP	NSKR	2.19	2.17	0.86		x	x	x	x	pr	pr	d	n	n	n		
..49	SSP	NSKR	2.92	1.83	1.37		x	x	n	x	n	n	n	n	n	n	is	is
..50	SSP	NSKR	2.5	1.25	1.18		x	x	x	x	d	n	n	n	n	n	dfr/p	
..51	SSP	NSKR	2.6	1.65	0.96		x	x	x	x	n	n	n	n	n	n	dvfr/d	dft
..52	SSP	NSKR	3.6	1.7	1.15		x	x	n	x	d	d	n	n	n	n		
..53	SSP	NSKR	3.26	4.3	1.65		x	x	n	x	d	n	n	d	n	n		
..57	SSP	NSKR	2.61	2.2	1.16		x	x	x	x	n	n	n	n	n	n	llfr	rlfr
..58	SSP	NSKR	2.64	1.77	0.91		x	x	n	n	n	n	n	n	n	n		
..59	SSP	NSKR	2.02	1.72	0.85		x	x	n	n	n	n	n	n	n	n		dft
..61	SSP	NSKR	5.54	2.16	1.49		x	x	x	x	d	d	d	i	n	n	dfr/d	llfr
..62	SSP	NSKR	3.61	2.53	1.4		x	x	x	x	n	n	n	n	n	n	dfr/d	
..63	SSP	NSKR	2.51	1.9	1.13		x	x	x	x	d	d	n	n	n	n		
..64	SSP	NSKR	3.35	1.91	0.86		x	x	x	x	pr	pr	sh	sh	d	d		
..65	SSP	NSKR	2.23	1.86	0.61		x	x	x	s	pr	pr	sh	sh	d	i		
..66	SSP	NSKR	2.43	1.41	0.62		x	x	x	n	d	d	n	n	n	n	vfr/d	vfr/p
..67	SSP	NSKR	3.37	1.8	0.9		x	x	x	x	d	d	n	i	n	n	vfr/dp	vfr/d
..68	SSP	NSKR	2.4	1.35	0.68		x	x	x	n	d	d	n	i	n	n		
..69	SSP	NSKR	2.42	1.37	0.61		x	x	x	x	d	d	n	n	n	n	vfr/p	
..70	SSP	NSKR	3.01	2.14	1.06		x	x	x	x	d	d	n	d	n	i		vfr/p
..71	SSP	NSKR	4.08	3.3	1.31		n	n	n	n	n	n	n	n	n	n	is	is
..72	SSP	NSKR	1.96	1.82	0.71		x	x	x	x	n	n	n	n	n	n		
..73	SSP	NSKR	3.28	3.01	1.07		x	x	x	s	d	d	n	n	n	n		
..74	SSP	NSKR	2.36	2	1.02		x	x	x	x	n	n	n	n	n	n	is	is
..76	SSP	NSKR	2.36	1.72	0.86		x	x	x	n	n	n	n	n	n	n	vfr/d	
..77	SSP	NSKR	3.77	1.91	1.5		x	x	x	s	n	n	i	d	d	i	vfr/d	

Table 6.3. Class 2 specimens split into two halves parallel to the Y axis (width)

..78	SSP	NSKR	3.51	2.9	1.71		x	s	s	x	n	n	d	i	n	d	vfr/p	
..79	SSP	NSKR	3.37	2.22	1.58		x	x	x	x	n	n	n	n	n	n	is	is
..80	SSP	NSKR	2.16	1.73	0.58		x	x	x	x	n	n	n	n	n	n	vfr/dp	
..81	SSP	NSKR	2.44	1.67	0.96		x	x	x	x	n	n	n	n	n	n	vfr/pd	vfr/p
..82	SSP	NSKR	1.94	1.32	0.62		x	x	x	x	d	d	sh	sh	n	n		
..83	SSP	NSKR	2.59	1.53	1.07		x	n	x	x	n	n	n	n	n	i		
..84	SSP	NSKR	2.28	1.81	1.04		x	x	x	x	n	n	i	d	n	n		
..85	SSP	NSKR	2.88	1.55	1.49		x	x	x	x	n	n	d	i	n	n	vfr/d	vdfr/d
255	SSP	NSKR	3.31	2.72	1.92		x	x	x	x	n	n	n	n	n	n	rlfr	
256	SSP	NSKR	2.9	2.8	1.07		x	x	x	x	d	d	i	d	n	n		
258	SSP	NSKR	2.94	1.82	1.29		x	x	x	x	n	n	n	n	n	n	rlfr	vfr/d
521	SSP	NSKR	2.73	2.39	1.01		x	x	s	s	pr	pr	n	n	n	n		
206	SSP	NSKR	3.08	2.61	0.77		x	x	x	x	pr	pr	n	n	n	n	dfr/p	vfr/d
..87	SSP	GIL	2.5	1.67	0.74		x	x	x	x	n	n	n	n	n	n		
..88	SSP	GIL	2.55	1.73	0.64		x	x	x	x	d	d	n	n	n	n		
..89	SSP	GIL	3.52	4.4	1.5		x	x	x	x	d	d	i	d	n	n		dfr/p
..90	SSP	GIL	2.8	1.3	1.32		x	x	x	x	n	n	n	n	n	n		
..92	SSP	GIL	2.85	1.77	1		x	x	n	n	n	n	n	n	n	n		
..93	SSP	GIL	1.68	1.35	0.57		x	x	x	x	pr	pr	d	i	n	n		
..94	SSP	GIL	1.46	1.67	0.49		x	x	x	x	n	n	n	n	n	n	is	is
..95	SSP	GIL	1.87	1	0.65		x	x	n	x	pr	pr	i	d	n	n		
..96	SSP	GIL	2.94	2.17	0.75		x	x	x	x	pr	pr	i	d	n	n		
..97	SSP	GIL	2.84	1.46	1.15		x	x	n	n	d	d	n	n	n	d	dfr/p	
..98	SSP	GIL	2.73	2.34	1.31		x	x	x	x	n	n	n	n	n	n		dfr/d
..99	SSP	GIL	2.94	1.77	0.91		x	x	x	x	d	d	d	n	n	n		
100	SSP	GIL	3.58	2.04	1.41		n	n	n	n	n	n	i	d	n	n		

Table 6.3. Class 2 specimens split into two halves parallel to the Y axis (width)

101	SSP	GIL	2.58	1.58	0.77				x	x	x	x	d	d	d	d	n	n		
102	SSP	GIL	2.59	2.21	0.82				x	x	x	n	d	d	n	n	n	n	dfr/d	
103	SSP	GIL	2.44	2.12	0.6				x	x	x	x	d	d	n	d	n	n		
104	SSP	GIL	2.75	2.21	0.93				x	x	x	x	d	d	n	d	n	n		
105	SSP	GIL	2.7	2.23	0.94				x	x	s	x	n	n	n	n	n	n		
106	SSP	GIL	3.26	2.85	1.3				x	x	x	x	n	n	n	n	n	n	is	is
107	SSP	GIL	2.67	1.77	0.59				x	x	x	x	pr	pr	n	n	n	n	dfr/p	
108	SSP	GIL	2.65	1.76	0.73				x	x	x	x	n	n	n	d	n	n		
109	SSP	GIL	2.46	1.85	0.84				x	x	n	n	pr	pr	n	d	n	n		dft
110	SSP	GIL	2.84	2.06	1.05				x	x	x	x	d	d	n	n	n	n		
111	SSP	GIL	2.6	1.75	1.44				x	x	x	x	n	n	n	n	n	n		dfr
112	SSP	GIL	2.91	1.75	0.75				x	x	x	x	pr	pr	n	n	n	n		pfr
113	SSP	GIL	2.9	1.95	0.9				x	x	n	x	d	d	n	n	n	n		dfr
114	SSP	GIL	3.05	2.39	1.16				x	x	x	x	pr	pr	n	n	n	n	dfr/p	
115	SSP	GIL	2.56	1.31	0.8				x	x	x	x	pr	pr	n	n	n	n		
116	SSP	GIL	2.77	2.31	0.76				x	x	x	x	d	n	n	n	n	n	dfr/pd	
117	SSP	GIL	3.04	2.49	1.02				x	x	n	n	n	n	n	n	n	n		
118	SSP	GIL	2.59	1.94	0.74				x	x	x	x	n	n	n	n	n	n	dfr/d	
119	SSP	GIL	2.4	0.86	0.81	Silicified Siltstone			x	x	n	x	n	n	n	n	n	n		
120	SSP	GIL	2.4	1.81	1.04	Pebbles			x	x	x	x	d	d	n	n	n	n	dfr/p	
257	SSP	GIL	2.45	2.3	0.7	**2.53**	**2.2**	**0.79**	x	x	x	x	pr	pr	n	n	n	n	split laterally	
121	Gen chert	NSKR	3.31	2.07	0.84				x	x	s	s	pr	pr	n	n	n	n		
122	Gen chert	NSKR	3.1	1.67	0.86				x	x	x	x	pr	pr	n	n	n	n		
123	Gen chert	NSKR	2.87	1.53	0.87				x	x	x	x	d	d	n	n	n	n		
124	Gen chert	NSKR	2.41	1.67	0.56				x	x	n	n	d	d	n	n	n	n		dfr/d
125	Gen chert	NSKR	2.33	1.38	0.76				x	x	x	x	d	d	n	n	n	n		dfr/p

Table 6.3. Class 2 specimens split into two halves parallel to the Y axis (width)

126	Gen chert	NSKR	2.05	1.9	0.9		x	x	x	x	d	d	i	d	n	n	vfr/d	vdfr/d
127	Gen chert	NSKR	3.5	1.48	1		x	x	x	x	d	d	n	d	n	n		
128	Gen chert	NSKR	2.6	1.2	1.32		x	x	s	n	pr	pr	d	i	i	d		
129	Gen chert	NSKR	4.05	1.89	1.17		x	x	x	x	n	n	n	n	n	n		dfr/d
130	Gen chert	NSKR	2.4	1.41	0.89		x	x	x	n	n	n	n	n	n	n	is	is
131	Gen chert	NSKR	2.4	3	0.83		x	x	x	x	n	n	n	n	n	n	vfr/d	vfr/dp
132	Gen chert	NSKR	4.2	2.51	1.36		x	x	n	n	d	d	n	n	n	n		
133	Gen chert	NSKR	4.15	1.3	1.17		x	x	x	e	n	n	n	n	n	n	dfr/p	
134	Gen chert	NSKR	2.73	2.1	1.26		x	x	x	x	n	n	n	n	n	n		rlfr
135	Gen chert	NSKR	3.25	3.7	1.27		x	x	n	n	n	n	n	n	n	n		dft
138	Gen chert	NSKR	2.89	1.94	0.97		x	x	x	x	d	d	n	n	n	n		
139	Gen chert	NSKR	2.9	2.02	1.19		x	x	x	x	d	d	n	n	n	n	dfr/p	dfr/p
140	Gen chert	NSKR	3.79	1.81	1.06		x	x	x	x	d	d	n	n	n	n		dfr
141	Gen chert	NSKR	3.57	2.64	1.57		x	x	x	x	n	n	n	n	n	n		dfr/d
142	Gen chert	NSKR	3.32	1.69	1.34		x	x	x	x	d	d	n	n	n	n	dfr/p	dfr/p
143	Gen chert	NSKR	2.67	1.63	0.76		x	x	x	x	n	n	n	n	n	n		
144	Gen chert	NSKR	3	2.25	1.26		x	x	x	x	n	n	n	n	n	n	rlfr	llfr
145	Gen chert	NSKR	2.82	1.61	0.75		s	s	s	s	d	d	sh	sh	i	d		vfr/p
146	Gen chert	NSKR	2.8	2.13	1.63		x	x	x	x	n	n	n	n	n	n	rlfr	
147	Gen chert	NSKR	2.92	1.61	1.06		x	x	x	x	n	n	n	i	n	n	is	is-dfr/p
148	Gen chert	NSKR	2.1	1.35	0.43		x	x	x	x	n	n	n	n	n	n	fr/d	
148	Gen chert	NSKR	2.9	1.85	1.52		x	x	x	x	n	n	d	i	n	n	is	is
150	Gen chert	NSKR	3.3	1.51	1.76		x	x	x	x	d	d	n	n	n	n	fr/d	vfr/pd
151	Gen chert	NSKR	3.67	1.88	1.17		x	x	n	n	n	n	d	i	n	n	dfr/d	
152	Gen chert	NSKR	2.35	1.32	0.75		x	x	x	x	d	d	i	d	n	n	vfr/d	vfr/d
520	Gen chert	NSKR	2.76	1.66	0.76		x	x	x	s	pr	pr	sh	sh	d	i		

Table 6.3. Class 2 specimens split into two halves parallel to the Y axis (width)

153	Gen chert	FR	2.9	1.81	0.69				x	x	x	x	pr	pr	sh	sh	d	i	dfr/p	
154	Gen chert	FR	3.94	2.43	1.76				x	x	x	x	n	n	n	n	n	n		vfr/p
155	Gen chert	GIL	3.49	2.46	1.1				x	x	x	x	pr	pr	i	d	d	i		
156	Gen chert	GIL	2.64	2	1.25				x	x	n	n	n	n	n	n	n	n		dft
157	Gen chert	GIL	2.3	1.77	0.92	Generic chert			x	x	x	x	d	d	n	n	n	n		
158	Gen chert	GIL	4.04	2.71	1.48	**3.68**	**2.4**	**1.16**	x	x	x	x	n	n	n	n	n	n	rlfr	llfr
159	Gen Mat	NSKR	5.49	3.27	1				s	s	n	n	n	n	n	n	n	n		
160	Gen Mat	NSKR	3.86	3.39	1.22				x	x	n	n	n	n	n	n	n	n		
161	Gen Mat	NSKR	3	1.75	1.2				x	x	x	x	n	n	n	n	n	n		dfr/d
162	Gen Mat	NSKR	3.43	2.96	0.7				x	x	x	n	n	n	n	n	n	n	dfr/d	dft
163	Gen mat	NSKR	3.3	2.23	1				x	x	x	x	n	n	n	n	n	n		
164	Gen mat	NSKR	2.8	2.31	0.67				x	x	x	x	n	n	n	n	n	n		
165	Gen mat	NSKR	6.4	3.81	1.51				x	x	x	x	n	n	n	n	n	n	dfr	
166	Gen Mat	FR	4.49	2.86	1.7				x	x	x	x	n	n	n	n	n	n	dfr/d	
167	Gen Mat	FR	2.6	2.86	0.7				x	x	x	x	n	n	n	n	n	n		
168	Gen Mat	FR	3.21	2.85	0.73				x	x	x	x	n	n	n	n	n	n		
169	Gen Mat	FR	4.42	3.51	1				x	x	x	x	n	n	n	n	n	n	dvfr/d	vfr/d
170	Gen Mat	FR	2.92	2.2	0.91				x	x	x	x	n	n	n	n	n	n		dfr/d
171	Gen Mat	FR	4.63	3.58	1.78				x	x	x	x	n	n	n	n	n	n		rlfr
172	Gen mat	GIL	3.85	2.91	0.8	Generic Material			x	x	x	x	n	n	n	n	n	n		
173	Gen Mat	GIL	5	3.52	1.25	**5.25**	**3.4**	**1.13**	x	x	x	x	d	d	i	n	d	n		
174	Qtz-ite	NSKR	3.55	3.1	1.2				x	x	x	x	n	n	n	n	n	n		
175	Qtz-ite	NSKR	3.3	3.1	1.3				x	x	x	x	n	n	n	n	n	n		
176	Qtz-ite	NSKR	4.4	2.9	1.39				x	x	n	n	n	n	n	n	n	n		dft
177	Qtz-ite	NSKR	5.15	3.36	1.86				x	x	s	x	n	n	d	n	n	n	dfr/p	dfr/p
178	Qtz-ite	NSKR	2.75	2.07	1.1				x	x	x	x	n	n	n	n	n	n		dfr/d

Table 6.3. Class 2 specimens split into two halves parallel to the Y axis (width)

179	Qtz-ite	NSKR	2.3	1.9	0.95				x	x	x	x	n	n	i	d	n	n		
180	Qtz-ite	NSKR	4.91	4.51	1.79				x	x	n	n	n	n	n	n	n	n		dft
181	Qtz-ite	GIL	2.87	1.27	1.14				x	x	x	x	n	n	n	n	n	n		
182	Qtz-ite	GIL	5.55	3.95	2.01	Quartzite			x	x	x	x	n	n	n	n	n	n	dfr/d	
183	Qtz-ite	GIL	3.81	2.75	1.61	**3.68**	**2.9**	**1.41**	x	x	x	x	n	n	n	n	n	n	dfr/d	
184	Quartz	NSKR	3.8	2.44	2				x	x	x	x	n	n	n	n	n	n		
185	Quartz	NSKR	2.9	2.05	1.11				x	x	x	x	n	n	n	n	n	n		
186	Quartz	GIL	2.68	2.17	1.2	Quartz			x	x	x	x	n	n	n	n	n	n		
187	Quartz	GIL	4.07	3.04	1.46	**3.94**	**2.7**	**1.73**	x	x	x	x	n	n	n	n	n	n		
Grand Total Means			3.34	2.52	1.17															

concluded, therefore, that this attribute can hardly be called a rare occurrence of bipolar technology. Additionally, unlike previous interpretations, these are rarely both major positive bulbs. The proximal is always a major bulb and the distal a minor one in appearance. As with the previous Class 1 materials, there were numerous small dorsal and ventral flakes removed from several specimens.

The shear pattern of the class 2 specimens was the type that I essentially endeavored to replicate during the experimental process. There were two major motivations for this rationale. The first was that if a pebble could be split in two halves across the Y axis then the minimum of waste would be created and the maximum of usable material provided. For example, if a knapper was splitting pebbles to acquire preforms then a pebble split into two relatively uniform halves would be the most beneficial. The other reason relates to the surface attributes of a split pebble stone. That is, with pebbles split in this manner, there are two ventral surfaces for analysis, one occurring on each split pebble half, with one the near mirror image of the other. Therefore, these specimens would provide the greatest opportunity for the description of bipolar flake features, such as the discriminant analysis of identifiable multivariate attributes produced during experimental bipolar reduction.

Figures 6.10, 6.11, 6.12, 6.13 and 6.14 all display classic transverse shears, through the Y axis, of the Class 2 specimens. Unfortunately, the replicated materials in these figures display little else other than the proximal and distal crushing common in

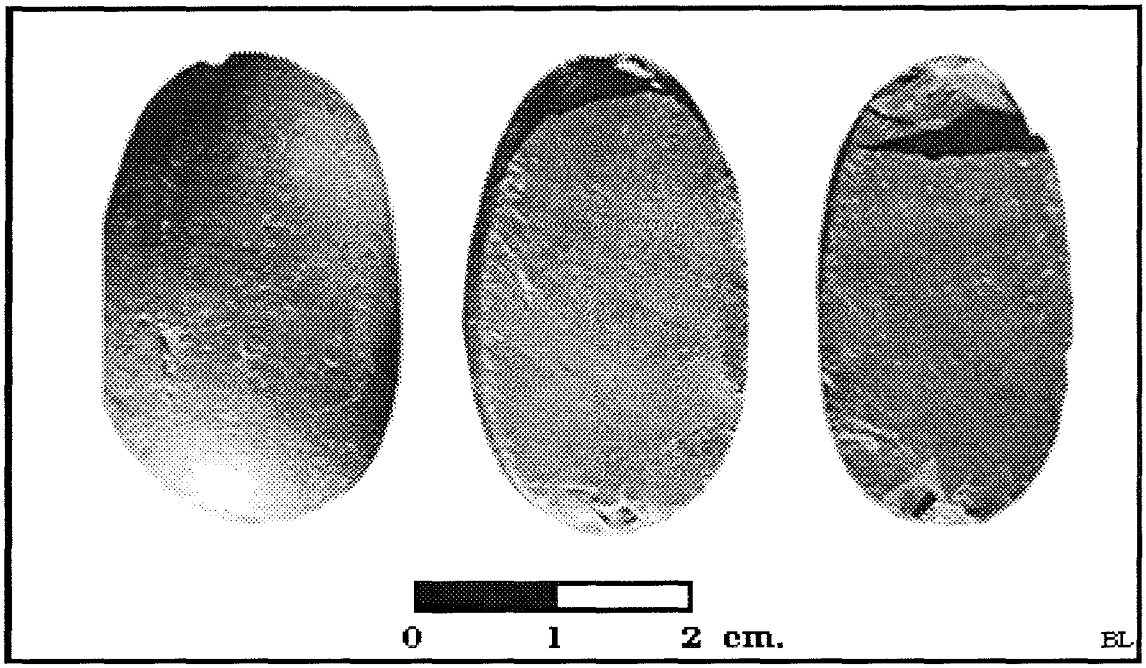

Figure 6.10. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 32).

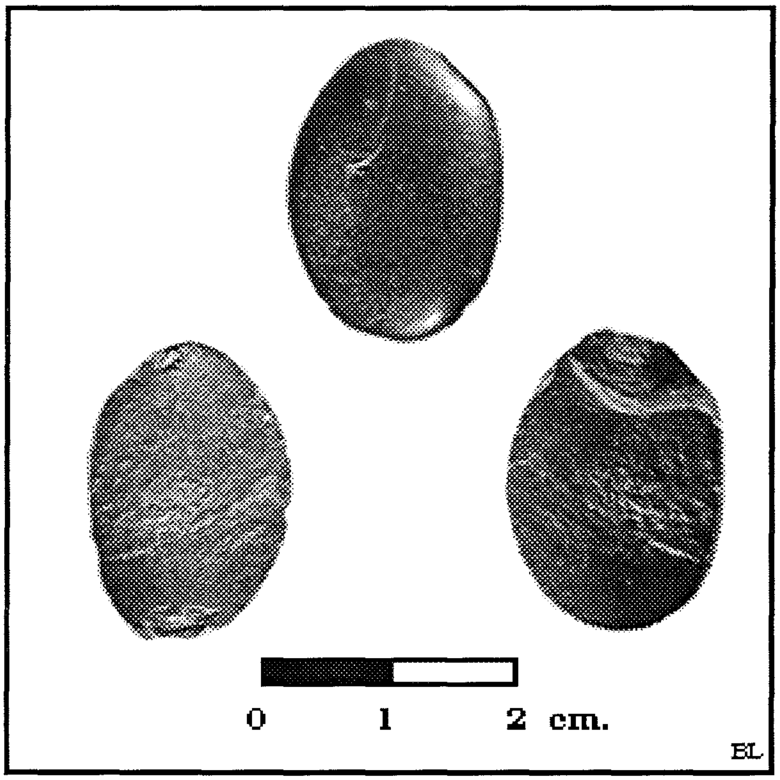

Figure 6.11. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 76).

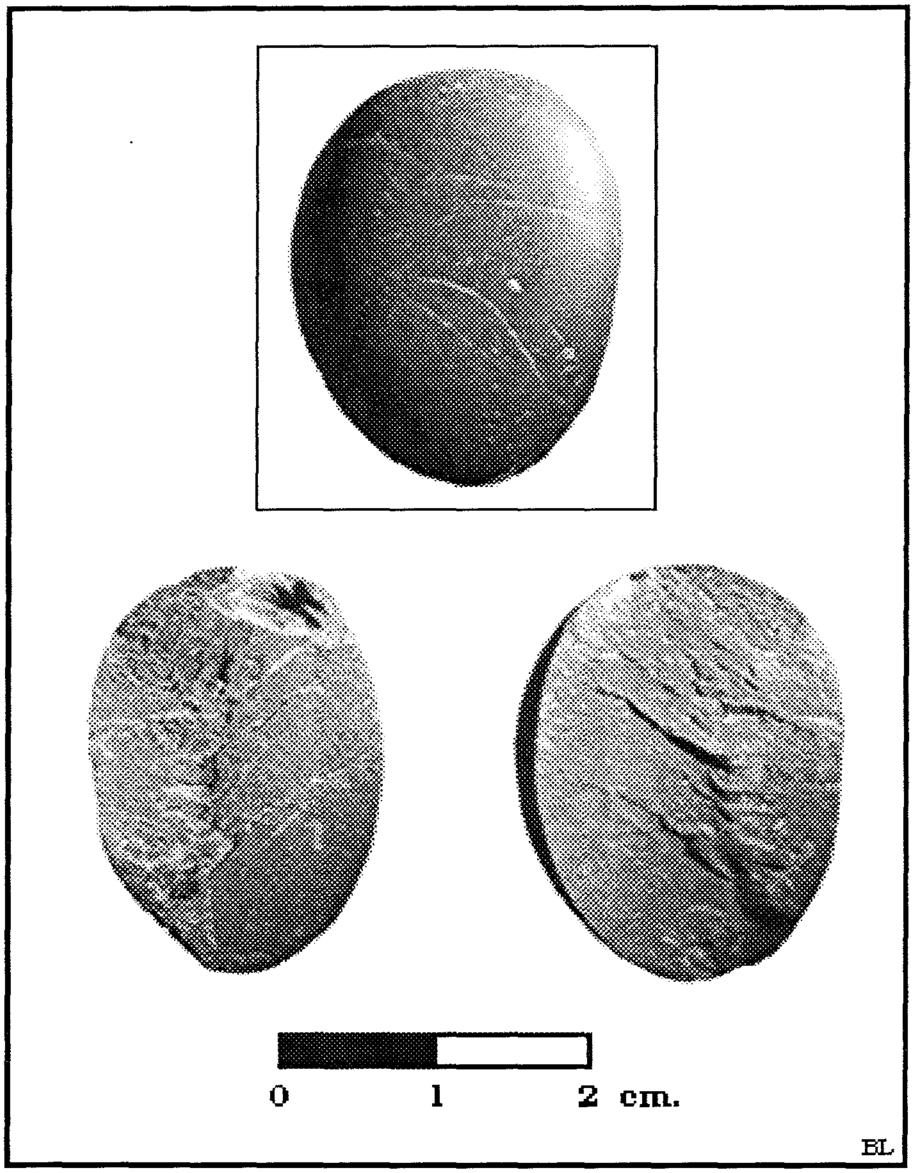

Figure 6.12. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 105).

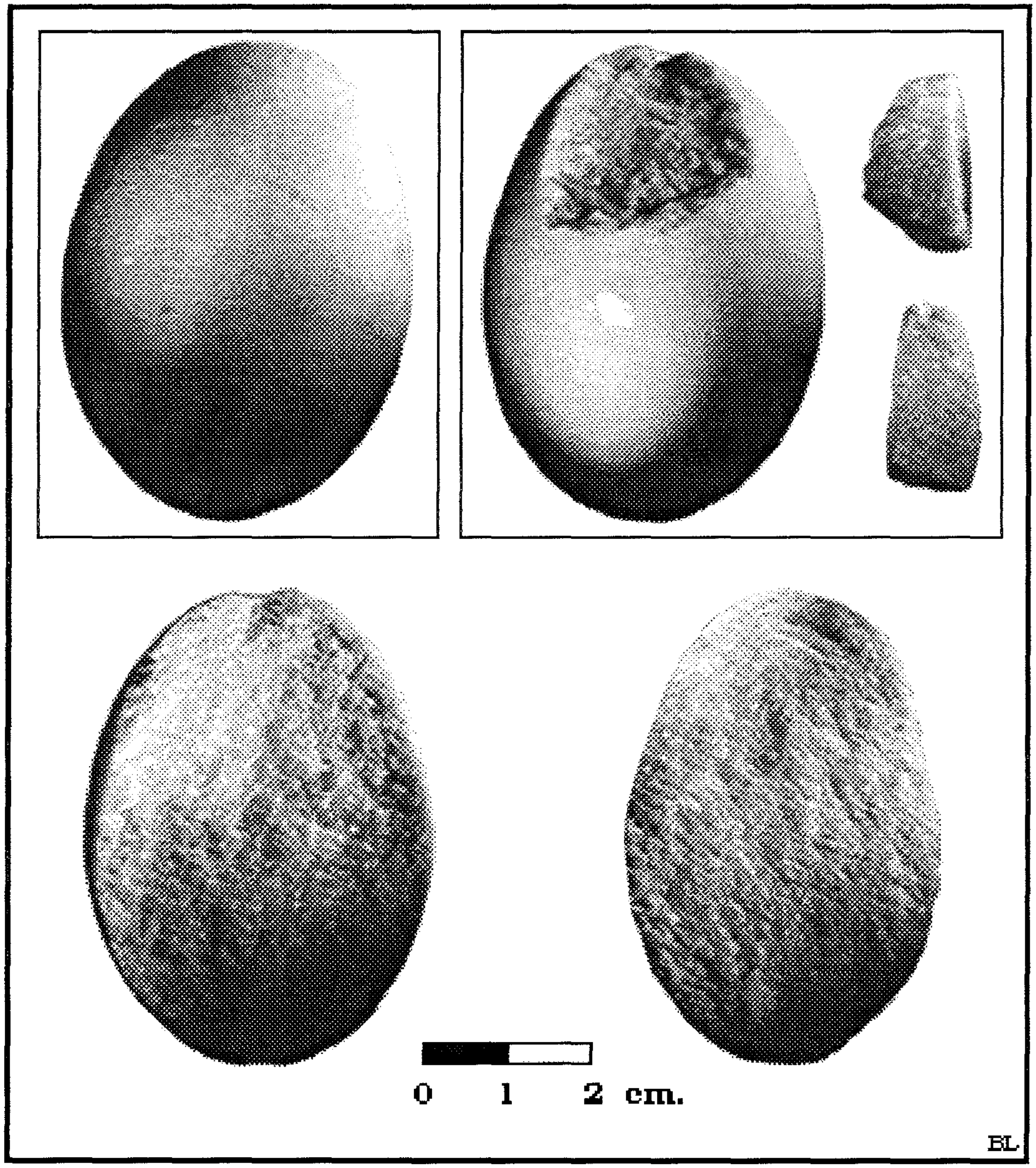

Figure 6.13. Class 2 quartzite pebble split parallel to the Y axis (specimen 182).

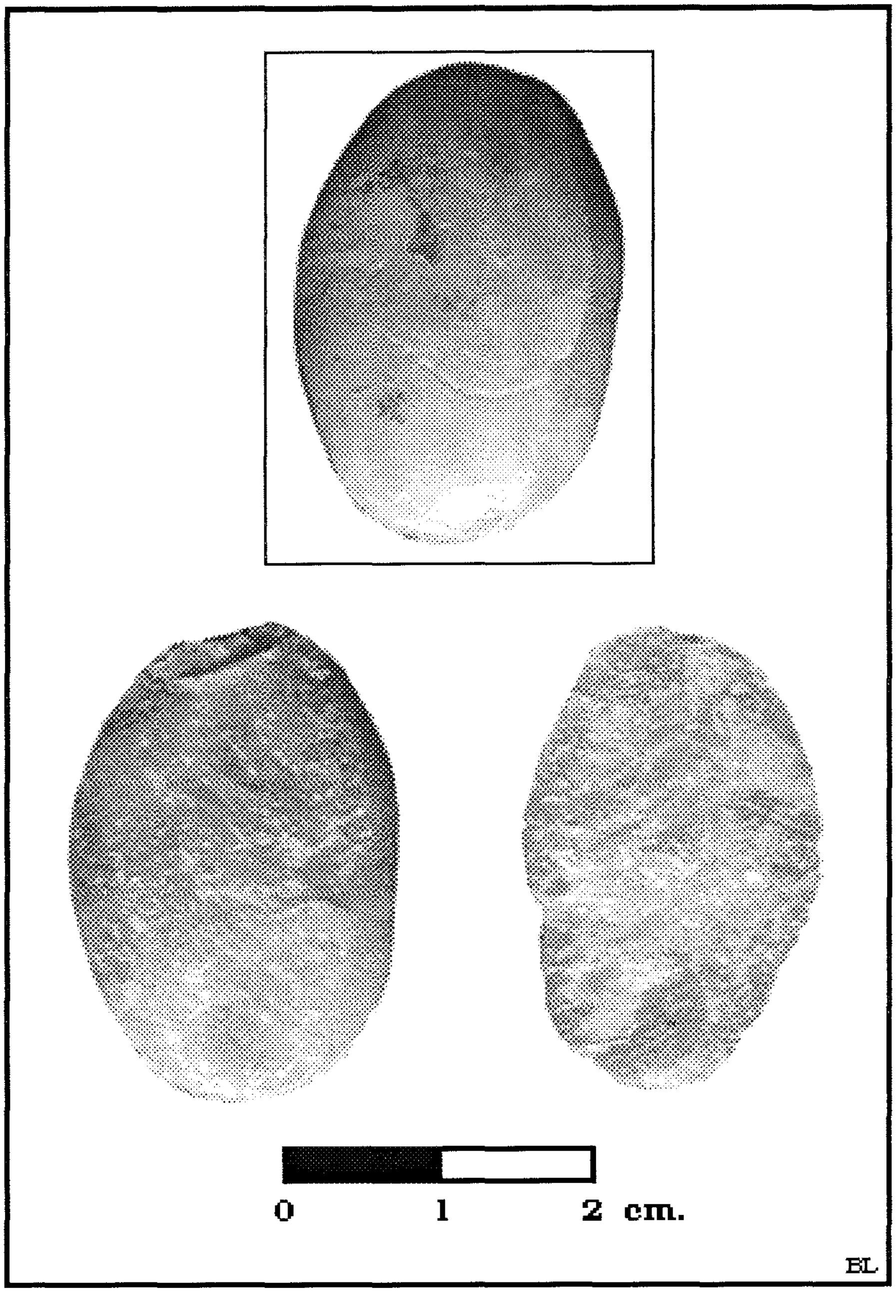

Figure 6.14. Class 2 quartz pebble split parallel to the Y axis (specimen 185).

this class. Actually, this is a common attribute of almost all bipolar materials. In fact, 74 specimens (45.7%) within Class 2 displayed none of the ventral surface attributes (as outlined in Table 6.3). This situation depicts the difficulty in identifying bipolar materials. Additionally, 33 of these specimens were silicified siltstone, which is a very fine grained material. If these specimens were not completely split pebble stones displaying proximal and distal impact crushing they could easily be misidentified as straight percussion flakes.

Within Class 2 there are similar materials to the above that could be separated from direct percussion materials and identified as bipolar by-products without the evidence of both proximal and distal impact crushing. For example, Figures 6.15 and 6.16 illustrate two specimens that would fit into this category. Both specimens in Figures 6.15 and 6.16 display the smooth sheared surface as in the previous illustrations, but the ventral surfaces also exhibit alternate positive diffuse and negative inverted bulbs of percussion on the proximal and distal ends. That is, one end displays a positive diffuse bulb of percussion and the other a negative inverted one. Another problem area for the identification of bipolar attributes on split pebble stones is with those specimens that have an irregularly sheared surface such as illustrated in Figures 6.17 and 6.18. Although the specimens from this class sheared as desired (across the Y axis) their ventral surfaces are such that they provide no observable surface features. Figure 6.19 also displays an irregular ventral surface, but this specimen has sheared proximal bulbs of percussion on

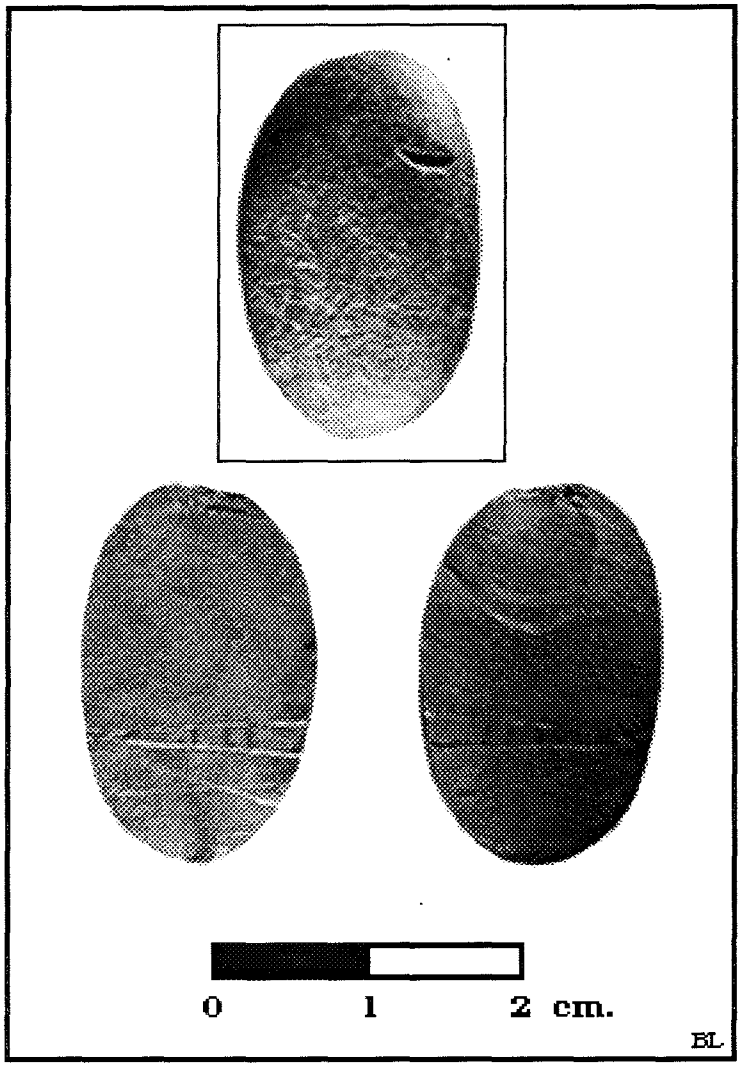

Figure 6.15. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 25).

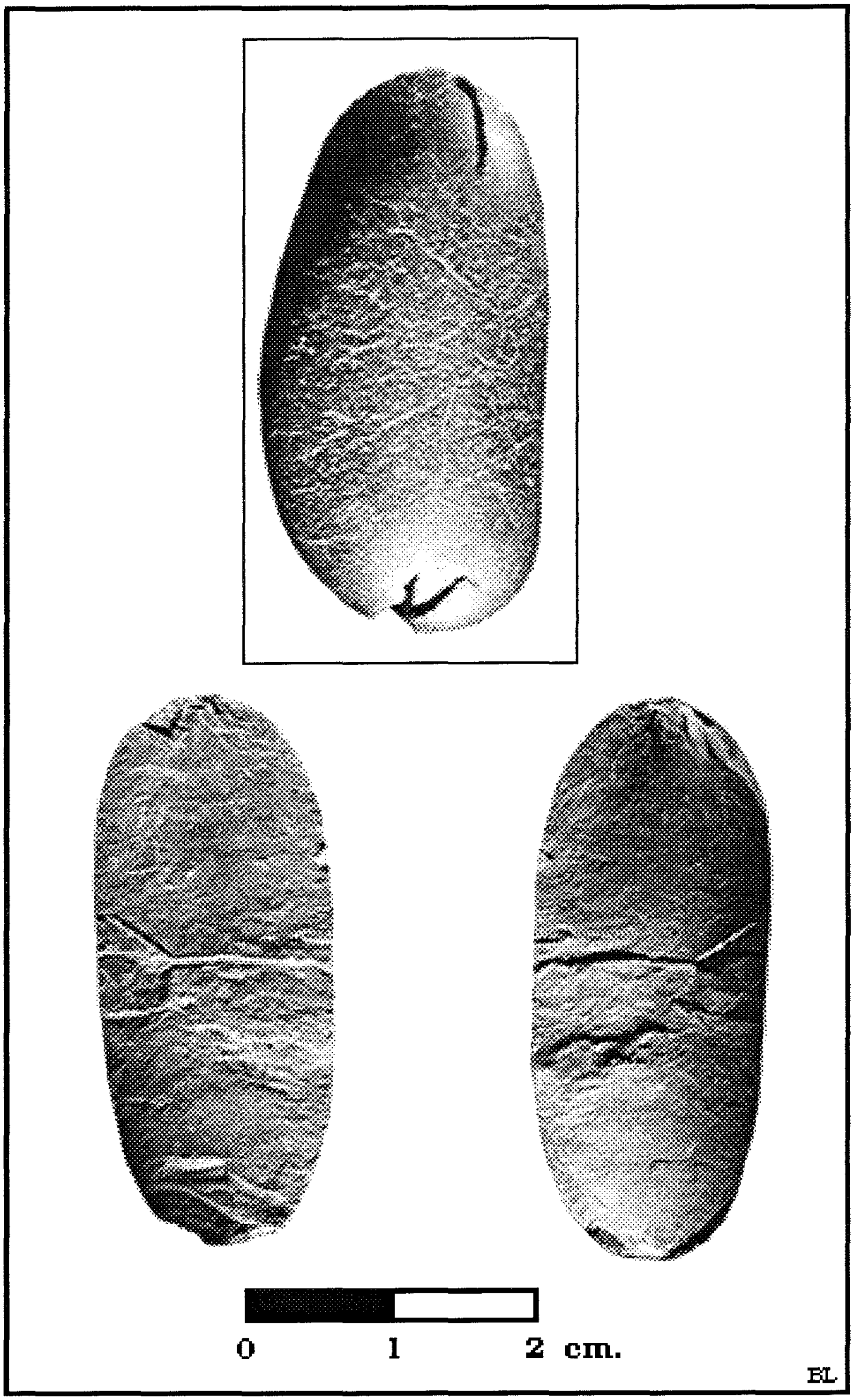

Figure 6.16. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 77).

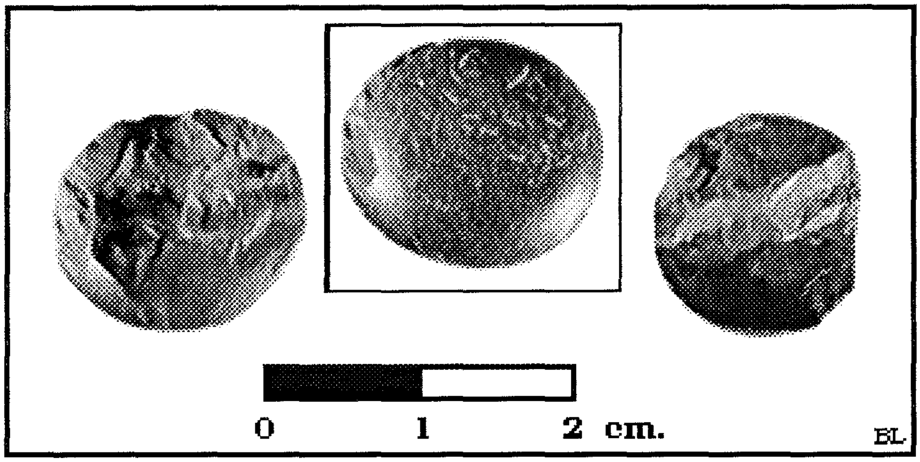

Figure 6.17. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 94).

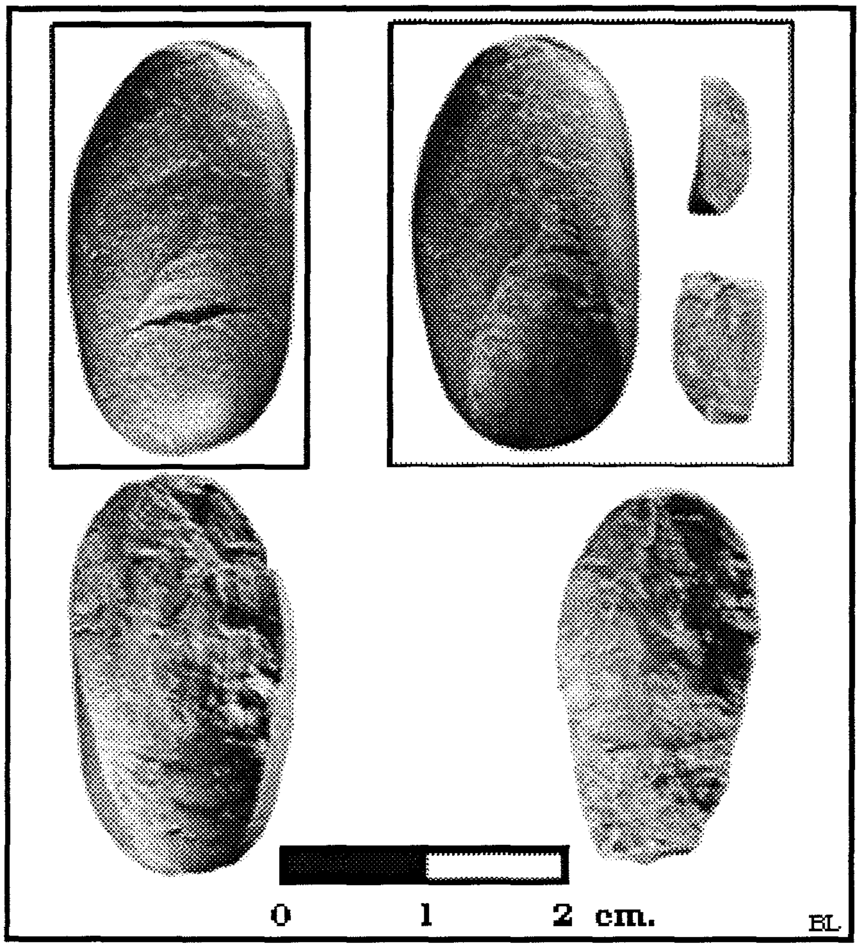

Figure 6.18. Class 2 generic chert pebble split parallel to the Y axis (specimen 147).

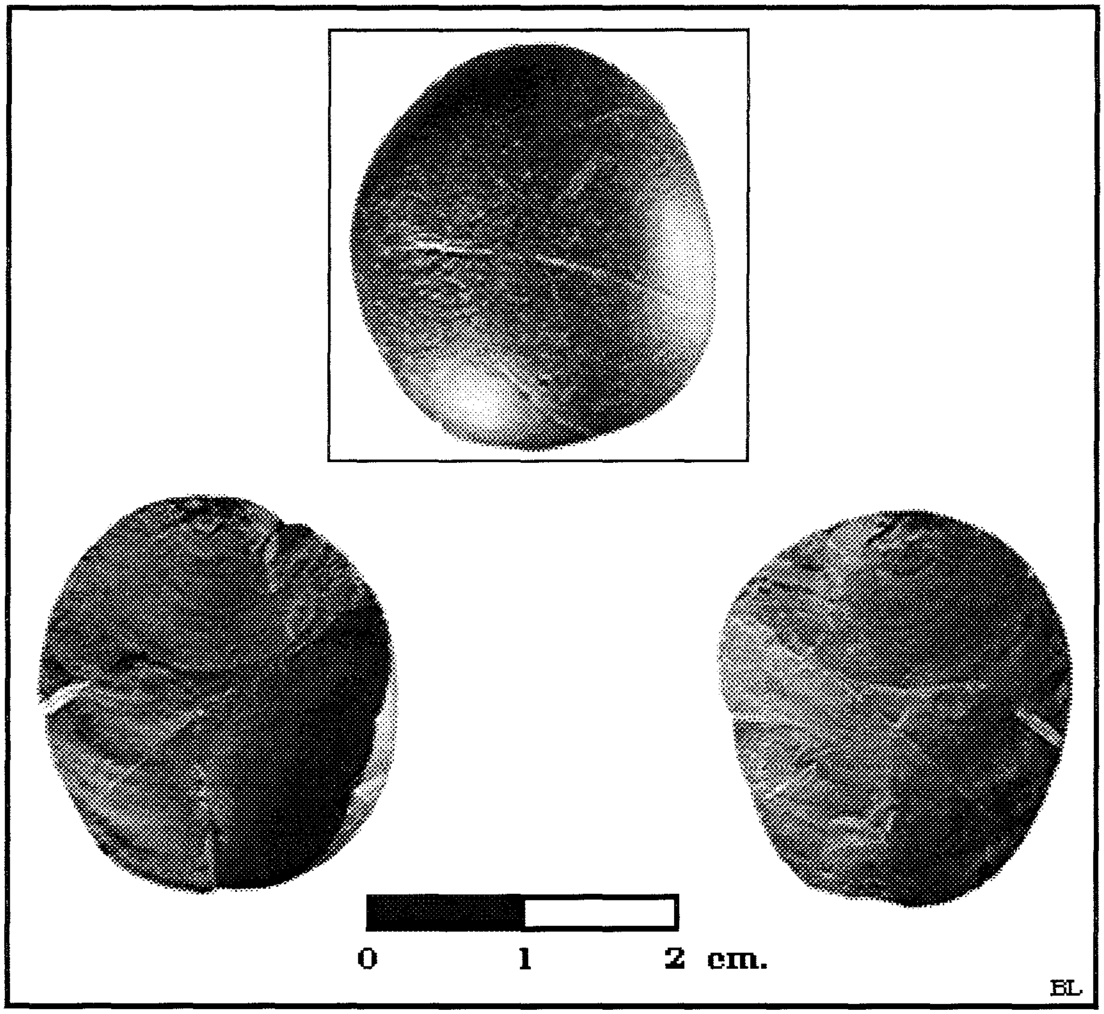

Figure 6.19. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 39).

both sections of the pebble. It is also evident that the coarseness of the individual sediments of the material in these specimens resulted in the poor shear.

Several specimens, such as those illustrated in Figures 6.20, 6.21, 6.22, 6.23 and 6.24, display diffuse lines of percussion in association with one or two other attributes. For example, Figures 6.20, 6.21, 6.23 and 6.24 also display either positive diffuse or negative inverted bulbs of percussion, or both, and Figures 6.22 and 6.23 are specimens with sheared bulbs. With these specimens the flow of force through the pebble was visible in the diffuse percussion lines and the bulbs of percussion could be readily identified as either distal or proximal. Being able to differentiate between distal and proximal bulbs is important since distal bulbs of force are an identifying aspect of bipolar technology.

Figure 6.20 displays a positive diffuse bulb of percussion on one end of one pebble half and none on the other. It is possible that the distal end of the other half may have also displayed this trait but the end of that piece crushed at the time of impact. The reason this is important is that the one half can be identified as a bipolar fragment and the other cannot. The fragment on the left can also be considered a bipolar specimen because the distal bulb of percussion truncates the opposing percussion lines of force. This characteristic did not occur frequently, but it did appear on 11 specimens of the Class 2 materials.

The most diagnostic specimens used for the discriminant analysis of the bipolar technique, and the clearest attributes, were attained with materials that displayed a very fine grained uniform

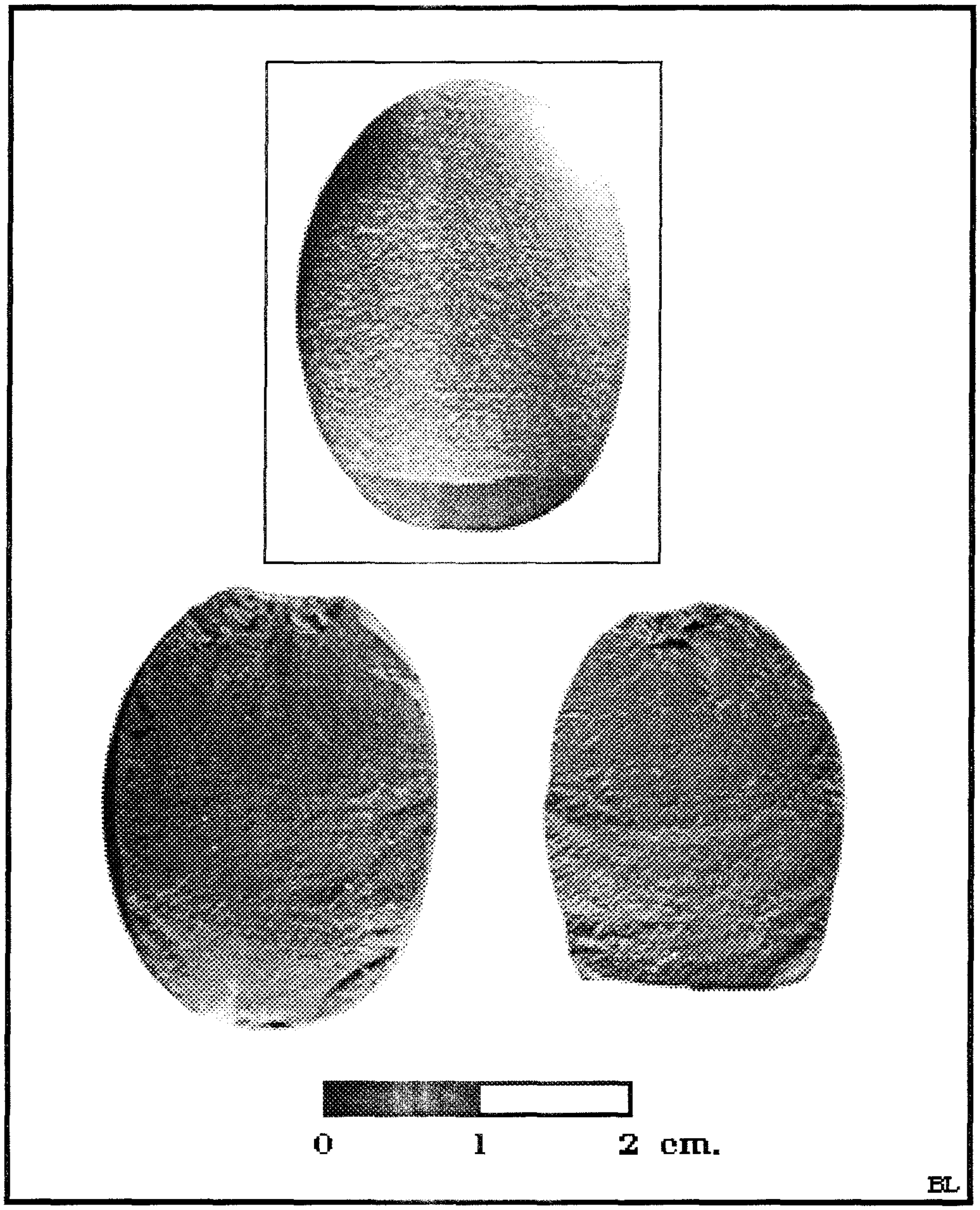

Figure 6.20. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 40).

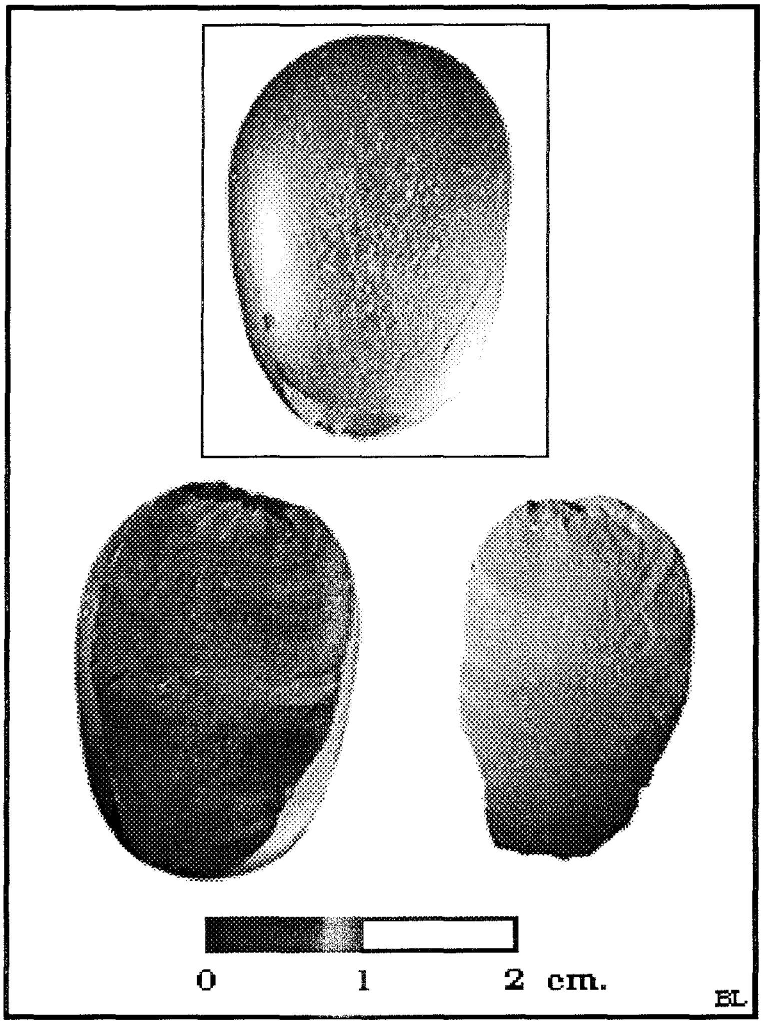

Figure 6.21. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 47).

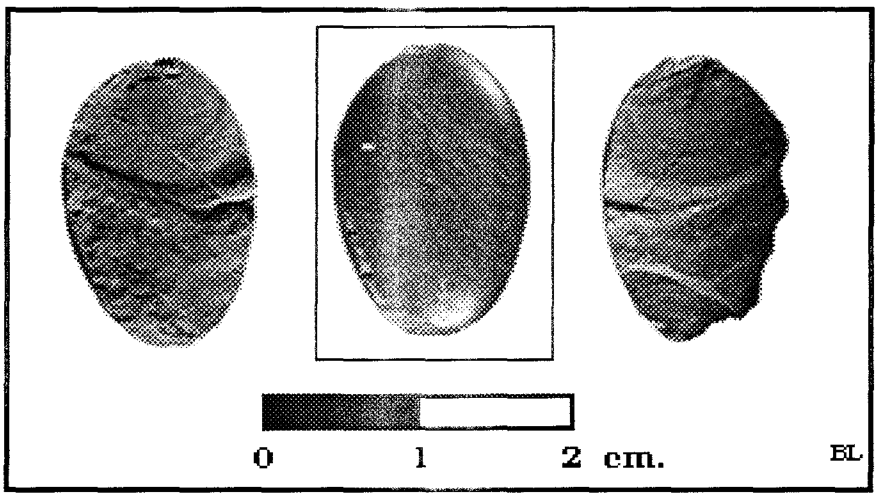

Figure 6.22. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 82).

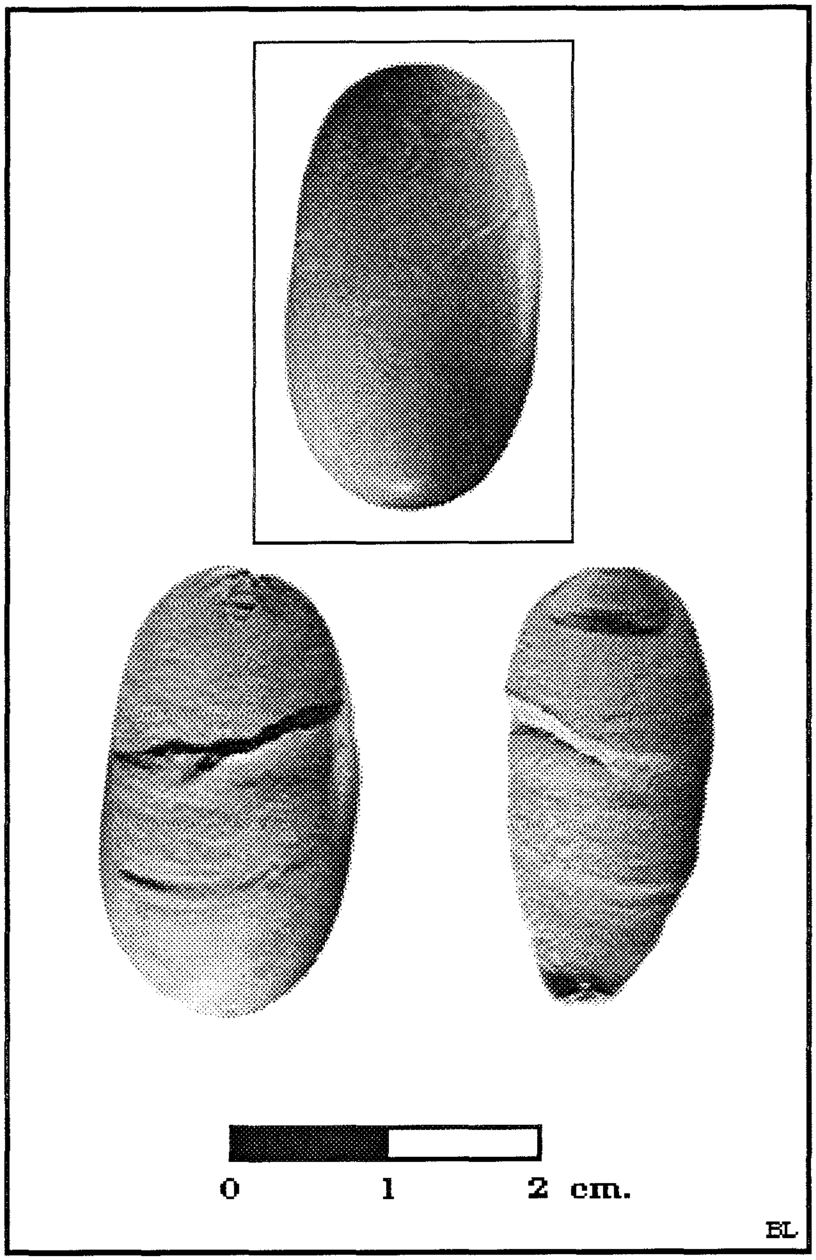

Figure 6.23. Class 2 generic chert pebble split parallel to the Y axis (specimen 143).

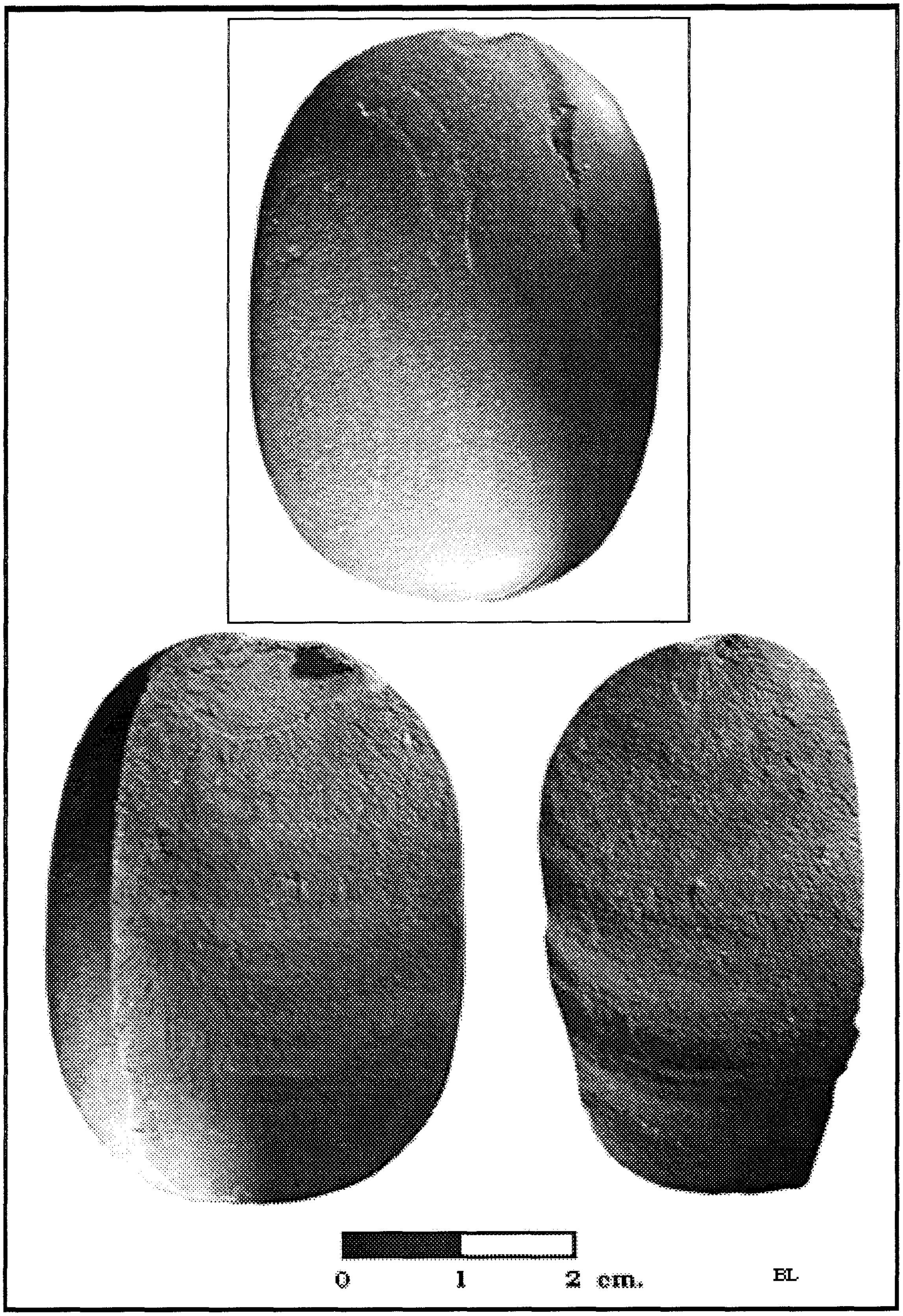

Figure 6.24. Class 2 generic material pebble split parallel to the Y axis (specimen 173).

matrix. These specimens frequently produced pronounced percussion lines along with numerous other attributes on the ventral surfaces of the experimentally replicated materials. They also frequently displayed two bulbs of percussion (one on the proximal end - one on the distal end).

Figures 6.25 and 6.26 illustrates two specimens that have proximal positive diffuse and distal negative inverted bulbs of percussion on one section and proximal negative inverted and distal positive diffuse on the other. The only occurrence of this characteristic was on these two specimens. Another unique attribute that occurred, among the specimens with two bulbs of percussion, was a proximal sheared bulb in conjunction with a distal positive diffuse or negative inverted bulb of force as illustrated in Figure 6.27, which displays a specimen with an upper sheared bulb and a distal positive diffuse bulb of percussion. Figures 6.28, 6.29 and 6.30 display specimens that have proximal sheared bulbs and a positive diffuse distal bulb on one half and an negative inverted distal bulb of percussion on the other section of the pebble. Class 2 specimens comprised 31.1% of the total replications.

6.1.2.3 *Class 3* includes pebbles that are split longitudinally down the X axis and along the Y axis, ending in an axial termination (in the same manner as the Class 2 specimens), but these specimens have only one complete half (Table 6.4). During the experimental stage one split pebble section broke randomly into two or more pieces following the initial impact of the applied force. A few sections appeared to break as a result of

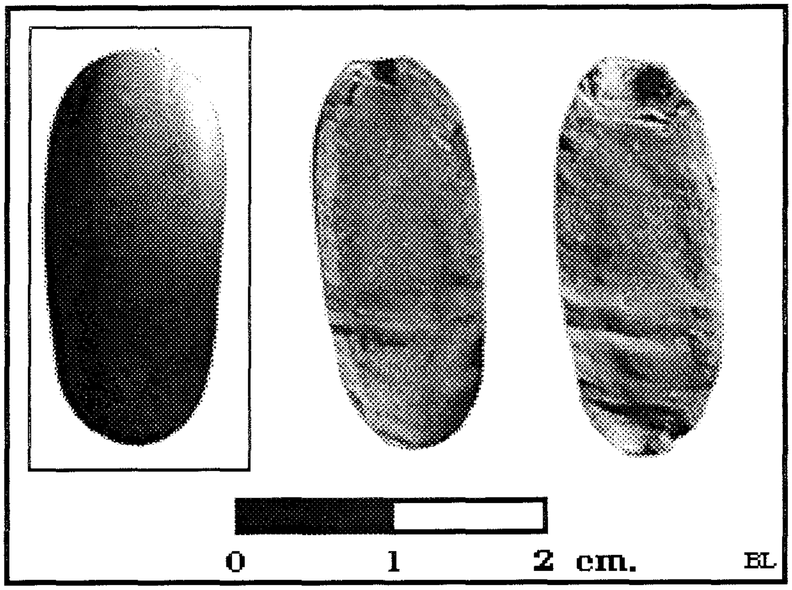

Figure 6.25. Class 2 generic chert pebble split parallel to the Y axis (specimen 128).

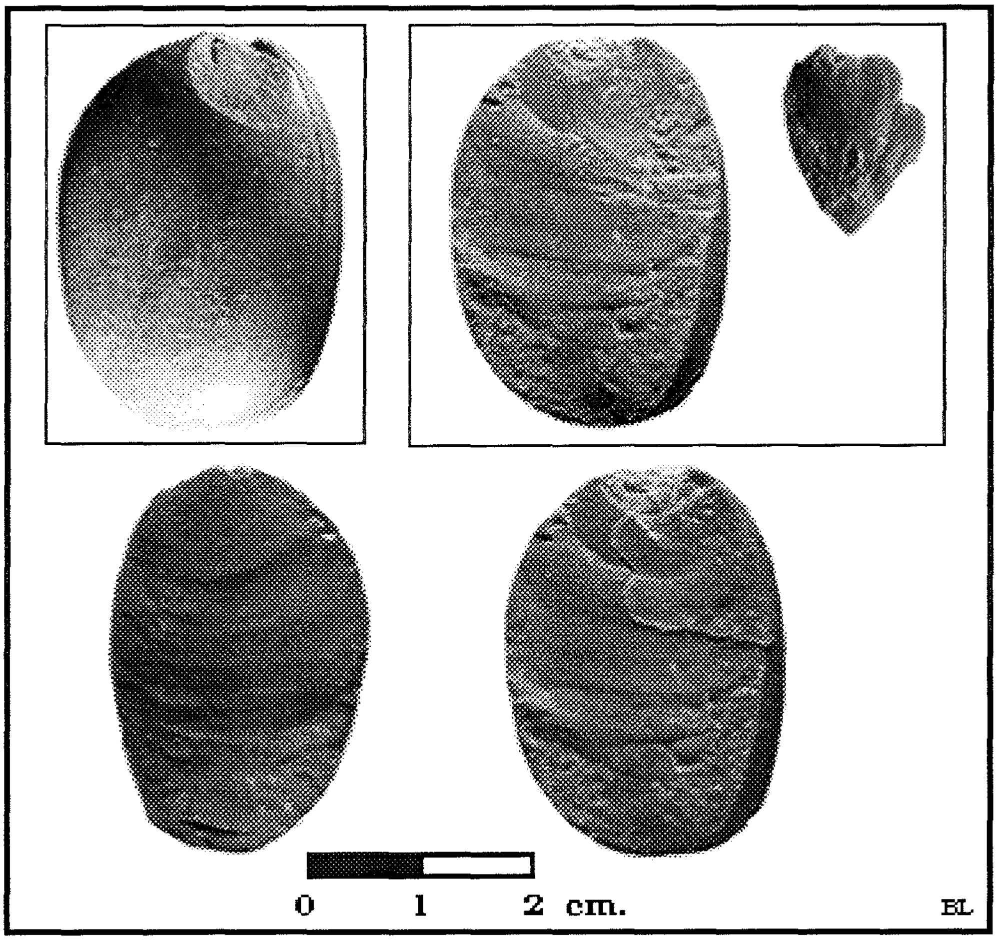

Figure 6.26. Class 2 generic chert pebble split parallel to the Y axis (specimen 155).

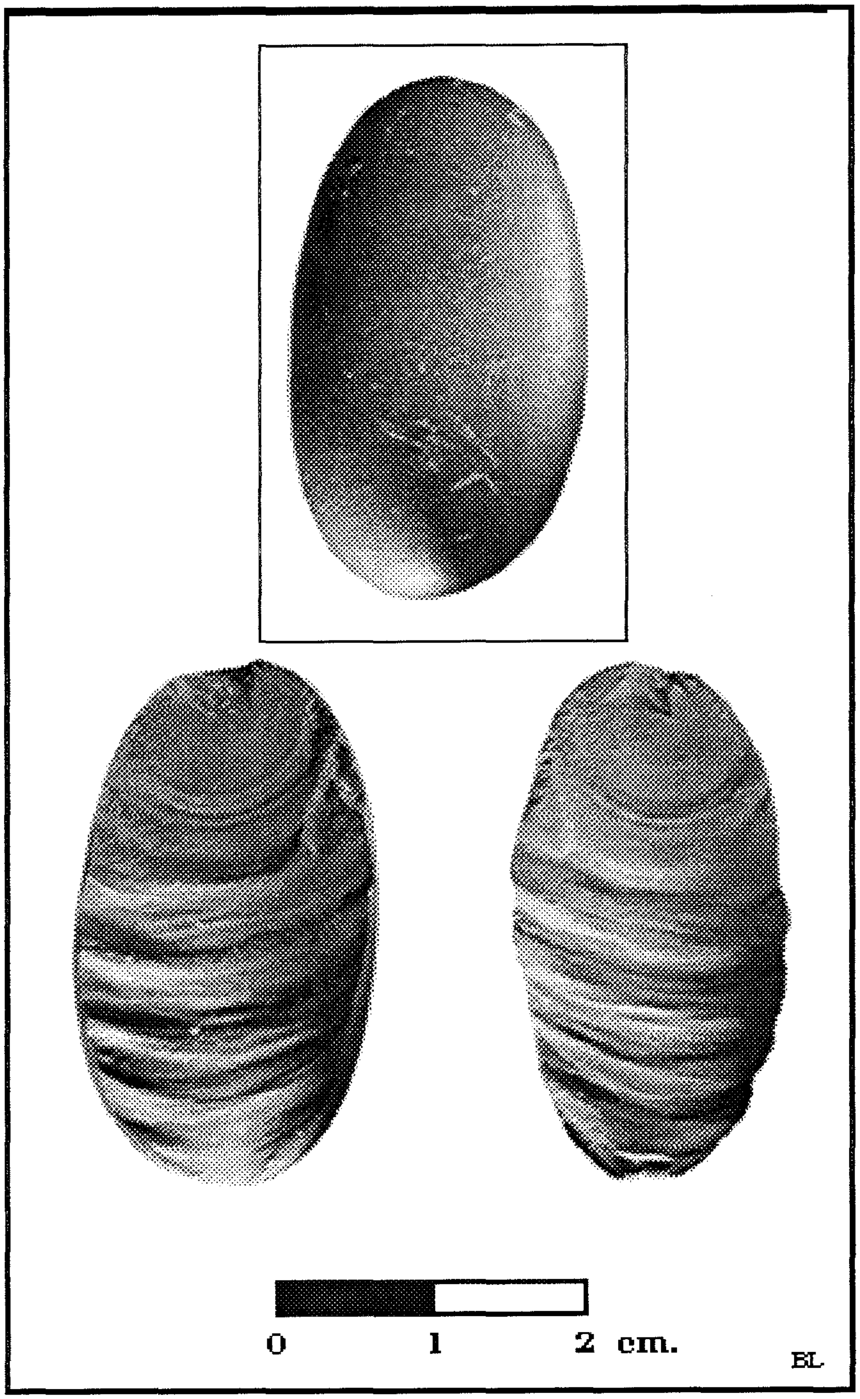

Figure 6.27. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 64).

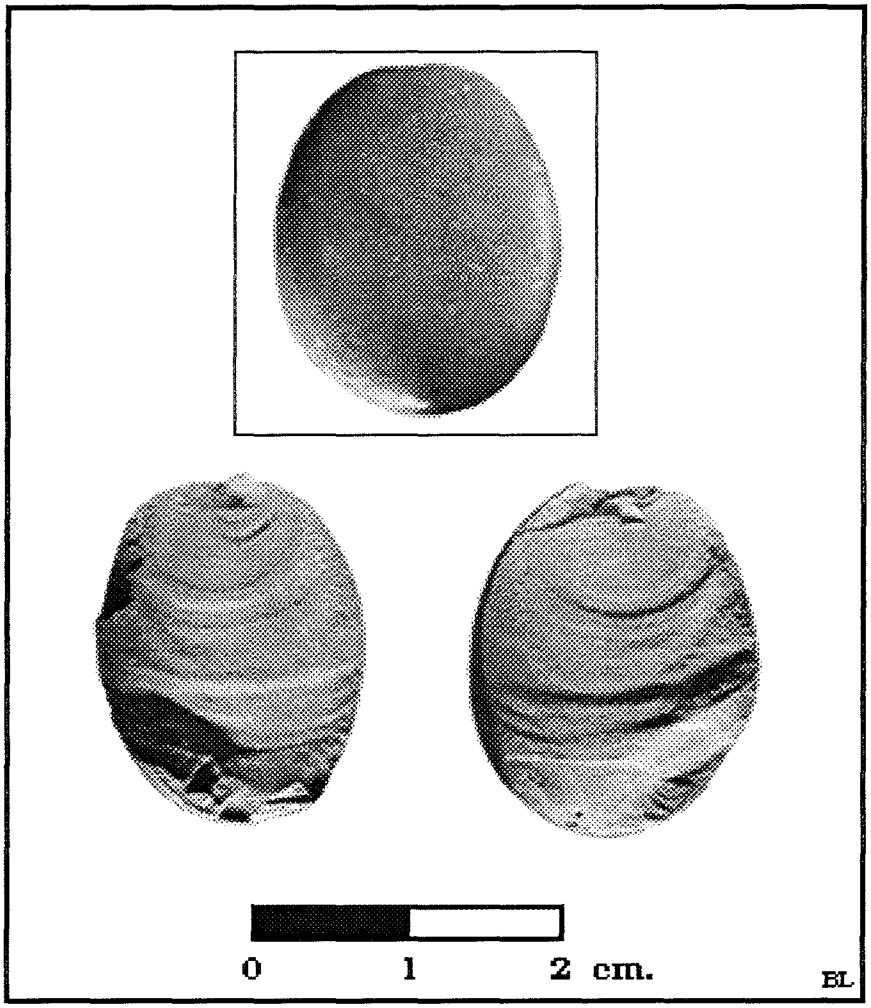

Figure 6.28. Class 2 silicified siltstone pebble split parallel to the Y axis (specimen 65).

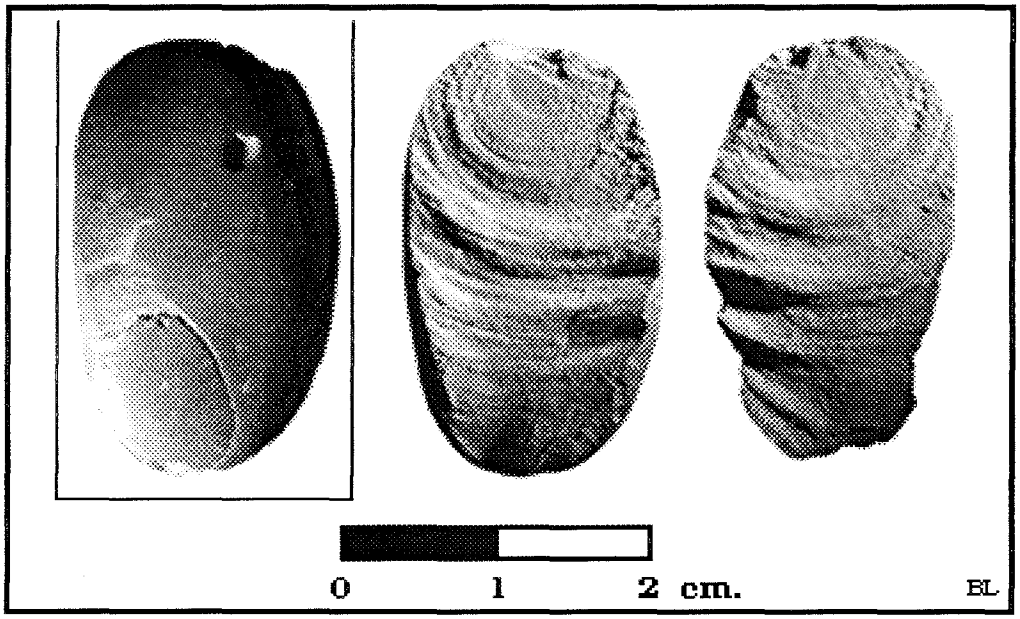

Figure 6.29. Class 2 generic chert pebble split parallel to the Y axis (specimen 153).

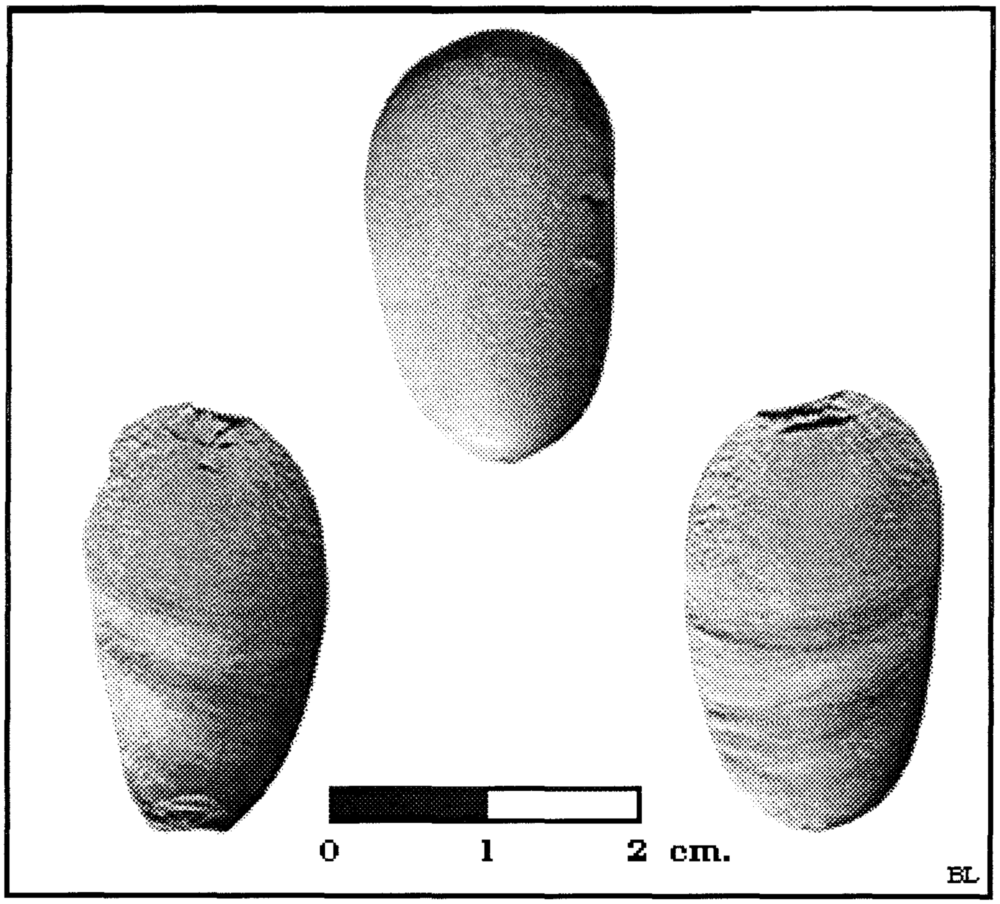

Figure 6.30. Class 2 generic chert pebble split parallel to the Y axis (specimen 520).

Table 6.4. Class 3 specimens split parallel to Y axis with one half complete

SP #	Material	Source	Dimensions (cm's)						PIC	DIC	PLED	PBP	DBP	Other	
	Type		Original			Means									
			L(X)	*W(Y)*	*T(Z)*	*L(X)*	*W(Y)*	*T(Z)*							
..86	SSP	NSKR	2.31	2	0.96				x	x	pr	sh	n	llfr vfr/d	vdfr/d
188	SSP	NSKR	2.6	2.01	0.99				x	x	d	n	n		
189	SSP	NSKR	4.11	1.68	1.43				x	x	d	n	n		
190	SSP	NSKR	2.81	1.77	0.99				x	x	pr	sh	n		
191	SSP	NSKR	3.14	1.55	0.77				x	x	pr	n	n	dfr/p	
192	SSP	NSKR	3.19	1.57	1.12				x	n	pr	pr	n	dfr/p	
193	SSP	NSKR	3.44	1.43	1.01				x	x	pr	d	n		
194	SSP	NSKR	2.27	1.67	0.69				x	x	pr	sh	d		
195	SSP	NSKR	2.61	1.3	0.67				x	x	pr	n	n		
196	SSP	NSKR	3.41	1.5	0.86				x	n	d	d	n		
197	SSP	NSKR	3.25	1.69	1				x	n	pr	n	n		
198	SSP	NSKR	4.65	2.37	2.33				s	s	n	n	n		
199	SSP	NSKR	3.64	3.23	1.63				x	n	d	d	n		
200	SSP	NSKR	2.64	1.85	0.8				x	n	n	n	n	dfr/p	
201	SSP	NSKR	3.14	1.89	0.98				x	x	d	d	n	dfr/d	
202	SSP	NSKR	2.78	1.95	0.81				x	n	d	n	n		
203	SSP	NSKR	4.18	2.33	1.71				x	x	n	n	n		
204	SSP	NSKR	2.43	2.27	0.69				x	n	pr	d	n	dfr/d	
205	SSP	NSKR	5.72	4.41	1.95				x	x	n	n	n	is	dfr/pd
207	SSP	NSKR	2.31	2	0.58				x	x	n	n	n	vfr/d	
208	SSP	NSKR	3	2.05	0.86				x	x	n	n	n		
209	SSP	NSKR	2.41	1.72	1.22				x	x	n	n	n	vfr/d	dfr/p
210	SSP	NSKR	2.17	1.1	0.5				x	x	d	sh	i		

Table 6.4. Class 3 specimens split parallel to Y axis with one half complete

211	SSP	NSKR	3.41	1.38	0.84				n	x	n	n	n	is	
213	SSP	NSKR	2.61	2.23	0.72				x	x	d	sh	n		
214	SSP	NSKR	2.06	1.4	0.79				x	n	d	i	n		
215	SSP	NSKR	2.06	1.33	0.73				x	x	n	i	n		
216	SSP	NSKR	3.87	1.95	1.84				x	x	n	n	n	is	vfr/d
516	SSP	NSKR	3.71	1.89	0.72				x	x	pr	sh	d		
217	SSP	GIL	3.12	1.7	0.86				s	s	n	n	n		
218	SSP	GIL	3.17	1.06	0.64				s	x	d	n	n		
219	SSP	GIL	2.51	1.81	0.83				x	x	n	n	n		
220	SSP	GIL	3.55	2	1.05				x	x	d	n	n	dfr/d	
221	SSP	GIL	2.45	1.78	0.71				x	x	n	n	n		
222	SSP	GIL	2.8	2.06	0.81				x	x	n	n	n	vfr/d	dfr/p
223	SSP	GIL	3.11	1.97	0.68				x	n	pr	i	n		
224	SSP	GIL	3.47	3.41	1.56	Silicified Siltstone			x	x	d	n	n		
225	SSP	GIL	2.81	2.5	0.86	Pebbles			x	n	pr	i	n		
226	SSP	FR	3.64	2.37	1.39	**2.98**	**2.19**	**1.18**	x	n	d	n	n		
227	Gen chert	NSKR	3.69	2.22	1.7				x	x	d	n	n	dfr/p	
228	Gen chert	NSKR	3.12	2.74	1.05				x	n	d	i	n		
229	Gen chert	NSKR	2.99	2.25	1.57				x	x	n	n	n	is	
230	Gen chert	NSKR	2.5	2.35	1.44	Generic chert			x	x	n	d	d		
231	Gen chert	GIL	3.31	1.71	0.85	**3.5**	**1.97**	**1.28**	x	x	n	n	n	dfr/p	
232	Gen mat	NSKR	3.57	1.91	0.62				x	x	n	n	n		
233	Gen mat	NSKR	6.57	4.99	2.01				x	x	n	n	n		
234	Gen mat	FR	3.35	3.06	1.21				x	x	n	n	n		
235	Gen mat	FR	2.57	2.13	0.81				x	x	n	n	n	dfr/d	
236	Gen mat	FR	4.24	3.11	1				x	x	n	n	n		

Table 6.4. Class 3 specimens split parallel to Y axis with one half complete

237	Gen mat	FR	3.05	2.86	1.09	Generic Material			x	x	n	n	n		
238	Gen mat	GIL	3.8	3.22	1.11	**3.69**	**2.57**	**0.87**	x	x	n	n	n		
239	Quartz	NSKR	3.38	1.66	1.17	***Quartz***			x	n	n	n	n	dfr/p	
240	Qtz-ite	NSKR	3.42	2.19	1.35				x	x	pr	d	n		
241	Qtz-ite	NSKR	4.53	3.31	1.55				x	x	n	n	n		
243	Qtz-ite	NSKR	3.2	1.74	1.01				x	x	n	n	n		
244	Qtz-ite	NSKR	4.71	3.62	1.45				x	x	n	n	n		
245	Qtz-ite	NSKR	3.35	2.77	1.39				x	x	n	n	n		
246	Qtz-ite	NSKR	2.51	1.73	0.71	Quartzite			x	x	n	n	n		
247	Qtz-ite	GIL	3.21	2.99	1.35	**3.32**	**2.59**	**1.35**	x	n	n	n	n		
Grand Total (average)			2.76	2.5	1.16										

impurities within the material, but more frequently the materials broken seemed to be quite uniform throughout the pebble's matrix. In these instances the one section of the pebble likely broke as the result of the application of too much applied or rebound force within the material, although the other half remained complete. This is a good example of how I had to use a very controlled bipolar technique so as not to apply too much pressure to the pebble, and thus break it, but still have an adequate amount of force to split the specimen. This class includes a total of 59 specimens consisting of: 39 silicified siltstone, 5 generic chert, 7 generic material, 1 quartz and 7 quartzite pebbles.

All but one Class 3 specimen displayed some proximal impact crushing and 44 showed visible distal impact crushing. Twenty nine (49.2%) of the Class 3 specimens exhibit percussion lines with 13 (22.0%) of those displaying pronounced lines of force. Four types of percussion bulbs were identified among the Class 3 materials: pronounced, sheared, diffuse, negative inverted. The majority were sheared and diffuse with only one positive pronounced bulb present. Among the Class 3 materials two bulbs of percussion on the same section of the complete half occurred on only four specimens (Figures 6.31, 6.32, 6.33 and 6.34).

Figures 6.31 and 6.32 both display pebble sections with a proximal sheared bulb of percussion and a positive diffuse distal bulb. It is noteworthy that the broken pebble sections of these specimens also display sheared proximal and positive diffuse distal bulbs. Because of the presence of these attributes on the

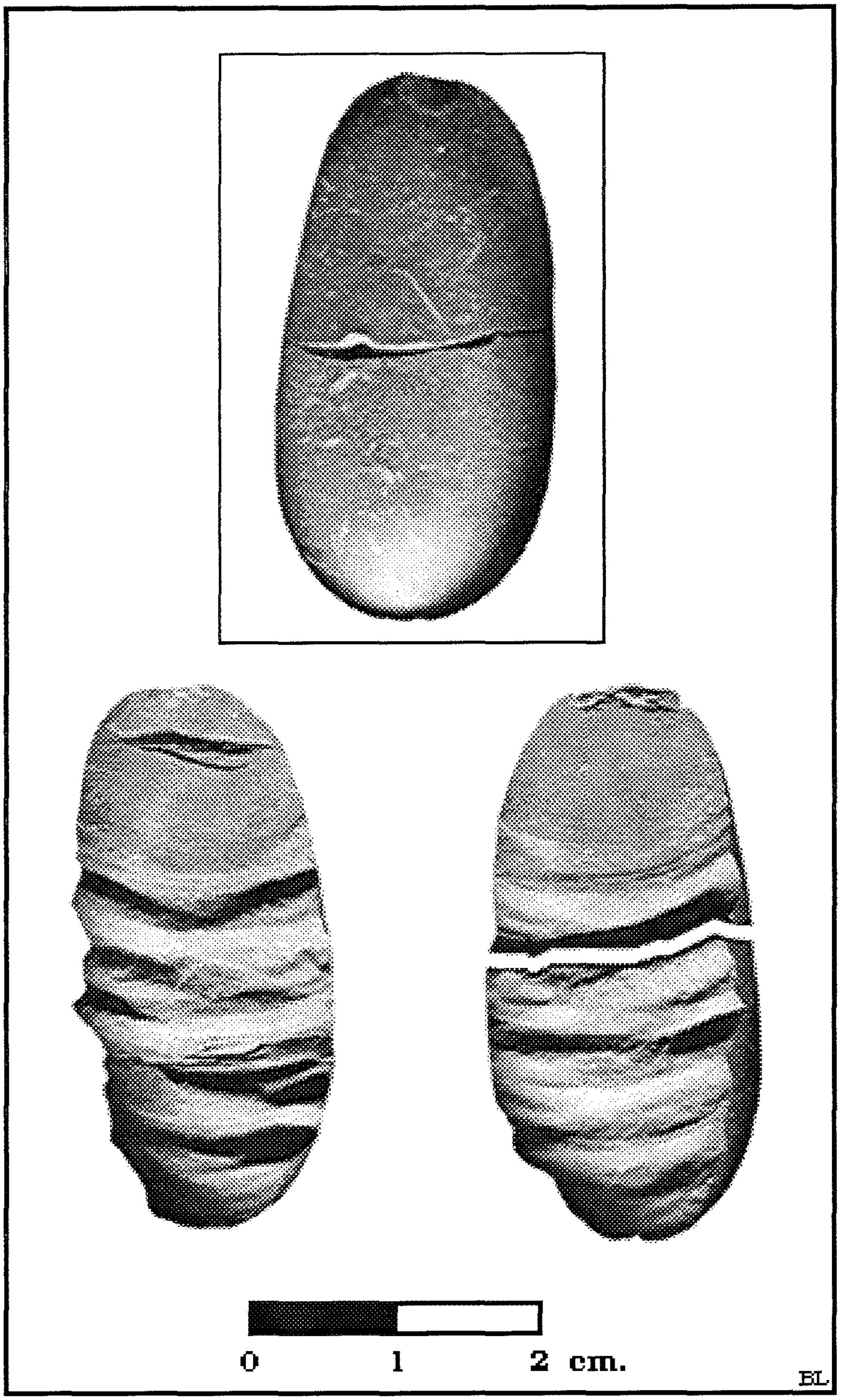

Figure 6.31. Class 3 silicified siltstone pebble split parallel to the Y axis - one section complete (specimen 516).

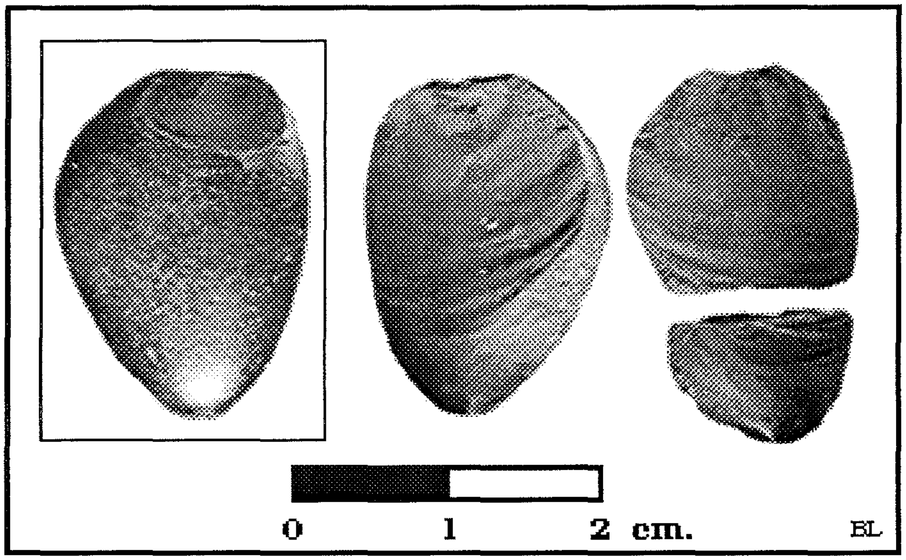

Figure 6.32. Class 3 silicified siltstone pebble split parallel to the Y axis - one section complete (specimen 194).

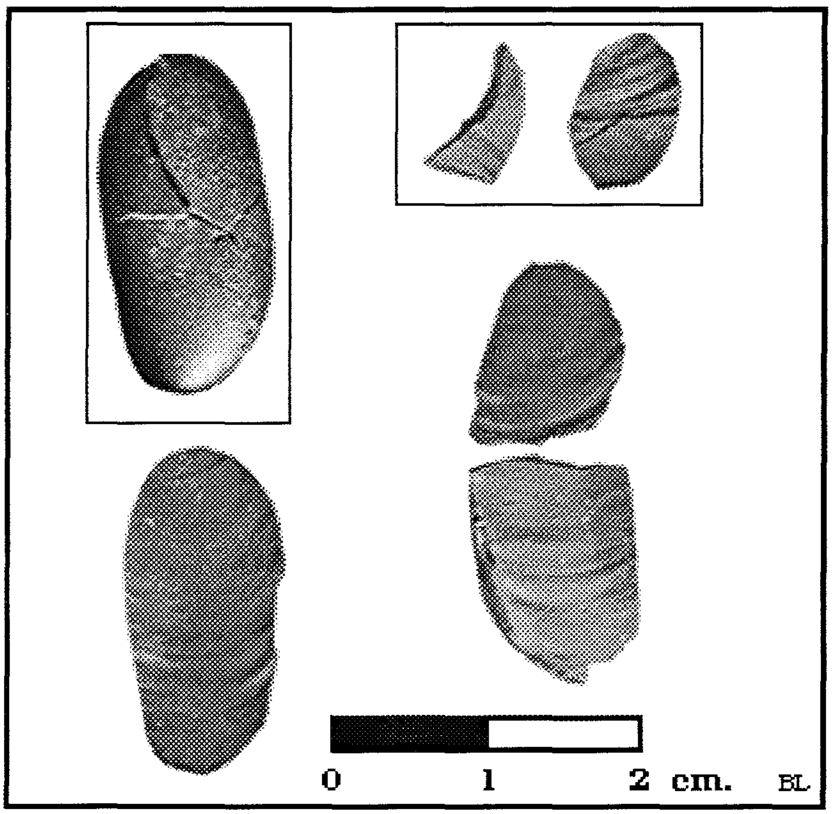

Figure 6.33. Class 3 silicified siltstone pebble split parallel to the Y axis - one section complete (specimen 210).

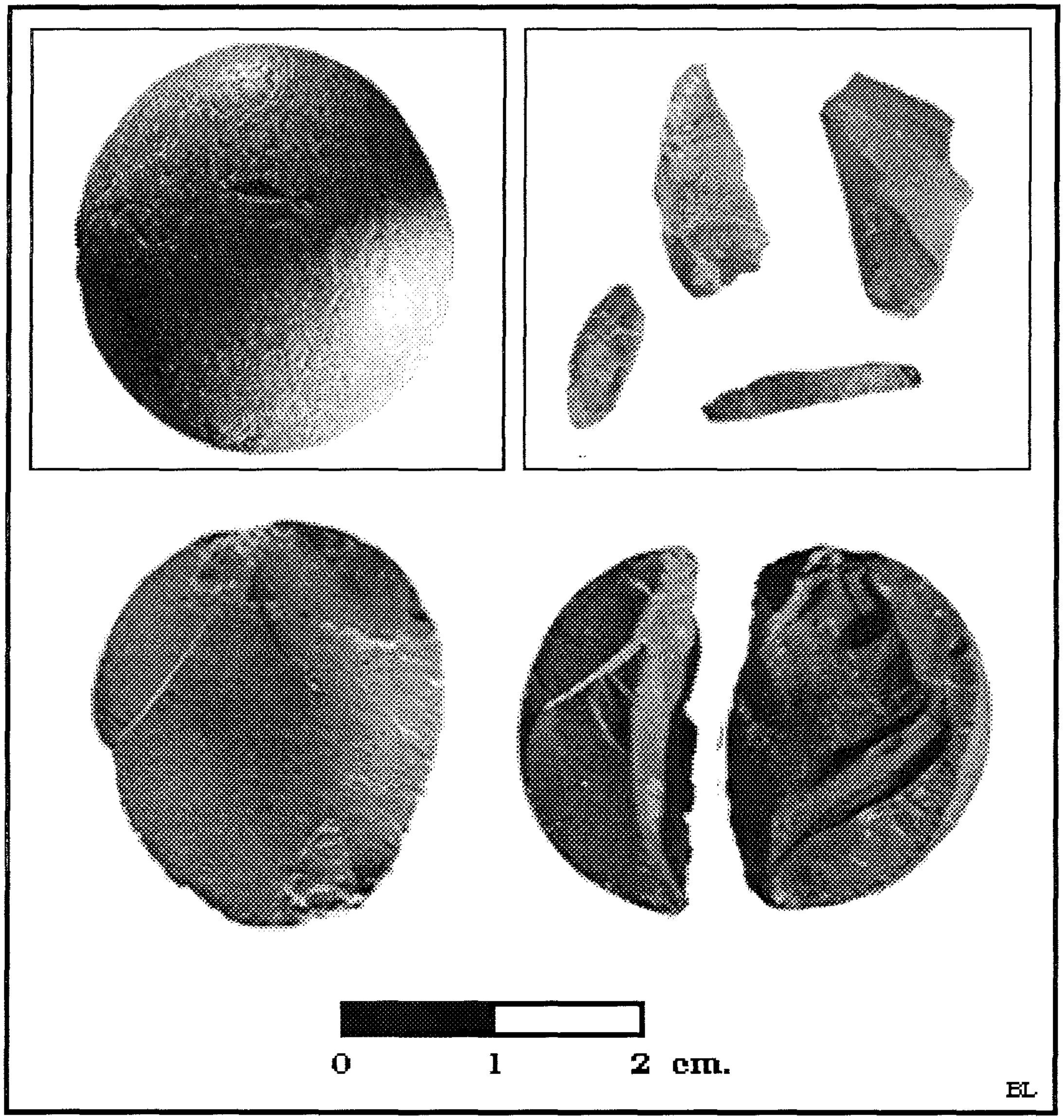

Figure 6.34. Class 3 silicified siltstone pebble split parallel to the Y axis - one section complete (specimen 230).

broken fragments the proximal ends could be identified as bipolar flakes even without the accompanying complete sections.

Figure 6.34 displays a pebble section with a proximal sheared bulb and a distal negative inverted bulb. The upper section of the broken half also has a proximal sheared bulb and therefore, on that basis it could be identified as a bipolar flake. Figure 6.34 is the fourth specimen in this class with the presence of two bulbs on the complete section. In this case both the proximal and distal bulbs are small and positive diffuse. Unlike the previous specimens, however, the broken fragments from this specimen display no identifiable attributes and it is quite evident that the impurities in the material are the reason for the irregular breakage of this specimen.

Fourteen specimens displayed proximal, with no distal, bulbs of percussion. However, several of these specimens can be identified as bipolar by-products, as can the broken fragments of the same specimen, because of the presence of sheared bulbs on those materials. Figures 6.35, 6.36 and 6.37 illustrate three such specimens with sheared proximal bulbs on the complete sections, as well as on the broken fragments.

Unfortunately, as illustrated in Figures 6.38 and 6.39, 29 specimens displayed only distal and proximal crushing with no other attributes visible. The troublesome thing is that the broken section of these specimens could easily be misidentified as being derived from straight percussion materials without the supporting evidence of the complete, associated, section that does display both distal and proximal crushing. Class 3 specimens comprised

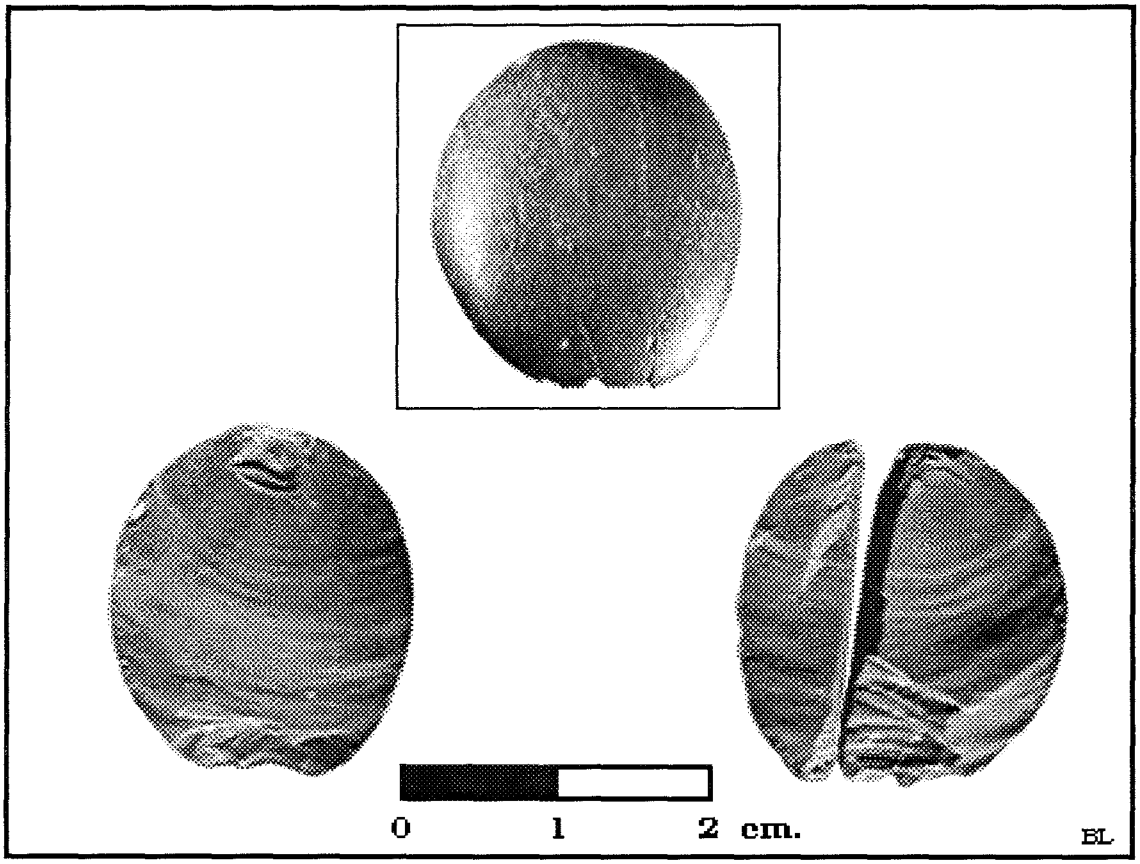

Figure 6.35. Class 3 silicified siltstone pebble split parallel to the Y axis - one section complete (specimen 86).

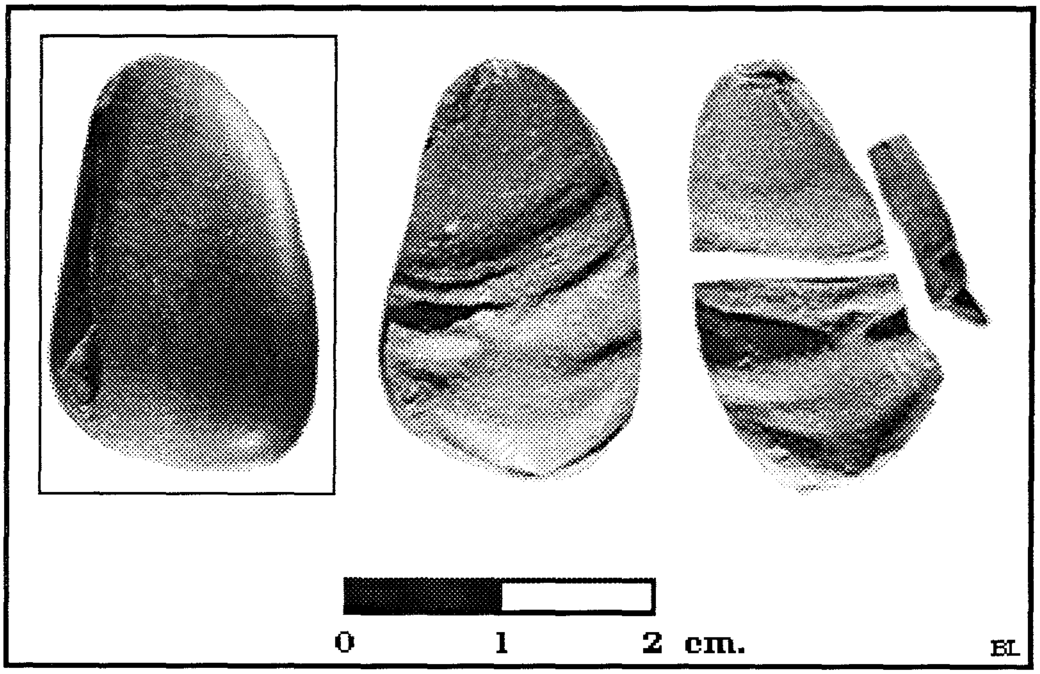

Figure 6.36. Class 3 silicified siltstone pebble split parallel to the Y axis - one section complete (specimen 190).

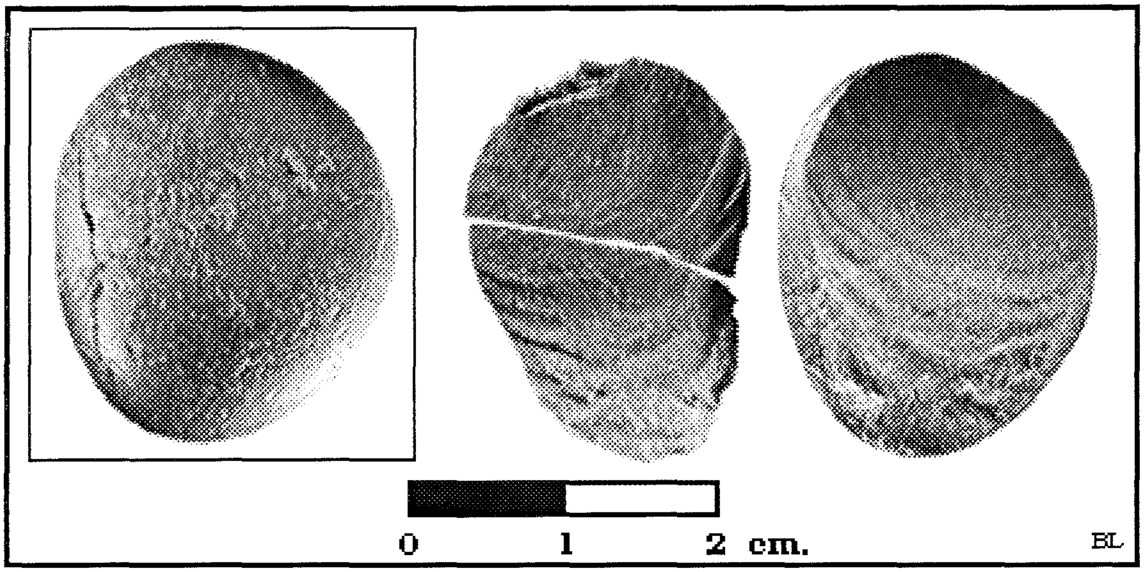

Figure 6.37. Class 3 silicified siltstone pebble split parallel to the Y axis - one section complete (specimen 213).

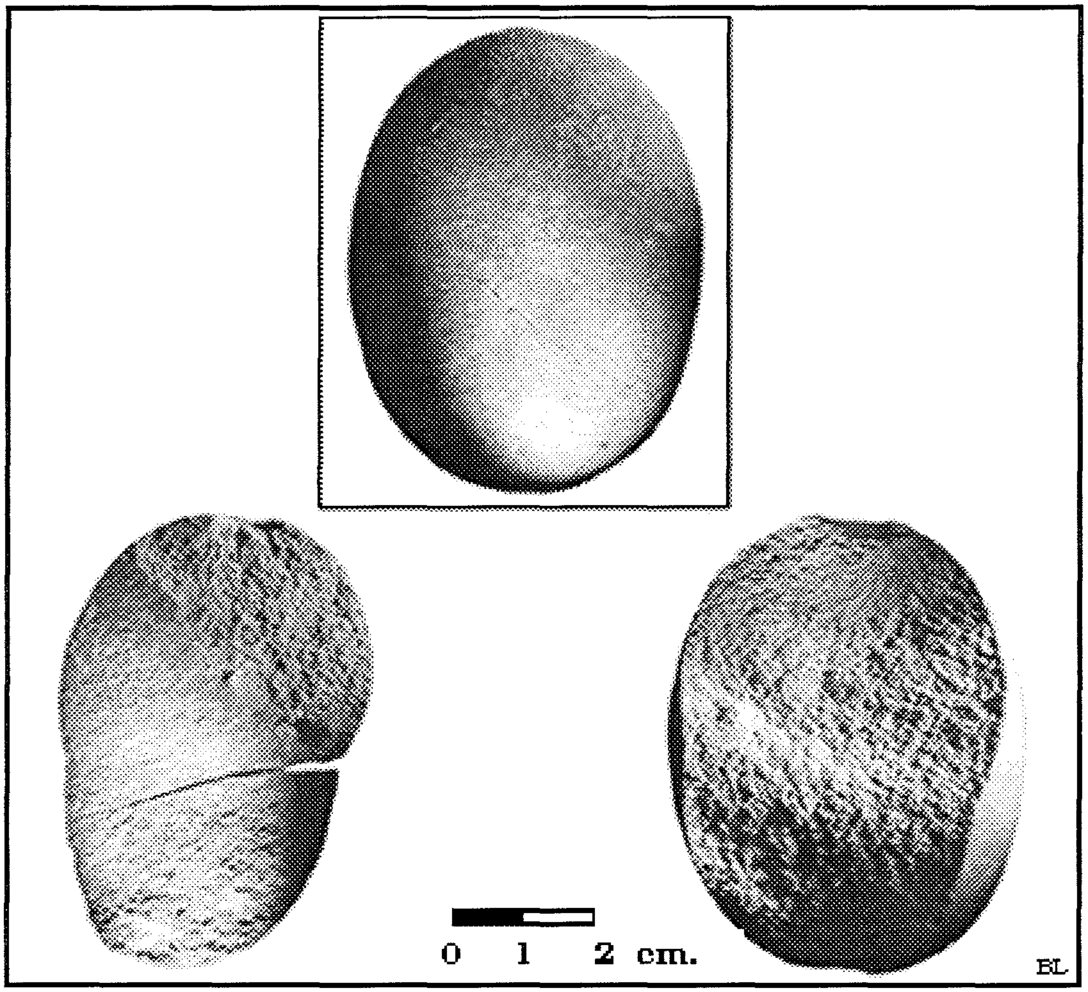

Figure 6.38. Class 3 generic material pebble split parallel to the Y axis - one section complete (specimen 233).

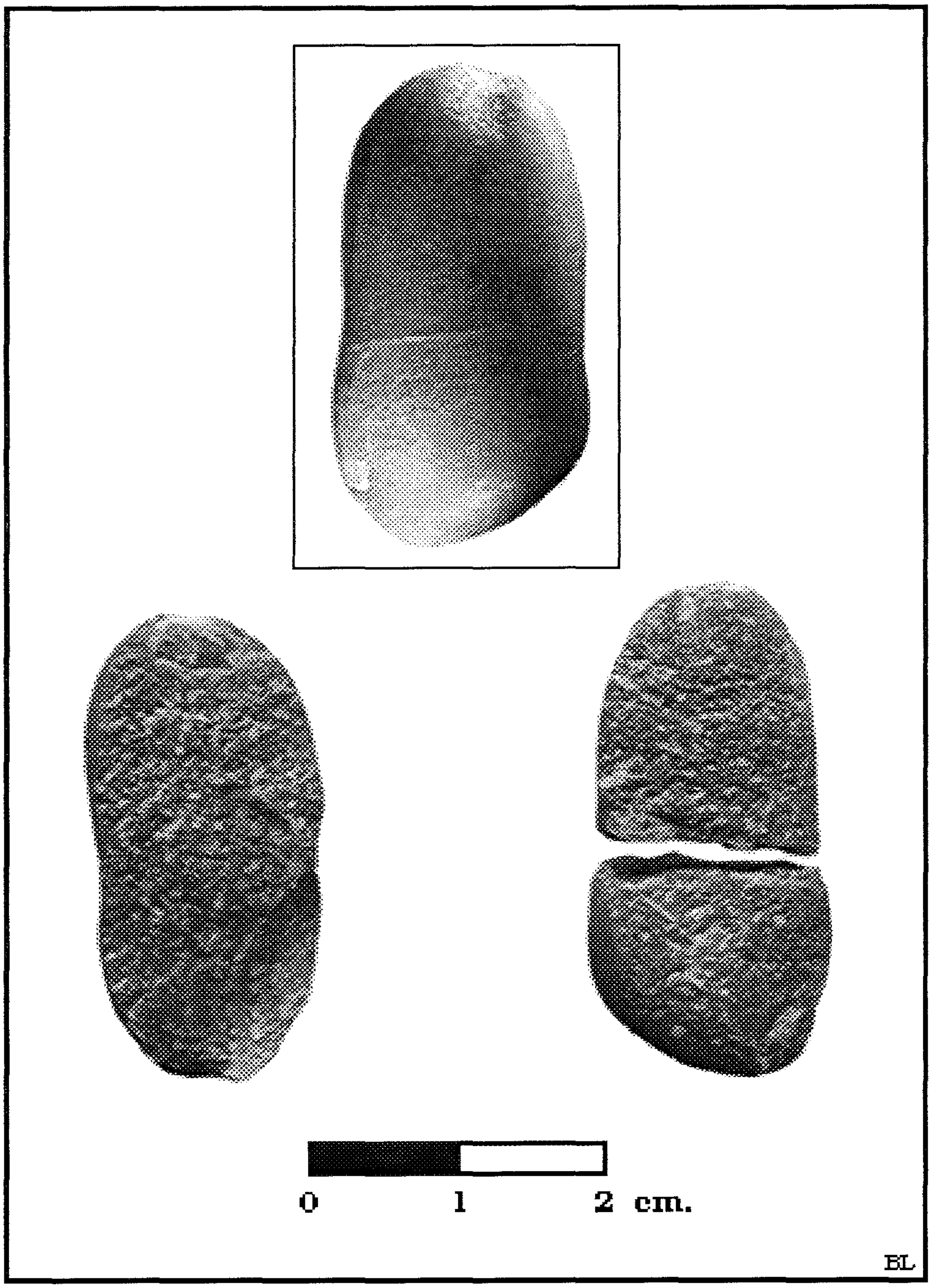

Figure 6.39. Class 3 quartzite pebble split parallel to the Y axis - one section complete (specimen 243).

10.9% of the total experimental replications.

6.1.2.4 *Class 4* includes an unusual group of 3 specimens (Table 6.5); 2 generic material and 1 silicified siltstone. These pebbles are split longitudinally down the X axis and transversely along parallel axes to the Y axis ending in an axial termination and producing three complete sections. This phenomenon of a double split was also recorded by Herbort (1988: 39). During his study he also noted that occasionally a cobble would double split with the central section displaying two planar surfaces. The pebbles within this class are at the large end of those used here and they all have slightly flatter, wider, ends. It is likely that the size and body shape of these pebbles were similar to that of larger cobbles, which allowed the force waves to disperse down through the specimens unevenly. Therefore, several wave fronts likely emanated down through the material simultaneously, thus allowing the pebble to shear in several parallel transverse directions. Figure 6.40 shows a Class 4 pebble of generic material. It is quite evident that the pebble sheared into three fairly uniform sections. Although this specimen displays proximal and distal crushing no other attributes are visible.

Figure 6.41 displays a silicified siltstone pebble of Class 4. This specimen is different from the previous one in that it did not shear completely evenly into the three sections. The one section sheared the length of the pebble but snapped at the distal end of the section. The other section snapped off just before the distal end of the pebble. It is possible that if I had applied slightly more

Table 6.5. Class 4 specimens split parallel to Y axis in three sections

SP#	Material Type	Source	Dimensions (cm's)						PIC			DIC			PLED			PBP			DBP		
			Original			Means			L	C	R	L	C	R	L	C	R	L	C	R	L	C	R
			L(X)	*W(Y)*	*T(Z)*	*L(X)*	*W(Y)*	*T(Z)*								*V*	*D*		*V*			*D*	
248	Gen mat	Fr	4.17	2.76	1.69	Generic material			x	x	x	x	x	x	n	n	n	n	n	n	n	n	n
249	Gen mat	Fr	3.03	2.02	1.11	**3.6**	**2.39**	**1.4**	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
250	SSP	GIL	7.71	5.15	2.4	***Silicified Siltstone***			x	x	x	x	x	x	pr	pr	n	i	pr	n	n	n	n
Grand Totals (Means)			5.94	3.96	2.05																		

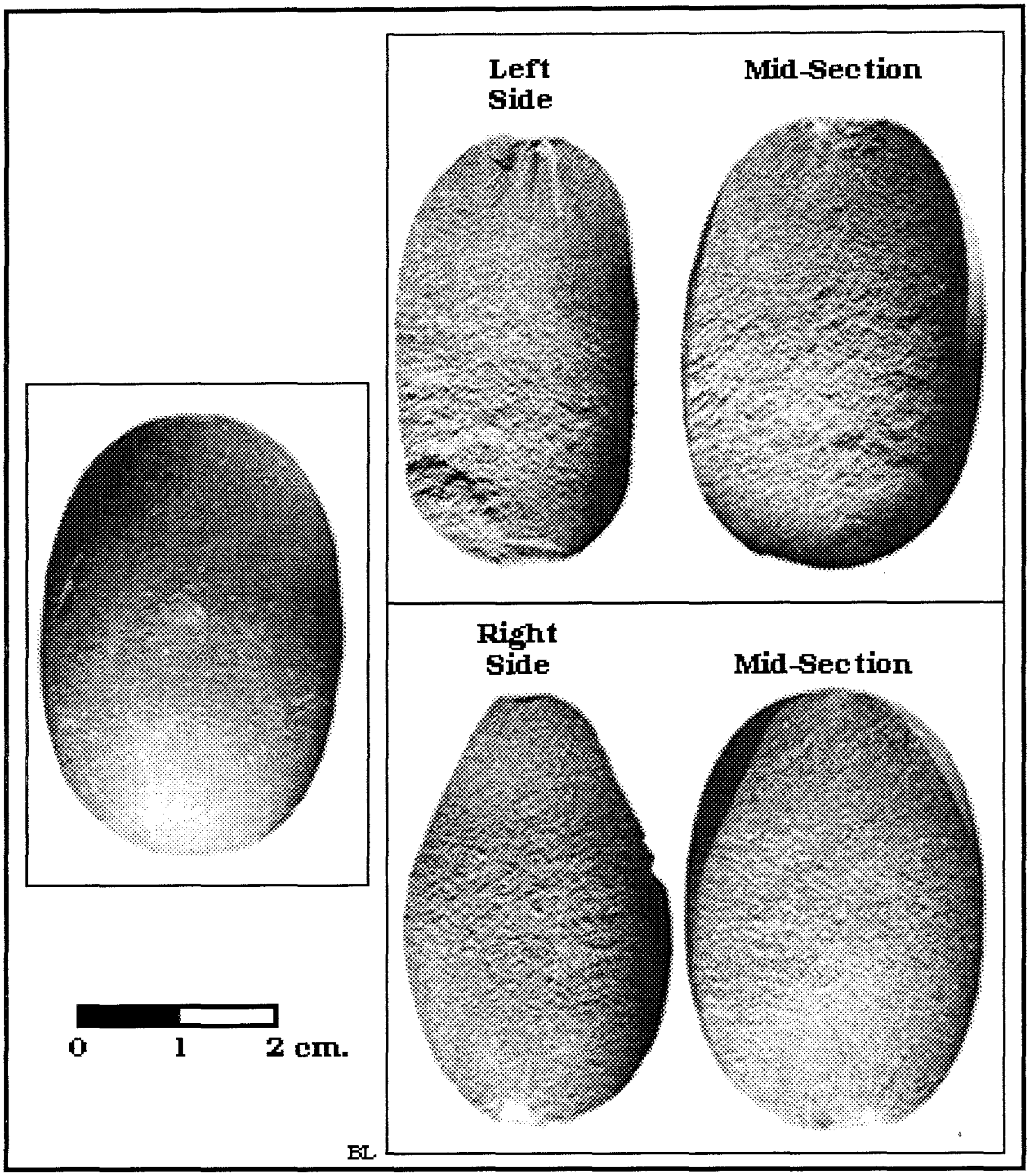

Figure 6.40. Class 4 generic material pebble split into three linear sections (specimen 248).

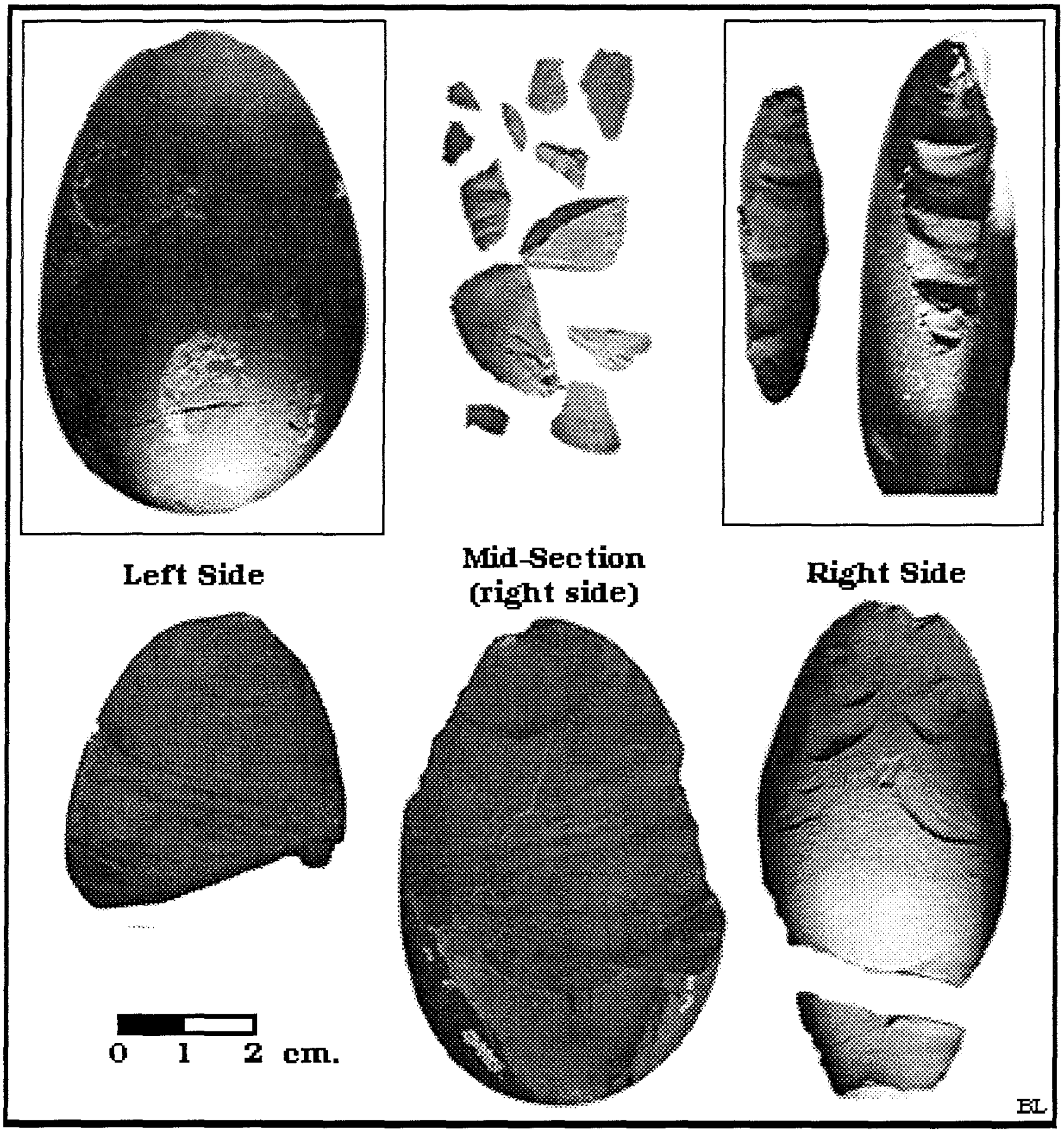

Figure 6.41. Class 4 silicified siltstone pebble split into three linear sections (specimen 250).

force this section may have sheared completely through the specimen as well. Only the ventral surfaces of the snapped section and its associated piece display any attributes. The snapped section has a pronounced positive proximal bulb and could easily be mistaken for a straight percussion flake. The associated section of this flake has a negative inverted proximal bulb of percussion, but as it displays proximal and distal impact crushing it could obviously be distinguished as the result of bipolar percussion.

6.1.2.5 *Class 5* includes one specimen (Table 6.6) of silicified siltstone. This specimen is even more unusual than the Class 4 specimens in that it has been split longitudinally and transversely into four pieces down the X axis and parallel to the Y axis that end in axial terminations (Figure 6.42). This pebble was fairly small, but it had relatively flat ends. It is possible that the same dispersal of energy took place within this specimen as it

Table 6.6.
Class 5 specimen split in four sections parallel to Y axis.

SP #	Material Type	Source	Dimensions (cm's) Original			
			L(X)	*W(Y)*	*T(Z)*	
251	SSP	NSKR	2.79	1.85	1.5	Irregular Fracture/ shear surface

obviously did in the Class 4 materials. Proximal and distal crushing is evident on the larger sections, but it would not be possible to identify the smaller piece as a bipolar by-product without the other associated fragments of the pebble.

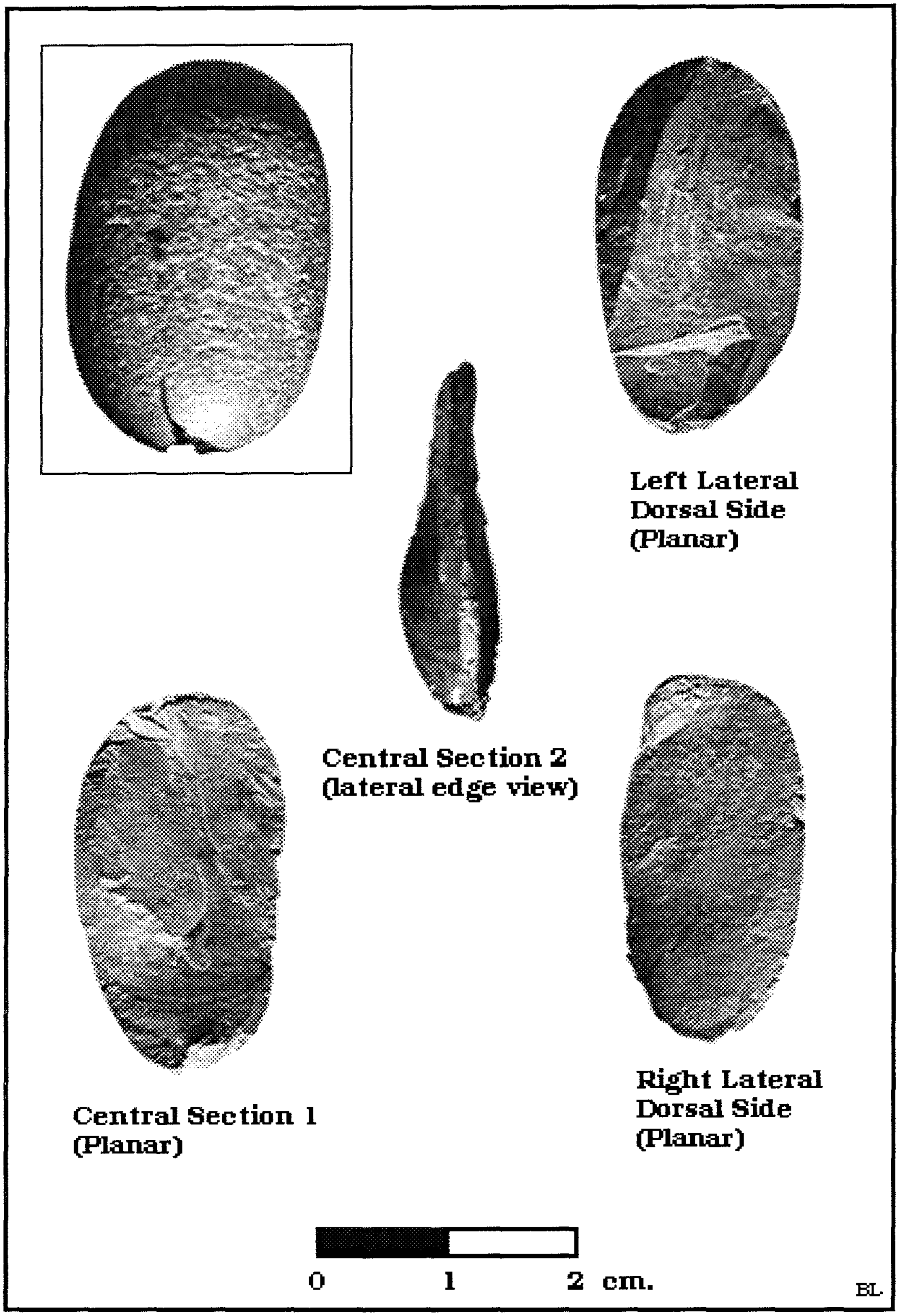

Figure 6.42. Class 5 silicified siltstone pebble split into four linear sections (specimen 251).

6.1.2.6 *Class 6* materials are the most undiagnostic of the experimental replications. This class includes the 39 pebbles that shattered into highly variable miscellaneous fragments (Table 6.7). Material sources are: 26 silicified siltstone, 11 generic chert, one generic material and one quartzite specimen. The original dimensions of these specimens are as listed in Table 6.7 and one specimen is illustrated in Figure 6.43 .

A major problem with these bipolar materials is that they could easily be mixed with straight percussion fragments with no means of being able to differentiate them. Regarding this type of shatter it is necessary to have the associated fragments and the presence of anvils with these materials to determine if they may or may not be bipolar by-products and even then it is largely speculation.

Several of these materials likely shattered because of their overall body shape, that is, they were quite round or fairly thick in relation to their width. As I previously noted this body form does not shear well and tends to shatter. However, in several cases it is just as likely that I applied too much force to the specimen and rather than shearing it, I shattered, or more appropriately, crushed it by the amount of force applied. Class 6 specimens comprised 8.1% of the total experimental replications.

6.1.2.7 *Class 7* specimens (Table 6.8) resulted from an inadequate amount of applied pressure during the replication causing the pebble to chip or partially flake at the proximal end. This left the majority of the pebble intact producing small primary flakes. These flakes usually exhibited feather terminations,

Table 6.7. Class 6 specimens shattered into miscellaneous variable fragments

SP #	Material Type	Source	Dimensions (cm's)					
			Original			Means		
			L(X)	*W(Y)*	*T(Z)*	*L(X)*	*W(Y)*	*T(Z)*
272	SSP	NSKR	2.56	1.76	0.74			
273	SSP	NSKR	2.95	1.71	1			
274	SSP	NSKR	4.71	2.79	1.45			
275	SSP	NSKR	1.74	1.11	0.8			
276	SSP	NSKR	2.87	1.85	0.89			
277	SSP	NSKR	3.22	1.45	0.75			
278	SSP	NSKR	2.6	2.34	0.89			
279	SSP	NSKR	2.67	0.83	0.66			
280	SSP	NSKR	3.59	2.37	1.29			
281	SSP	NSKR	2.96	1.73	0.72			
282	SSP	NSKR	3.01	2.41	1.02			
283	SSP	NSKR	3.86	3.55	2.47			
284	SSP	NSKR	3.21	2.6	1			
285	SSP	NSKR	2.9	2.46	0.71			
286	SSP	NSKR	2.05	1.71	0.73			
287	SSP	NSKR	2.17	1.09	0.4			
288	SSP	NSKR	2.15	1.18	0.86			
289	SSP	NSKR	2.53	1.09	0.68			
290	SSP	NSKR	2.99	2.04	1.22			
291	SSP	GIL	3.44	1.8	1.31			
292	SSP	GIL	2.12	1.41	1.09			
293	SSP	GIL	2.69	2.54	1.05			
294	SSP	GIL	2.86	1.5	0.9			
295	SSP	GIL	2.89	2.15	0.99	Silicified Siltstone Pebbles		
296	SSP	GIL	2.3	2.2	1.01			
297	SSP	FR	3.49	2.51	0.79	**3.03**	**2.14**	**0.77**
259	Gen chert	NSKR	5.38	2.55	1.91			
260	Gen chert	NSKR	3.11	1.81	1.16			
261	Gen chert	NSKR	2.96	1.42	0.67			
262	Gen chert	NSKR	3.01	1.56	0.86			
263	Gen chert	NSKR	2.37	1.57	0.71			
264	Gen chert	NSKR	3.95	2.51	1.7			
265	Gen chert	NSKR	2.92	1.36	1.12			
266	Gen chert	GIL	2.14	1.49	0.98			
267	Gen chert	GIL	3.6	2.72	1.27			
268	Gen chert	GIL	2.52	1.81	1.05	Generic chert		
269	Gen chert	GIL	2.85	2.14	0.92	**4.12**	**2.35**	**1.42**
270	Gen mat	FR	5.14	3.07	1.77	***Generic Material***		
271	Qtz-ite	NSKR	4.12	3.46	1.3	***Quartzite***		
Grand Total (means)			3.34	2.61	1.02			

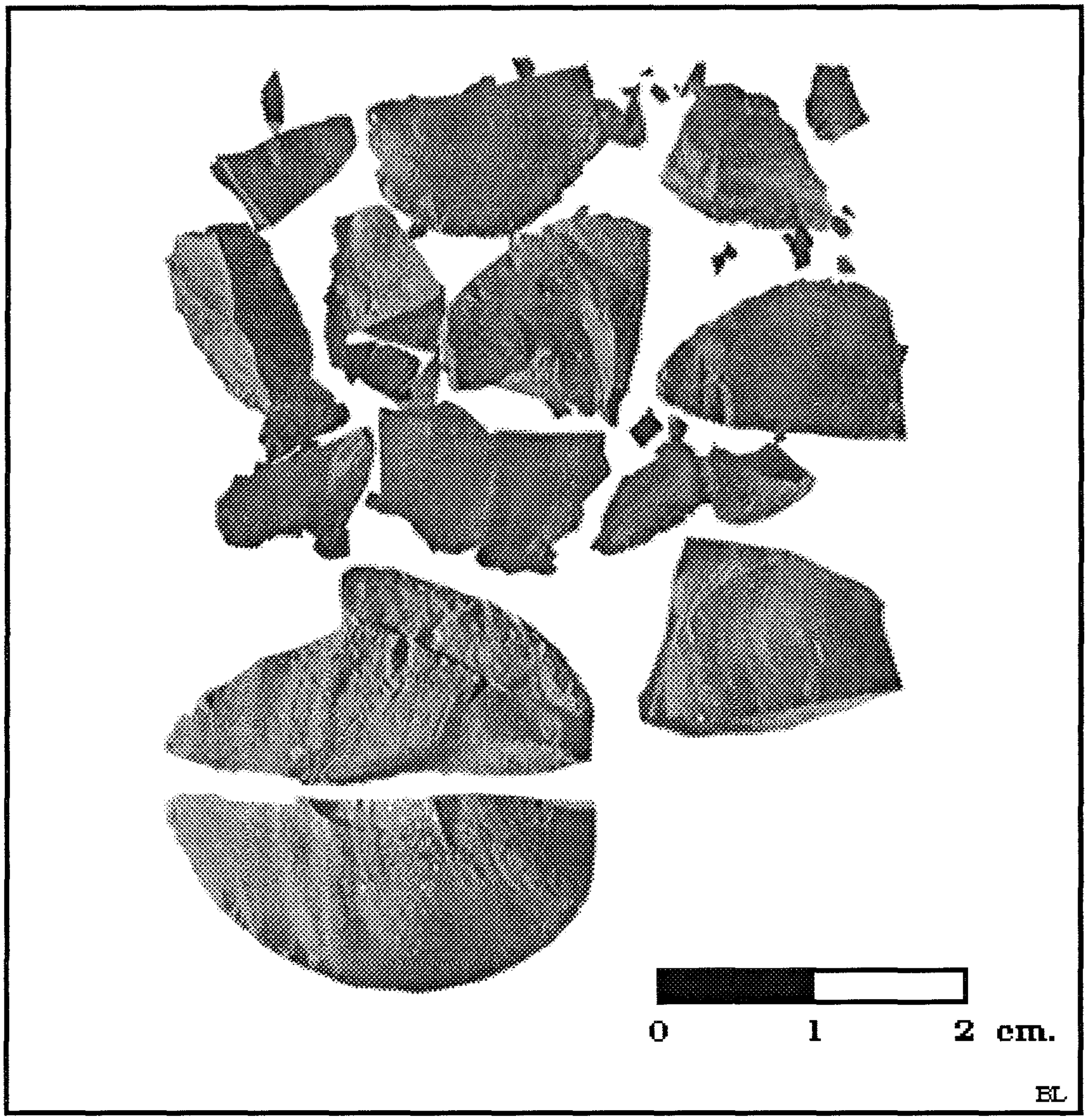

Figure 6.43. Class 6 shattered silicified siltstone pebble (specimen 282).

Table 6.8. Class 7 specimens with inadequate pressure applied

Sp#	Material Type	Source	Dimensions (cm's)					
			Original			Means		
			L(X)	W(Y)	T(Z)	L(X)	W(Y)	T(Z)
298	SSP	NSKR	2.58	1.14	0.83			
299	SSP	NSKR	3.32	2.6	0.99			
300	SSP	NSKR	3.57	1.81	0.89			
301	SSP	NSKR	2.67	2.15	0.56			
302	SSP	NSKR	2.48	2.06	0.82			
303	SSP	NSKR	3.03	2.1	1			
304	SSP	NSKR	2.98	1.41	0.81			
305	SSP	NSKR	2.37	1.85	0.69			
306	SSP	NSKR	2.72	2.07	1.16			
307	SSP	NSKR	3.38	1.32	0.77			
308	SSP	NSKR	3.94	2.56	1.34			
309	SSP	NSKR	2.96	2.84	1.23			
310	SSP	NSKR	3.21	1.92	0.73			
311	SSP	NSKR	3.21	2.69	1.34			
312	SSP	NSKR	2.56	1.59	0.59			
313	SSP	NSKR	2.54	2.27	1.15			
314	SSP	NSKR	2.19	2.15	0.76			
315	SSP	NSKR	3.3	2.21	1.16			
316	SSP	NSKR	2.67	1.57	1.3			
317	SSP	NSKR	2.5	1.41	1.02			
318	SSP	NSKR	2.6	1.9	1.39			
319	SSP	NSKR	2.51	2.06	1.11			
320	SSP	NSKR	3.35	2.12	0.96			
321	SSP	NSKR	3.07	2.61	1.67			
322	SSP	NSKR	3.31	2.73	1.17			
323	SSP	NSKR	2.96	1.59	0.91			
324	SSP	NSKR	2.94	2.54	0.86			
325	SSP	NSKR	2.86	1.65	1.11			
326	SSP	NSKR	3.29	2.89	1.23			
327	SSP	NSKR	2.46	1.63	0.82			
328	SSP	NSKR	5.55	4.2	1.75			
329	SSP	NSKR	2.99	2.04	1.5			
330	SSP	NSKR	3.05	2.41	1.05			
331	SSP	NSKR	3.36	2.04	1.58			
332	SSP	NSKR	2.51	1.28	0.7			
333	SSP	NSKR	4	2.37	1.41			
334	SSP	NSKR	2.4	1.97	0.91			
335	SSP	NSKR	2.84	1.36	0.93			
336	SSP	NSKR	4.1	2.11	1.39			
337	SSP	NSKR	2.72	1.58	0.83			
338	SSP	NSKR	2.82	2.14	0.62			
339	SSP	NSKR	5.8	2.61	1.12			
340	SSP	NSKR	4.01	3.14	1.61			

Table 6.8. Class 7 specimens with inadequate pressure applied

341	SSP	NSKR	2.51	1.89	0.69	
342	SSP	NSKR	2.96	2.03	1.32	
343	SSP	NSKR	3.41	2.32	1.27	
344	SSP	NSKR	2.7	1.43	1.08	
345	SSP	NSKR	2.79	2.27	0.54	
346	SSP	NSKR	2.61	2	0.73	
347	SSP	NSKR	2.94	1.05	1.05	
348	SSP	NSKR	3	2	1.01	
349	SSP	NSKR	2.86	1.82	0.75	
350	SSP	NSKR	2.55	2.31	0.52	
351	SSP	NSKR	3.37	3.32	1.3	
352	SSP	NSKR	3.08	2.31	1.05	
353	SSP	NSKR	3.93	1.57	1.34	
354	SSP	NSKR	2.89	1.45	1.33	
355	SSP	NSKR	5.9	2.87	1.98	
356	SSP	NSKR	4.81	4.41	1.49	
357	SSP	NSKR	2.82	1.78	1.05	
358	SSP	NSKR	3.72	2.27	0.78	
359	SSP	NSKR	3.59	1.58	0.56	
360	SSP	NSKR	1.87	1.5	0.71	
361	SSP	NSKR	2.01	1.59	0.8	
362	SSP	NSKR	2.27	1.23	0.91	
363	SSP	NSKR	2.41	1.66	0.86	
364	SSP	NSKR	3.2	1.26	0.51	
365	SSP	NSKR	2.31	1.63	0.87	
366	SSP	NSKR	2.61	1.27	0.8	
367	SSP	NSKR	2.68	1.69	0.91	
368	SSP	NSKR	2.57	1.86	0.71	
369	SSP	GIL	3.19	2.01	0.95	
370	SSP	GIL	3.12	2.75	1.04	
371	SSP	GIL	2.31	1.84	0.7	
372	SSP	GIL	2.49	2	0.81	
373	SSP	GIL	3.2	1.93	0.67	
374	SSP	GIL	2.91	2.25	0.86	
375	SSP	GIL	2.4	2	0.67	
376	SSP	GIL	2.55	1.56	0.68	
377	SSP	GIL	3.07	2.89	1.64	
378	SSP	GIL	1.91	1.81	0.64	
379	SSP	GIL	3.29	2.16	1.21	
380	SSP	GIL	3.5	2.69	1.85	
381	SSP	GIL	2.41	2.23	0.97	
382	SSP	GIL	2.58	1.41	0.86	
383	SSP	GIL	2.85	1.82	1.09	
384	SSP	GIL	2.96	1.75	0.86	
385	SSP	GIL	4.25	2.56	1.44	
386	SSP	GIL	2.2	1.61	0.6	
387	SSP	GIL	1.7	1.02	0.42	

Table 6.8. Class 7 specimens with inadequate pressure applied

388	SSP	GIL	2.25	2.27	1.01			
389	SSP	GIL	2.87	2.34	0.97			
390	SSP	GIL	2.93	2.2	0.97			
391	SSP	GIL	3.95	1.6	0.96			
392	SSP	GIL	2.22	1.39	0.47			
393	SSP	GIL	2.73	1.37	1.31			
394	SSP	GIL	2.59	2.3	0.74			
395	SSP	GIL	3.56	1.4	1.23			
396	SSP	GIL	2.41	1.9	0.86			
397	SSP	GIL	3.53	2.33	0.96			
398	SSP	GIL	2.72	2.48	1.21			
399	SSP	GIL	2.99	2.51	0.66			
400	SSP	GIL	3.14	2.09	0.85			
401	SSP	GIL	2.59	1.94	0.8			
402	SSP	GIL	2.91	2.25	0.86			
403	SSP	GIL	3.07	2.12	0.7			
404	SSP	GIL	2.84	2.2	1.16			
405	SSP	GIL	3.62	2.17	0.96			
406	SSP	GIL	2.46	1.03	1.2			
407	SSP	GIL	3.6	1.77	0.7			
408	SSP	FR	2.96	2.29	1.03			
409	SSP	FR	2.7	2	0.63			
410	SSP	FR	3.82	2.36	1.07			
411	SSP	FR	3.16	1.67	0.77	Silicified siltstone pebbles		
412	SSP	FR	2.56	1.66	0.76			
413	SSP	FR	2.99	1.57	1.06	**2.79**	**1.36**	**0.95**
414	Gen chert	NSKR	2.71	1.44	1.13			
415	Gen chert	NSKR	2.66	1.64	0.91			
416	Gen chert	NSKR	4.06	2.21	1.01			
417	Gen chert	NSKR	2.32	1.96	1.14			
418	Gen chert	NSKR	2.45	2.3	1.23			
419	Gen chert	NSKR	2.36	1.39	0.64			
420	Gen chert	NSKR	4.41	3.51	1.53			
421	Gen chert	NSKR	3.21	2.3	1			
422	Gen chert	NSKR	4.41	1.96	1.41			
423	Gen chert	NSKR	3.27	2.78	0.8			
424	Gen chert	NSKR	3.69	3.56	1.22			
425	Gen chert	NSKR	2.54	1.76	0.96			
426	Gen chert	NSKR	2.41	1.89	0.75			
427	Gen chert	NSKR	2.9	1.42	0.77			
428	Gen chert	NSKR	2.14	1.68	0.78			
429	Gen chert	NSKR	1.97	1.4	0.66			
430	Gen chert	NSKR	3.16	2.21	1.01			
431	Gen chert	NSKR	3.13	1.4	1.34			
432	Gen chert	NSKR	2.91	1.41	0.94			
433	Gen chert	NSKR	2.86	1.45	0.87			
434	Gen chert	NSKR	2.9	2.21	1.39			

Table 6.8. Class 7 specimens with inadequate pressure applied

435	Gen chert	GIL	3.07	2.72	1.01			
436	Gen chert	GIL	4.71	2.53	2.05			
437	Gen chert	GIL	1.85	1.62	0.59			
438	Gen chert	GIL	2.62	2.47	1.77			
439	Gen chert	GIL	2.22	1.94	0.64			
440	Gen chert	GIL	3.3	2.06	1.43			
441	Gen chert	GIL	2.6	2.19	1.66			
442	Gen chert	GIL	2.92	2.41	1.3			
443	Gen chert	GIL	2.59	2.13	0.7			
444	Gen chert	GIL	3.87	3.46	1.22	Generic chert		
445	Gen chert	FR	2.53	1.91	0.69	**2.62**	**1.68**	**0.91**
446	Gen mat	NSKR	4.1	1.75	1.33			
447	Gen mat	NSKR	3.58	3.96	1.21			
448	Gen mat	NSKR	4.19	3.53	1.22			
449	Gen mat	NSKR	2.91	1.64	0.91			
450	Gen mat	NSKR	4.09	2.63	0.8			
451	Gen mat	NSKR	4.91	2.96	1.12			
452	Gen mat	NSKR	3	1.71	0.57			
453	Gen mat	NSKR	5.21	4	2.08			
454	Gen mat	NSKR	4.16	2.56	1.58			
455	Gen mat	NSKR	4.89	3.1	1.3			
456	Gen mat	GIL	3.9	2.31	1.2			
457	Gen mat	GIL	3.43	2.3	1.01			
458	Gen mat	GIL	3.95	3.27	1.46			
459	Gen mat	GIL	2.82	2.32	0.89			
460	Gen mat	GIL	2.91	2.54	1.01			
461	Gen mat	FR	4.26	3.21	0.92			
462	Gen mat	FR	3.2	1.84	0.72			
463	Gen mat	FR	4.61	3.34	1.62			
464	Gen mat	FR	5.12	2.52	1.17			
465	Gen mat	FR	3.76	2.78	1.39			
466	Gen mat	FR	4.63	2.46	1.17			
467	Gen mat	FR	2.85	2.01	1.49			
468	Gen Mat	FR	5.14	3.11	1.33			
469	Gen mat	FR	4.54	3.5	1.44			
470	Gen mat	FR	3.09	2.11	0.64	Generic material		
471	Gen mat	FR	2.31	2.23	0.62	**3.21**	**1.99**	**0.98**
472	Qtz-ite	NSKR	6.71	3.54	1.96			
473	Qtz-ite	NSKR	5.85	3.07	2.11			
474	Qtz-ite	NSKR	6.05	3.81	1.41			
475	Qtz-ite	NSKR	3.04	3	1.24			
476	Qtz-ite	NSKR	2.49	2.17	0.89			
477	Qtz-ite	NSKR	6.25	3.99	1.94			
478	Qtz-ite	NSKR	4.27	4.77	1.67			
479	Qtz-ite	NSKR	4.65	4.37	1.11			
480	Qtz-ite	NSKR	3.49	2.41	1.01			
481	Qtz-ite	NSKR	6.68	4.05	1.75			

Table 6.8. Class 7 specimens with inadequate pressure applied

482	Qtz-ite	NSKR	2.62	1.96	0.85			
483	Qtz-ite	GIL	4.73	3.77	1.45	Quartzite		
484	Qtz-ite	FR	3.54	3.13	1.07	**5.13**	**3.34**	**1.52**
GRAND Totals (means)			3.06	2.135	0.95			

although step and hinge types were also produced.

There are several reasons why I identified these materials as a separate category and assigned them to their own class. First, once I began the replications, I was trying to precisely control the application of applied pressure. The problem was that often I did not apply an adequate amount of force to the specimen so rather than splitting or shattering the material I was merely chipping it. However, once this occurred the pebble was now altered from its original proportions and I felt strongly that it would very likely react differently should I attempt a second replication of splitting the specimen. Additionally, I was curious how often this situation would repeat itself throughout the experimentation process. Therefore, once I had altered a pebble (in any form) I no longer attempted to apply further pressure to the specimen.

In total, Class 7 specimens amounted to 186 specimens that comprised 35.9% of the total experimental replications. These materials include: 116 silicified siltstone, 32 generic chert, 26 generic material, and 13 quartzite specimens. Figures 6.44, 6.45, 6.46, 6.47 and 6.48 illustrate several of the Class 7 specimens that have had small flakes chipped from their proximal ends.

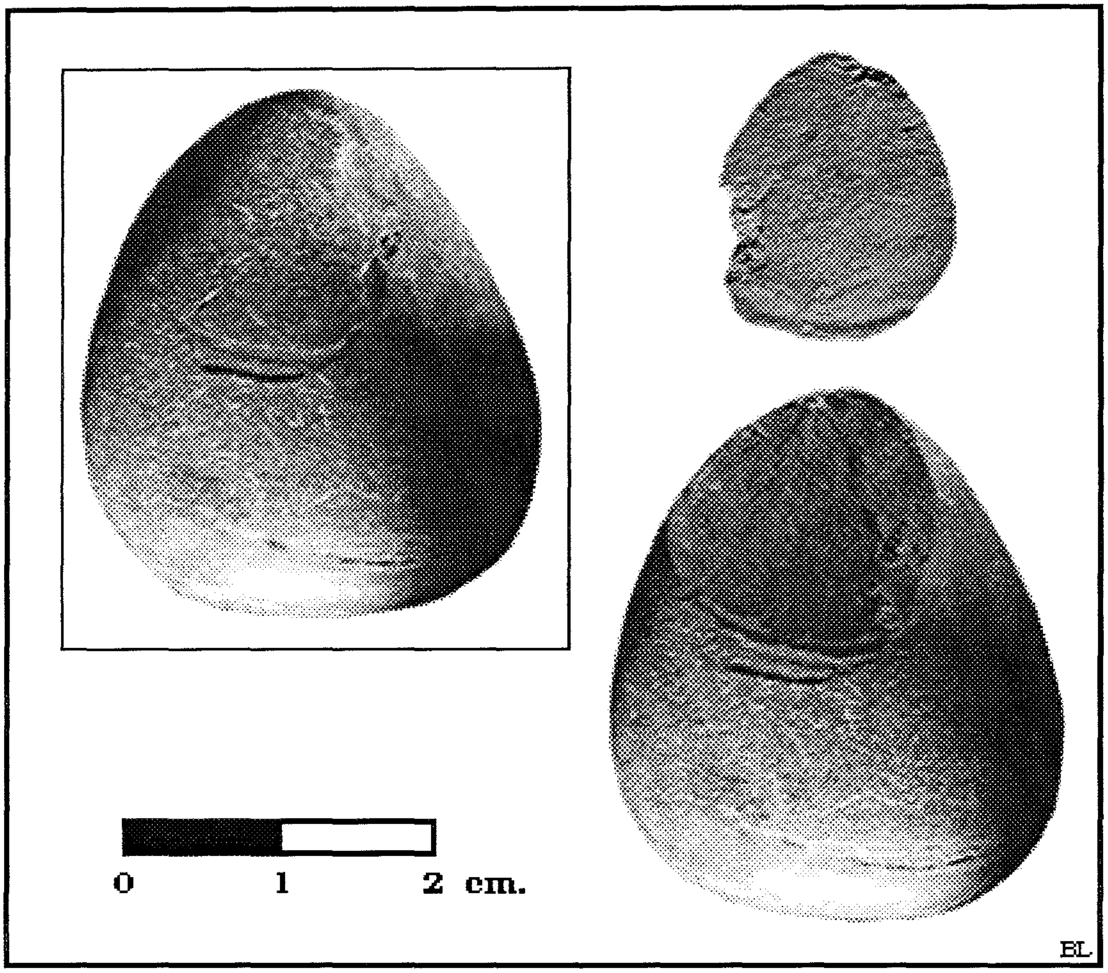

Figure 6.44. Class 7 silicified siltstone pebble displaying proximal chipping - insufficient application of applied pressure (specimen 322).

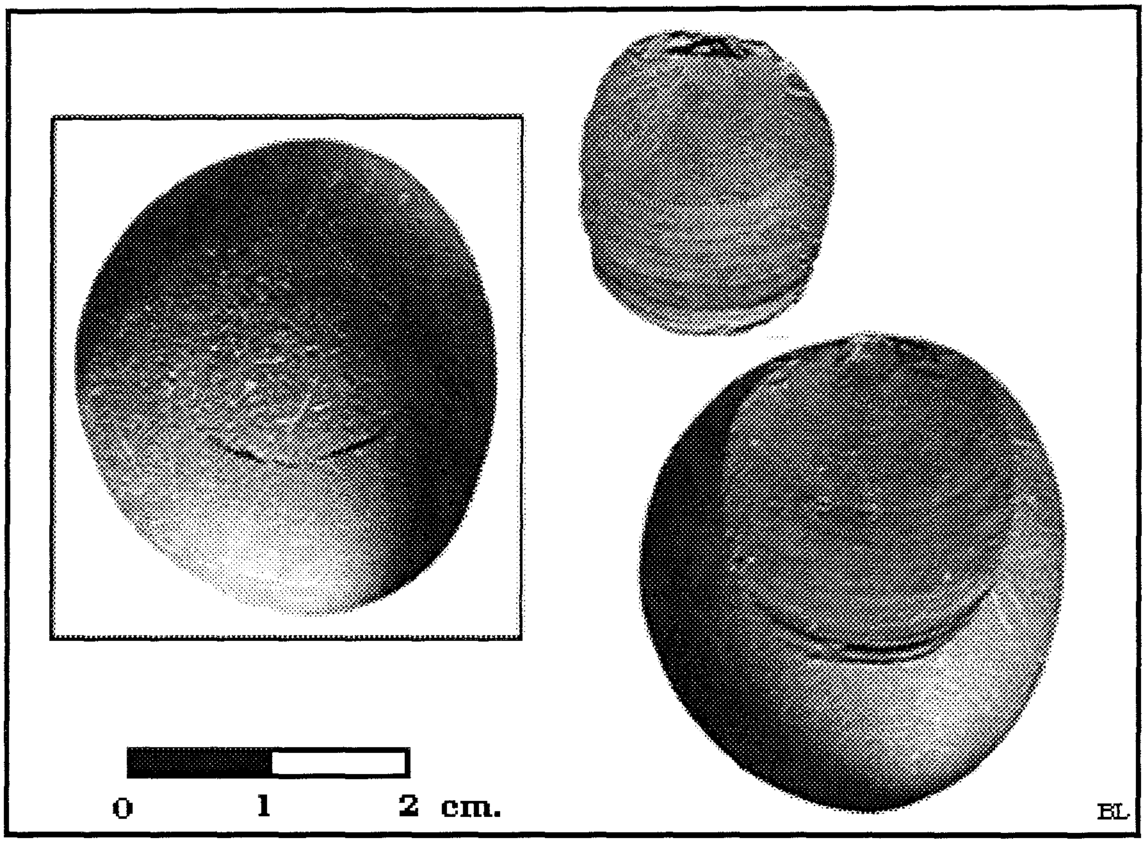

Figure 6.45. Class 7 silicified siltstone pebble displaying proximal chipping (specimen 326).

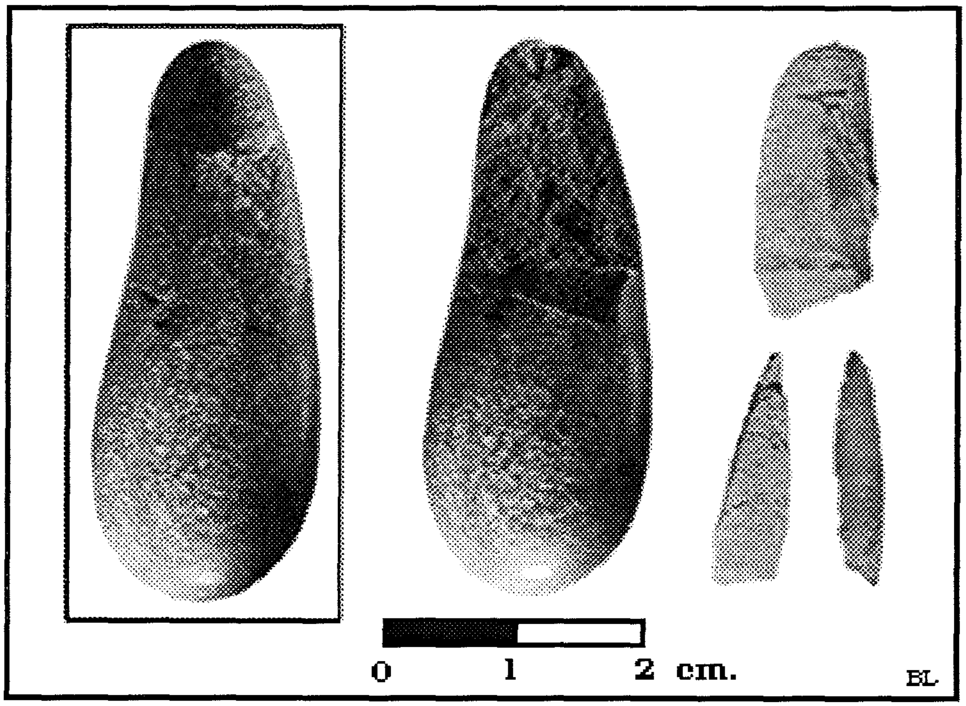

Figure 6.46. Class 7 generic material pebble displaying proximal chipping (specimen 446).

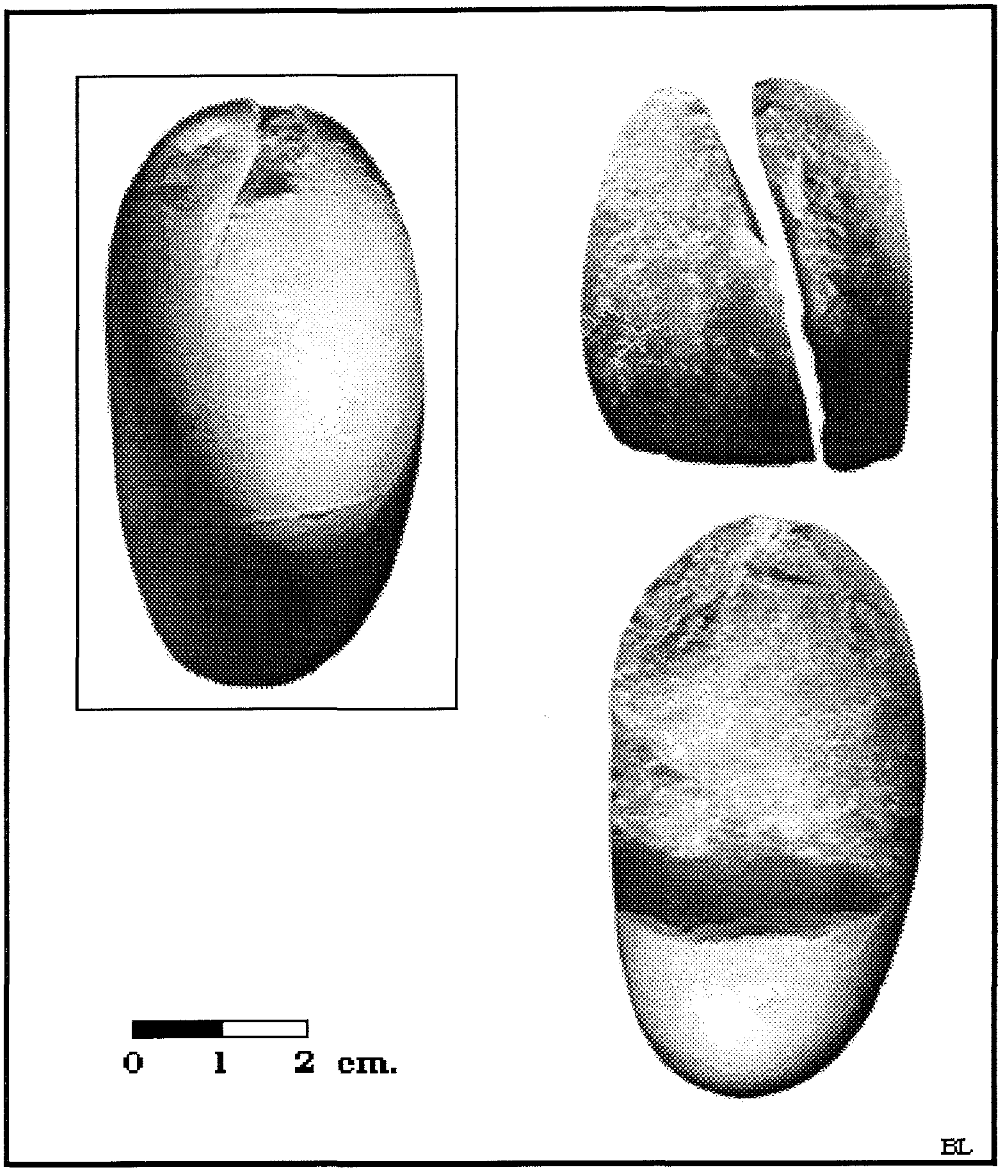

Figure 6.47. Class 7 quartzite pebble displaying proximal chipping - insufficient application of applied pressure (specimen 472).

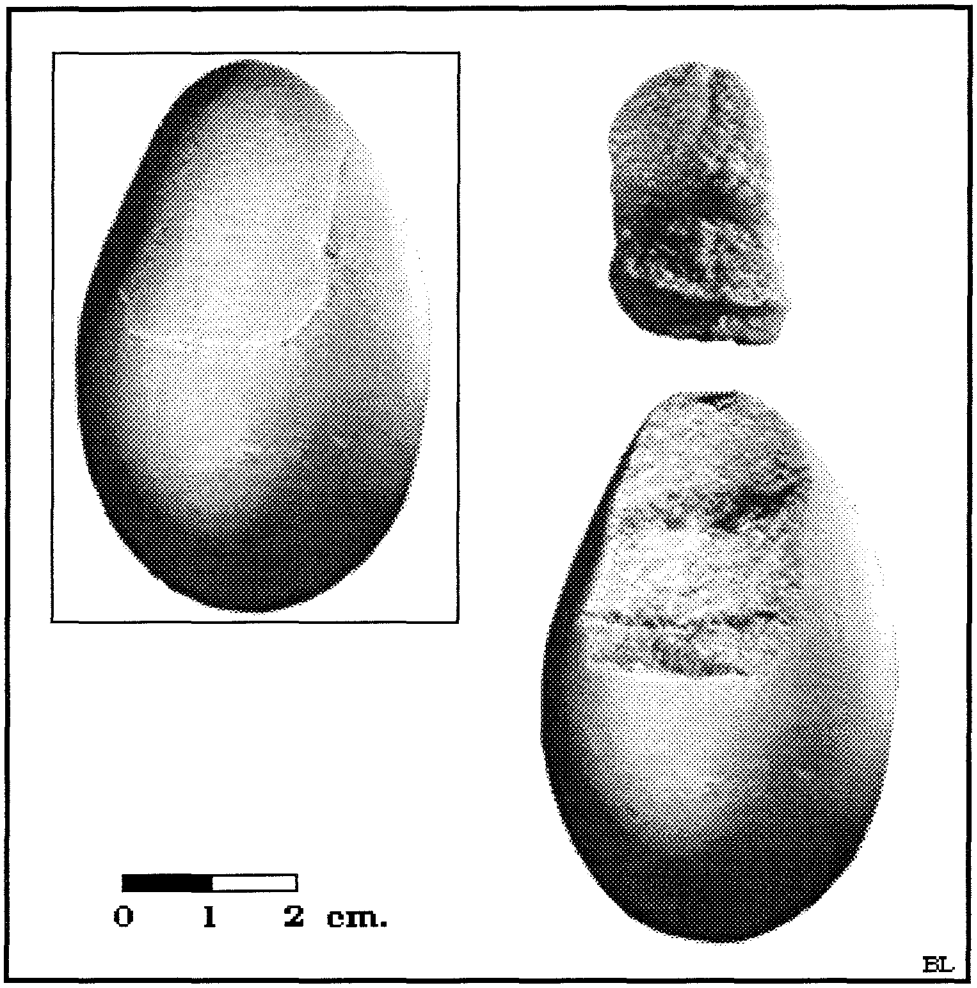

Figure 6.48. Class 7 quartzite pebble displaying proximal chipping - insufficient application of applied pressure (specimen 477).

6.1.2.8 *Class 8* specimens are another unique class of bipolar flakes identified here as citrus-section flakes. These specimens fractured into long linear wedge-shaped fragments that end in axial terminations. Largely because these specimens all end in axial terminations they all display some distal, as well as proximal, impact crushing.

Citrus-section flakes have been previously recorded within the archaeological record. For example, Meyer (1978:16) noted in his analysis of the Key Lake Archaeological Survey, Saskatchewan, that the predominant lithic technology for that study area consisted of bipolar technology that was used to work cobble stones. Further, although he recognized a variety of bipolar materials as being present in the Key Lake area he noted that linear flakes were quite abundant. One type of linear flake of particular interest that he recorded was identified as orange-section linear flakes (Meyer 1978:18), which are identical to the Class 8 specimens outlined here.

This class of bipolar fracture is directly related to the over-all body form of the material being worked, which is to say that these flakes derive from a pebble or cobble that is fairly round with a width to thickness ratio being nearly equal. I have previously noted that with an ellipsoid-shaped body the spherical waves pass through a larger portion of a specimen creating a highly variable area of central pressure within the material as the force waves emanate through the material. When the applied and rebound force exerts an equal amount of pressure within the material the specimen will usually either shatter or fracture into these unusual citrus-section flakes.

If too much pressure is applied or the material contains impurities the specimen will tend to shatter. However, when the material in question has a matrix that is fairly dense and compact throughout the specimen the wedge-shaped citrus section flakes are the usual end result, in part because of the outer circular shape of the original specimen, and in part because the material fractures down through the X axis, but at odd angles to the Y and Z axes. The 26 specimens from this class are listed in Table 6.9. They include: 16 silicified siltstone, 3 quartz and 7 generic chert specimens.

Figures 6.49, 6.50, 6.51 and 6.52 illustrate four silicified siltstone specimens that display the classic citrus-section flake form. That is, they have a long straight linear ridge between the two ventral surfaces of the flake, a smooth curved shape along the exterior dorsal side of the fragments and they end in an axial termination. Figures 6.53 and 6.54 illustrate two quartz pebbles of this type. Class 8 specimens comprised 5.0% of the total replications.

6.1.2.9 *Class 9* specimens (Table 6.10) have an irregular shear that produces two surfaces, apparently caused by equal (or unequal) amounts of force being exerted towards the center of the pebble, with one complete half. Whereas the one section is complete the other half of the specimen is shattered into numerous pieces. These materials typically display two flake scars one on both the distal and proximal ends of the ventral

Table 6.9.
Class 8 specimens displaying citrus section fractures

SP #	Material Type	Source	Dimensions (cm's) Original L(X)	W(Y)	T(Z)	Means L(X)	W(Y)	T(Z)
485	SSP	NSKR	3	2.01	1.44			
486	SSP	NSKR	2.94	1.99	1.71			
487	SSP	NSKR	3.19	2.17	1.6			
488	SSP	NSKR	4.91	2.5	1.96			
489	SSP	NSKR	3.42	2.3	1.54			
490	SSP	NSKR	2.59	1.37	0.95			
491	SSP	NSKR	3.48	2.8	1.46			
492	SSP	NSKR	2.64	1.8	1.06			
494	SSP	NSKR	2.77	1.64	0.94			
495	SSP	NSKR	3.12	1.75	0.78			
496	SSP	GIL	3.43	2.96	1.66			
497	SSP	GIL	2.4	1.35	0.71			
498	SSP	GIL	2.93	1.66	1.11			
499	SSP	GIL	2.51	2.01	1.36	Silicified Siltstone		
500	SSP	GIL	2.38	2.08	1.36	pebbles		
501	SSP	GIL	3.59	2.56	1.12	**3.3**	**2.285**	**1.28**
502	Quartz	NSKR	3.39	2.42	1.81			
503	Quartz	GIL	2.86	2	1.23	Quartz		
504	Quartz	NSKR	3.21	2.27	1.18	**3.3**	**2.345**	**1.495**
505	Gen chert	NSKR	2.5	1.7	1.22			
506	Gen chert	NSKR	3.81	2	1.68			
507	Gen chert	NSKR	2.55	2.09	1.1			
508	Gen chert	NSKR	2.45	2	1.08			
509	Gen chert	NSKR	3.54	2.53	1.55			
510	Gen chert	NSKR	2.98	2.1	1.05	Generic chert		
511	Gen chert	GIL	3.65	2.94	1.47	**3.08**	**2.32**	**1.345**
Grand Totals (Means)			3.33	2.48	1.46			

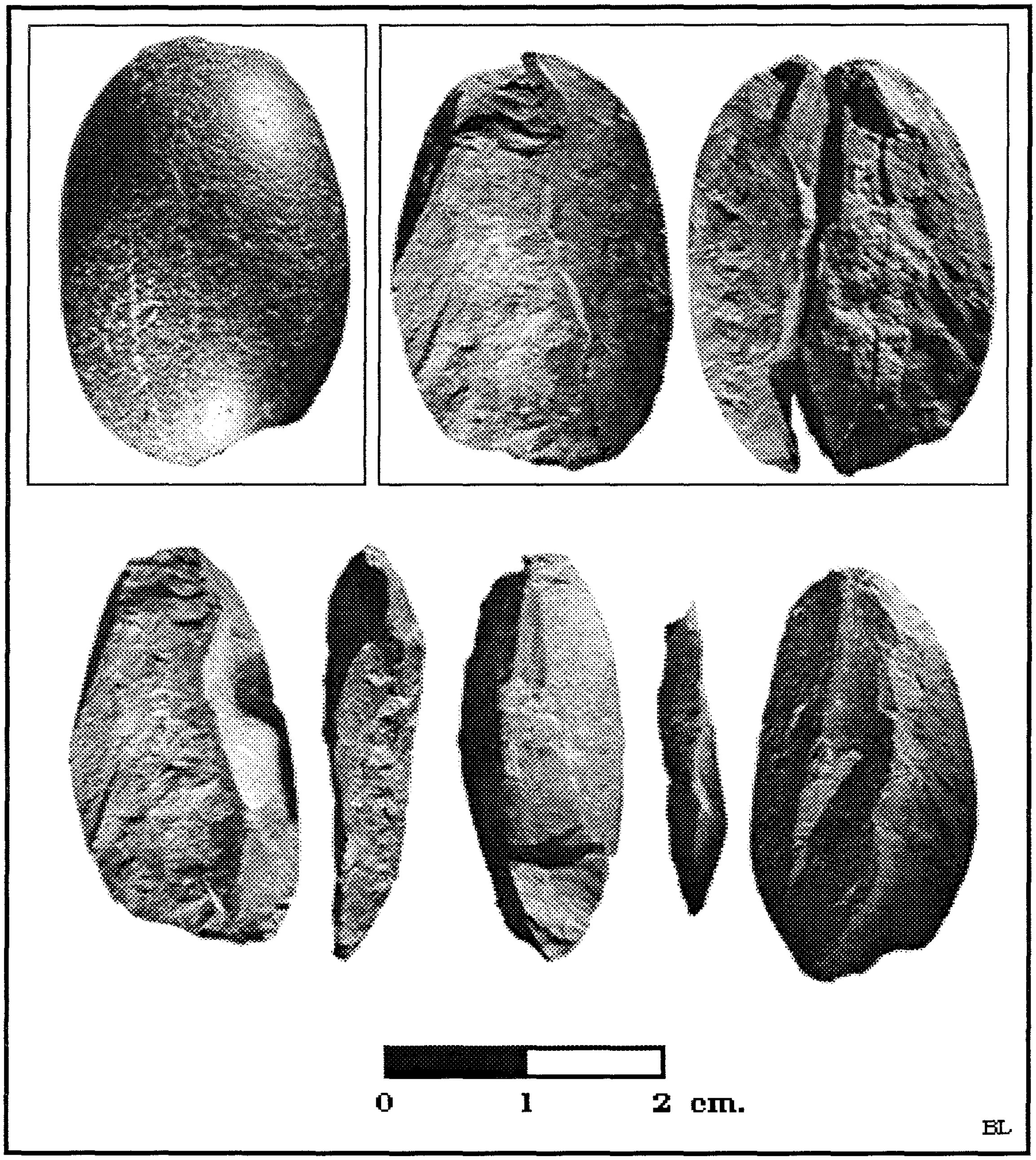

Figure 6.49. Class 8 silicified siltstone pebble displaying citrus-section fracturing (specimen 486).

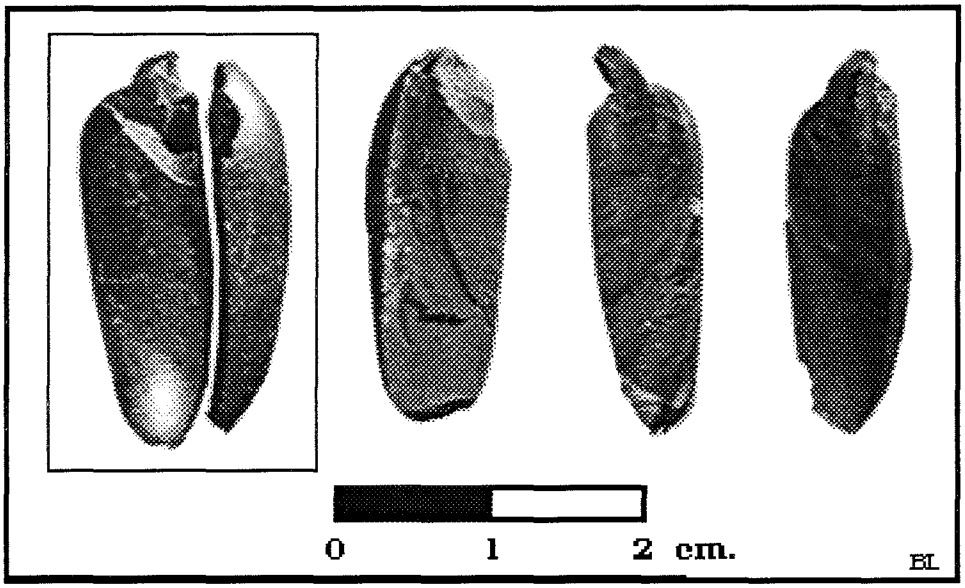

Figure 6.50. Class 8 silicified siltstone pebble displaying citrus-section fracturing (specimen 490).

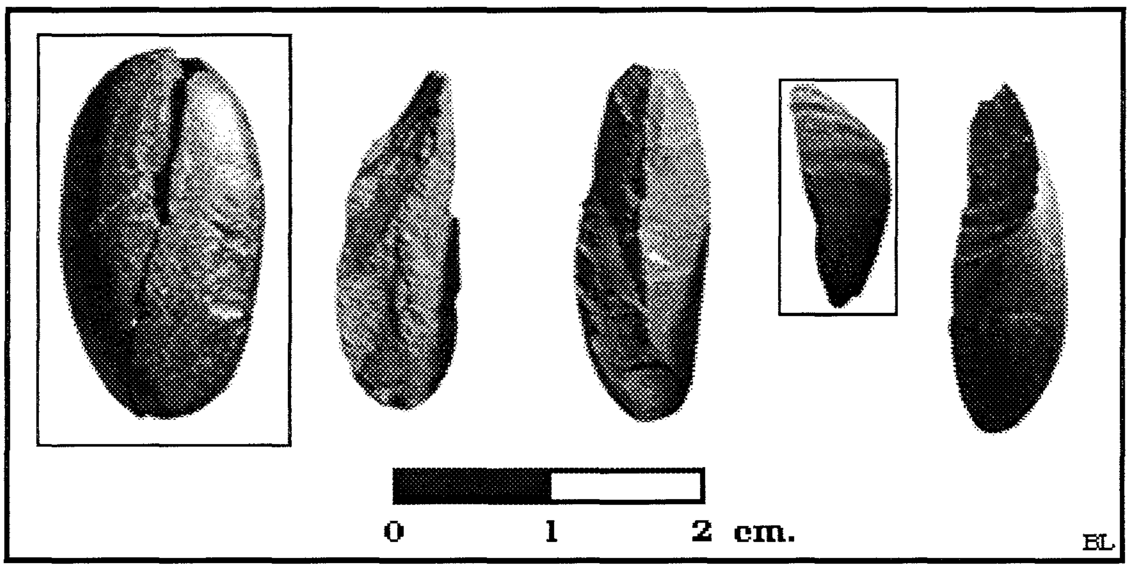

Figure 6.51. Class 8 silicified siltstone pebble displaying citrus-section fracturing (specimen 497).

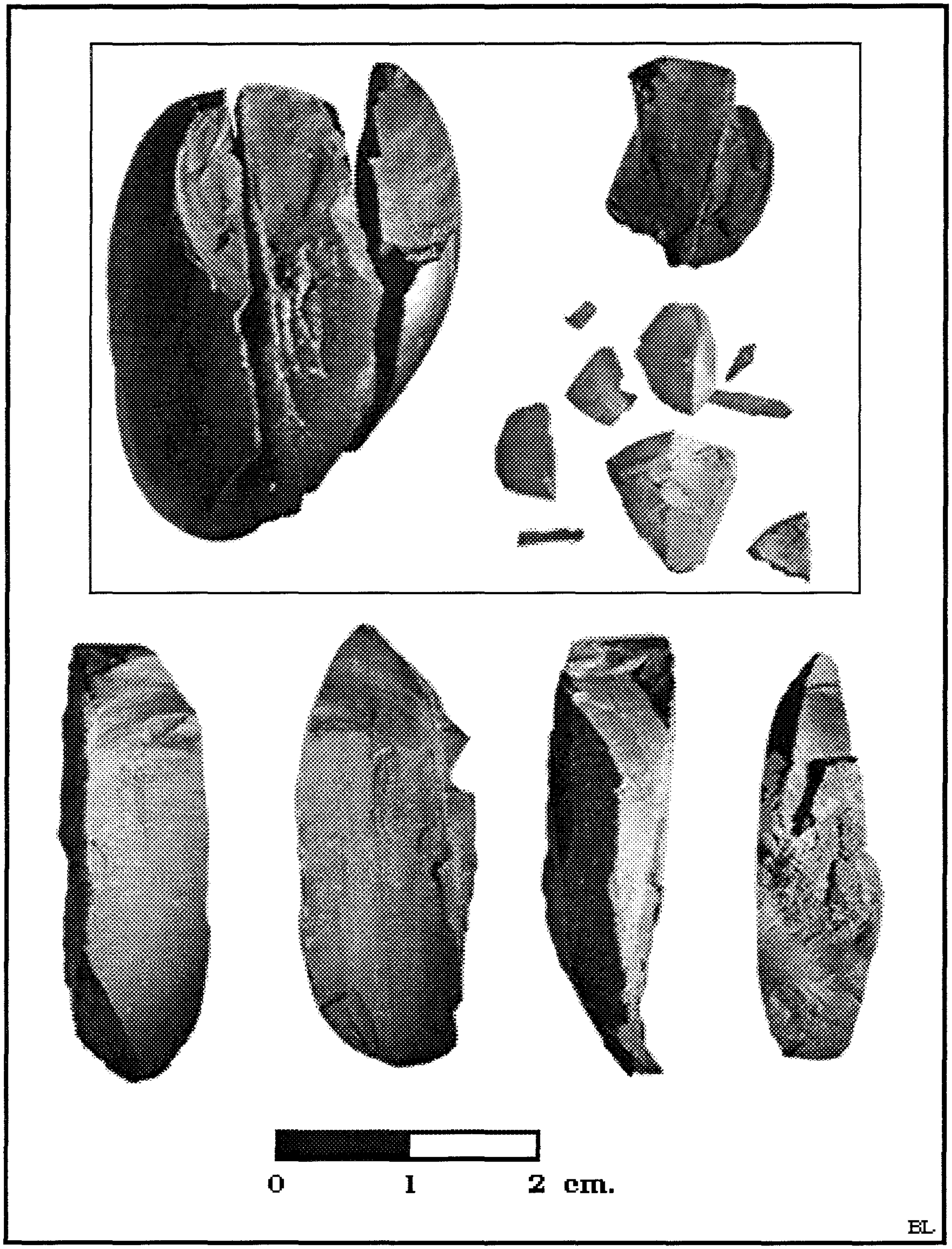

Figure 6.52. Class 8 silicified siltstone pebble displaying citrus-section fracturing (specimen 501).

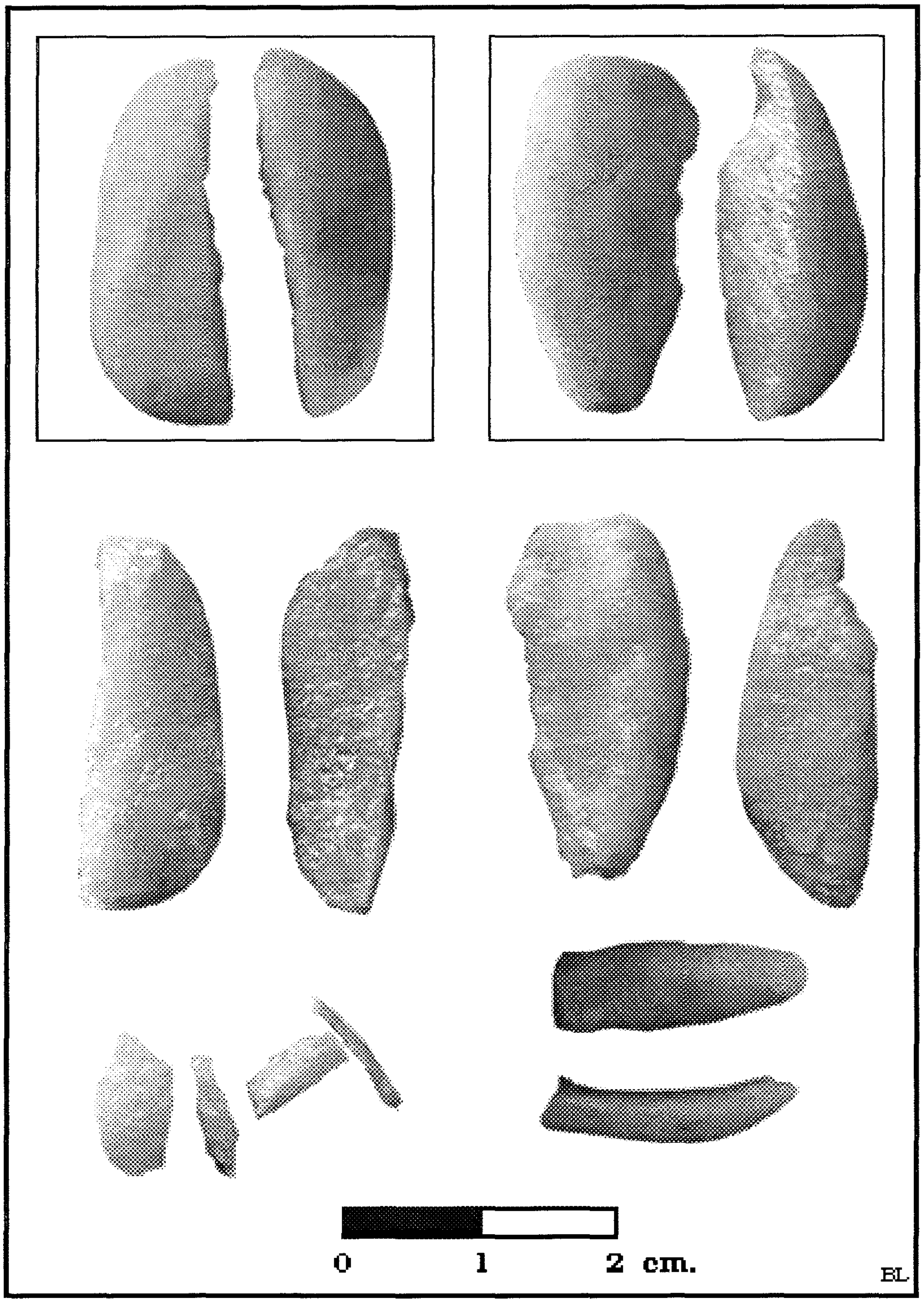

Figure 6.53. Class 8 quartz pebble displaying citrus-section fracturing (specimen 503).

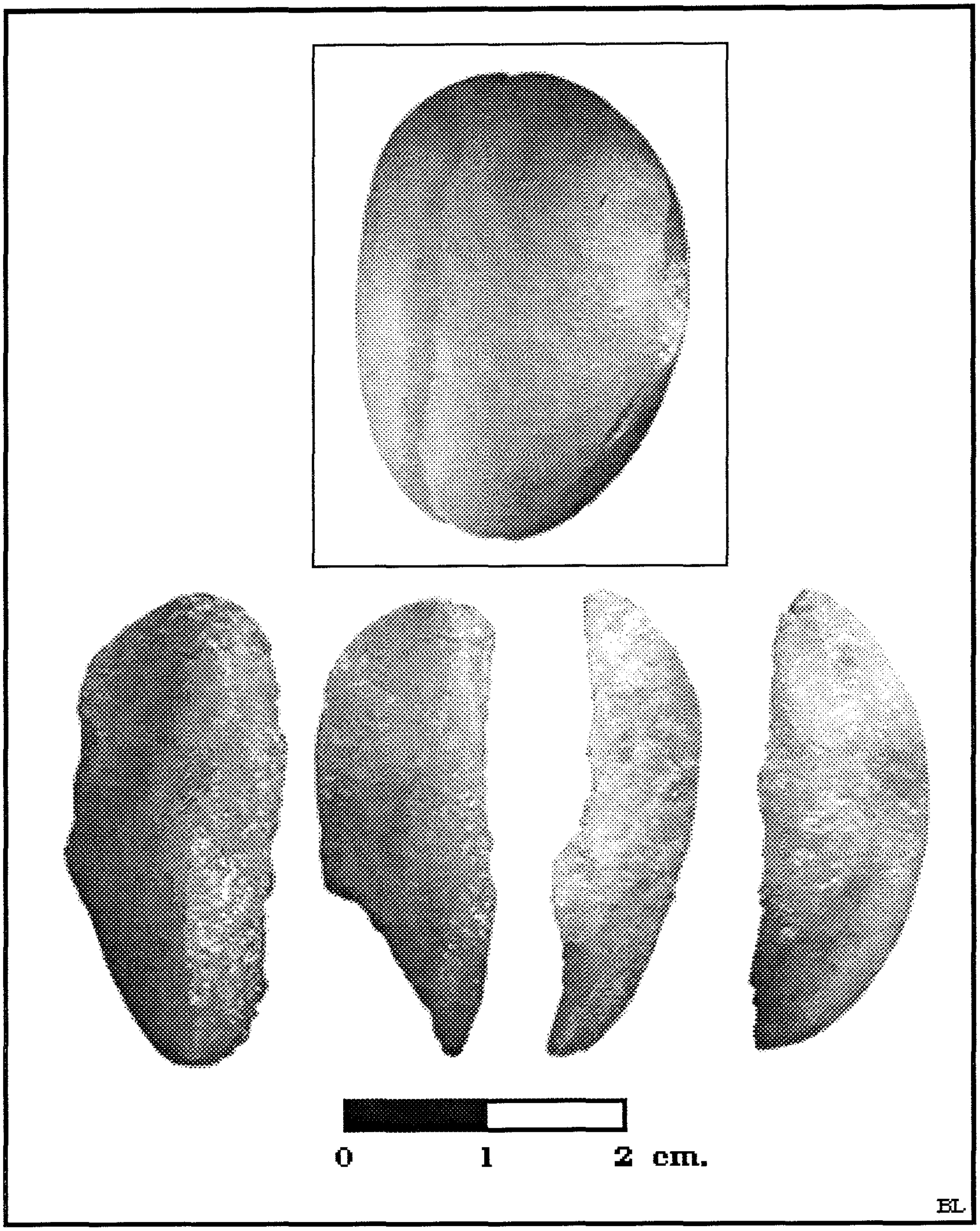

Figure 6.54. Class 8 quartz pebble displaying citrus-section fracturing (specimen 504).

Table 6.10. Class 9 specimens fractured irregularly

SP #	Material Type	Source	Dimensions (cm's) Original L(X)	W(Y)	T(Z)	Means L(X)	W(Y)	T(Z)
493	SSP	NSKR	3.79	2.51	2.05			
516	SSP	NSKR	3.71	1.89	0.72			
517	SSP	NSKR	2.81	2.09	1.69	Silicified siltstone		
518	SSP	NSKR	2.44	1.56	0.89	pebbles		
519	SSP	GIL	3.91	3.07	1.21	**3.81**	**2.48**	**0.97**
242	Qtz-ite	NSKR	4.08	2.97	1.51	***Quartzite***		
512	Gen chert	NSKR	2.6	1.96	0.93			
513	Gen chert	NSKR	2.81	1.93	0.83			
514	Gen chert	NSKR	3.39	1.59	0.86	Generic chert		
515	Gen chert	NSKR	3.98	2.02	1.35	**3.29**	**1.99**	**1.14**
Grand Totals (means)			3.845	1.955	1.035			

surface of the complete pebble section joining at about the mid-point of the specimen. This is evident from the percussion lines that indicate the force was generated equally from both the dorsal and proximal impact points and terminating centrally within the specimen.

This class of materials is perhaps the most difficult of the classes listed here to analyze, especially since most of the specimens had a fine grained, uniform matrix. Two exceptions are illustrated in Figures 6.55 and 6.56, which are composed of silicified siltstone but display a number of impurities. However, that does not account for the other specimens, or the fact that these specimens fractured quite differently from other similar materials, which tended to shatter completely. One explanation may be that the pebble was not perpendicular with the anvil, when the force was applied to its proximal end. Rather than having the spherical waves pass down through the specimen fairly

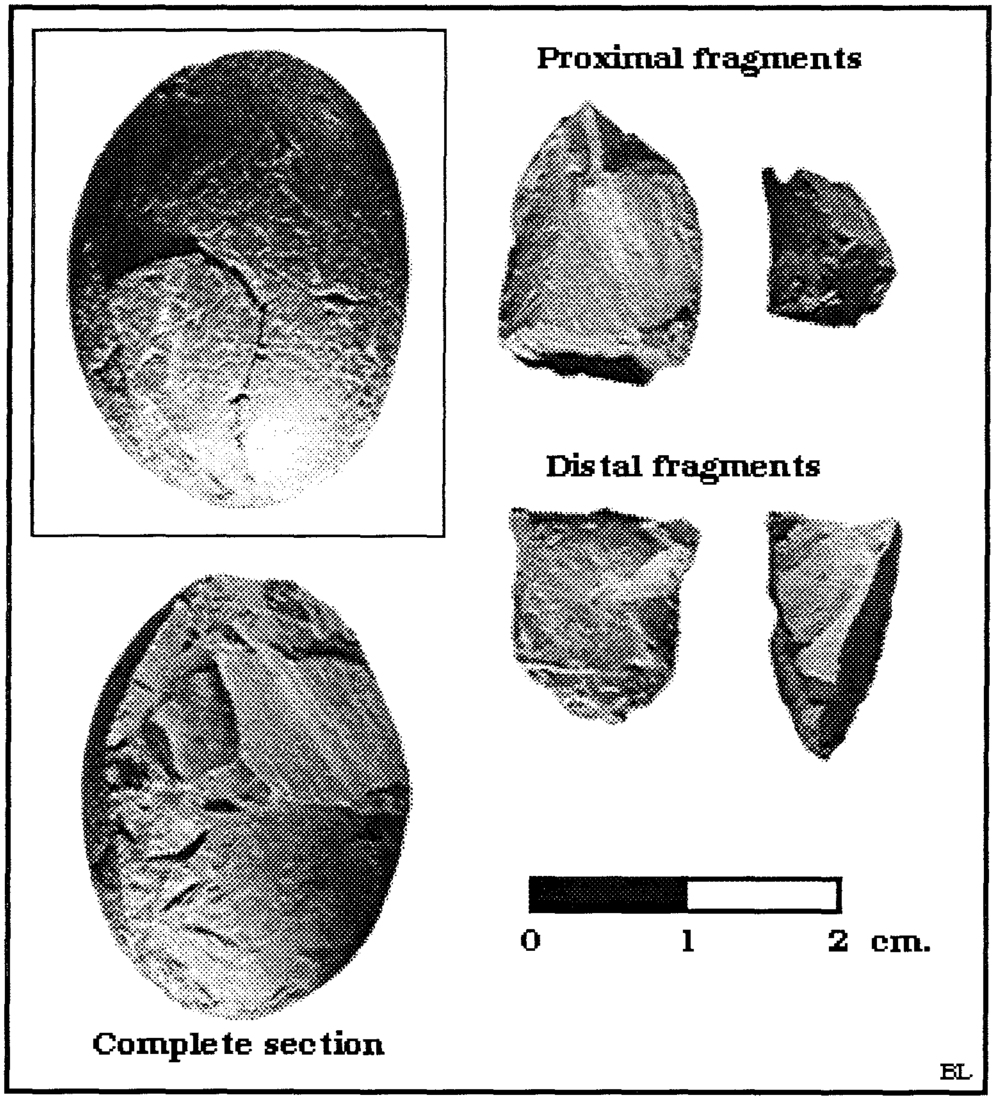

Figure 6.55. Class 9 silicified siltstone pebble displaying irregular fracture (specimen 517).

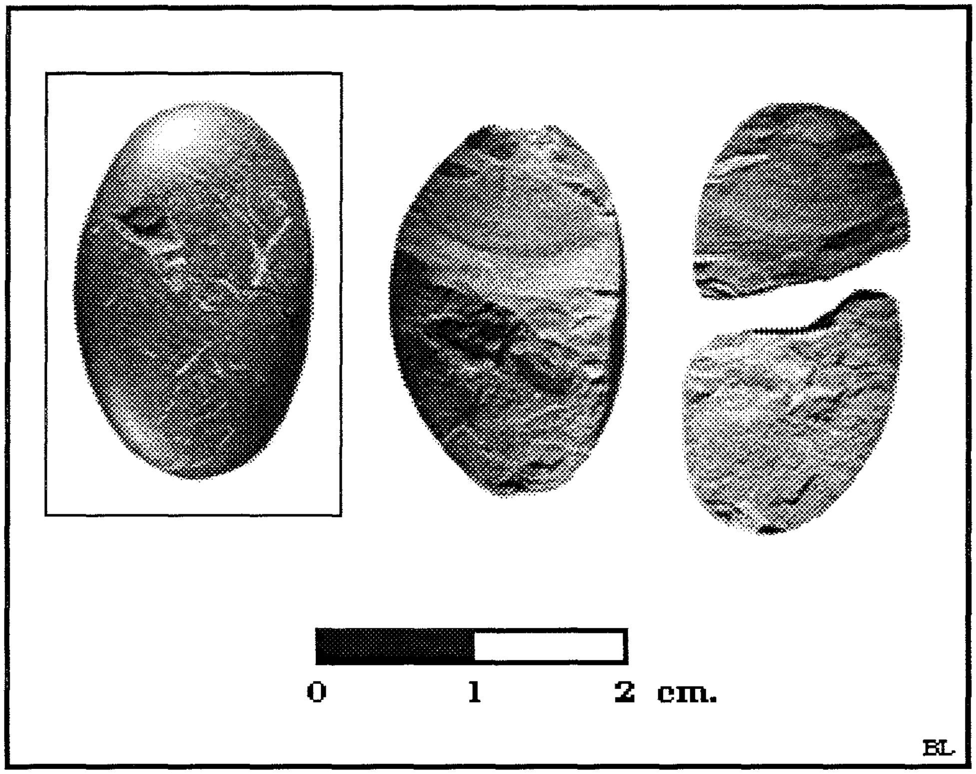

Figure 6.56. Class 9 silicified siltstone pebble displaying irregular fracture (specimen 518).

evenly this may have caused most of the applied pressure to emanate down one side more strongly than the other. If this was the case, though, then it would seem reasonable that the rebound force from the anvil would apply unevenly to the opposite face causing a proximal flake to be removed from one face while a distal flake was removed from the opposite face. However, this was not the situation as that type of fracture did not occur among any of the experimental replications. One specimen as illustrated in Figure 6.57 is almost of that type, but even in this case the fractures occurred along the one face of the material. It is also interesting that the fractures occurred parallel to the Z axis with this specimen, whereas all others of this class fractured transversely parallel to the Y axis.

One consistency with this class is that force did emanate from the end of the specimen and commonly terminated at the central point of the pebble. This is very evident through an examination of Figures 6.55, 6.56, 6.58, 6.59, 6.60, and 6.61, which all display this unique occurrence.

If the amount of applied force was such that the rebound force equaled it then the spherical waves would come in contact along the outer, approximately central point of the pebble. The strain at this point would cause the two flakes, one distal and one proximal, to detach from the main body of the specimen. If the pressure within the material had been just slightly greater then it is likely that the stress within the specimen would have caused it to completely shatter.

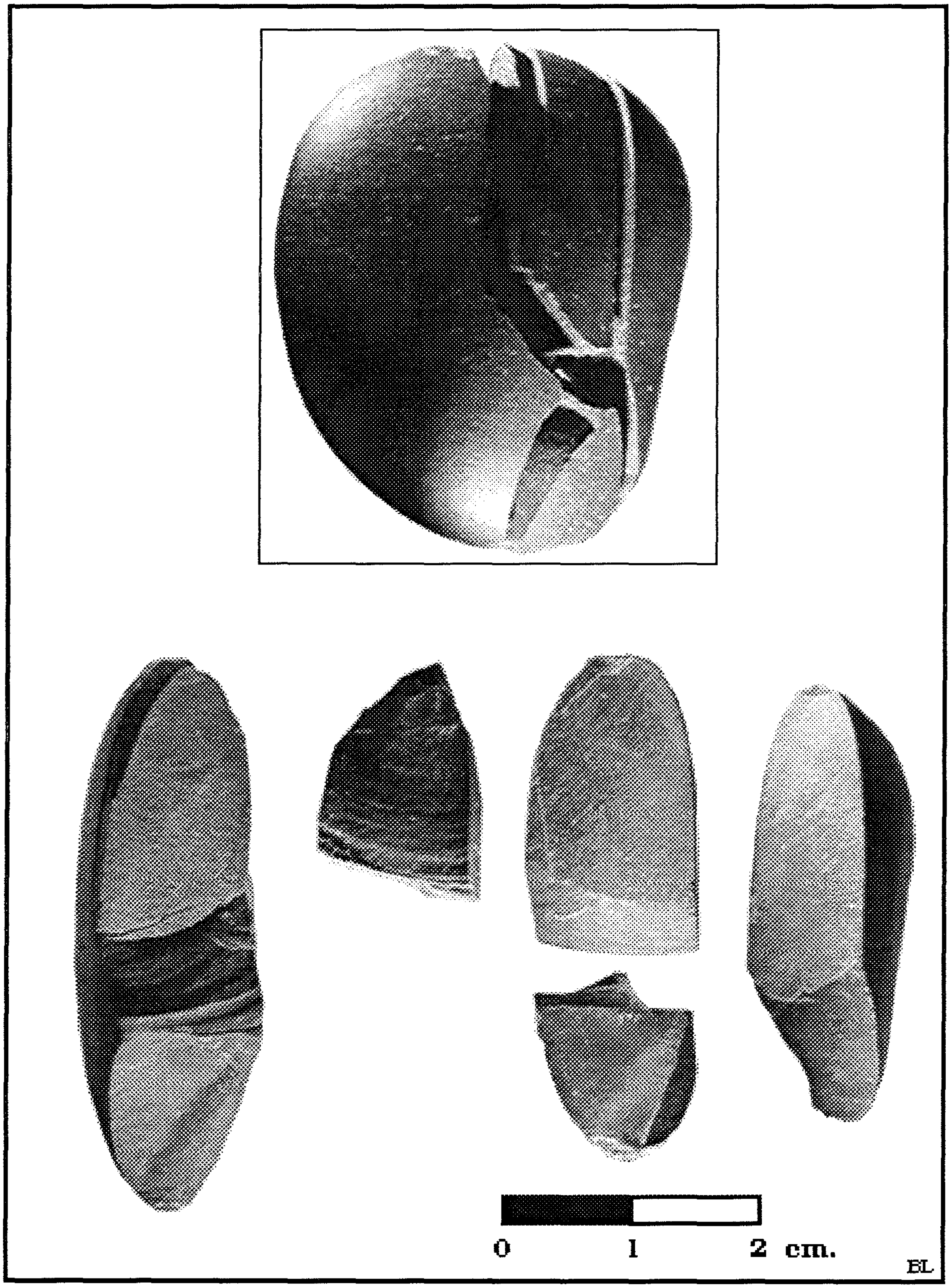

Figure 6.57. Class 9 silicified siltstone pebble displaying irregular fracture (specimen 519).

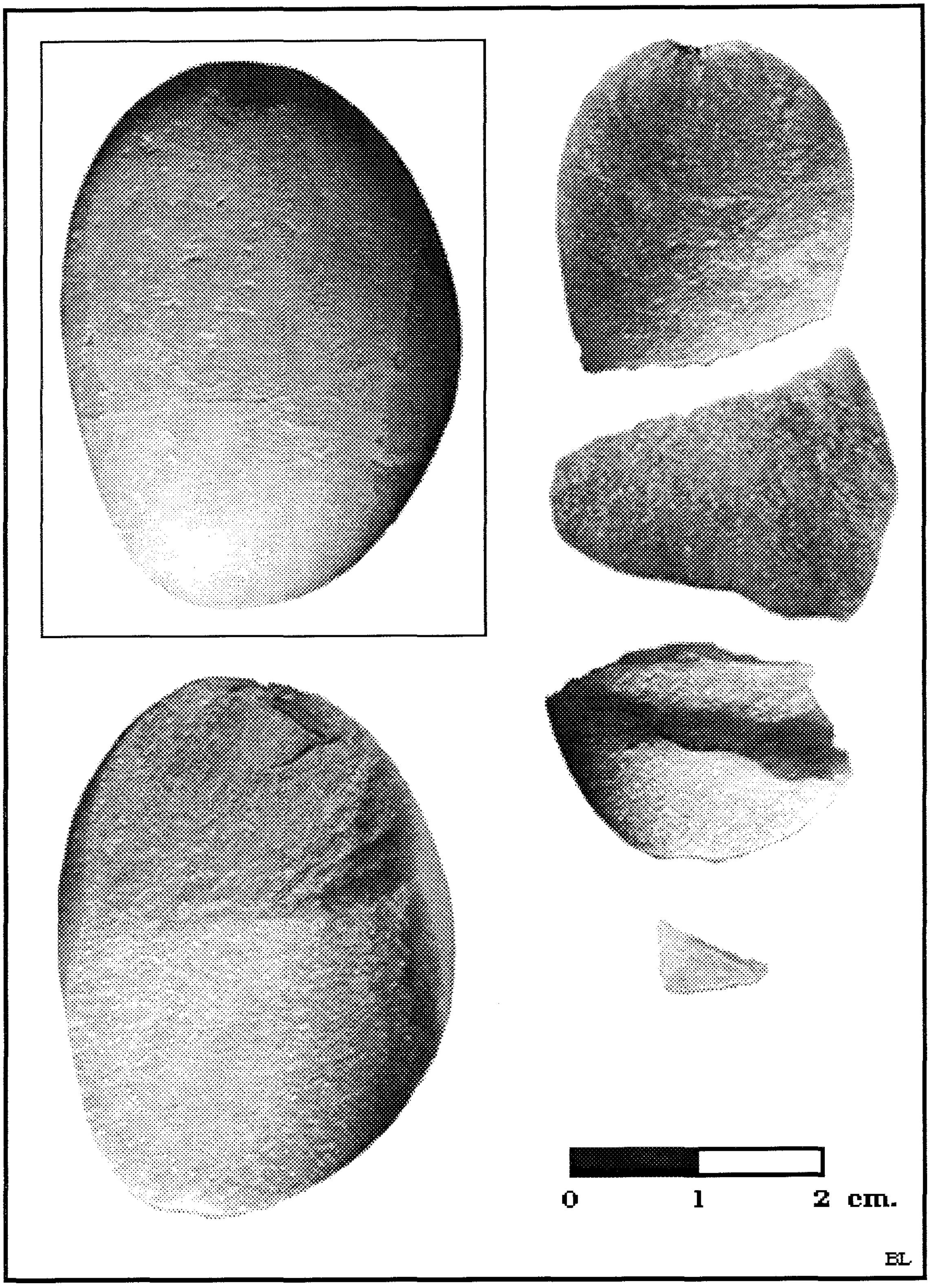

Figure 6.58. Class 9 quartzite pebble displaying irregular fracture (specimen 242).

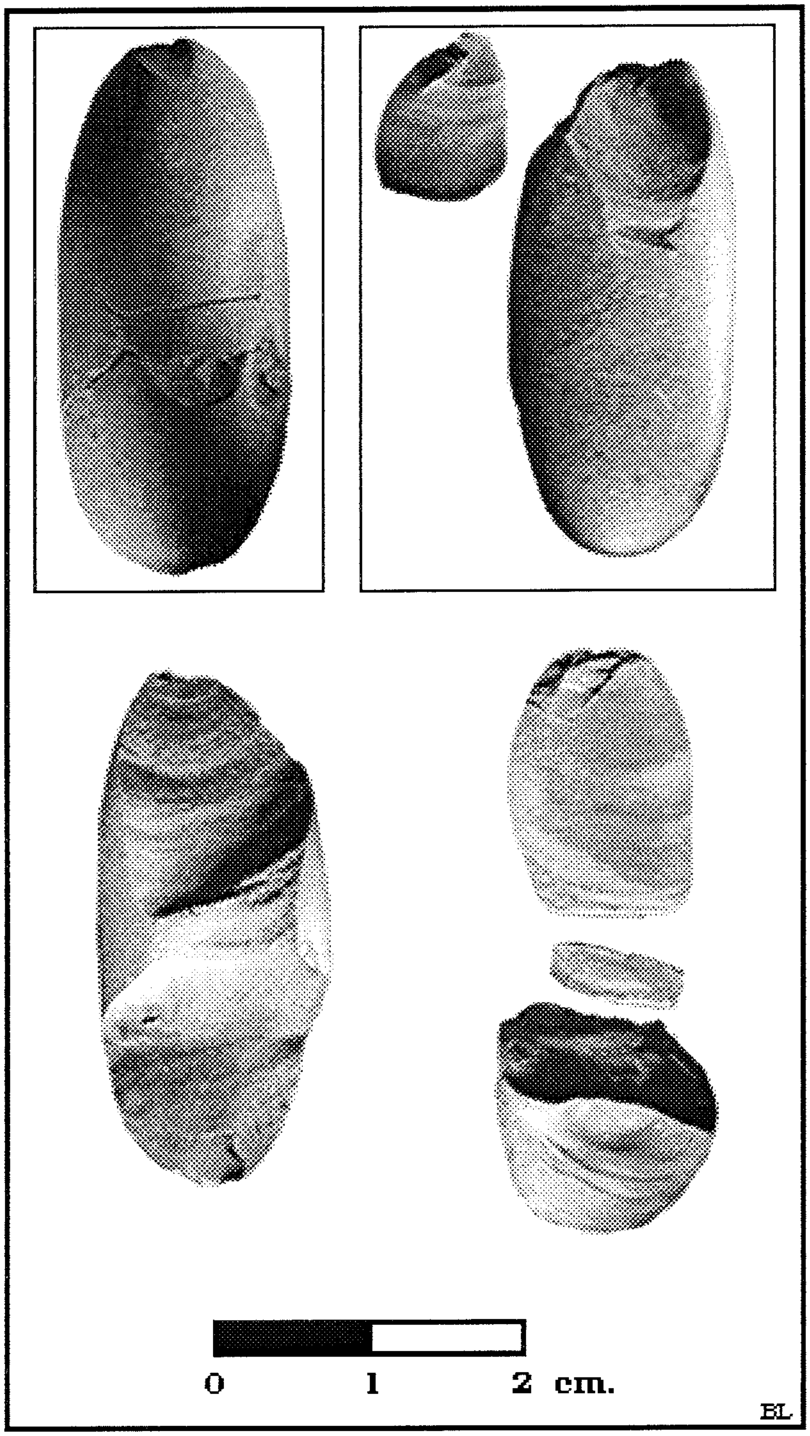

Figure 6.59. Class 9 generic chert pebble displaying irregular fracture (specimen 514).

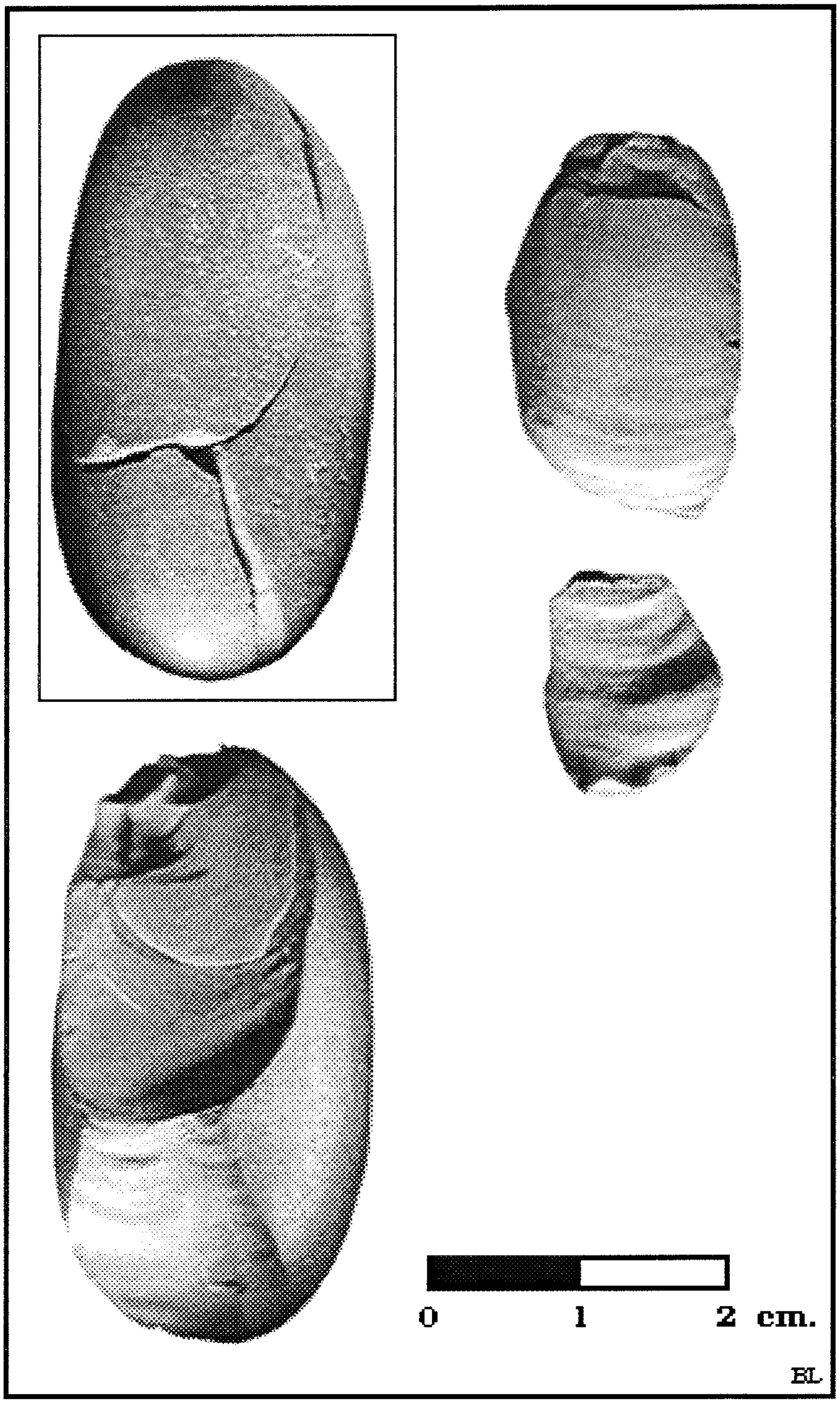

Figure 6.60. Class 9 generic chert pebble displaying irregular fracture (specimen 515).

Figure 6.61. Class 9 quartzite pebble displaying irregular fracture (specimen 513).

Figure 6.62 illustrates another Class 9 specimen, but this one is again just slightly different from the previous ones. This specimen also had proximal, distal and lateral flakes detached. The interesting thing with this specimen is that the complete section very closely resembles those bipolar pieces know as pièces esquillées. Pièces esquillées are wedge shaped and typically exhibit paired flake surfaces. These flake surfaces are created from the detachment of flakes at opposite ends of the specimens and morphologically resemble the Class 9 materials. The difference here is that while pièces esquillées are believed to be formed primarily through use, the Class 9 specimens were produced during the bipolar pebble splitting process. Pièces esquillées will be outlined more fully in Section 7.

There is no difficulty in identifying any of the complete sections of the Class 9 materials as being bipolar by-products. The very nature of the specimens with proximal and distal crushing, and more importantly opposing flake scars, readily identify these pieces as being derived from bipolar technology. The problem arises when trying to differentiate the proximal and distal detached flakes, or fragments, from non-bipolar materials. That is, they could not be identified as bipolar materials without the original associated piece. If any of those small flakes were found out of context or as isolated finds they would surely be identified as straight percussion flake debris. Unfortunately, this situation will continue to plague bipolar analysts because without the associated original pieces or the tools of manufacture, these types of materials simply cannot be differentiated from straight

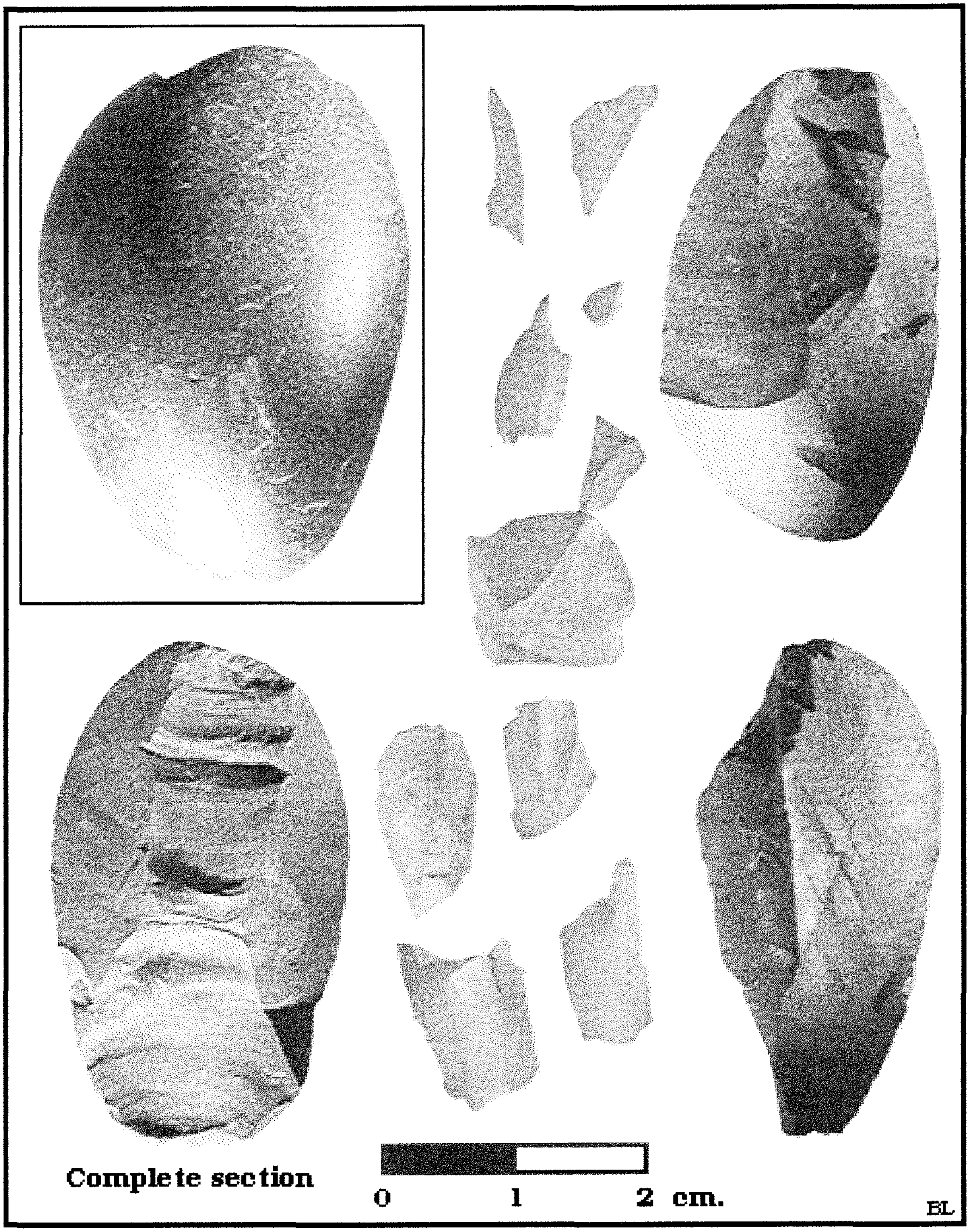

Figure 6.62. Class 9 silicified siltstone pebble displaying irregular fracture (specimen 493).

percussion debitage. Class 9 specimens consist of five silicified siltstone, one quartzite and four generic chert pebbles that comprise 1.9% of the total experimental replications (Table 6.10).

6.1.2.10 *Class 10* specimens(Table 6.11) comprise the final category of the experimentally replicated bipolar materials and consist of only five silicified siltstone specimens. Class 10 specimens are split into two sections down the X axis and transversely parallel to the Y axis. However, unlike the Class 2 materials that terminate at the distal end of the specimens, these have one section that ends in a feather termination above the point of contact with the anvil. Honea (1965:261) described bipolar flakes similar to these, noting that they had terminated above the point of anvil contact producing a flake that was about 3/4 of the pebble core length. Sollberger and Patterson (1976: 40) argued that because these flakes did not terminate at the anvil contact point they could not be considered true bipolar flakes. However, the evidence here clearly shows that these flakes can be and are produced using the bipolar method.

Several reasons may be suggested for this type of fracture. First, it is likely that there was not enough pressure applied to these specimens. Second, when force was applied it is possible that the pebble was slightly off the perpendicular from its contact with the anvil. These circumstances would have allowed the force to emanate down the outer portion of the pebble and thus terminate in a feather termination before the end of the pebble. Typically,

Table 6.11. Class 10 - one section ending in a feather termination

SP #	Mat. Type	Source	Dimensions (cm's)			PIC		DIC		PLED		PBP		DBP		Other	
			Original			L	R	L	R	L	R	L	R	L	R	L	R
			L(X)	W(Y)	T(Z)												
..54	SSP	NSKR	3.05	1.94	1.17	x	x	n	n	pr	pr	d	i	n	n	dfr/p	dft
..55	SSP	NSKR	6.4	3.6	3.1	x	x	n	n	pr	pr	i	pr	n	n		dft
..75	SSP	NSKR	2.55	2.05	0.98	x	x	x	n	d	d	d	i	n	n	vfr/d	
..91	SSP	GIL	3.13	4.15	0.9	x	x	n	n	pr	pr	d	i	n	n		dft
212	SSP	NSKR	3.2	2.1	0.99	x	x	pr	i	pr	pr	i	sh	n	n		
Grand Total Means			3.125	2.02	1.08												

flakes displaying feather terminations commonly occur among straight percussion materials.

Figure 6.63 displays one specimen from the Class 10 materials with a feather termination flake removed from the pebble core that could not be differentiated from a straight percussion flake. That is, it displays a fairly positive pronounced proximal bulb of percussion, pronounced lines of force and a distal feather termination that are all common straight percussion attributes. If the other section of this specimen was not associated with it this would be analyzed as a classic percussion flake rather than a by-product of bipolar technology; a truly exacerbating dilemma for lithic analysts. However, although the detached flakes from the specimens illustrated in Figures 6.64, 6.65 and 6.66 are in essence similar to the one in Figure 6.63, these latter can be identified as bipolar flakes. The detached flakes in Figures 6.64 and 6.65 both display negative inverted proximal bulbs of percussion.

The flake in Figure 6.66 has a sheared bulb and as already noted this is a distinctive bipolar attribute.

6.2 Summary

Of the 521 replications only the Class 6 and Class 7 materials contained no specimens that displayed any identifying bipolar attributes. This is not surprising since the Class 6 materials were reduced to numerous fragments of waste debitage while the Class 7 specimens were incomplete bipolar reductions.

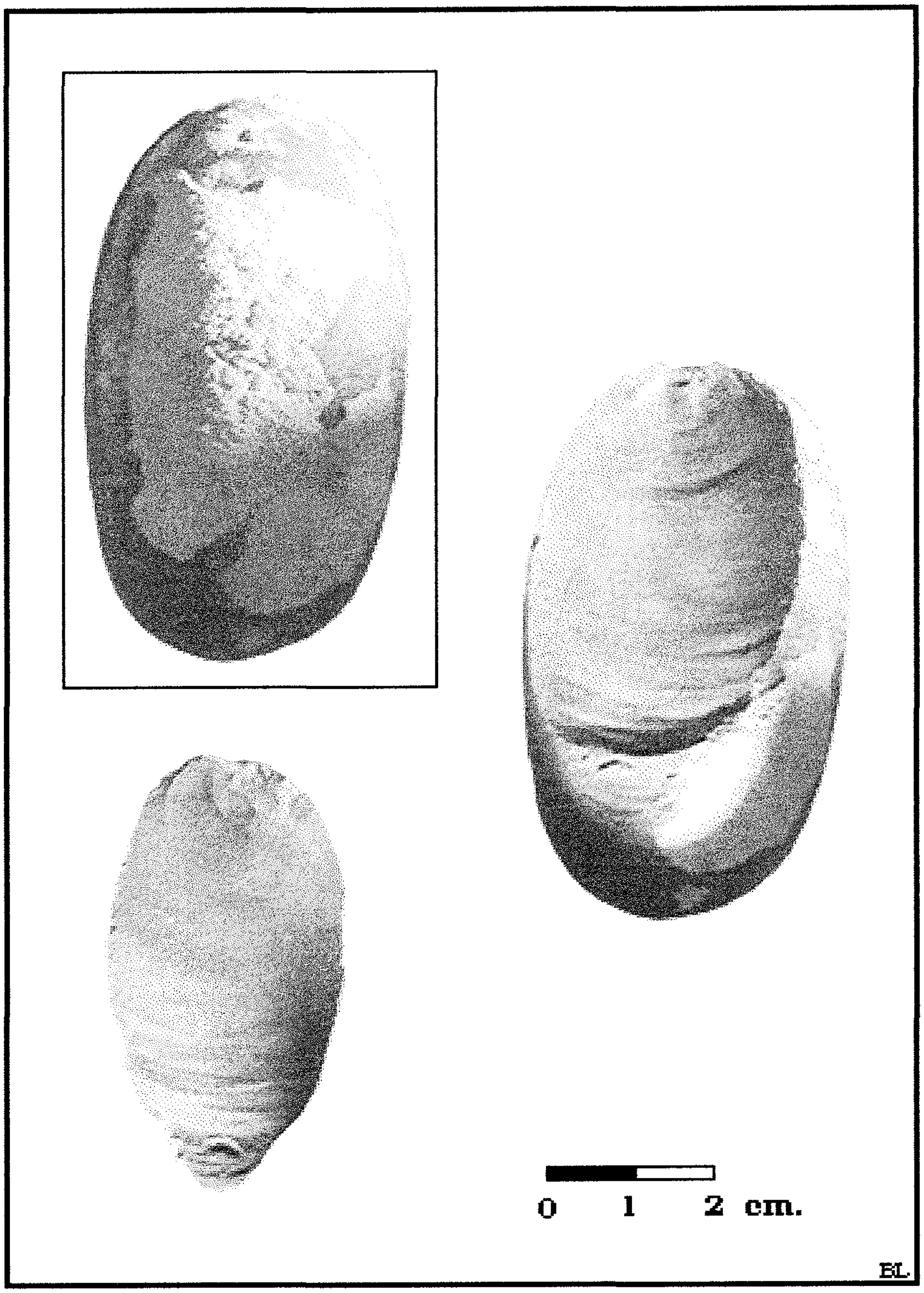

Figure 6.63. Class 10 silicified siltstone pebble displaying a feather termination (specimen 55).

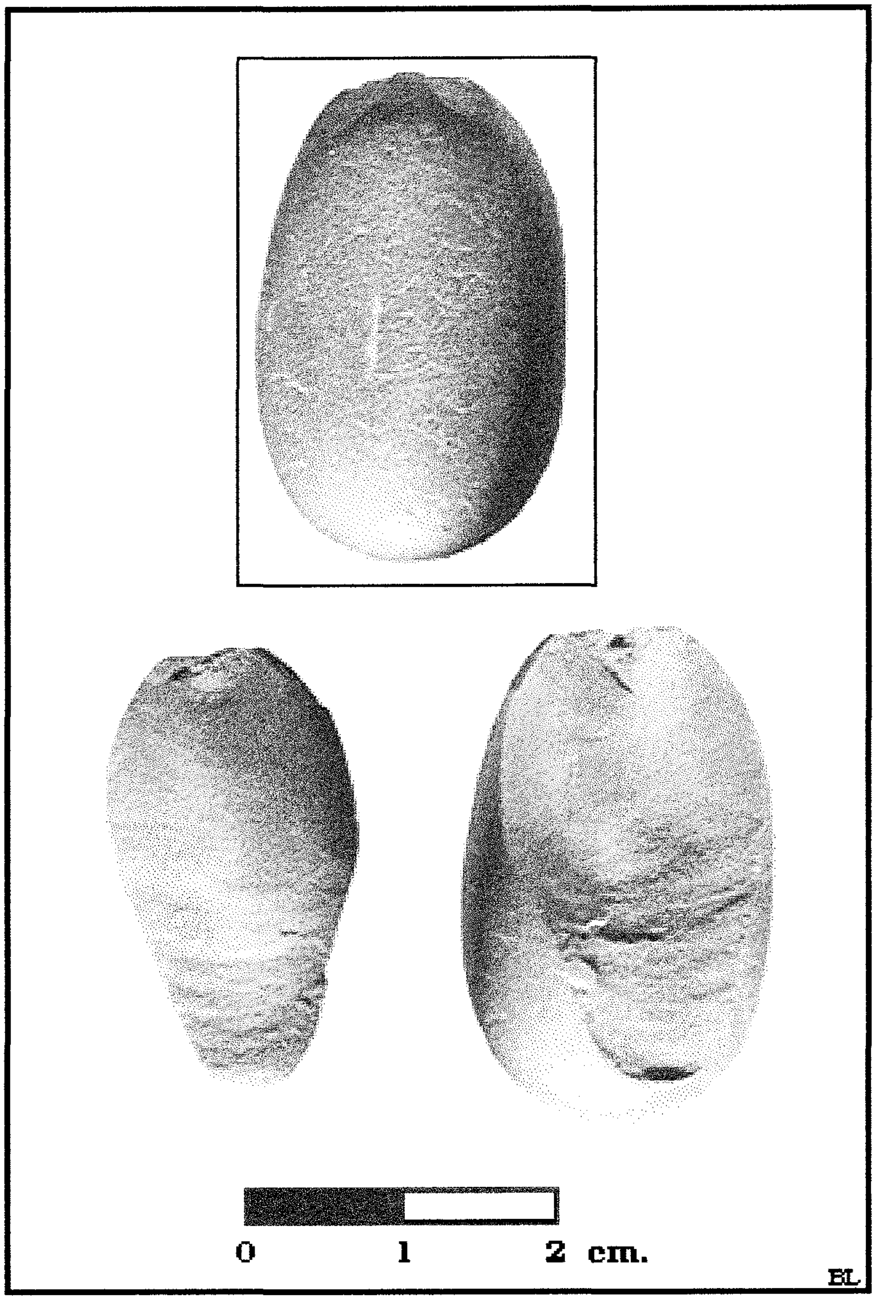

Figure 6.64. Class 10 silicified siltstone pebble displaying a feather termination (specimen 54).

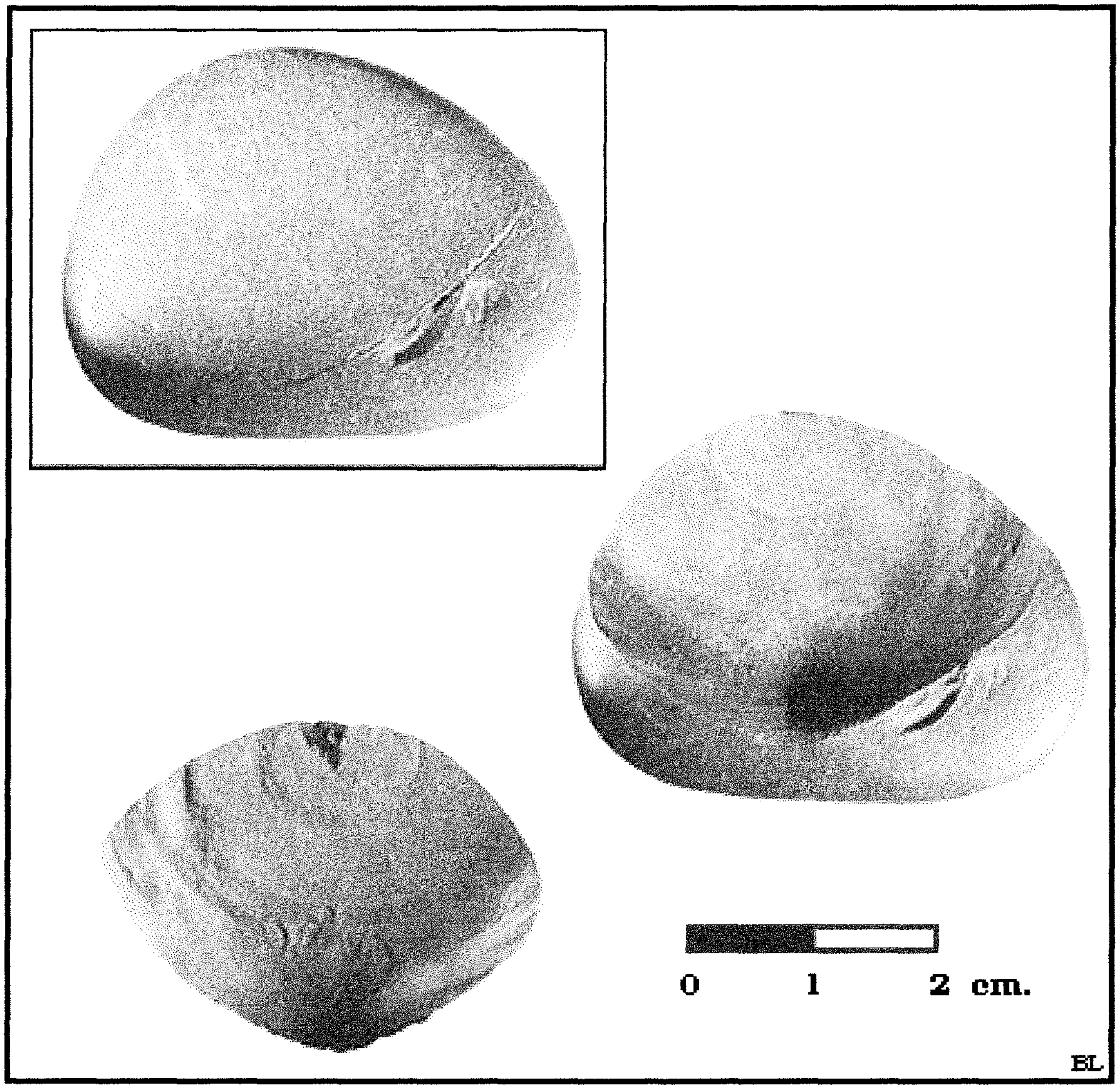

Figure 6.65. Class 10 silicified siltstone pebble displaying a feather termination (specimen 91).

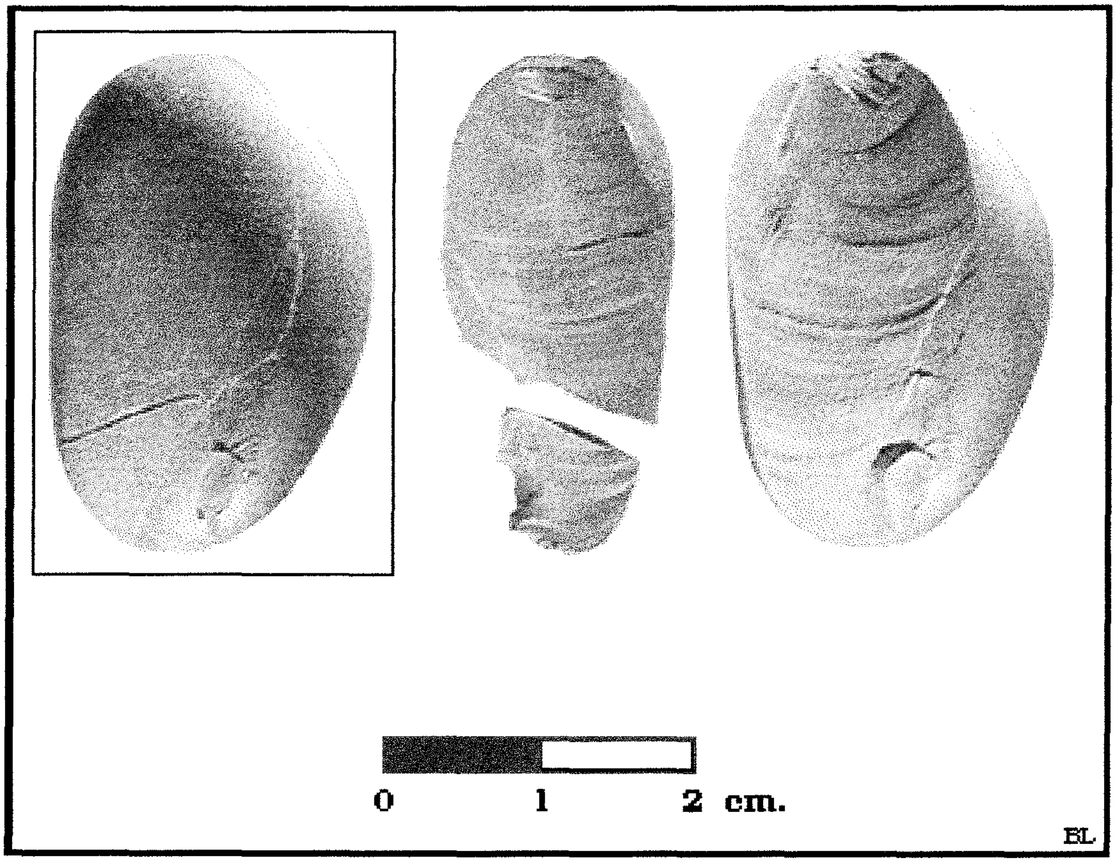

Figure 6.66. Class 10 silicified siltstone pebble displaying a feather termination (specimen 212).

Therefore, if we remove the 39 Class 6 specimens from the data set, that is, those pieces that completely shattered, this would leave 482 completed replications. If we then also remove Class 7 from the data set, which includes those specimens that had an inadequate amount of pressure applied during the replication causing the pebble to chip or partially flake at the proximal end, that would leave 296 completed replications; that is, materials that were successfully split. It is interesting to note that of these remaining 296 replications only 16 specimens (1 Class 2; 14 Class 3; 1 Class 4) did not have at least one fragment that could be positively identified as a bipolar by-product.

In order for a specimen to be identified as a bipolar by-product it had to display at least one of the following combination of attributes:

1. One split pebble half displaying both proximal and distal impact crushing.

2. One split pebble section displaying both distal and proximal bulbs of percussion on a single specimen.

3. One split pebble section displaying a positively identifiable distal bulb of percussion.

Although not every fragment of each specimen displayed these attributes at least one section of each did. This is quite significant since 280 or 94.6% of these replications contained identifiable bipolar traits.

7. CURRENT TYPOLOGICAL BIPOLAR ARTIFACT CLASSIFICATIONS

7.1 Literature review of the bipolar technique - an abridged synopsis.

In 1963, Binford and Quimby first described the bipolar technique in North America. Since that initial identification of this technology, it has been frequently recorded in a wide range of assemblages and temporal time frames. For example, Honea (1965) states that he found evidence suggesting the bipolar flaking technique occurred in both east-central Texas and north-central New Mexico. The studied artifactual material from Texas sites came from the McGee Bend Reservoir area and the New Mexico material was from the Cochiti Reservoir sites to the west-northwest of Santa Fe. He compared the material from these sites with experimentally replicated bipolar flaking debris using unworked pebble cores, hammerstones, and stone anvils collected from the above sites. Losey (1971) noted that a variety of bipolar pebble and cobble cores were represented within the Stony Plains Quarry site assemblage and Leaf (1979b) described several bipolar cores within his report on the El Dorado sites in Kansas. Leaf (1979b) described these as having surfaces of percussion at opposite ends of a striking axis, a striking platform and a base with the surface resting on the anvil exhibiting crushing and small flake scars. Brose (1970), in describing the Summer Island site in Michigan, noted the presence of 259 bipolar cores with the recovered assemblage of artifacts. He defined these cores with reference to the six bipolar types as defined by Binford and Quimby (1963) and he noted that they all displayed clear evidence of having been produced by bipolar percussion. Johnson (1987) described a large number (189) of cores from the Carson Mound site in northwestern Mississippi. Johnson (1987) stated that most of the multiple platform cores show edge wear although edge battering on single platform cores is confined to the platform rather than the base. Ball (1987) reported bipolar split pebble stones from a variety of sites in Alberta. Root (1994) noted a variety of bipolar core types from the Bobtail Wolf site, within the Knife River flint primary source area in North Dakota, containing Archaic and late prehistoric artifact deposits. Fox (1979) even noted that the only core forms represented in an early 17th century historic Huron Attignawantan lithic assemblage were bipolar.

The bipolar technique appears to be ubiquitous throughout North America, as is evident from this very brief review of archaeological literature. In fact, Knudson (1978) has commented that the bipolar technique may be one of the most common lithic reduction techniques represented within North American artifact assemblages. Therefore, I felt that a review of the previously identified classifications of bipolar artifacts from the archaeological record should be presented here. However, since the research outlined here primarily examines pebble stones rather than bipolar materials, the former will be addressed separately within the next chapter. The inclusion of the following classification systems is primarily intended to provide a synthesis of the current information regarding bipolar technology.

7.2 Classes of Bipolar Artifacts

It should be noted that the bipolar core classifications are based primary upon the examination and study of larger materials. Small pebble stones such as those examined within this report are in a class by themselves and do not readily fit into the above categories. This is directly related to the fact that the outcome of the application of the bipolar technique, the effect of this method on pebble stones, and the end products produced are quite different from what researchers view as materials resulting from bipolar reduction produced from larger pieces of lithic raw material.

7.2.1 Binford and Quimby (1963) bipolar core (outils écaillés) classification. A number of classifications have been developed for bipolar cores. The first North American classification of these artifacts was presented by Binford and Quimby (1963: 289-296) who identified six classes of bipolar cores based on the morphology of their percussion surfaces as outlined below.

7.2.1.1. **Class 1: Ridge area core.** This core is described as having a basal zone of percussion consisting of unmodified cortex and a series of overlapping cones of percussion or a ridged impact zone of percussion. Flake scars originate at the ridge and dominate the cleavage faces while the basal scars tend to be diminutive and irregular and usually terminate in hinge fractures (Figure 7.1).

7.2.1.2. **Class 2: Point-area core.** This core is characterized by a third cleavage face that is essentially the end of the core from which flakes originating at the ridge detach. The core is reduced to a point of percussion at the zone of impact while the base remains an area (Figure 7.2). In this instance the term area relates to the surface of the core's distal or proximal end that retains a flat plane.

7.2.1.3. Class 3: Ridge-point core. With this type of core the basal zone of percussion is a greatly battered and bruised point while the impact zone is a ridge of percussion. This type is thought to be produced by uncontrolled breakage in the early phases of core manufacture resulting in a cone of percussion or a point of percussion at the impact zone (Figure 7.3).

7.2.1.4. **Class 4: Right-angled ridge core.** This type is somewhat ambiguous in that it is supposed to result from the failure of producing a core form similar to Class 3. That is, with a point of percussion as the base, opposed by a ridge of percussion. However, it appears that this form has opposing points of percussion and, actually, it is very much like the Class 5 and 6 types below (Figure 7.4).

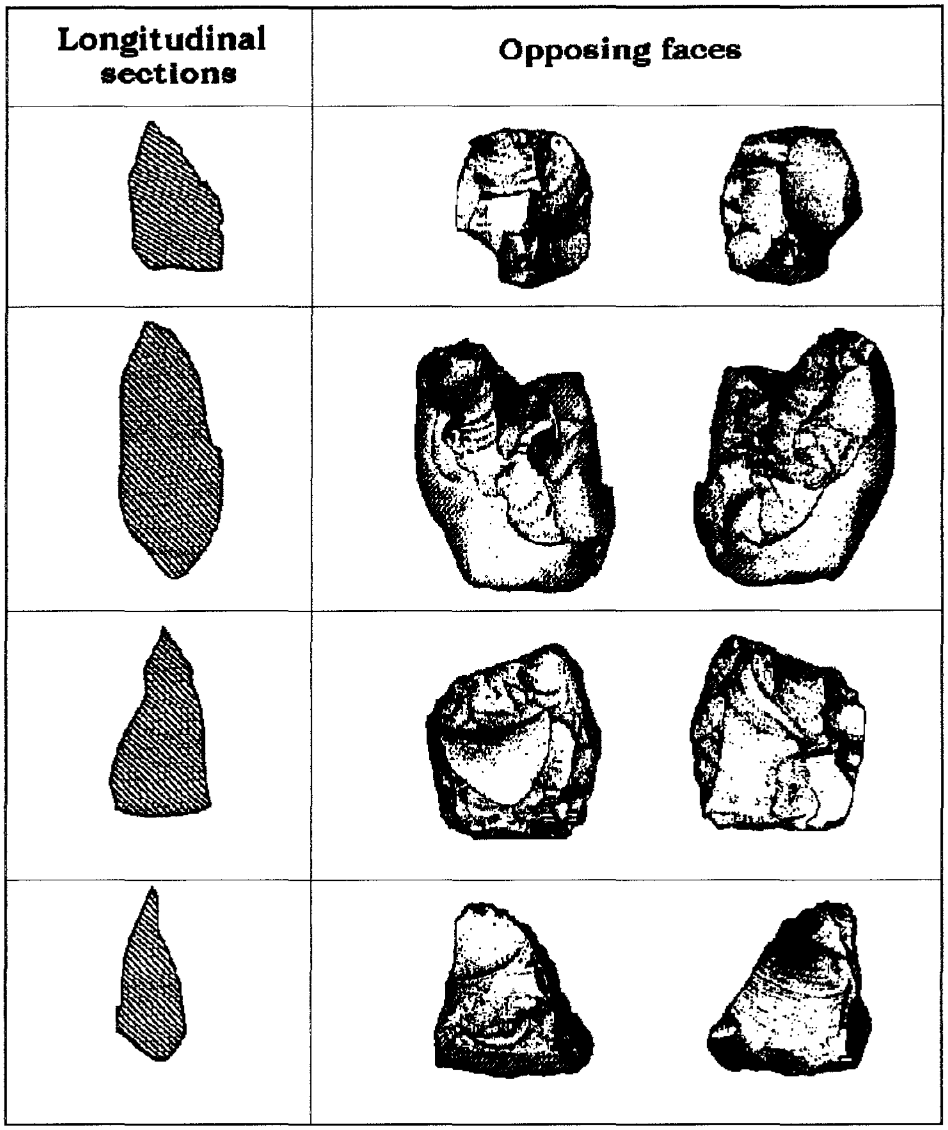

Figure 7.1. Binford and Quimby's ridge-area bipolar core type (from Binford and Quimby 1972: 357).

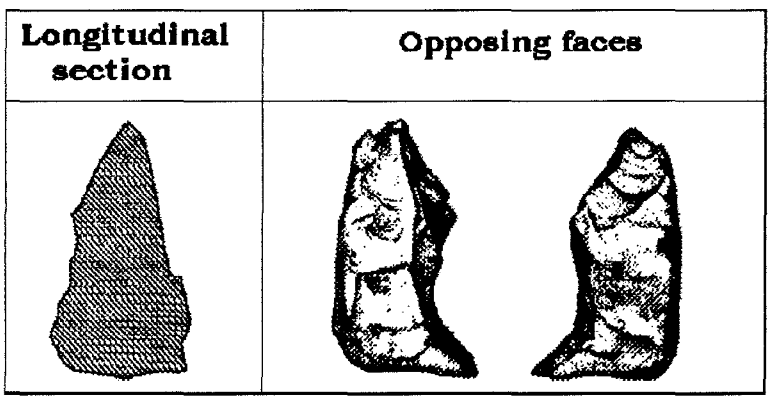

Figure 7.2. Binford and Quimby's point-area bipolar core type (from Binford and Quimby 1963: 359).

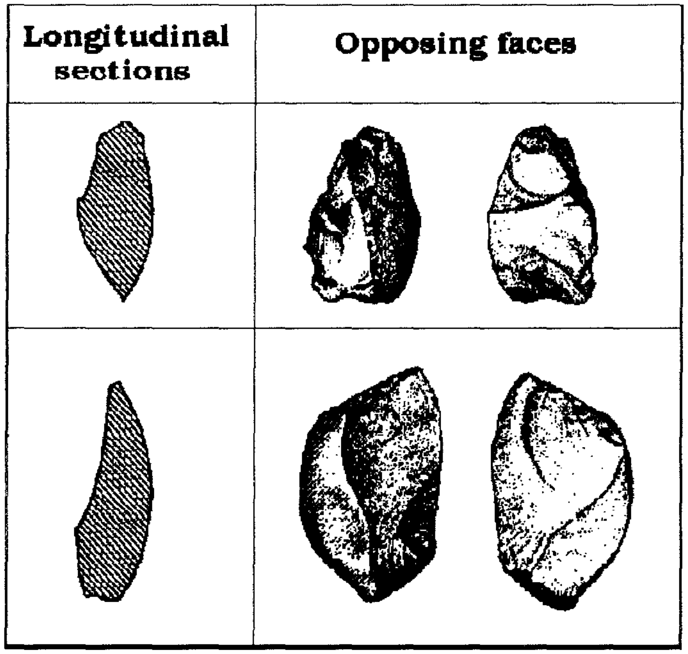

Figure 7.3. Binford and Quimby's ridge point bipolar core type (from Binford and Quimby 1972: 359, 361).

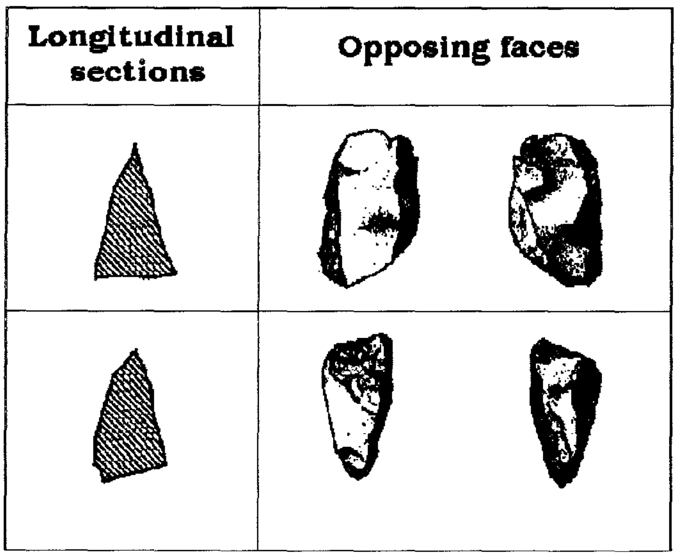

Figure 7.4. Binford and Quimby's right-angled ridged bipolar core type (from Binford and Quimby 1963: 361).

7.2.1.5. Class 5: Opposing ridge core. This core has opposed ridges of percussion in which it is impossible to determine which ridge served as the base and which served as the impact zone (Figure 7.5). It is suggested that both ridges variously served as base and zone of impact.

7.2.1.6. Class 6: Opposing point core. This is Binford and Quimby's (1963) final bipolar type. This form is characterized by opposing ridges that are approximately at right angles to one another. It is apparently produced from the core originally having a ridge opposite an area. With successive removal of flakes from both ends of the core the terminal flake scars eventually converge forming a ridge at right angles to the upper ridge of percussion Figure 7.6).

7.2.2 Leaf's (1979a) bipolar core (outils écaillés) classification.

Another classification scheme for bipolar cores was presented by Leaf (1979a). His model is actually a reworking of the classification system of Binford and Quimby (1963) with a few additions. According to Leaf (1979a), Binford and Quimby's (1963) classification system more strictly defines nine classes of bipolar cores and not six as they suggested. He proposed his core reduction model to account for the variation of form in bipolar cores.

To precisely illustrate the variation in bipolar core forms he places the three kinds of percussion surfaces, as defined by Binford and Quimby (1963), within a three way table classification of the striking surfaces and basal surfaces. His classification

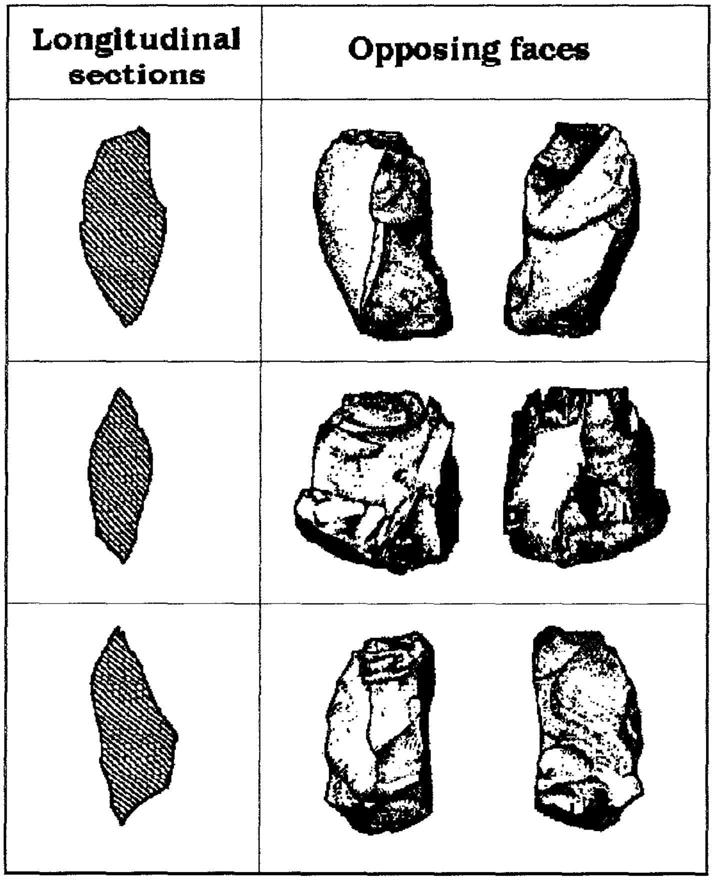

Figure 7.5. Binford and Quimby's opposing ridge bipolar core type (from Binford and Quimby 1972: 360).

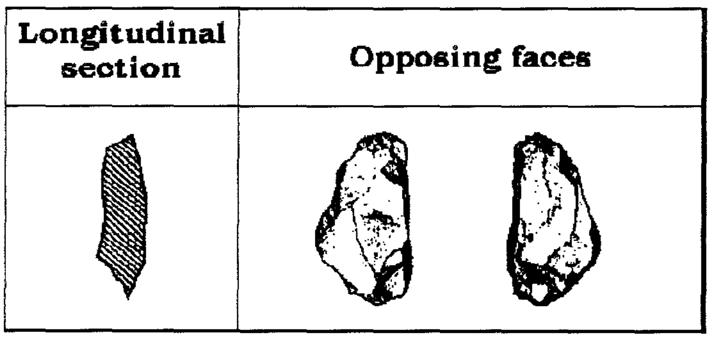

Figure 7.6. Binford and Quimby's opposing point bipolar core type (from Binford and Quimby 1972: 361).

system is outlined in Table 7.1.

Table 7.1. Outline of Leaf's (1979a) Bipolar Core Types

		STRIKING PLATFORM		
		Area	Ridge	Point
BASE	Area	BC	BC	BC
	Ridge	BC	BC	BC
	Point	BC	BC	BC

BC: Suggested bipolar core forms

As illustrated in Table 7.1, Leaf's (1979a) posited model defines nine classes of bipolar cores: area-area, area-ridge, area-point, ridge-area, ridge-ridge, ridge-point, point-area, point-ridge,point-point. In this classification scheme Leaf (1979a) identifies Binford and Quimby's (1963) opposing-ridge and opposing-point types as ridge-ridge and point-point, respectively. Leaf's (1979a) ridge-ridge type (among others) is illustrated in Figure 7.7., although the point-point type is not depicted within his report.

Leaf's (1979a) data regarding his bipolar core classes are not well outlined, but apparently inverting ridge-area and point-area types creates his area-ridge and area-point forms. Additionally, although he does illustrate the former ridge-area and point-area types (Figure 7.7.) he does not display all the types that he proposes. He does explain that his reason for this further classification is that if large flake scars appear to originate from the base rather than the point, then, for example, a point-area core as defined by Binford and Quimby (1963) should be inverted and classed as an area-point type. It is not entirely clear if this is a

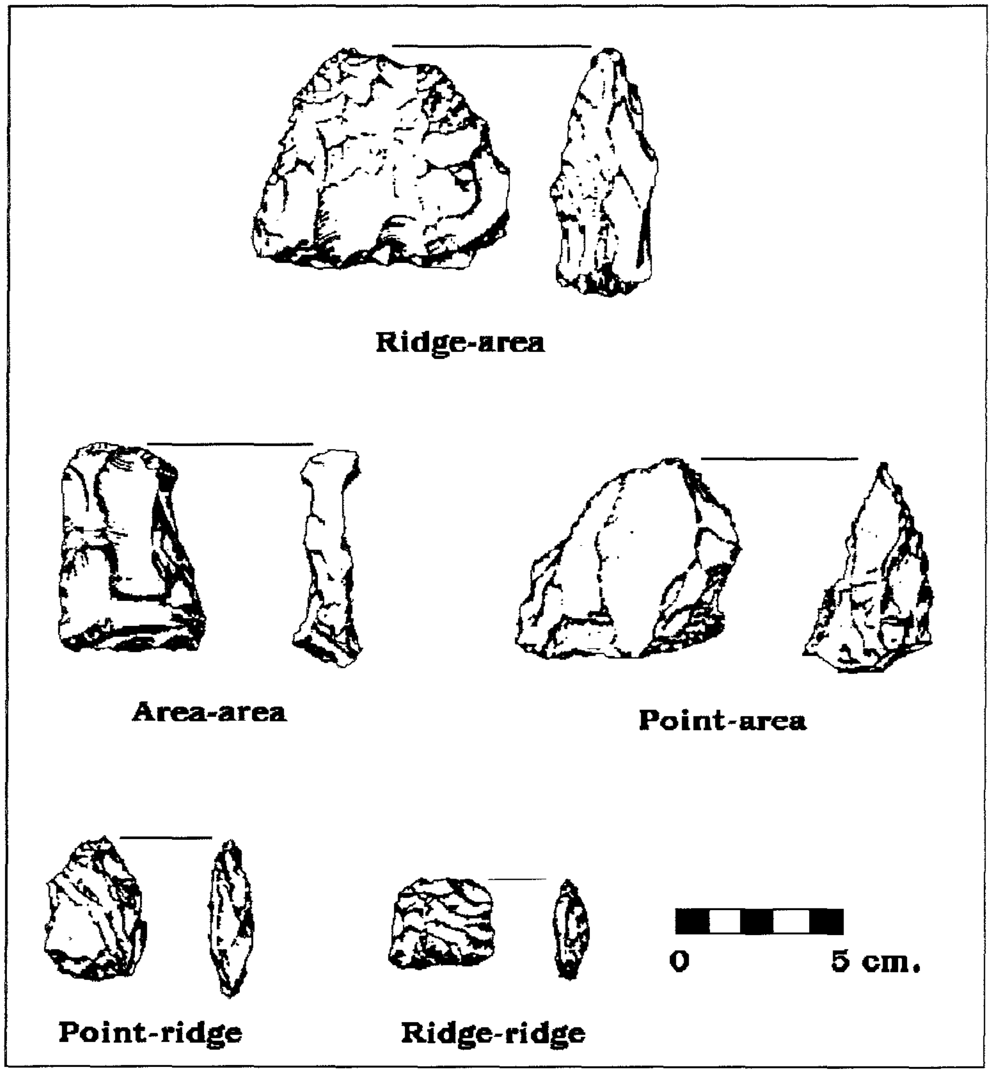

Figure 7.7. Bipolar core types as defined by Leaf (from Leaf 1979a).

valid change or if it is just an over-classification.

One form of bipolar core Leaf (1979a) proposes that seems to have validity is the area-area type (Figure 7.7.). The area-area form is one of the few bipolar cores that Leaf (1979a) proposed that he does illustrate within his report. This type has opposing areas in which the zone of percussion is an area of unmodified cortex, or an area that is relatively flat, from which no flakes have been struck. Rather, flakes have been detached solely along the edges. This type was not defined by Binford and Quimby (1963).

The only other bipolar core form illustrated by Leaf (1979a) is the point-ridge type (Figure 7.7) that is essentially Binford and Quimby's (1963) ridge-point form.

7.2.3. Honea's (1965) bipolar core (outils écaillés) classification. Another classification scheme for bipolar cores was presented by Honea (1965: 262-263). He identified three main classes of bipolar cores based on the location and number of primary percussion platforms and the direction of flake removal, as follows:

7.2.3.1. Single-ended. Flakes have been removed from only one end of the core (Figure 7.8.).

7.2.3.2. Double-ended. Flakes are alternately removed from both ends of the core (Figure 7.8.).

7.2.3.3. Multi-platformed. This type is similar to the double ended classification except that the core has been rotated so that flakes have been removed from the lateral edges of the core as well as both ends (Figure 7.8.).

Honea (1965) further divided each of these classes, based on

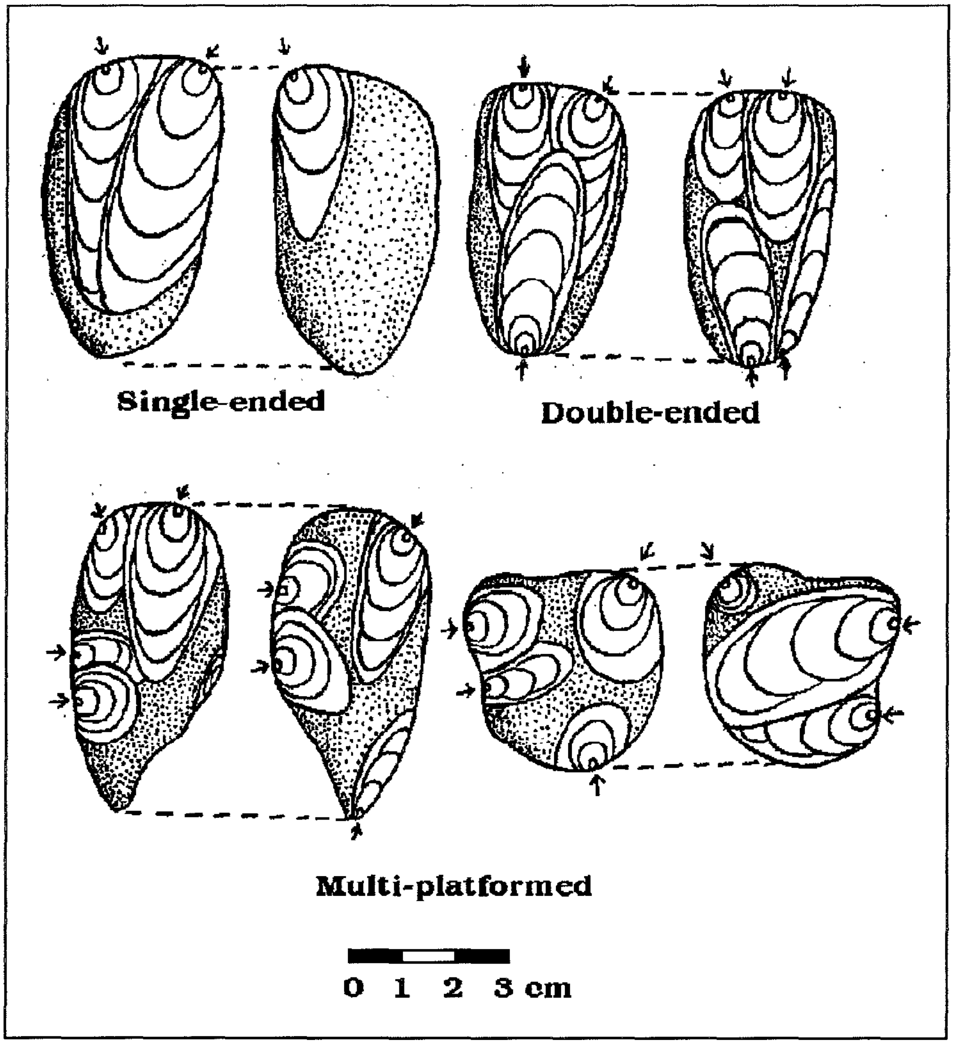

Figure 7.8. Types of bipolar cores as defined by Honea (from Honea 1965: 262).

their platform development into:

7.2.3.3.1. **Plain platform.** Naturally convex, concave or plane, cortex covered surface of one end of the core.

7.2.3.3.2. **Unfaceted platform.** This platform is the resultant flake scar created by a single flake removed at a right or slightly oblique angle to the length of the core and direction of intended primary flaking.

7.2.3.3.3. **Faceted platform.** This form is made by striking off a series of roughly parallel flakes from the top of the core at approximate right angles to the intended direction of flaking. It is believed to be made less frequently on pebble cores.

7.2.3.3.4. **Prepared platform.** Unfaceted and faceted cores are occasionally prepared in the Levallois fashion. That is, the cortex is trimmed off the core surfaces by multi-directional, unifacial, or bifacial percussion flaking before preparation of the platform.

7.2.4 **Herbort's (1988) bipolar core (outils écaillés) classification.** Herbort (1988) also classed a number of bipolar cores, although he based his system primarily on the shearing tendencies of the material. Herbort (1988: 37-39, 45-46) lists six main types of core shearing that produce his core classes, these are: tranchette, truncation, spall, double split, longitudinal and lateral. Unfortunately, they are not well defined.

7.2.4.1. **Tranchette.** These shear transversely, but not longitudinally through the Y axis, but rather obliquely to it through the mid -section of the core (Figure 7.9). This appears to

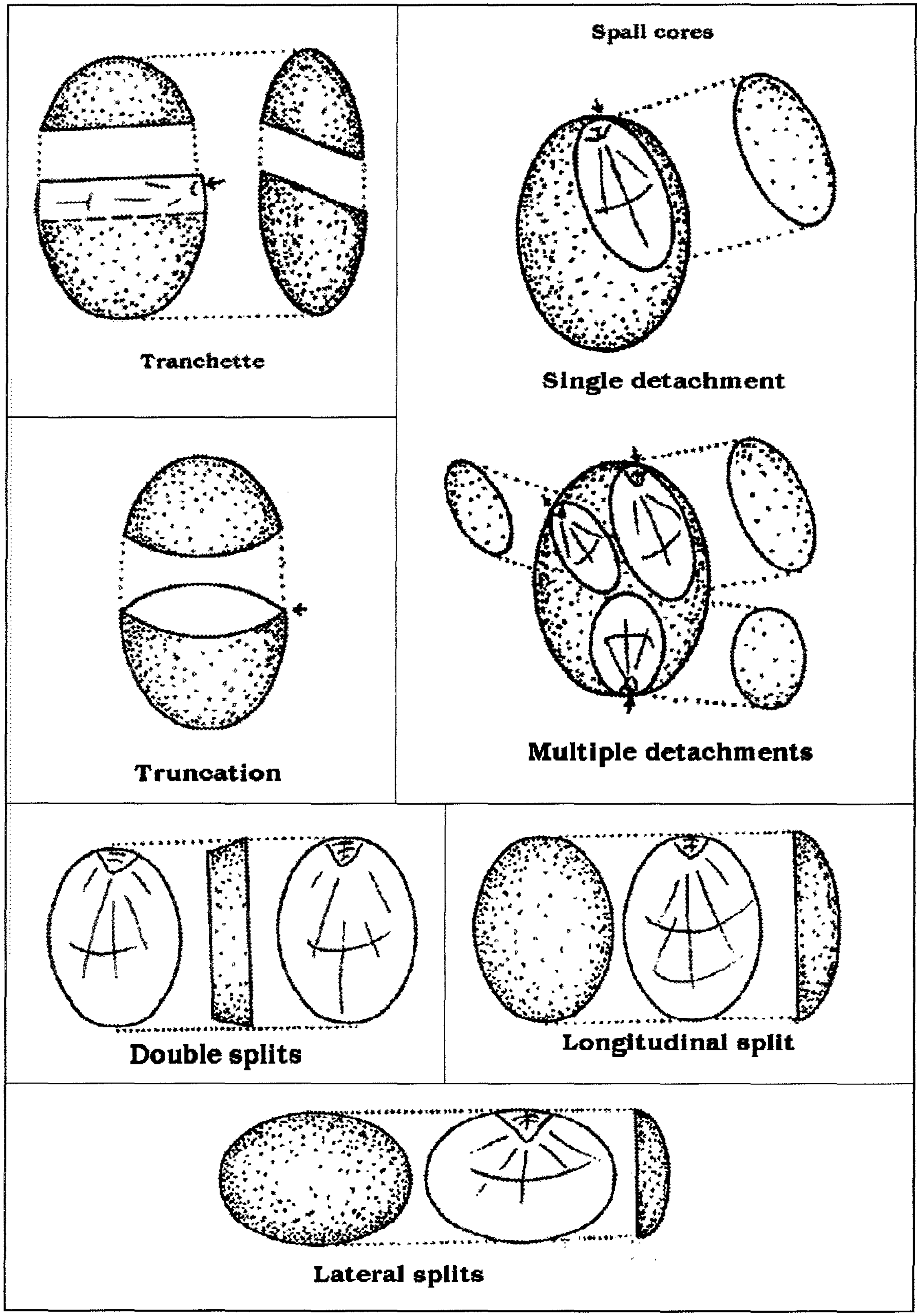

Figure 7.9. Variations of bipolar fracturing (from Herbort 1988: 45-46).

be an extremely odd fracture pattern.

7.2.4.2. **Truncation.** This type also shears transversely, but as above, it does not shear longitudinally through the Y axis; it appears to fracture perpendicular to the point of anvil contact (Figure 7.9).

7.2.4.3. **Spall.** This core type (Figure 7.9) is produced by the detachment of flakes that Herbort (1988) calls spalls. The spalls are removed from any of a number of locations. These cores in essence are identical to Honea's (1965) multi-platformed type (Figure 7.8.).

7.2.4.4. **Double split.** These cores are produced when the specimen shears longitudinally in the same direction producing three sections (Figure 7.9).

7.2.4.5. **Longitudinal split.** These specimens are produced by the core splitting longitudinally down the X axis and ending in an axial termination (Figure 7.9.). In this instance the core was resting on the anvil with the X axis perpendicular to it with the force being applied at the proximal end of the specimen.

7.2.4.6. **Lateral split.** These materials are produced by the core shearing down through the Y axis producing a laterally split specimen with an axial termination (Figure 7.9.). In this instance the core had its lateral edge resting on the anvil with the Y axis perpendicular to it. Force was then applied at the proximal end of the specimen's lateral edge. During the initial testing of materials I attempted both longitudinal and lateral replications. Although I did manage to split several specimens laterally I found the pieces harder to hold and I had a lower success ratio of shearing the materials when compared to the longitudinally replicated ones. Therefore, I preferred the longitudinal rather than the lateral split for my experimentations.

7.2.5. Root's (1994) bipolar core (outils écaillés) classification. In a report by Root (1994) on the Bobtail Wolf site, a multicomponent lithic workshop and campsite in the Knife River flint primary source area, western North Dakota, he outlines four classes of bipolar cores. He classified his bipolar cores based on the reduction technology that characterizes their manufacture as defined by the types of flake initiation, propagation, and termination, which he states allows for the distinction between non-bipolar and bipolar percussion (Root 1994: 44-47). His classification regarding bipolar cores is as follows (these forms were not illustrated in the original):

7.2.5.1. Bipolar cores, not rotated. These cores have a single platform and exhibit areas of crushing and splintering on opposite ends of the cobble, flat flake scars that create a multifaceted core form, negative flake scars that often run the length of the core, no negative bulbs of force, a predominance of wedging flake initiations, pronounced compression rings on flake scars from compressed controlled propagation, and axial flake terminations.

7.2.5.2 Bipolar cores, rotated. These cores exhibit more than one combination of platform states.

7.2.5.3. Bipolar and freehand cores, predominantly bipolar. These cores display evidence of bipolar and freehand detachments with the majority by the bipolar technique.

7.2.5.4. Bipolar and freehand cores, predominantly freehand. These cores display evidence of bipolar and freehand detachments with the majority by freehand methods.

7.2.6. Binford and Quimby's (1963) bipolar flake classification. Bipolar flakes have the same range of variation as straight percussion materials, however, they have the added enigma that they are abundantly more difficult to identify.

Several researchers have attempted classifications of these materials, for example Binford and Quimby (1963) first identified two classes with five variations of bipolar flakes. They divided the classes bases on whether flakes originated at the basal zone of percussion or the impact zone of percussion. These forms are outlined as follows:

7.2.6.1. Class 1. These flakes are derived from the base of the core through contact with the anvil.

7.2.6.1.1. Variety A. Flakes of this type are derived from the corner of the core having a basal area of percussion. The overall shape of these flakes is stated to be triangular in form with little or no bulb of percussion evident on the ventral surface. These flake types display no positive bulbs of percussion although some have negative bulbs. There are no illustrations of this type provided by Binford and Quimby (1963).

7.2.6.1.1. Variety B. These flakes are stated to originate from the broad lateral face of a core having a basal area of percussion. The ventral faces display moderate positive bulbs of percussion and the dorsal faces exhibit multiple, parallel, longitudinally oriented flake scars. These flakes are triangular or lamellar in form. There are no illustrations of this type provided by Binford and Quimby (1963).

7.2.6.2. Class 2. These flakes are derived from the impact zone of percussion of the core.

7.2.6.2.1. Variety C. These flakes are detached from the lateral core face by the impact of blows at the upper ridge or point of percussion in which the zone of impact is very narrow. The ventral surface has a developed positive bulb of percussion and the dorsal surface displays two or three parallel scars that converge to form a ridge (Figure 7.10.). There are generally several hinge fractures near the base of the flake. These flakes are either lamellar or excurvate in form.

7.2.6.2.2. Variety D. These flakes are detached in the same manner as Variety C except that it is the basal zone of percussion that is very narrow. These flakes are small and the ventral surfaces almost entirely consist of a positive bulb of percussion. Dorsal surfaces are irregularly scarred near the base of the flake. Distal ends also commonly display terminal hinge fractures. These flakes are generally ovate or conchoidal in form. Figure 7.10. represents the one Variety D bipolar flake that Binford and Quimby (1963) illustrate.

7.2.6.2.3. Variety E. These flakes are detached from the end of the core by the impact of blows at the upper ridge or point of percussion in which the basal zone of percussion is

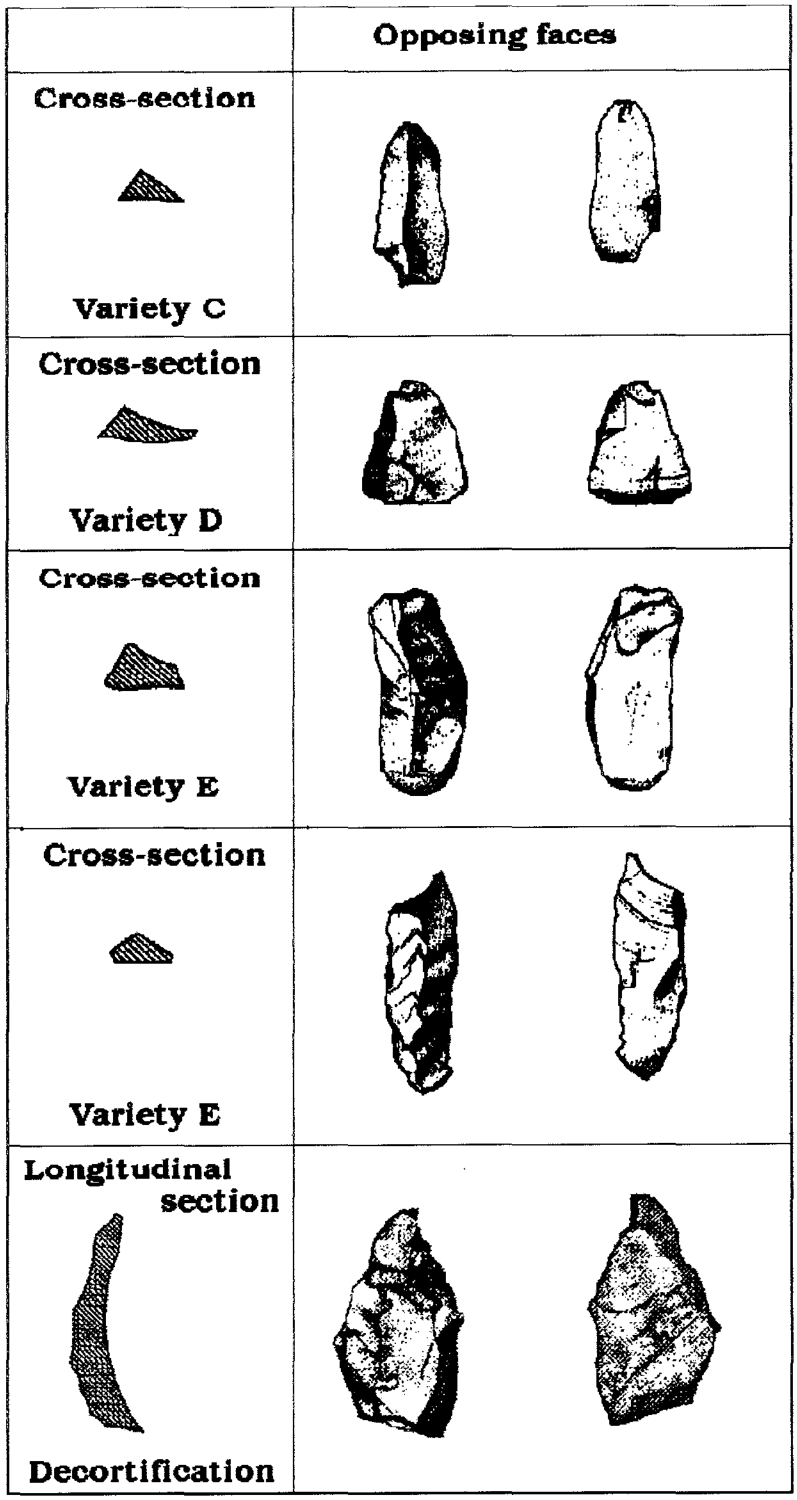

Figure 7.10. Bipolar flakes as defined by Binford and Quimby (1963: 354, 363).

very narrow. The ventral surfaces have a well-developed positive bulb of percussion and the dorsal surfaces exhibit a single, longitudinally oriented flake scar. These flakes are either lamellar or expanding in form. Binford and Quimby (1963) illustrate two Variety E bipolar flakes as displayed in Figure 7.10.

Binford and Quimby (1963) outline one other flake type within their report. These flakes are decortification flakes (Figure 7.10.) that have unmodified cortex and ventral faces that display scarring. For some reason they have chosen to label this flake type separately from their other varieties. They indicate that strong negative bulbs are common on these materials, but that some specimens also display strong positive bulbs as well.

7.2.7. Kobayashi's (1975) bipolar flake classification. Kobayashi (1975: 117) classified bipolar flakes into four large groups, based on their ventral surface attributes as outlined below. Although his bipolar flake illustrations are not very clear they are included here for comparison purposes.

7.2.7. 1. Group A. These bipolar flakes to have one or a twin bulb on the ventral surface at only the proximal end (Figure 7.11.). Flakes with axial terminations of distal ends, shattered ends, hinge fractures, or feather edges are included in this group. Many of these may actually be the upper section of Kobayaski's (1975) Group
D Type.

7.2.7. 1. Group B. Flakes that have one or twin bulbs at only the distal end where it was in contact with an anvil. These specimens include those types with shattered striking platforms

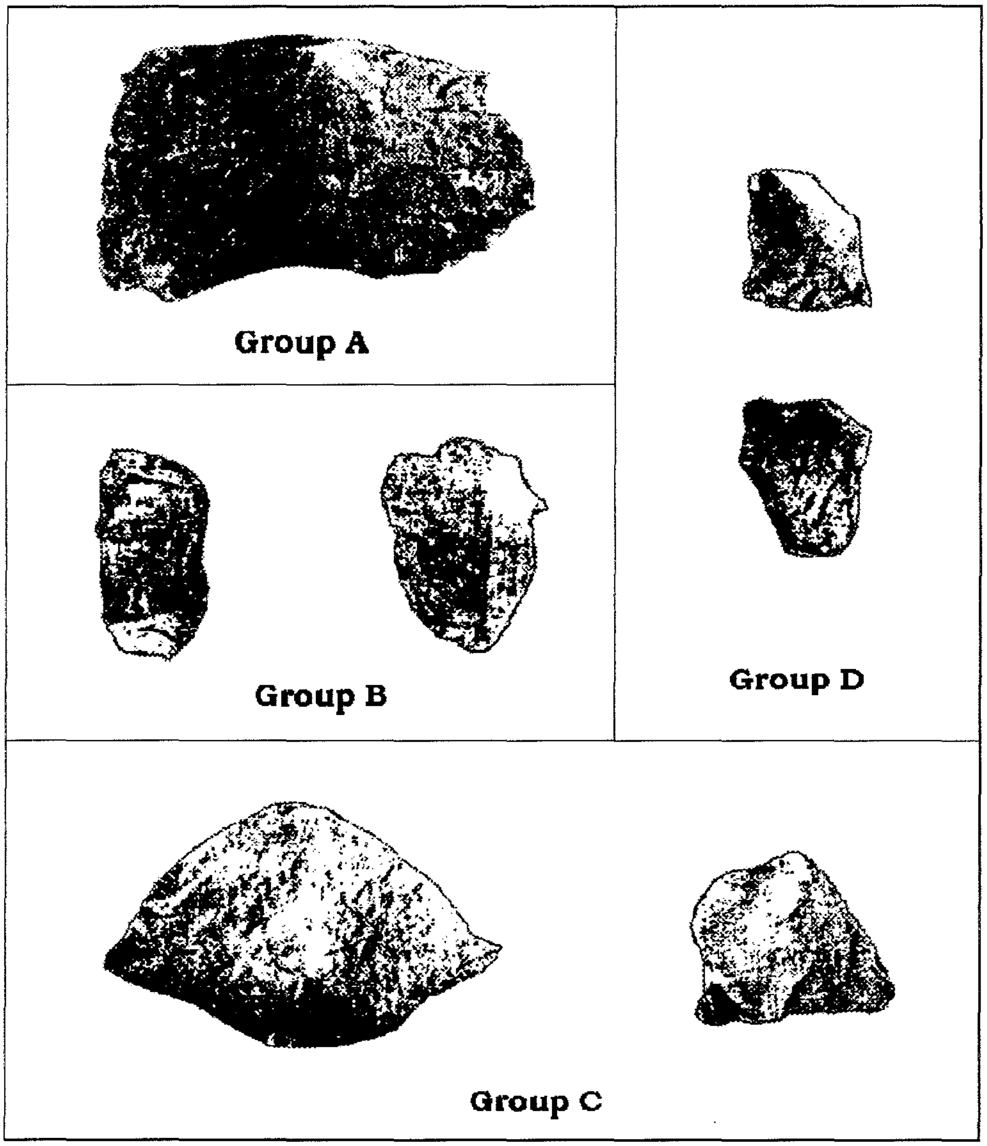

Figure 7.11. Bipolar flakes as defined by Kobayashi (1975: vi-x).

and feather edges (Figure 7.11.). It is possible that these flakes may be the lower, or distal portions of Kobayashi's (1975(Group D type.

7.2.7. 1. Group C, are bipolar flakes in which a twin bulb is found at both the proximal and distal ends (Figure 7.11.). This type was previously recognized by researchers, such as Honea (1965), who state that occasionally, a bipolar flake will exhibit a major positive bulb of percussion on the proximal end and a minor positive bulb of percussion of the distal end of the ventral surface of the flake. Honea (1965) indicated that these attributes are formed when percussion of a combined primary and secondary force coincide, caused by a mechanical force being applied at both ends of a core.

7.2.7.1. Group D. Flakes that are removed from the same core by one percussion blow. Flakes are removed from the striking platform, and the distal end that was in contact with the anvil, and two flakes are detached from different faces at the same time (Figure 7.11.).

As noted with the core classification systems, bipolar flake varieties also tend to overlap, especially in regard to their distinguishing attributes. This characteristic is very noticeable in Section 6 of this thesis where different technological classes displayed the same or similar attributes, which makes separating bipolar materials by attributes alone very difficult.

7.2.8. Pièces esquillées or wedges? The use of the terms pièces esquillées and wedge is not consistent within New World archaeological literature. Some reports use the term pièces esquillées, to describe a specific artifact, while others appear to prefer the use of the term wedge to describe fundamentally similar materials. For example, when one term is used the other is always associated with it; pièces esquillées (wedge), or wedge (pièces esquillées). Still others treat the use of these terms within the literature as non-equivalent. Although this has created further confusion, it is apparent from a study of the literature that these specimens do indeed relate to equivalent materials.

Pièces esquillées were first identified in Upper Paleolithic assemblages by Bardon and Bouysonnie (1906). MacDonald (1968) first introduced the term pièces esquillées to New World archaeology in his report on the Debert site in central Nova Scotia. In the Debert report MacDonald (1968) referred to the bipolar technique of producing pièces esquillées from pebble cores or small angular fragments of material. He also noted that they occur predominantly in industries that use small raw material in association with pitted anvil stones. This is essentially the same interpretation for items classed as wedges by other researchers.

Pièces esquillées are defined as being generally rectangular in form and exhibiting bipolar flaking from paired crushed and battered surfaces. Primary flakes driven from both faces by direct percussion exhibit extreme concentric ripples emanating from the point of percussion. On the edge, opposite the primary platform, multiple short flakes are driven back on both faces (the result of the force reflected by a hard anvil). The irregularly battered or primary edge tends to become concave with extreme use as a core while the evenly crushed or secondary edge usually maintains a receding straight profile determined by the shape of the surface that is acting as the anvil. Magne (1985:168) notes that pièces esquillées are formed through some function that alludes lithic researchers. However, as the Class 9 specimens in Section 6 illustrate, this may or may not entirely be the case. Many may have been shaped largely through the initial processes of bipolar reduction. Two specimens from France that exhibit the typical distinguishing characteristics of pièces esquillées are illustrated in Figure 7.12 (Hayden 1980).

In the archaeological literature wedges are referred to as hand wedges or bipolar cortex flakes that are made on flake and core remnants that are for the most part the products of bipolar flaking (Ranere 1975). They are generally thought to be used for removing thin strips of cedar and for working wood, bone and antler (Flenniken 1981; MacDonald 1968; Hayden 1980; Ranere 1975). Ranere (1975) identifies two types of wedges, one that has a broad base and another that from a maximum width around midpoint tapers in both directions to opposing bits, thus being tabular in form. LeBlanc (1992), identifies Ranere's (1975) latter form as a pièces esquillées.

According to MacDonald (1968), pièces esquillées differ from most concepts of a tool, since there is no stage at which they can be considered finished. They are initially short spalls or blocky fragments, which rapidly disintegrate through use until they reach a size that is difficult to hold, at which time they are discarded. To MacDonald (1968) pièces esquillées represent true tools that were used for "wedging" and slotting. To be useful as a wedge, a bipolar

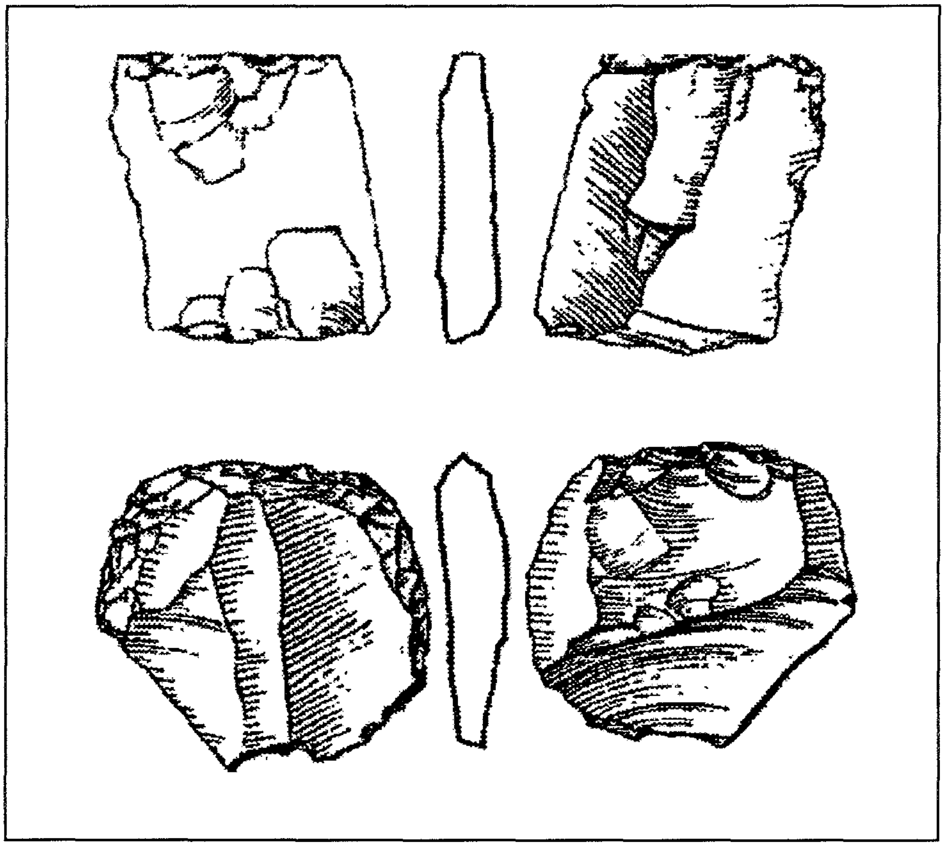

Figure 7.12. Two pièces esquillées exhibiting typical distinguishing attributes (from Hayden 1980: 6).

object must be capable of being handled, set in place, and held effectively (Lothrop and Gramly 1989) and large enough to hold firm while the blow is delivered. Although they are applied to soft and relatively elastic materials, the wedges themselves are usually damaged and worn, either on the edge struck by the percussor or on both edges (Keeley 1980; Shott 1989).

LeBlanc (1992) sees two major problems with the mixed interpretations regarding pièces esquillées, wedges and bipolar cores. These are the misconception of the nature of bipolar technology in reduction systems and the oversight relating to other experimental and archaeological information. In a study by Flenniken (1981) exhausted bipolar cores were used in wedging and splitting deer and elk bone. Flenniken's (1981) results tend to support the general utility and prehensility of bipolar objects used as wedging tools. Brose (1970) remarked that the bipolar cores represented in the Summer Island site assemblage, Michigan, may have been employed as wedges or scrapers, but that such usage was not sufficient to be recognized with the heavily battered ridge edges resulting from the bipolar technique. Lothrop and Gramly (1989) described pièces esquillées from the New York Vail sites. As well, Ellis and Lothrop (1989) noted the presence of pièces esquillées at the Potts site in New York. They also added that their function was unimportant at this site and he states that the precise function of pièces esquillées remains a matter of further debate. Wright (1972) described a number of wedges from a number of Shield Archaic sites as displaying distinct bipolar crushing on at least two opposite edges. Most of the plates Wright

(1972) provides are not clear; however, in conjunction with his description of wedge material he does provide an illustration of what he refers to as being wedges or pièces esquillées.

Shott (1989) clouds the issue by arguing that wedges are expediently produced bipolar cores, not wedges. Similarly, Goodyear (1993) believes that pièces esquillées simply represent bipolar cores. There is also further debate regarding whether wedge-shaped objects are pièces esquillées rather than bipolar reduction cores (Lothrop and Gramly 1989; Morlan 1973; Shott 1989). Morlan (1973) treats these artifacts as being equivalent and includes in this category all flakes with limited facial as well as marginal retouch on opposite margins of both faces. Part of the problem of identification and classificaiton of these materials is that use-wear often appears on many of these bipolar cores.

Most reports that debate the issue of pièces esquillées, wedges and bipolar cores do not illustrate the supposed differences that they observe between these materials. It is likely that there are justifiably very few if any true differences between the attributes of these objects. If a piece of material, whether a bipolar core or merely a chunk of lithic debris, was used for splitting wood or antler it would be logical that during that process it would develop the attributes of a pièces esquillées or a wedge. This evolution of the original piece of lithic material would essentially transpire during the pounding, turning and bipolar impacting that would necessarily take place from the use of one of these specimens during the splitting of the object being manipulated. It is also clear from an examination of the Class 9 specimens outlined in Section 6 of this thesis that the general use of the bipolar technique during manufacture of the implement also contributes to the unique shape of these materials.

7.2.9. **Spurred end scrapers.** Spurred end scrapers have a lateral pointed projection and are suggested to be artifacts diagnostic of Paleoindian times (Rogers 1986). This conclusion is based on the observance by Rogers (1986) that they are located on Wisconsin, but not Holocene, terraces. A typical spurred endscraper, which comes from Kansas, is illustrated in Figure 7.13 (Rogers 1986). MacDonald (1968) notes that microscopic examination illustrates clearly that in every example of a spurred end scraper the bipolar flakes were removed after the scraper had been completed and were not part of the manufacturing or resharpening process. One interpretation of this is that the spur was first employed to slot material and that in the event that a wedge was not readily available the scraper itself was hammered into the slot that likely caused the bipolar removal of flakes.

7.2.10. **Domed-scrapers (domed scraper planes).** According to Hardaker (1979) the first step in manufacturing a domed-scraper is to split a round cobble. This process produces a dome-shaped core with a flat ventral surface. Next, the distal surface of the dome-shaped core is placed on an anvil. When the ventral surface along the lateral edge of the dome shaped core is struck the flakes originate around the core. A typical scraping plane is illustrated in Figure 7.14. The types of flakes obtained in this manner will vary from step flakes to concave-convex flakes to blades, depending on the shape of the dome preform and its

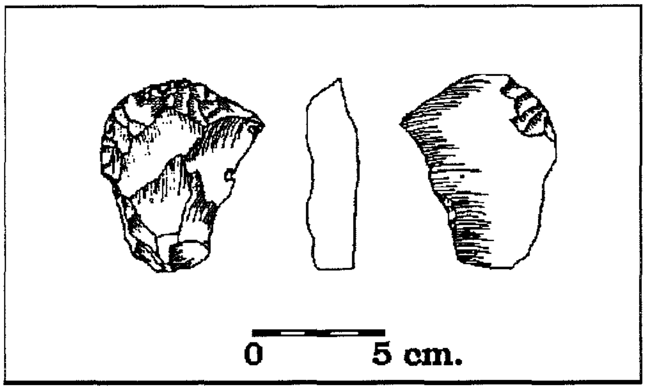

Figure 7.13. A spurred endscraper (from Rogers 1986: 339).

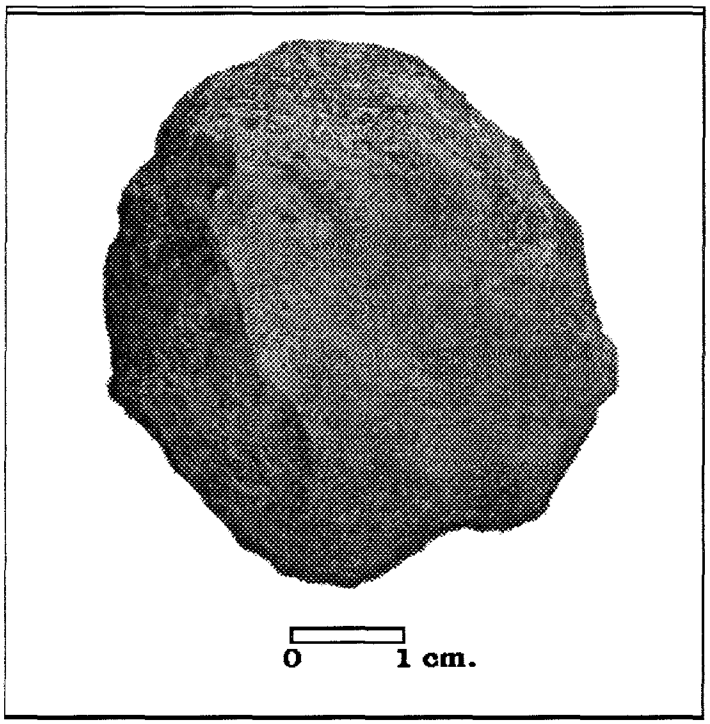

Figure 7.14. Domed scraping plane.

constantly altered shape.These items frequently display battering marks on their proximal end as a result of the significant amount of stress they undergo during their manufacture. Hardaker (1979) interprets these battering marks as being diagnostic of bipolar flaking technology since he believes that percussion forms would not display these attributes. I do not agree with this interpretation, however, as freehand straight percussion forms would definitely display proximal battering.

7.2.11. **fabricators.** Fabricators were thought to be stone tools used to make other stone tools. White (1968) argues that many if not all fabricators were bipolar flaked cores used for the derivation of flakes. These flakes were then used as tools without further modification. White (1968) reasoned that if fabricators were tools used to make other stone tools then they should correlate with formal tools within assemblages, but they did not. White (1968) re-analyzed the published descriptions of prehistoric lithic assemblages in certain Australian sites. He then analyzed the distribution of fabricators in these assemblages from the perspective that they were cores. It was found that what were thought to be cores at one site were inversely proportional to the number of fabricators, indicating to him that the latter were in reality an alternate type of core. In considering these findings he proposed that the term fabricator be dropped in favour of the term scalar core. A scalar core as he defined it is a bipolar core with opposing ends battered, splintered and bruised. In essence, the characteristics of scalar cores are identical to and could easily be placed in a number of the previously noted bipolar core types.

8. COMPARISON OF EXPERIMENTALLY REPLICATED SPECIMENS WITH PREVIOUS BIPOLAR CLASSIFICATIONS

8.1 Analysis and comparison of bipolar core and flake classifications.

The experimental bipolar materials outlined in Section 6 consist of ten technological classes of replicated split pebble stones. The analysis of these materials revealed a number of interesting findings. In order to more clearly outline the significance of these observations they are compared here primarily with regard to previous bipolar classification systems.

Pebble stone materials really require a unique classification system because they do not readily fit into other bipolar flake or core classes. This is largely because other classification systems are based on the examination of larger pieces of raw material unlike the small pebbles analyzed within this study. Many pieces of larger materials may have been subjected to multiple applications of force creating numerous flake scars and altering the specimens considerably from their original shape. The ultimate outcome, with regard to large cores, was to attain as much usable material as could be removed from a specimen, therefore it was repeatedly worked to detach as many flakes as possible. With the pebble stones that were used in the experimental replications of this study, each specimen was subjected to only one application of force. Consequently, much of the original form of a pebble was retained. Furthermore, with the small pebble stones used for this study, the ultimate goal was also to attain as much usable material as possible. However, in this instance that meant shearing the pebble into two sections that would provide two preforms from which finished tools could then be manufactured. This was done in an attempt to, as closely as possible, simulate the archaeological context. Therefore, if pebble stones were subjected to similar multiple applications of applied force that were required to reduce a large cobble this would have diminished the small pebble beyond use.

As I noted previously, the experimentally replicated pebble stone materials do not fit into the bipolar core classifications of Binford and Quimby (1963), Leaf (1979a) and Honea (1988). Those classifications deal with the reduction of larger pieces of raw material.

The only bipolar core classification system outlined in Section 7 that has any relationship to the materials outlined here is that of Herbort (1988). His method of analysis was also a technological (physics based) one that separated specimens based on their shear patterning. This is the method used within this thesis. One restrictive aspect in Herbort's (1988) classification system is his neglect to separate materials beyond their shearing pattern. In other words, he considers all specimens displaying a singular longitudinal split as a single class with the exception of those pieces that have a double split.

Since the majority of experimentally replicated specimens analyzed within this thesis display longitudinal splits ending in axial terminations, Herbort's (1988) classification system is inadequate for this analysis. Of significance in Herbort's (1988) system is that he listed several classes of bipolar fracturing that are not represented within the experimental materials of this thesis. As well, shear patterns presented in the experimental assemblage are not accounted for in Herbort's (1988) system. These differences will be addressed within the discussion below of my specific classes.

Among the bipolar flake classifications of Binford and Quimby (1963) and Kobayashi (1975) only the latter relates to the materials defined within section 6. As noted above for the bipolar cores classified by Binford and Quimby (1963), the bipolar flakes they identified also relate to a different class of materials than the pebble stones used here. Therefore, the resultant flake by-products of their study are quite different and do not relate to any of the experimental materials identified in Section 6.

The system used by Kobayashi (1975) separates bipolar flakes into four groups and is based on ventral attributes. As a result, his four groups can be applied to those materials experimentally replicated in this study. Unfortunately, each of his groups can be applied to several of my classes of flake materials since they are not based on technological divisions. Therefore, their usefulness for this study is quite limited. Specific comparison will be made in the following sections.

Since none of the prior bipolar core or flake classification systems could be applied to the materials experimentally replicated in this study, it was necessary to develop a system unique to these materials. This resulted in 10 technological classes, as identified in Section 6. Unlike previous classifications that use attributes to separate each class, my method relies upon the shear or shatter patterning displayed on the materials. However, specific attributes are used to define the separate classifications and, more importantly, to determine if bipolar materials can be positively identified. I felt that this method was fundamental to this study because these divisions would best identify the presence of bipolar techniques when applied to pebble stone materials.

8.2 Class 1.

As noted in Section 6, although the Class 1 bipolar specimens all split longitudinally down the X axis, relative to the Z axis and end in an axial termination, they actually consist of four styles of fracture. As illustrated in Figure 8.1 the Zingg indices produced two loose and slightly scattered clusters among the Class 1 materials, although there was no distinction between the 4 styles and all are represented in both groups Class 1 specimens are about equally represented by oblate and bladed pebble forms. These indices indicate that these specimens vary in overall shape, but that they are all relatively thin.

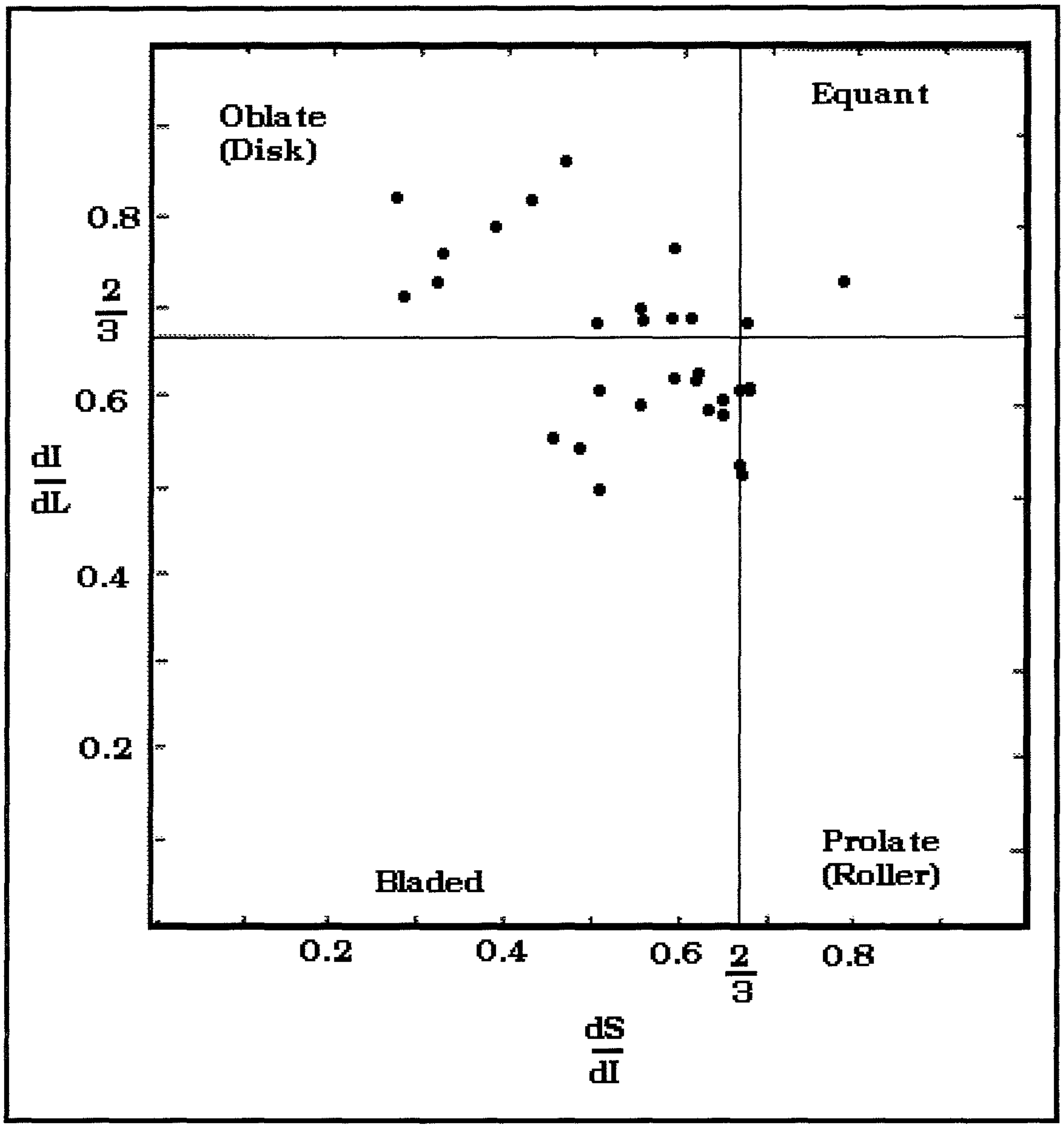

Figure 8.1. Classification of Class 1 pebble shapes (*Zingg* indices after Zingg 1935 in Blatt, *et al*, 1980: 80).

8.2.1. Style 1. The Style 1 specimens are probably the most unique in this class because these specimens are strongly curvate. The unique fracture of the Style 1 materials was probably the result of the main applied force exerted upon the lateral portion of the specimen, shearing the small curvate section from the body of the pebble stone. Nine pieces within Class 1 displayed a Style 1 fracture, which included 6 silicified siltstone pebbles, and 1 quartzite, 1 generic material and 1 generic chert pebble.

Previous interpretations regarding bipolar flaked materials note that this type of fracture has not been identified. The problem is that it would be quite difficult to separate these materials from typical percussion flakes. For example, while this type of fracture is obviously very rare in bipolar materials it is a common type of flake form among typical percussion materials.

Only two of the Style 1 specimens of the Class 1 materials displayed proximal bulbs of percussion. These materials would fall into Kobayashi's (1975) Group A bipolar flake class. There were no distal bulbs identified among the Style 1 specimens.

8.2.2. Style 2. Style 2, Class 1, specimens display a form of fracture common in most bipolar materials. These specimens are linear and shear longitudinally down the X axis and end in an axial termination. These materials contrast with the other experimental specimens identified here because they shear transversely. They split relative to the Z axis longitudinally along a lateral edge of the pebble stone. Interestingly, only four specimens displaying this fracture pattern occurred among the 30 Class 1 replicated materials and only one of these could be positively identified as a bipolar by-product based on the presence of proximal and distal bulbs of percussion. This specimen (#3) would be identified by Kobayashi (1975) as a Group C bipolar flake. Additionally, one section of specimen 2 would fit into Kobayashi's (1975) Group A bipolar flake class.

8.2.3. Style 3. These specimens have a unique fracture pattern. While the pebbles shear longitudinally down the X axis ending in an axial termination, they have fractured obliquely to the Z axis as illustrated in Figures 6.6, 6.7 and 6.8. Style 3 materials also display irregularly sheared surfaces. There are 12 Style 3 specimens in Class 1. Only one section of specimen 136 fits into Kobayashi's (1975) flake classification as a Group A component.

8.2.4. Style 4. These specimens display typical bipolar shear patterns; they split longitudinally down the X axis in a linear and straight trajectory. These materials are different from the other classes in that they split parallel to the Z axis. There are five specimens of this style within the Class 1 materials. Specimen 1 would fit into Group A of the Kobayashi (1975) classification system; however, the others specimens are amorphous and would not fit into any other of his categories.

8.2 Class 2.

Class 2 specimens are separated from the previous Class 1 materials on the basis that they shear longitudinally down the X axis, but they are split transversely across the Y axis. These specimens consist of two complete sections that end in an axial termination. As I noted previously this type of shear occurs most often in pebble stones that are relatively narrow and flat. This interpretation is supported by the Zingg indices, as illustrated in Figure 8.2, that clearly exhibits among the Class 2 specimens the strong clustering toward the oblate pebble form.

Specimens that conform to the Class 2 shear pattern are the most technologically advantageous since these specimens split in a manner that would provide a maximum amount of usable material. This shear pattern is the most desirable among fractured pebble stones because when a pebble stone is split in this mode it instantly provides the stone worker with two preforms with which to manufacture both simple and more elaborate tools. In fact, this point is illustrated by the wide range of pebble stone artifacts that are represented within the archaeological record as depicted in Section 9.

Of the 521 replications conducted, 162 specimens, or 30.9%, consisted of Class 2 specimens. Of these, 35 specimens would be identified by Kobayashi (1975) as Group A, 3 as Group B, and 15 as Group C bipolar flakes. The remaining materials are all amorphous and would not fit into any of his bipolar flake classes.

The above identifications based on Kobayashi's (1975) bipolar flake groups illustrates the previous point made that separating materials by attributes alone does not take into consideration their technological divisions. Three of his four flake groups have been identified within this one technological class.

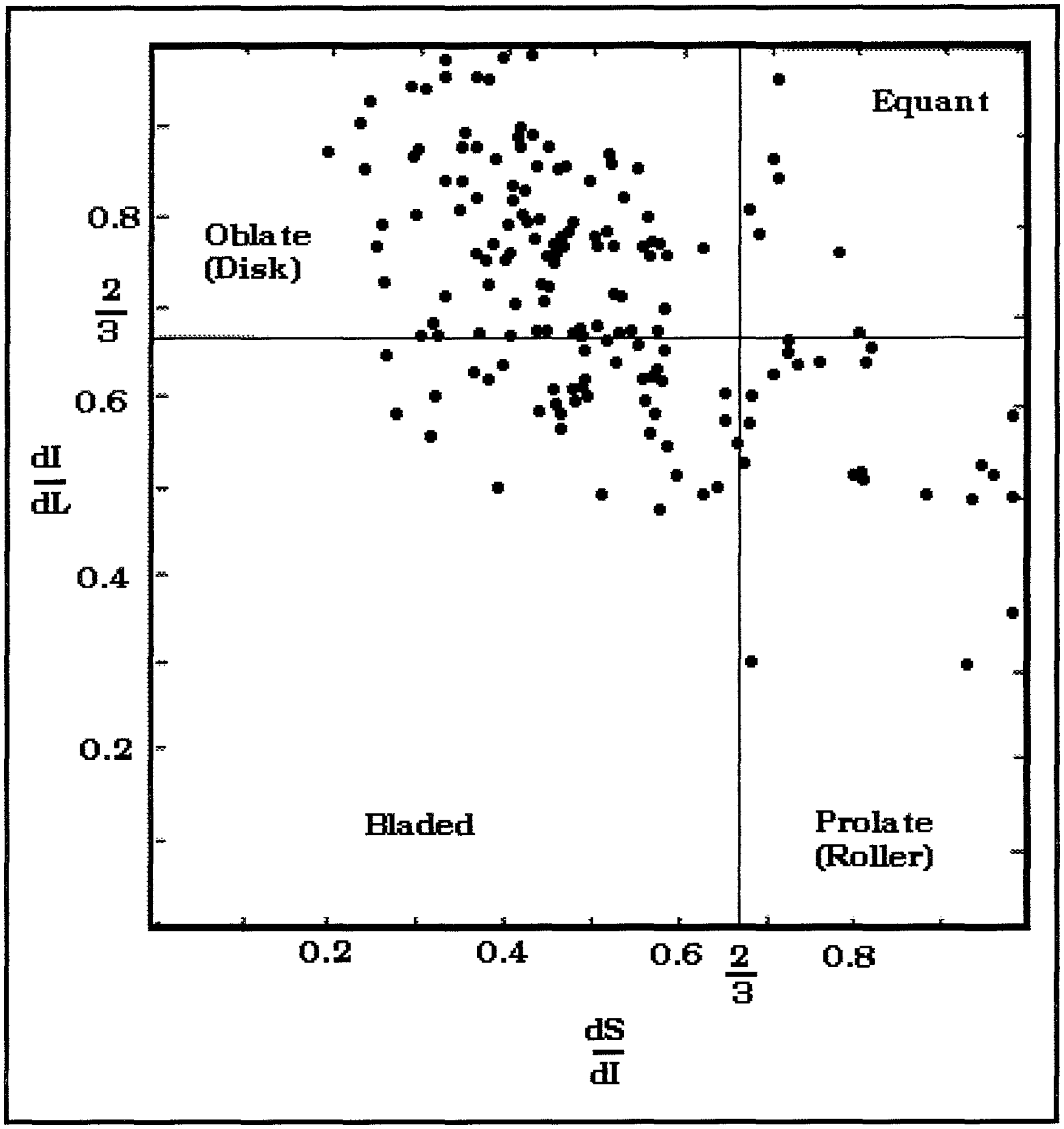

Figure 8.2. Classification of Class 2 pebble shapes (Zingg indices after Zingg 1935 in Blatt, *et al.* 1980: 80).

Furthermore, all of the Group A Kobayashi (1975) bipolar materials could just as easily be identified as straight percussion specimens since they are based only on the presence of proximal bulbs of percussion.

Only the materials based on Kobayashi's (1975) Group B and C classification could positively be identified as bipolar materials if located out of context. Because the Class 2 materials are based on complete sections it would be unlikely that these pieces would be mis-identified as non-bipolar by-products.

8.2 Class 3.

The Class 3 materials resemble the Class 2 materials with one exception. Although the shear pattern for this class of materials is the same as for Class 2, only one split pebble section of the experimentally replicated specimens remained complete following the replication. The other section either snapped or shattered following the application of force to the specimen. These specimens, however, would still provide the stone worker with a preform from the one complete section and the possibility of several expedient use tools from the broken half of the pebble.

It would be expected that Class 3 specimens should closely resemble the Class 2 materials. As illustrated by the Zingg indices outlined in Figure 8.3 this is in fact the case.

Of the 58 specimens within Class 2, 15 pebble sections would fit into Kobayashi's (1975) Group A and four into his Group C bipolar flake classification. Only the four specimens based on his

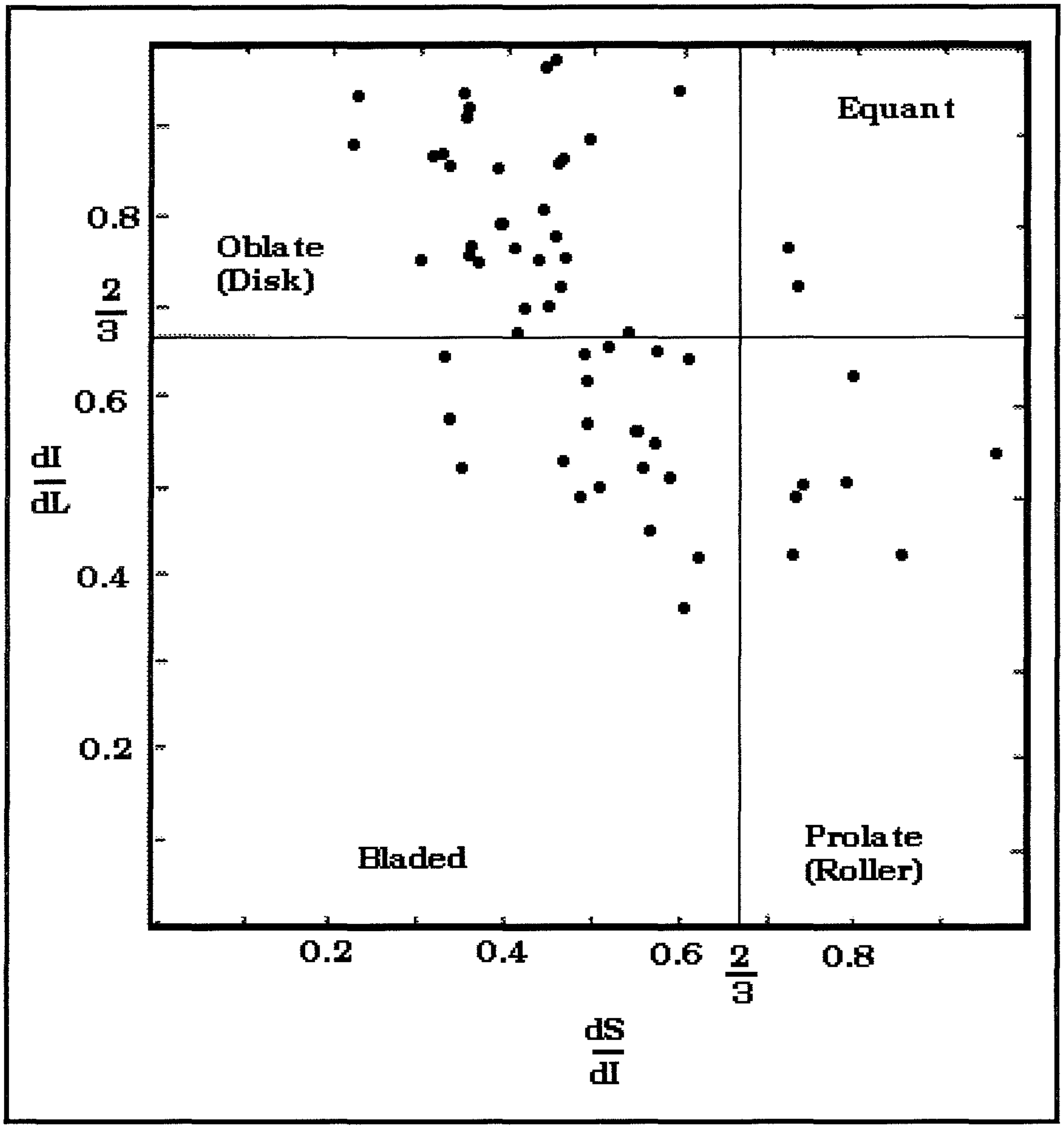

Figure 8.3. Classification of Class 3 pebble shapes (Zingg indices after Zingg 1935 in Blatt, *et al*, 1980: 80).

Group C classification could positively be identified as bipolar.

The remaining Class 3 materials are quite amorphous and if they were located out of context it would be difficult to identify them positively as bipolar materials.

8.2 Class 4.

Class 4 specimens are unique in that the pebbles experimentally replicated fractured along a double split. These materials shear longitudinally down the X axis and transversely parallel to the Y axis ending in an axial termination. However, rather than one transverse split parallel to the Y axis, two shear planes occurred among the Class 4 specimens. Zingg indices for the Class 4 specimens clustered along the oblate/bladed interface, as illustrated in Figure 8.4, indicating that these forms are also fairly thin in relation to the overall body form.

It is noteworthy that of the previously noted bipolar core classifications the Class 4 specimens are the only ones among these experimentally replicated materials that have been formally identified. Herbort (1988) also noted a double split among the cobbles within his experimental study. There are only three specimens within this class. One of these, a section of specimen 250, would fit into Kobayashi's (1975) classification system. In this instance the section would be identified as a Group A flake; the remaining pieces are amorphous.

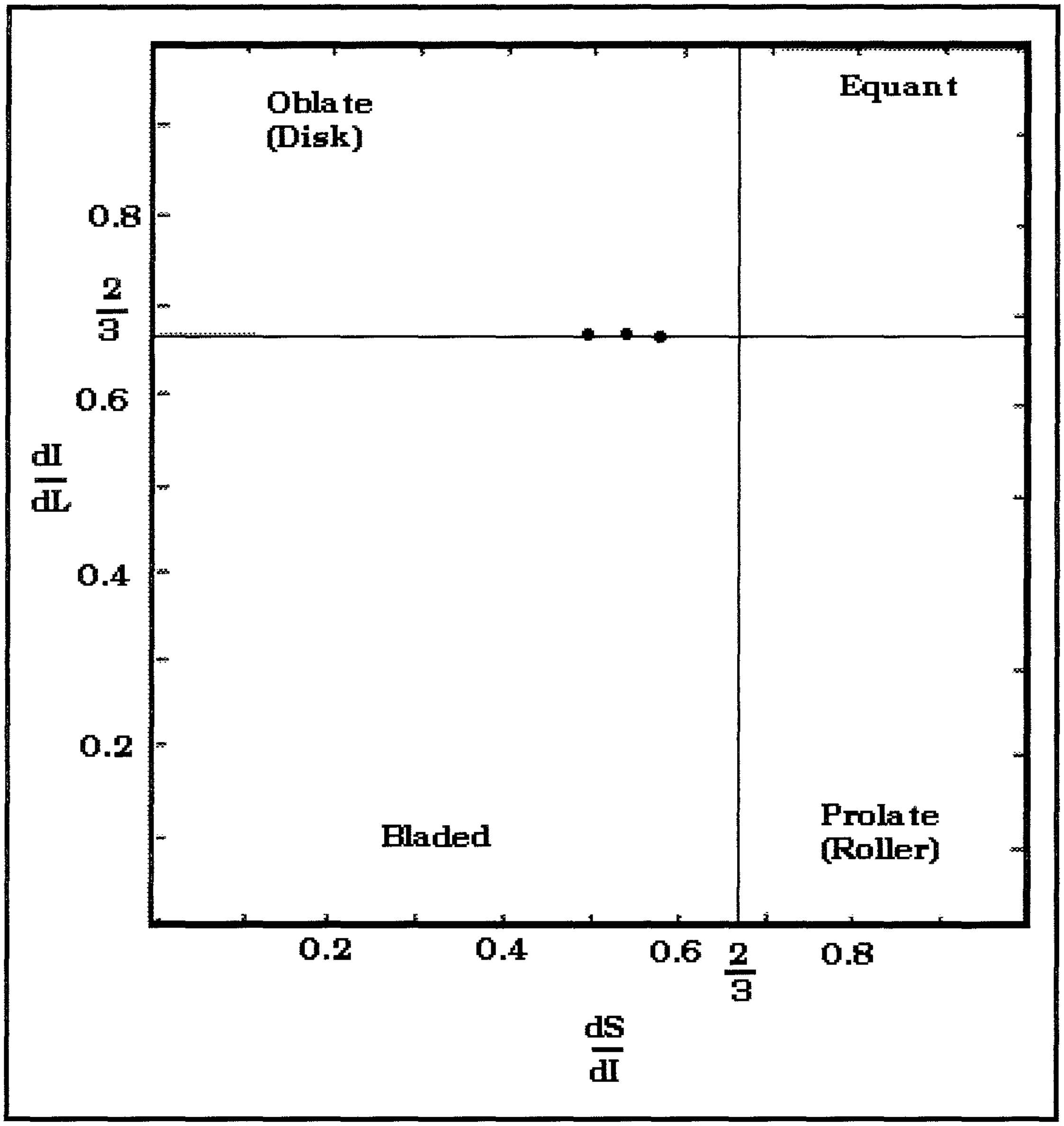

Figure 8.4. Classification of Class 4 pebble shapes (Zingg indices after Zingg 1935 in Blatt, *et al*, 1980: 80).

8.2 Class 5.

Only one specimen was placed within this class. The shear pattern of this specimen was truly unusual and no other reference could be located for its occurrence. Although the pattern of shearing for this specimen was essentially the same as the Class 4 materials, this pebble split transversely into four approximately planar sections. Even though the complete outer section displayed distal and proximal crushing and could be identified as bipolar, none of the sections from this pebble fit into Kobayashi's (1975) classification scheme. It is interesting to note that the Zingg indices place this specimen on the equant/prolate interface indicating that this pebble was fairly thick through the midsection, although this pebble was also one of the larger specimens used in the experimental replications (Figure 8.5).

8.2 Class 6.

Class 6 materials consist of pebble stone specimens that shattered during the replication. The Zingg indices as illustrated in Figure 8.6, indicate that these specimens are scattered among all four forms. Oddly, however, they are well represented by oblate and bladed forms. It was initially anticipated that these specimens would be more strongly represented by the thicker equant and prolate types.

Of the 521 replicated pieces 42 specimens were placed into this class. Although it might be possible to identify surface

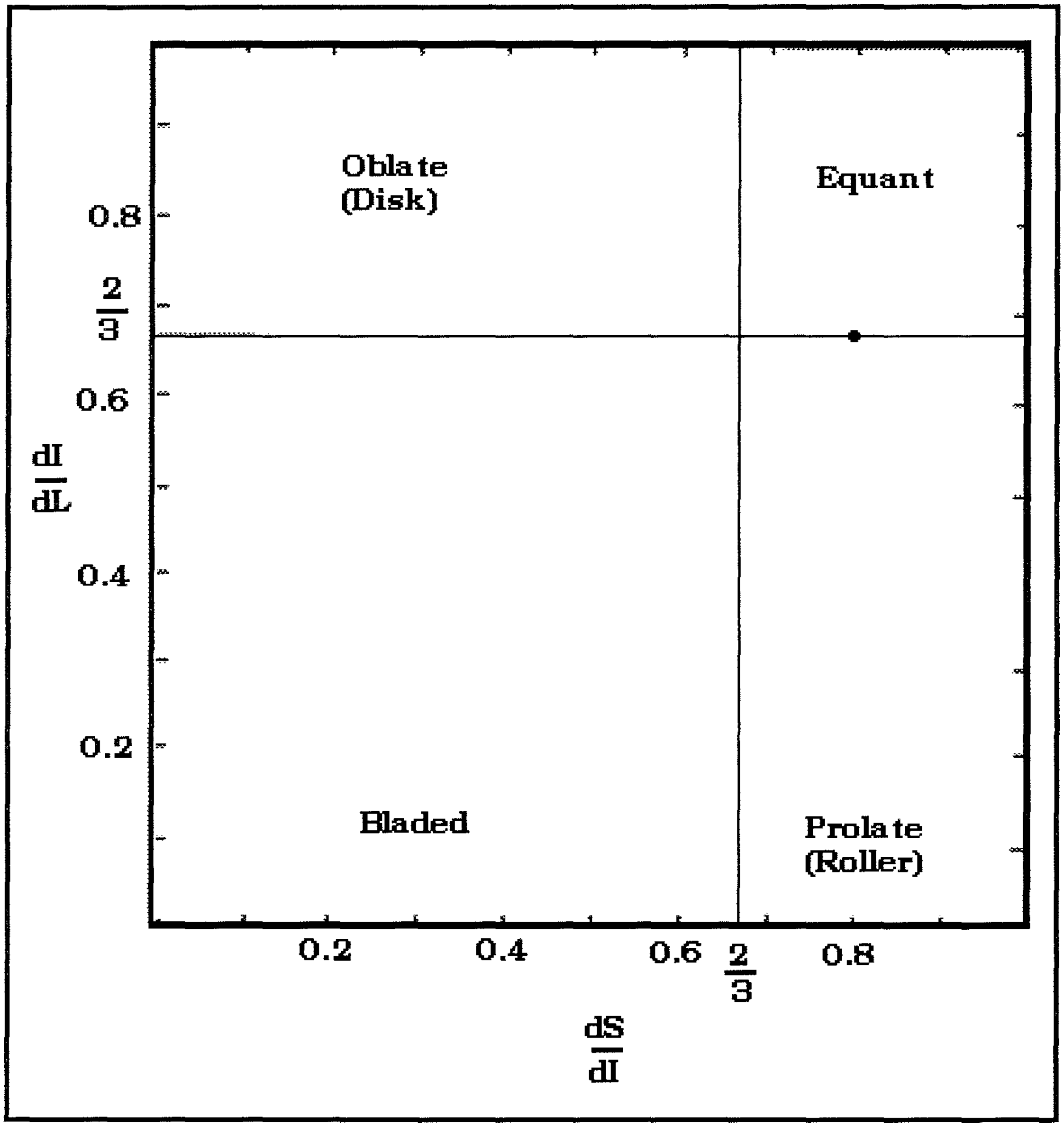

Figure 8.5. Classification of Class 5 pebble shapes (*Zingg* indices after *Zingg* 1935 in Blatt, *et al*, 1980: 80).

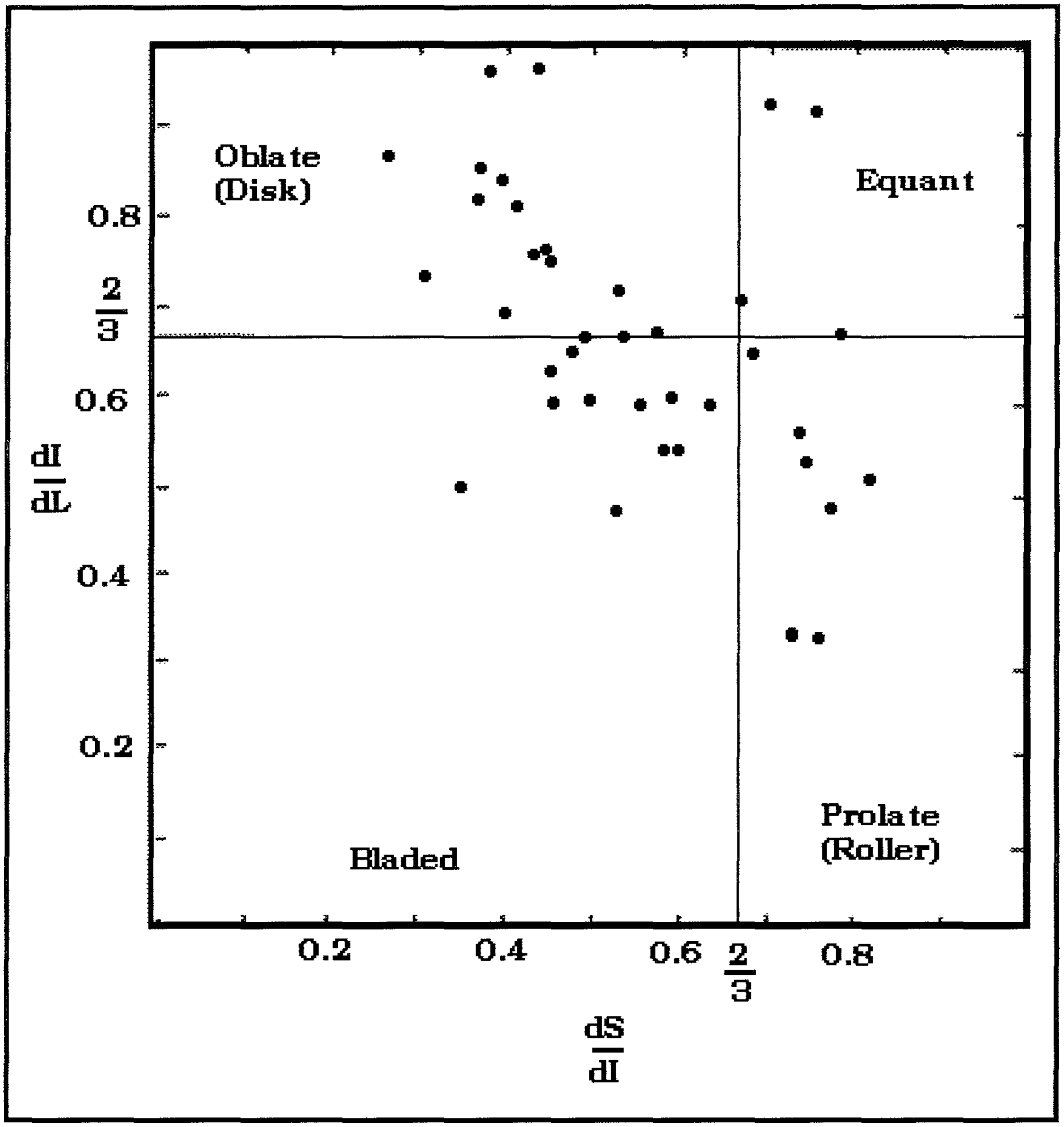

Figure 8.6. Classification of Class 6 pebble shapes (*Zingg* indices after Zingg 1935 in Blatt, *et al*, 1980: 80).

attributes on a select number of fragmented pieces, it was not attempted here. As noted previously, the materials experimentally replicated were divided based primarily on their technological divisions and not on the individual surface attributes that could be identified. Because of the general indistinctive nature of shatter materials were placed into this class without further analysis.

8.2 Class 7.

This technological class of materials is based on the inadequate amount of applied pressure causing a small flake to detach from the proximal end of the pebble stone. Morphologically, these specimens could be compared to Herbort's (1988) single detachment spall cores; however, unlike the materials he describes, I did not deliberately attempt to produce a flake. As noted in Section 6, the production of flakes was an unintentional outcome of the experimental process and developed because of the lack of applied force. Because I was separating materials based on technological divisions, once I had altered the specimen I did not feel that I should attempt to apply force to it a second time. I felt the pebble would fracture differently because it had already been altered. Therefore, once the pebble displayed any alteration it was classified as a replicated specimen. Again, because classes were based on technological divisions the flaked materials were not subjected to further analysis and therefore

Zingg indices were also not calculated for the Class 7 specimens. A total of 187 pebbles, or 35.9%, consisted of Class 7 specimens.

8.2 Class 8.

Class 8 specimens consist of pebble stones that fractured longitudinally down the X axis into numerous linear wedge-shaped sections that end in axial terminations. These materials are identified as citrus-sections based on their over-all morphology; the dorsal surface is curvate retaining the original pebble form and the interior ventral surface is linear and wedge shaped. As noted in Section 6 the Class 8 specimens developed from round pebbles because of the highly variable internal forces that exert pressure within this body shape. As illustrated in Figure 8.7, the Zingg indices for the Class 8 specimens cluster at the interface of all four forms. Therefore, these specimens were narrow, thick and long in relation to the overall body size. This class consists of 26 specimens or 5% of the total experimental data set.

An interesting aspect of the Class 8 specimens is that the physics of the spherical waves involved following impact on the pebble largely control how that material will shear. In other words, in trying to split a pebble stone longitudinally and transversely (if the material is more ellipsoid in shape rather than flat) this class of fracture will likely occur. The tendency of round pebble stones is to either produce citrus-section fragments or to shatter.

As additional interesting aspect of Class 8 materials is that

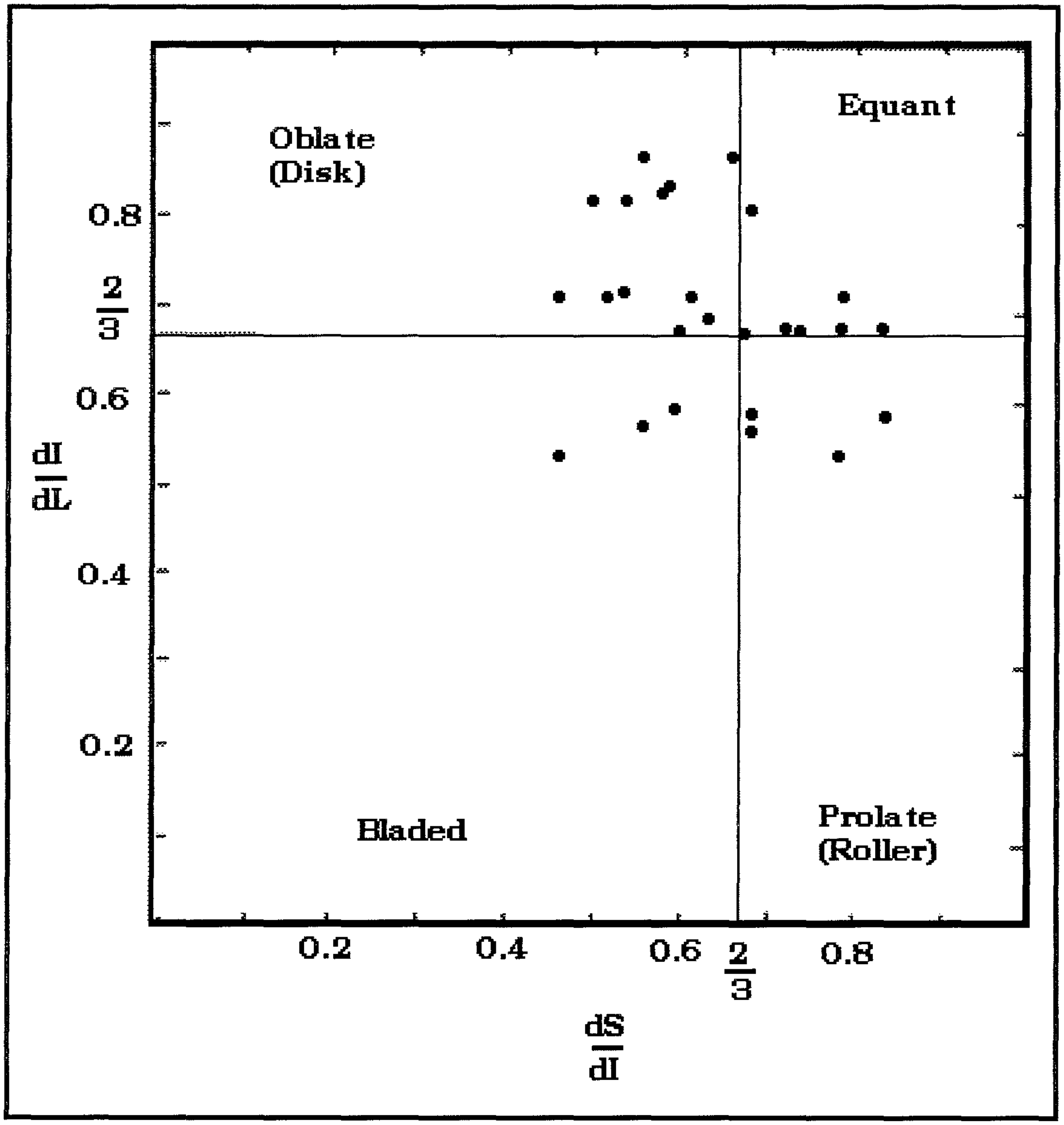

Figure 8.7. Classification of Class 8 pebble shapes (Zingg indices after Zingg 1935 in Blatt, *et al*, 1980: 80).

these specimens do not fit into any previous bipolar flake classification system. However, this form of material has been previously identified within an archaeological assemblage that contained other bipolar materials (Meyer 1978). In fact, the materials that Meyer (1978) noted within the Key Lake Archaeological Survey are identical to the Class 8 specimens identified here.

8.2 Class 9.

With Class 9 materials, one pebble half is a complete section while the contrasting half is snapped in two sections at about the mid-point of the specimen. Apparently, this type of fracture occurred because there was a fairly equal amount of force exerted within the specimen from both the proximal and distal ends of the pebble. The evidence for this occurrence is present on both the complete and broken pebble sections, which display divergent percussion lines on the ventral surfaces of the specimens. The Zingg indices for this class are loosely scattered along the interface of the oblate and bladed forms (Figure 8.8). A total of nine specimens displayed this unique form of fracture.

Although the complete sections do not fit into any previous bipolar flake or core classification systems the broken sections are exactly the same as the Group D materials identified by Kobayashi (1975). His Group D flakes are formed by a single percussion blow on the proximal end of a core that is in contact with an anvil. This detaches two flakes (one from each end of the specimen) in

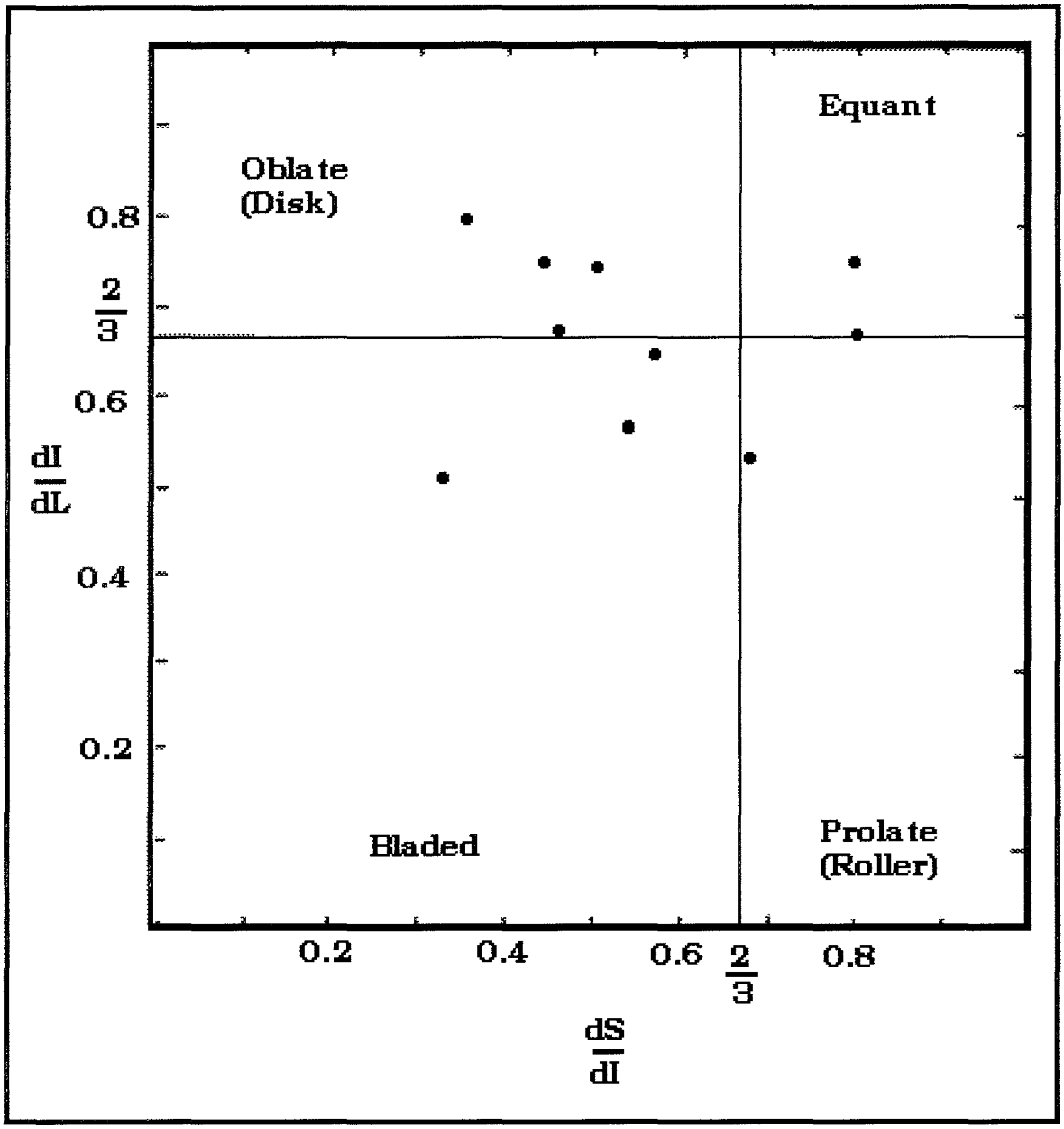

Figure 8.8. Classification of Class 9 pebble shapes (Zingg indices after Zingg 1935 in Blatt, *et al.* 1980: 80).

precisely the same fashion as the broken sections from the Class 9 materials were produced.

The complete sections are interesting in that they resemble other bipolar materials. For example, many of these specimens closely resemble those materials identified as pièces esquillées. It has generally been interpreted that pièces esquillées form largely through use, however, as I noted in Section 7 this may not be entirely the case. The primary form of pièces esquillées may often be created during the initial core reduction stage. Additionally, the complete sections of several specimens could be misidentified as bi-directional cores, which is obviously not the case. Furthermore, one specimen displays four ventral surface scars. Therefore, that specimen could be misidentified as having been subjected to multiple applications of force in an attempt to remove numerous flakes.

8.2 Class 10.

This is the final technological category developed from the experimental replications and consists of five specimens. These specimens are composed of pebble stones that are split longitudinally down the X axis and transversely across the Y axis. However, rather than ending in an axial termination one section terminates above the anvil contact point and ends in a feather termination. These Class 10 flakes are about two-thirds the length of the original pebble.

Class 10 specimens are separated from the Class 7 materials because, rather than just chipping the end of the pebble, long linear flakes were produced. The flakes produced would fit into Kobayashi's (1975) Group A materials and the complete sections resemble Herbort's (1988) single detachment spall cores. However, here again I did not intentionally produce these materials.

There are actually several possible explanations for this type of fracture. First, there may have not been enough applied force to permit the specimen to shear in an axial termination. Second, there may be flaws within the pebbles that redirected the applied force causing the flake to detach with a feather termination. More likely, the application of force was slightly displaced from the perpendicular causing the force wave to emanate away from the center line of the specimen. The Zingg indices for the Class 10 specimens is clustered toward the oblate pebble form (Figure 8.9).

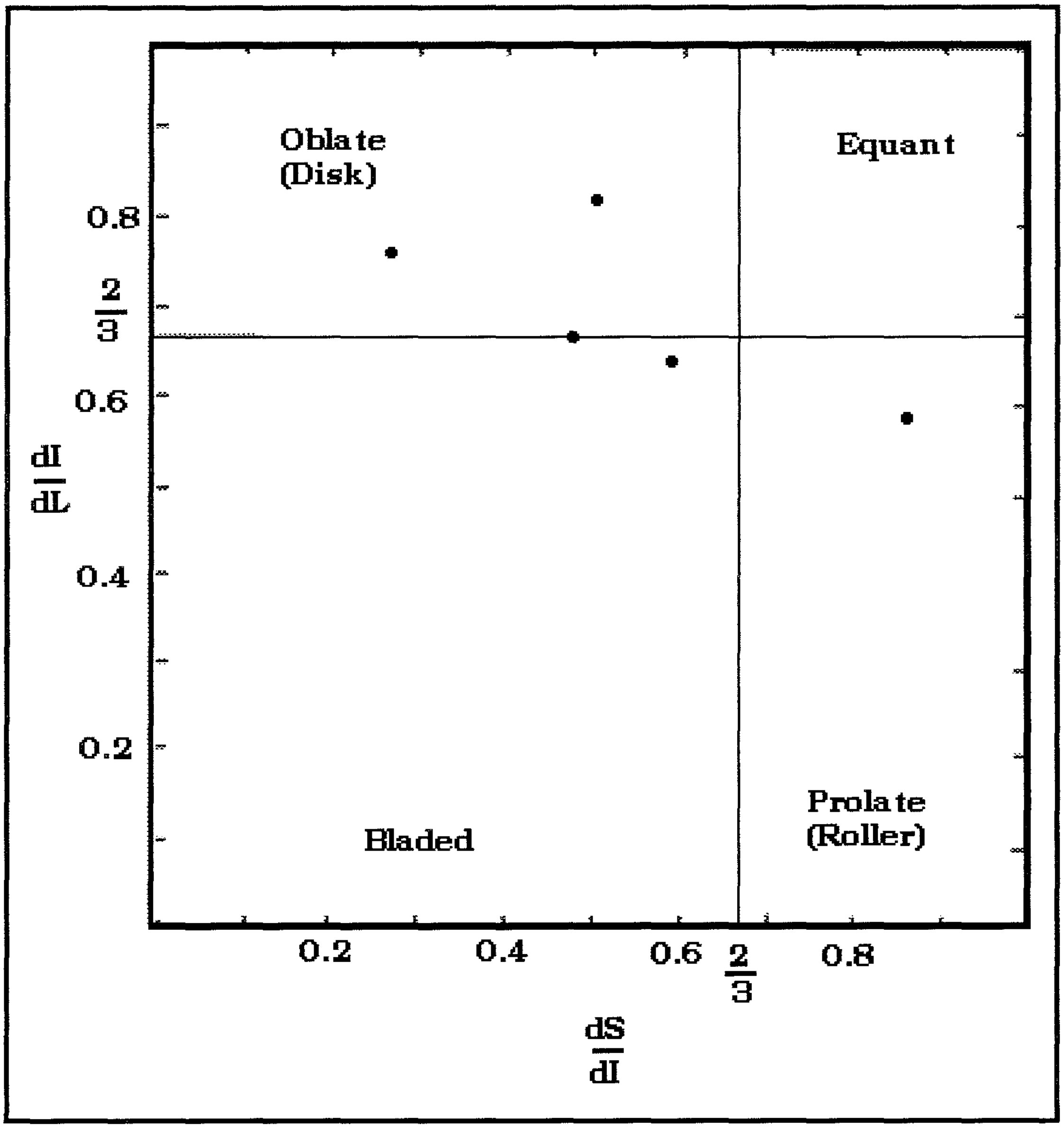

Figure 8.9. Classification of Class 10 pebble shapes (Zingg indices after Zingg 1935 in Blatt, *et al*, 1980: 80).

9. A REVIEW OF SELECT PEBBLE STONE COLLECTIONS ON THE NORTHERN PLAINS

Pebble stone artifacts from the Northern Plains have been frequently noted within the archaeological literature and are quite abundant throughout North America (for example, Ball 1987; Low 1994; McPherron 1967, Quigg 1977, 1978; Reeves 1972; Walker 1980, 1984, 1992). The following discussion is not to be considered an exhaustive review of all Northern Plains pebble stone collections. They are merely representative of their regional locations and, as such, they should properly be considered only in that manner. Their inclusion here is necessary in order to enable an objective comparison of archaeological materials with the experimentally replicated specimens analyzed.

9.1 Southern Manitoba

In a study of lithic collections within the Pembina Valley, in southern Manitoba (Figure 9.1), it was noted that many of the artifact assemblages were represented by bipolar cores that largely consisted of pebble stones (Low 1994). The southern Manitoba pebble stones had been modified by bipolar technology and are presented here as a comparison to the bipolar silicified

Figure 9.1. Map of North America showing archaeological site and pebble collection locales pertinent to this thesis.

siltstone materials that will be identified within the Gowen sites and the Marvel Houston collection later in this section.

9.1.1 The Sandhill, Killdeer and Deleurme Sites. Of the 997 cores identified from the Sandhill, Killdeer and Deleurme sites 16.5% consist of pebble stone materials. Pebble stone cores from these sites are all quite amorphous, although several do display multiple striking platforms (Low 1994: 36, 45, 48). Many of these striking platforms were created from the shaping of the pebble core into a tool. As a matter of fact, many of the pebble cores represented are small (2-4 cm) discoidal artifacts that have several edges worked forming a bifacial tool (Low 1994: 45).

The important thing is that these specimens do not display evidence that a great deal of fore-thought went into their manufacture. These items were chipped using bipolar reduction, to produce only one or more sharp edges, to be used as an expedient tool and then very likely discarded. Only in a few cases were the materials worked beyond the initial fracture. Figures 9.2, 9.3 and 9.4 illustrate the range of the recovered Pembina Valley bipolar pebble core tools. Most of the specimens, as those items displayed in Figures 9.2 and 9.3, have had one or two edges removed only; these are the most common types identified within this area. However, Figure 9.4 shows two specimens that do display more planning in their construction. Figure 9.4: A is of a specimen that has two edges that have been bifacially formed and Figure 9.4: B has three bifacial edges. The Sandhill site is the only one in this area at which the more intricately manufactured specimens manufactured from pebbles were recovered. Pebble

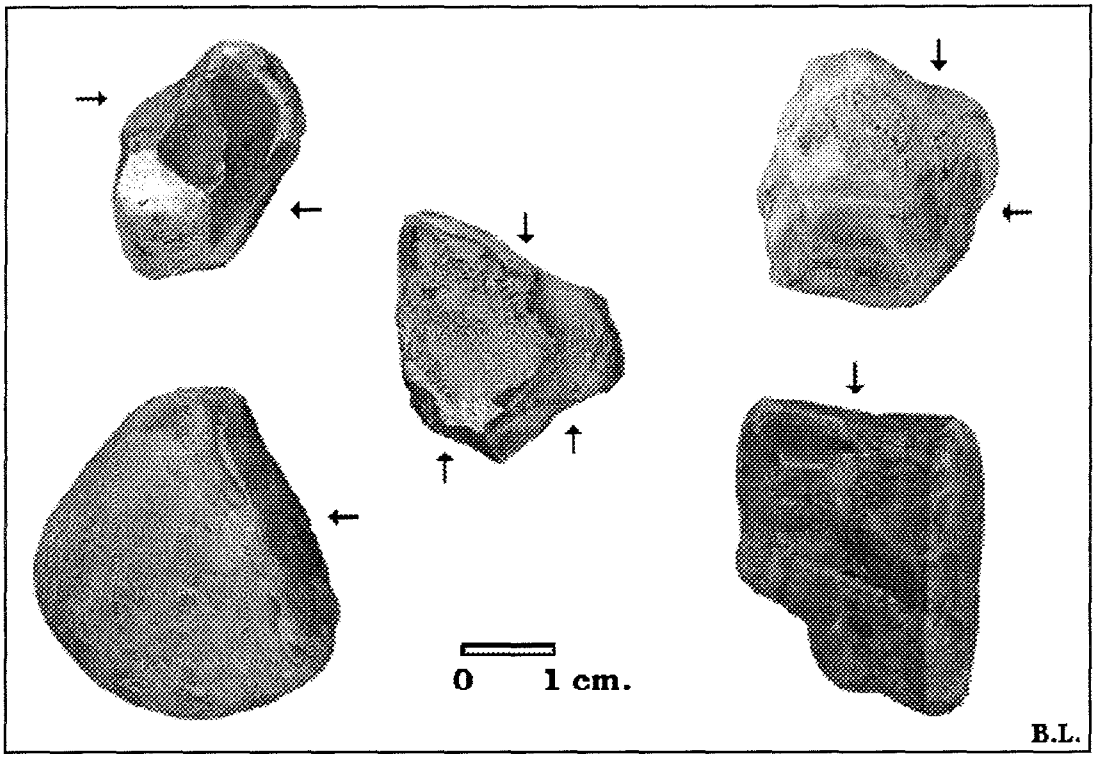

Figure 9.2. sample of Deleurme site (Manitoba) pebble stone artifacts (Low 1994).

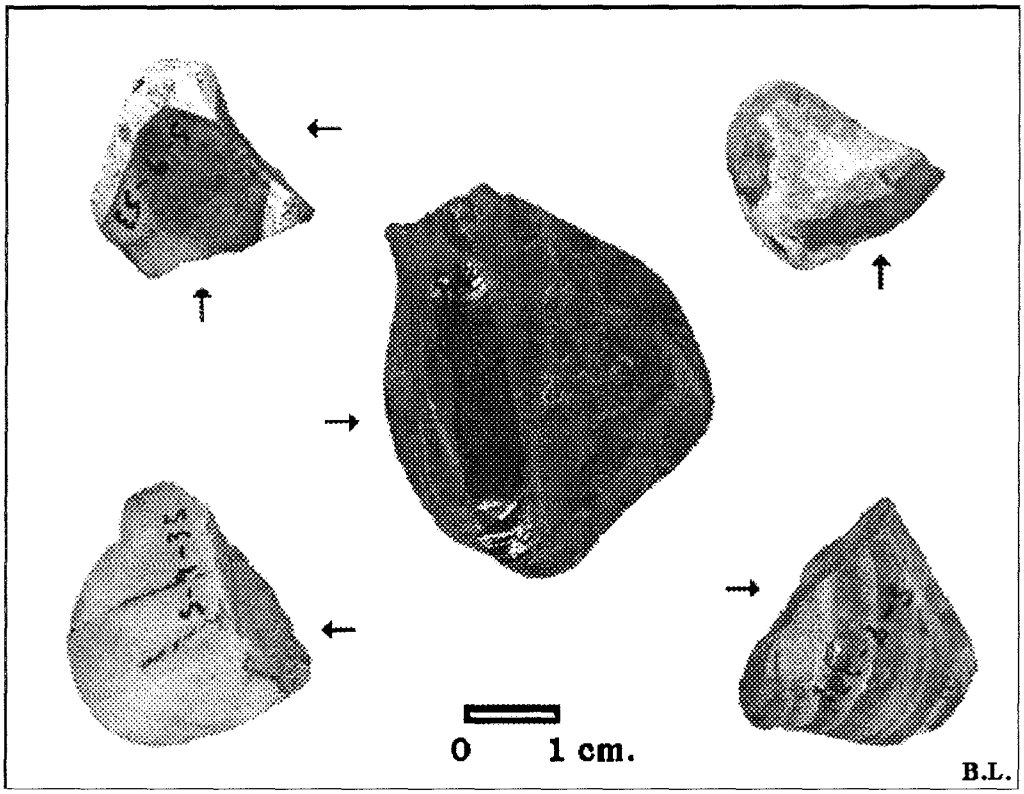

Figure 9.3. sample of Killdeer site (Manitoba) pebble stone artifacts (Low 1994).

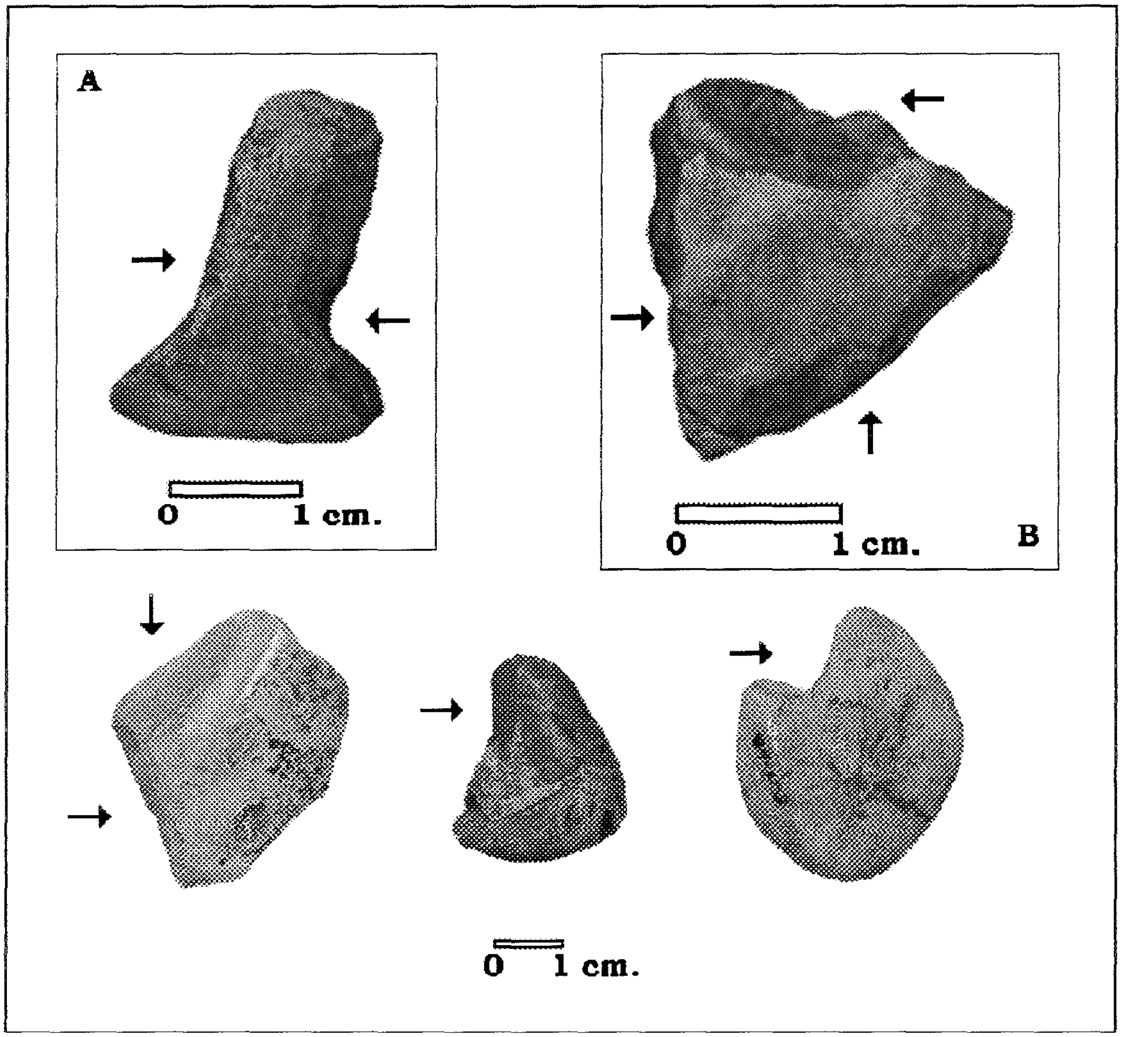

Figure 9.4. sample of Sandhill site (Manitoba) pebble stone artifacts (Low 1994).

stone materials identified from the other locations consisted of what appear to be randomly constructed items.

9.1.2 Merganser, Deleurme East, Valenta, Pelican I, Pelican II and Smith sites. Although the Sandhill, Killdeer and Deleurme sites are the largest of the collection locales identified in the Pembina Valley, these six sites illustrate that the use of pebble stone materials was not restricted to one locale, but rather, that they were used throughout southern Manitoba. These six sites contained only 105 cores (Low 1994) but of these, 30.5% consist of pebble stones. The pebble stone specimens from these sites are also expediently manufactured; they are both rough and haphazard in their appearance and largely mirror those from the Sandhill, Killdeer, and Deleurme sites.

9.1.3 Discussion. The Pembina Valley materials consist of a variety of chert and quartzite pebbles that are quite distinct from the silicified siltstone materials depicted throughout the majority of this thesis. Whereas silicified siltstone pebbles are generally split then worked, the Pembina Valley pebble stones were not split and usually had several edges bifacially worked so that they could be used as a tool, leaving the majority of the specimens intact. That the Pembina Valley specimens are also bipolar materials is evident from the presence of opposing bipolar crushing on the majority of the materials. It is also interesting to note that none of these materials relate to any of my classes as defined in Section 6.

Most of the pebble stone specimens indicate that this was an expedient technology, used to supplement other resources, not a main component of the materials used by the people that produced them.

Lithic recoveries from southern Manitoba are composed almost exclusively of local materials derived and collected within the glacio-fluvial deposits of this region (Low 1994: 1995d). The heavy use of the local cryptocrystalline materials within archaeological sites in this locale attest to the importance of this area for the pre-contact collection of lithics. For example, the frequency with which local material has been recovered within southern Manitoba, and the types of artifact recoveries at these sites, indicate that pre-contact lithic resources at these sites would have been quite extensive as evident from the total surface area of collection (Low 1994: 51). Interestingly, although Swan River chert occurs throughout southern Manitoba there was an unmistakable use of pebble stone materials as well (Low 1994, 1995d, 1996a).

Determining the age of the southern Manitoba pebble stone artifacts is difficult as the materials recovered within the Pembina Valley sites noted above consist of surface collected lithics and, therefore, there are no chronometric dates. There are, however, two bodies of suggestive evidence that can be used. One line of evidence is the recovery of several Paleoindian projectile point sections. Unfortunately, as noted above, these were surface collected and therefore cannot be tied to any firm context. However, they do indicate antiquity of use of these collection areas. The other trait that may provide some information is the degree of patination found on a small percentage of the recovered lithics (Low 1994: 72). Patina is the chemically induced surface alteration of siliceous stone over time and under certain environmental conditions (Honea 1964:14). The factors and conditions generally required for the formation of patina on cryptocrystalline material are: the permeability of the material, the type of impurities it contains, its microstructure, and the conditions of the surrounding soil (Kelly and Hurst 1956:194). While environmental factors might control the over-all thickness of patina that will form on a piece of lithic material, they do not account for the highly variable and mixed levels of patination on a single specimen. For example, some artifacts recovered from this locale display one face with heavy patina, the face next to this may have none, then there will be a face that is thinly patinated, then another face will be totally covered with patination (Low 1994: 74). What this indicates is an extended and continuous period of lithic exploitation and re-use within this locale (Low 1994: 75). Furthermore, the type of artifacts and the variation of patination indicates that the pebble stone materials from the southern Manitoba collection locales may have been used for several thousand years (Low 1994: 77).

9.2 Saskatchewan

9.2.1 Gowen sites.

Another group of pebble stone materials that I examined are from the Saskatchewan assemblages of the Gowen sites (Figure 9.1) that have been analyzed by Walker (1980, 1984. 1992). Walker (1992) noted that the Gowen I lithic assemblage consists of 226 stone tools (Walker 1992: 43) and 3767 debitage fragments (Walker 1992: 65). The Gowen II lithic assemblage contained 350 stone tools (Walker 1992: 71) and 12,935 pieces of lithic debitage (Walker 1992: 93-93). The differences in numbers of pieces recovered between Gowen I and Gowen II is thought to be primarily related to the larger area of excavation that took place at Gowen II (Walker 1992: 91).

It is significant that Walker (1992: 66) notes the Gowen site locale does not have abundant sources of good quality lithic resources suitable for stone tool production, although he states that the proximity of the South Saskatchewan River does provide access to quartzite cobbles and smaller chert pebbles within the exposed glacial till. In fact, the highest frequency of bipolar cores within the Gowen I and II site assemblages are derived from split silicified siltstone pebbles (Walker 1992). As previously noted, pebble stones, particularly silicified siltstone materials, are a very fine grained lithic material that adept flintknappers can use to manufacture some finely crafted implements. The range and quality of items made from theses materials should attest to this observation. The pebble stone materials of these assemblages will be discussed in the following section.

9.2.1.1 Gowen I. Walker (1992:64) noted that the most common type of core found at the Gowen 1 site in central Saskatchewan is the bipolar core that displayed percussion surfaces at both ends. This is not surprising as five anvils and five hammerstones were also recovered during excavations at this location. Additionally, the close proximity of silicified siltstone pebble materials that are ideally suited to the bipolar method of reduction exposed within the glacial tills of the South Saskatchewan river further support the use of the bipolar technique at this location. In addition, a large portion of the lithic materials at Gowen I is derived from silicified siltstone pebbles, that Walker (1980, 1984, 1992) identifies as black chert or pebble chert materials. Walker (1992: 65) described three end products of split pebble stone materials: cleanly split pebbles, specimens with irregular cleavage faces, and lithic debitage. He further notes that shatter may have been the most common result of producing these materials based on the amount of angulated black chert fragments recovered at the site (Walker 1992: 65).

Also, of the 24 recorded bipolar cores at the Gowen I site, 11 are derived from silicified siltstone pebbles. Consequently, silicified siltstone pebbles represent a total of 45.8% of the bipolar cores recovered. In addition, 90 stone tools are also made from silicified siltstone representing 39.8% of the total stone tool category. These items include: 2 Gowen projectile points, 13 endscrapers (1 spurred/graver tip), 10 gouges(scraping planes), 1 graver, 22 residual retouch materials, and 42 other fragments in various stages of modification.

Of note among the above tools identified within the Gowen I site is, first, the wide range of artifacts that were manufactured from silicified siltstone pebbles. These items include everything from projectile points to retouch flakes. This is an indication of the extensive and varied use that this material received at this site, thus resulting in the frequency with which it occurred.

Furthermore, it shows the importance of this material as a valued lithic resource to the inhabitants of this site. Moreover, a review of the Gowen materials provides evidence that, at one stage of lithic reduction, silicified siltstone pebbles were being split to be used as preforms in the manufacture of such items as projectile points. Walker (1992: 90) notes that, in fact, it appeared that successfully split pebble stones were used to fabricate projectile points. These items would have required a higher level of technical expertise in their manufacture as well as a larger time commitment than expedient tools would require. In this situation, by splitting the pebble into two fairly uniform sections, the knapper immediately has two preforms available from which to work. This in itself would decrease the time expended in the manufacture of projectile points, as the time required to make the initial preform is much reduced.

All of the projectile points identified at the Gowen I site, including the two silicified siltstone Gowen specimens, are from the Early Middle Prehistoric Period (7500 B.P. - 5000 B.P.), as identified by Walker (1992). Two of these are illustrated in Figure 9.5: A and B.

Many silicified siltstone pebble stone materials at the Gowen I site were also used to produce implements that required less technical expertise to manufacture, such as scrapers. In fact, 37% of the endscrapers are manufactured from split silicified siltstone pebbles (Walker 1992: 49), which was used more than any other lithic material to produce scrapers at this site.

A variety of the Gowen I scrapers are illustrated in

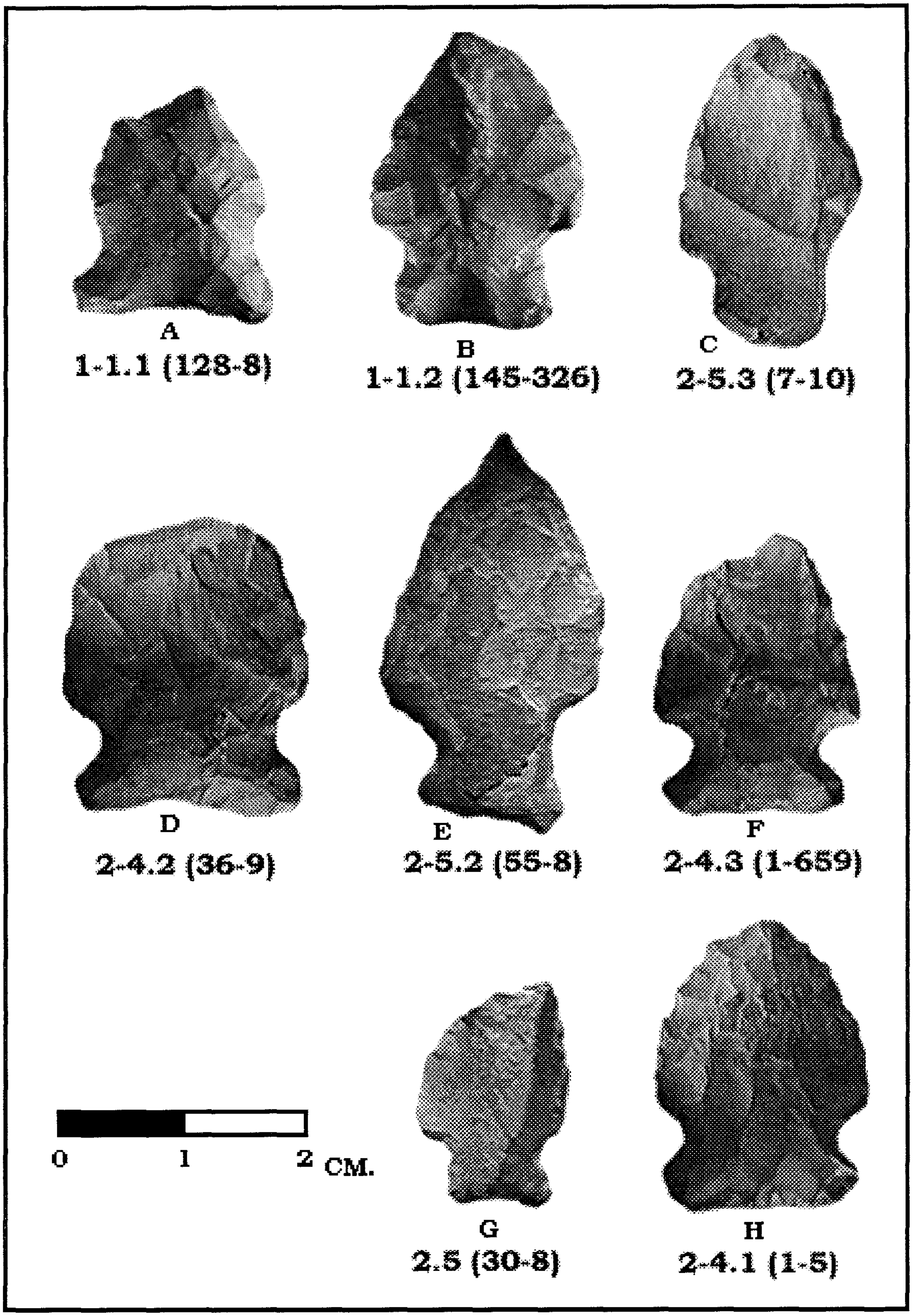

Figure 9.5. Sample of Early Middle Prehistoric period projectile points from the Gowen sites, Saskatchewan (Gowen I - A & B/ Gowen II - C - H).

Figures 9.6 and 9.7: A & B. One rather interesting specimen, among this class of tools, consists of a small distally spurred endscraper (Figure 9.7: A). Walker (1992: 50) identifies the spur on this specimen as a graver tip. This specimen is actually remarkably similar to spur-end scrapers diagnostic of the Paleoindian period. One major difference with this item, however, is that rather than the spur extending laterally from the leading, proximal edge (as they do with Paleoindian materials - Figure 7.2) the spur on this specimen extends down from the base of the scraper's distal end, as illustrated in Figure 9.7: A.

MacDonald (1968) noted, after an examination of Paleoindian spur-end scrapers, that the bipolar flakes were likely removed after the tool had been manufactured and not during the manufacturing process. However, this may not be the case with the Gowen I specimen. For example, the scraper illustrated in Figure 9.7: A, is composed of silicified siltstone, a relatively soft, somewhat fragile material, that displays no residual, or secondary impact scars. In other words, the item appears to have been purposefully manufactured from a bipolarly split pebble as a scraper with a distal spur.

A further class of note within the Gowen I assemblage is a number of scraping planes that Walker (1992) identifies as gouges. Of these materials, 10 specimens, or 43.5%, are comprised of silicified siltstone. One of these items is illustrated in Figure 9.7: C. Generally, these items are manufactured from harder materials such as quartzite, which lends itself well to this method of manufacture. The majority of scraping planes identified within

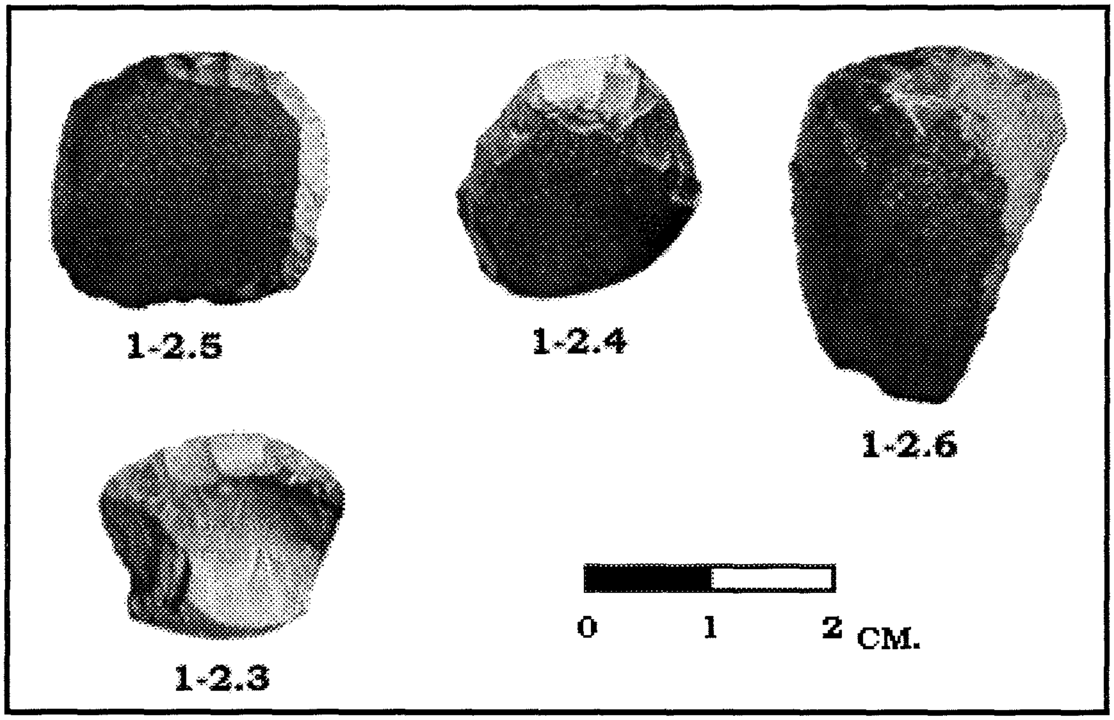

Figure 9.6. Sample of scrapers from the Gowen I site, Saskatchewan.

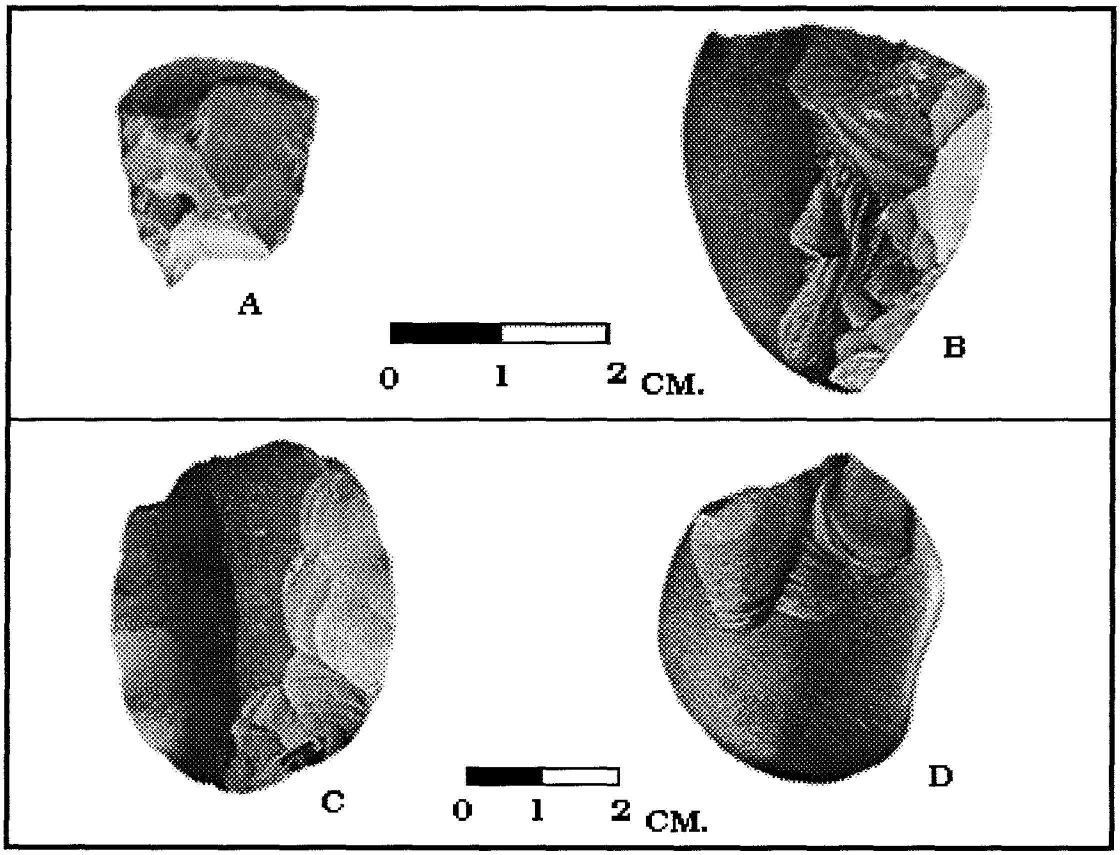

Figure 9.7. Miscellaneous artifacts from the Gowen I site, Saskatchewan.

the Gowen I site are also manufactured from quartzite. As previously defined, the first step in manufacturing a scraping plane is to split a specimen in the same manner as that previously described for a pebble stone. Once the specimen is sheared the dorsal end of one split section is placed on an anvil and the ventral surface struck along and around the outer edge of the specimen as previously noted in Section 7.2.10.

In addition to the more finely manufactured items, numerous pieces of silicified siltstone were used as expedient items as well. These materials consist of 61 residual retouched fragments. One of these specimens is illustrated in Figure 9.7: D, which displays the working or retouch on one end of a split silicified siltstone pebble.

9.2.1.2. Gowen II. Walker (1992: 89) notes that the lithic artifacts and their reduction sequence at the Gowen II site is almost identical with that of Gowen I and this is supported by the present analysis. Observed differences between the assemblages of these sites is relatively minor. Much of this difference is because Gowen II was subjected to more extensive excavations, which as a result, produced a bigger sample.

One surprising difference is that only one anvil and three hammerstones are recorded for the Gowen II site (Walker 1992: 71). The reason this is surprising is that Gowen II actually has a larger percentage of bipolar materials per its assemblage than does Gowen I from which five anvils and five hammerstones were recovered. At the Gowen I site, for example, 45.8% of the silicified siltstone pebble cores are bipolar, while at the Gowen II site 59.6%

of the cores manufacture from this material are identified as bipolar. The Gowen II materials manufactured from silicified siltstone include 26 complete bipolar cores and 39 bipolar core fragments (Walker 1992: 90). In addition to the above, while 39.8% of the tools within the Gowen I assemblage are manufactured from silicified siltstone pebbles, 45.5% of the Gowen II stone tool are composed of this material .

The Gowen II stone tools include items very similar in form to the Gowen I materials and include: 22 scraping planes (gouges), 9 Gowen projectile points, 12 miscellaneous projectile points, 35 endscrapers, 5 side scrapers, 1 perforator, 1 miscellaneous tool, and 74 residual retouched items (Walker 1992: 71). A variety of projectile points from this site are illustrated in Figure 9.5: C-H.

9.2.1.3. Discussion. Walker (1992: 65) notes that the variable outcome of pebble stone materials derived from the bipolar technique (as represented within the Gowen sites) may be related to differences in the processing of this material. That is, whereas the thinner specimens appear to be more susceptible to transverse breaks, the oblong-shaped pebbles would tend to shatter. I have previously noted in Section 5 that this phenomenon is not directly related to the type of applied lithic reduction, but rather, to the movement of spherical waves within bodies of differing form. Regarding the body shape of a pebble, as previously noted, a thin pebble does shear in a transverse break across the Y axis much more frequently than they tend to shatter. However, at the Gowen sites all of the anvils used, as illustrated in Figure 9.8, are small, relatively thin, light specimens averaging

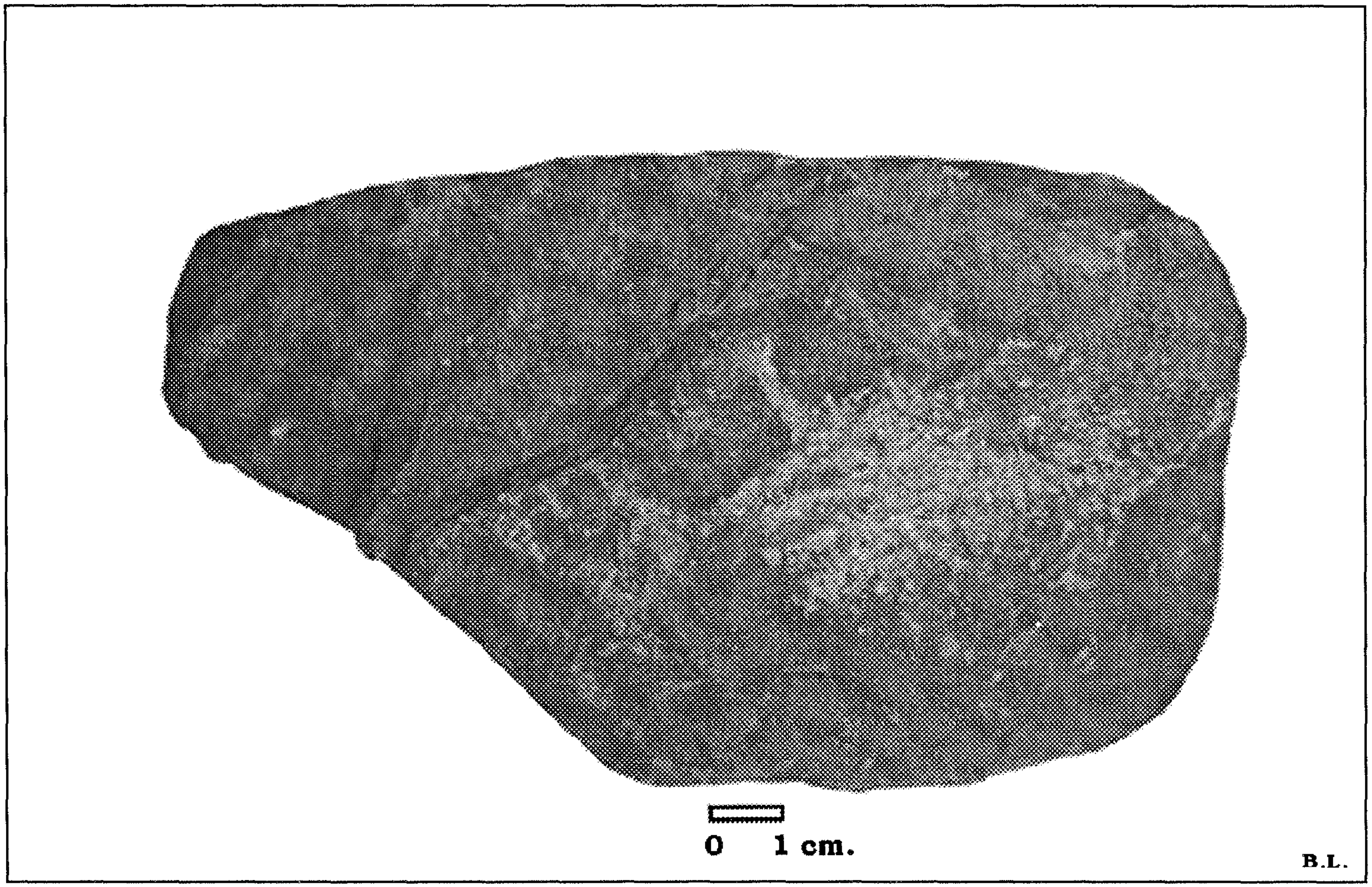

Figure 9.8. Typical Gowen sites anvil used for the bipolar splitting of pebble stones.

2 cm x 8 cm x 15 cm in size. As noted in Section 4.2 (Tool Selection) small anvils would require the application of much more applied force on the proximal end of the pebble, thus increasing the frequency with which pebbles would shatter. This partially accounts for the high percentage of silicified siltstone debitage recorded within these sites. Several researchers, (for example, Cross 1983: 97; Shelley 1990: 192) have noted in similar situations that it is also necessary to consider that there may have been individuals with different levels of technological expertise working with the lithic materials as well.

It is not known why larger, more efficient anvils were not used, especially considering that the Gowen sites were late summer/early fall occupations (Walker 1992). Because of the season of occupation, access to better quality anvils should not have been a problem. What may be the case is that the anvils used were all that were available within the local glacial gravels, although this is not likely and has not been confirmed. As well, smaller anvils are much more portable.

The high frequency of silicified siltstone materials recorded at the Gowen sites is noteworthy as the presence of large numbers of fractured pebble stones (and their associated fragments) provides further evidence of the extensive use of the bipolar technique on the Northern Plains. The uniqueness of the Gowen bipolar materials is largely related to the extensive use of silicified siltstone pebbles as the major lithic material. In part this is because of the close proximity of the South Saskatchewan River, which is one source of this material. In part, it also may actually relate to silicified siltstone pebbles being a preferred lithic material, rather than their being used only as a last resort. Frankly, it is quite difficult to imagine that a lithic material that was so extensively used, not only at the Gowen sites, but across the Northern Plains, was collected only during extreme circumstances when "better" material was not available. Furthermore, Odell (1989: 164-165) notes that where raw material availability is scarce tools would display evidence of being more fully used. However, the evidence from the Gowen sites does not support this as the majority of evidence indicates the production of new tools was the primary activity and not the reforming or retouching of completed tools (Walker 1992). The evidence does support, however, the role that pebble stones played in the lithic technology of the Gowen site occupants, especially considering that other lithics are available throughout the region.

As a final point, both Gowen I and II are recorded as Early Middle Prehistoric period occupations that were occupied about 6000 B.P. (Walker 1992). This supports the hypothesis (Problem 4) in Section 2 of this thesis, that a distinct bipolar pebble stone usage may have existed within this time period.

9.2.2. Marvel Houston Collection. Marvel Houston was an avocationalist who collected and recorded a variety of archaeological materials around the town of Ruthlinda (Figure 9.1), in west-central Saskatchewan, over a period of many years. This collection was brought to my attention in 1995 by Muriel Carlson who was sorting and cataloging these materials on behalf of the

Estate of Marvel Houston. Muriel had discovered that I was researching pebble stone materials and bipolar technology and, as it turns out, a large portion of the Marvel Houston collection consists of specimens manufactured from silicified siltstone pebble stones. The Marvel Houston collection has since been donated to the Herschel Museum, Herschel, Saskatchewan.

I examined 82 specimens of silicified siltstone from the Marvel Houston collection (Table 9.1), of which the majority consisted of projectile points; although a variety of tools were identified, as well as several miscellaneous pieces of split or fractured pebble stone materials. These included: four Oxbow projectile points, four McKean projectile points, three Pelican Lake projectile points, 15 Besant projectile points, six indeterminent projectile points, four bifaces, six endscrapers, two sidescrapers, two perforators, 17 split pebble cores, and 19 retouched flakes (Table 9.1). As with the Gowen site materials, these specimens also show the wide range of implements that were made from silicified siltstone pebbles.

Figure 9.9 displays several miscellaneous items, including two perforators (#65 and #77 - Table 9.1.), two end scrapers (#6 and #69 - Table 9.1.), one sidescraper (#66 - Table 9.1.), two split pebble cores (#61 and #67 - Table 9.1.) and one retouched tool (#21 - Table 9.1.). (The specimen numbers here are my own and do not relate to the original catalogue; they are provided for table reference only).

Two specimens of note in Figure 9.9 are numbers 61 and 69, which display distinct bipolar attributes on their ventral surfaces.

Table 9.1. Marvel Houston collection of silicified siltstone split pebble materials.

Cat #	Specimen Description					
..1	Biface	2-6 mm Ovate Body	Working edge/Convex	Ret/Thin	2 Workeded edges	Ind Break
..2	Biface	2-6 mm Ovate Body	Working edge/Convex	Ret/Thin	2 Workeded edges	Ind Break
..3	Projectile point	Besant Convex Base	Ovate Body Side Notch	2-6 mm Ret/Thin	Complete	Bifacial
..4	Projectile point	Besant Straight Base	Ovate Body Side Notch	2-6 mm Ret/Thin	Complete	Bifacial
..5	Projectile point	McKean Concave Base	Ret/Thin Basal Notch	2-6 mm	Complete	Bifacial
..6	Endscraper	Distal End	Unifacial	2-6 mm	3 edges Worked	
..7	Retouched Tool	2-6 mm	Cortex present			
..8	Projectile point	Besant Convex Base	Ind Break Side Notch	0 - 2 mm Ret/Thin	Base/Mid-section	Bifacial
..9	Projectile point	Pelican Lake Corner Notch	Ind Break Ret/Thin	0 - 2 mm	Base/Mid-section	Bifacial
10	Sidescraper	Convex Base Ovate Body	Retouched 2-6 mm	Unifacial	1 worked lateral edge	
11	Projectile point	Besant Straight Base	Ovate Body Side Notch	2-6 mm Ret/Thin	Complete	Bifacial
12	Projectile point	Besant Convex Base	Ret/Thin Side Notch	2-6 mm	Bifacial	Ovate Body
13	Endscraper	Retouched Unifacial	Distal right lateral edge worked 2-6 mm		Working end convex	
14	Projectile point	Mid-section	Ovate Body	2-6 mm	Bifacial retouch	Ind Style

Table 9.1. Marvel Houston collection of silicified siltstone split pebble materials.

15	Biface	Triangular Ret/Thin	Straight working edges	0 - 2 mm	2 edges worked	Ind Break
16	Split Pebble Core	2-6 mm	Cortex present			
17	Retouched Tool	Unifacial	2-6 mm	2 edges worked		
18	Split Pebble Core	2-6 mm	No Cortex			
19	Projectile point	Ind Style Triangular	Mid-section/Tip Ind Break	2-6 mm	Ret/Thin	Bifacial
20	Endscraper	Triangular Convex Base	3 edges worked Retouched	2-6 mm	Unifacial	Distal End
21	Retouched Tool	Unifacial	1 edge worked			
22	Retouched Tool	1 edge worked	Distal Fragment	2-6 mm	Unifacial	Ovate Body
23	Projectile point	Ind Style	Mid-section	2-6 mm	Ret/Thin	Bifacial
24	Split Pebble Core	2-6 mm	Cortex present			
25	Retouched Tool	Ovate Body	1 edge worked	2-6 mm	Retouched	Distal Frag
26	Split Pebble Core	2-6 mm	Cortex present			
27	Split Pebble Core	2-6 mm	Cortex present			
28	Projectile point	Oxbow Concave Base	Ovate Body Side Notch	2-6 mm Ret/Thin	Bifacial Base/Mid-section	Ind Break
29	Split Pebble Core	2-6 mm	Cortex present			
30	Split Pebble Core	2-6 mm	Cortex present			
31	Retouched Tool	0 - 2 mm	Cortex present			
32	Projectile point	Ind Style Ind Base	Base/Mid-section Ind Notch	2-6 mm Ret/Thin	Bifacial Ind Break	Triangular
33	Projectile point	Besant Straight Base	Ovate Body Side Notch	2-6 mm Ind Break	Ret/Thin Base/Mid-section	Bifacial

Table 9.1. Marvel Houston collection of silicified siltstone split pebble materials.

34	Projectile point	Ind Style Ovate Body	Mid-section/Tip Ind Break	2-6 mm	Ret/Thin	Bifacial
35	Biface	Ind Break	Ovate Body	2-6 mm	Ret/Thin	
36	Retouched Tool	2-6 mm	Unifacial	Ovate Body		
37	Split Pebble Core	2-6 mm	Cortex present			
38	Retouched tool	Ovate Body	2-6 mm	Unifacial	3 edges worked	
39	Retouched Tool	Ovate Body	2-6 mm	Unifacial	1 edge worked	
40	Retouched Tool	2-6 mm	1 edge worked			
41	Retouched Tool	2-6 mm Straight Base	1 edge worked	Unifacial	Lateral Fragment	Ovate Body
42	Split Pebble Core	2-6 mm	Cortex present			
43	Split Pebble Core	2-6 mm	Cortex present			
44	Retouched Tool	2-6 mm	Cortex present			
45	Endscraper	2-6 mm	Unifacial	Ovate Body	Complete	
46	Projectile point	Ind Style Mid-section	Ind Break Ret/Thin	2-6 mm	Bifacial	Triangular
47	Retouched Tool	Working edge Concve/Convex Ovate Body		2-6 mm	1 edge worked	Unifacial
48	Retouched Tool	2-6 mm	Unifacial	Ovate Body		
49	Retouched Tool	2-6 mm	2 edges worked	Bifacial		
50	Retouched Tool	2-6 mm	Unifacial			
51	Split Pebble Core	2-6 mm	Cortex present	2 pieces		
52	Retouched Tool	2-6 mm	Cortex present			

Table 9.1. Marvel Houston collection of silicified siltstone split pebble materials.

53	Projectile point	Besant Straight Base	Ovate Body Side Notch	2-6 mm Ret/Thin	Bifacial Base/Mid-section	Ind Break
54	Retouched Tool	Ovate Body Ind Break	Working edge/Convex	2-6 mm	1 edge worked	Unifacial
55	Split Pebble Core	2-6 mm	Cortex present			
56	Split Pebble Core	2-6 mm	Cortex present			
57	Endscraper	Ovate Body	2-6 mm	Distal End	1 edge worked	Unifacial
58	Retouched Tool	2-6 mm	Unifacial			
59	Projectile point	Besant Straight Base	Base/Mid-section Ret/Thin	2-6 mm Side Notch	Bifacial	Ovate Body
60	Split Pebble Core	2-6 mm	Cortex present			
61	Split Pebble Core	2-6 mm Partly sheared proximal bulb of percussion with slight inversion at point of impact Pronounced ripple lines	Cortex present	Inverted diffuse bulb of percussion		
62	Projectile point	Pelican Lake Straight Base	Base/Mid-section Corner Notch	0 - 2 mm Ind Break	Bifacial retouch	Triangular
63	Projectile point	Oxbow Concave Base	Triangular Side Notch	2-6 mm Ret/Thin	Bifacial	Complete
64	Projectile point	Oxbow Concave Base	Ovate Body Side Notch	2-6 mm Ret/Thin	Bifacial	Complete
65	Perforator	Drill Ret/Thin	Straight working edge	2-6 mm	Bifacial	Complete
66	Sidescraper	Retouched Ovate Body	1 edge worked	2-6 mm	Unifacial	Convex Base
67	Split Pebble Core	2-6 mm	Pronounced ripple lines	Cortex presen	Proximal bulb of percussion	
68	Split Pebble Core	2-6 mm	Diffuse ripple lines	Cortex presen	Diffuse proximal bulb of percussion	

Table 9.1. Marvel Houston collection of silicified siltstone split pebble materials.

69	Endscraper	Triangular Inverted proximal bulb of percussion	Distal End	2-6 mm	2 edges worked	Unifacial
70	Projectile point	Oxbow Concave Base	Ret/Thin Side Notch	2-6 mm Ovate Body	Bifacial	Complete
71	Projectile point	Besant Straight Base	Ovate Body Side Notch	2-6 mm Ret/Thin	Bifacial	Complete
72	Projectile point	Besant Straight Base	Ret/Thin Side Notch	2-6 mm Triangular	Bifacial	Complete
73	Projectile point	Pelican Lake Concave Base	Triangular Corner Notch	2-6 mm Ret/Thin	Bifacial	Complete
74	Projectile point	Besant Straight Base	Ret/Thin Side Notch	2-6 mm Triangular	Bifacial	Complete
75	Projectile point	McKean Concave Base	Ovate Body Basal Notch	2-6 mm Ret/Thin	Bifacial	Complete
76	Projectile point	McKean Concave Base	Ret/Thin Ovate Body	2-6 mm	Bifacial	Complete
77	Perforator	Drill	Straight working edge	2-6 mm	Bifacial	Complete
78	Projectile point	Besant Concave Base	Ret/Thin Side Notch	2-6 mm Ovate Body	Bifacial	Complete
79	Projectile point	Besant Convex Base	Ret/Thin Side Notch	2-6 mm Ovate Body	Bifacial	Complete
80	Projectile point	Besant Straight Base	Ret/Thin Side Notch	2-6 mm Ovate Body	Bifacial	Complete
81	Projectile point	Besant Side Notch	Ret/Thin Concave/Convex Base	2-6 mm Ovate Body	Bifacial	Complete
82	Projectile point	McKean	2-6 mm	Bifacial	Complete	

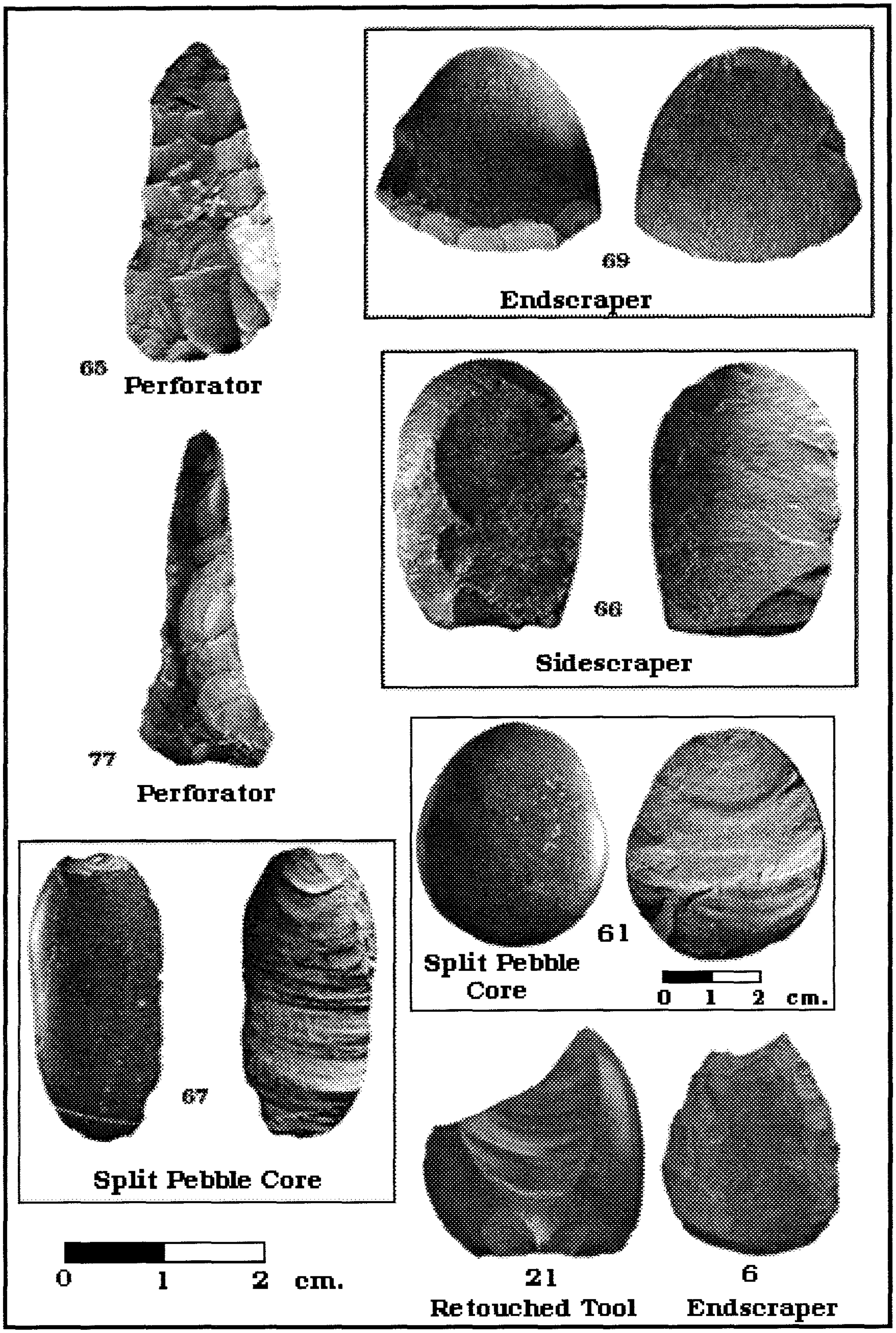

Figure 9.9. Miscellaneous silicified siltstone materials from the Marvel Houston collection.

Specimen 61 is a split pebble that displays pronounced percussion lines and a sheared proximal bulb of percussion with a slight inversion at the point of impact on its ventral surface. Specimen 69 is an endscraper that has a slightly negative inverted proximal bulb of percussion on the ventral surface of the tool.

Even more interesting than the miscellaneous materials with this collection are the wide range of projectile points. The Marvel Houston collection contains projectile points ranging from the Middle/Late Middle Prehistoric period, with the Oxbow (4700-3000 B.P.), McKean (4150-3100 B.P.) and Pelican Lake (3800-1850 B.P.) materials, to the initial Late Prehistoric period, represented by Besant (2000-1200 B.P.). (Figure 9.10 illustrates three Oxbow, two McKean and two Pelican lake projectile points, and Figure 9.11 illustrates a sample of the Besant points, from the Marvel Houston collection).

9.2.2.1 **Discussion.** In part, I included the Marvel Houston materials here because they provide further evidence of the extent of bipolar technology as applied to pebble stone materials. Additionally, like many of the Gowen site materials, these specimens are manufactured from silicified siltstone pebble stones. Finally, these artifacts were collected in west-central Saskatchewan and, thus, they provide further evidence for a geographic and temporal movement of bipolar technology across the Northern Plains. This point will be expanded on more fully in Section 10.

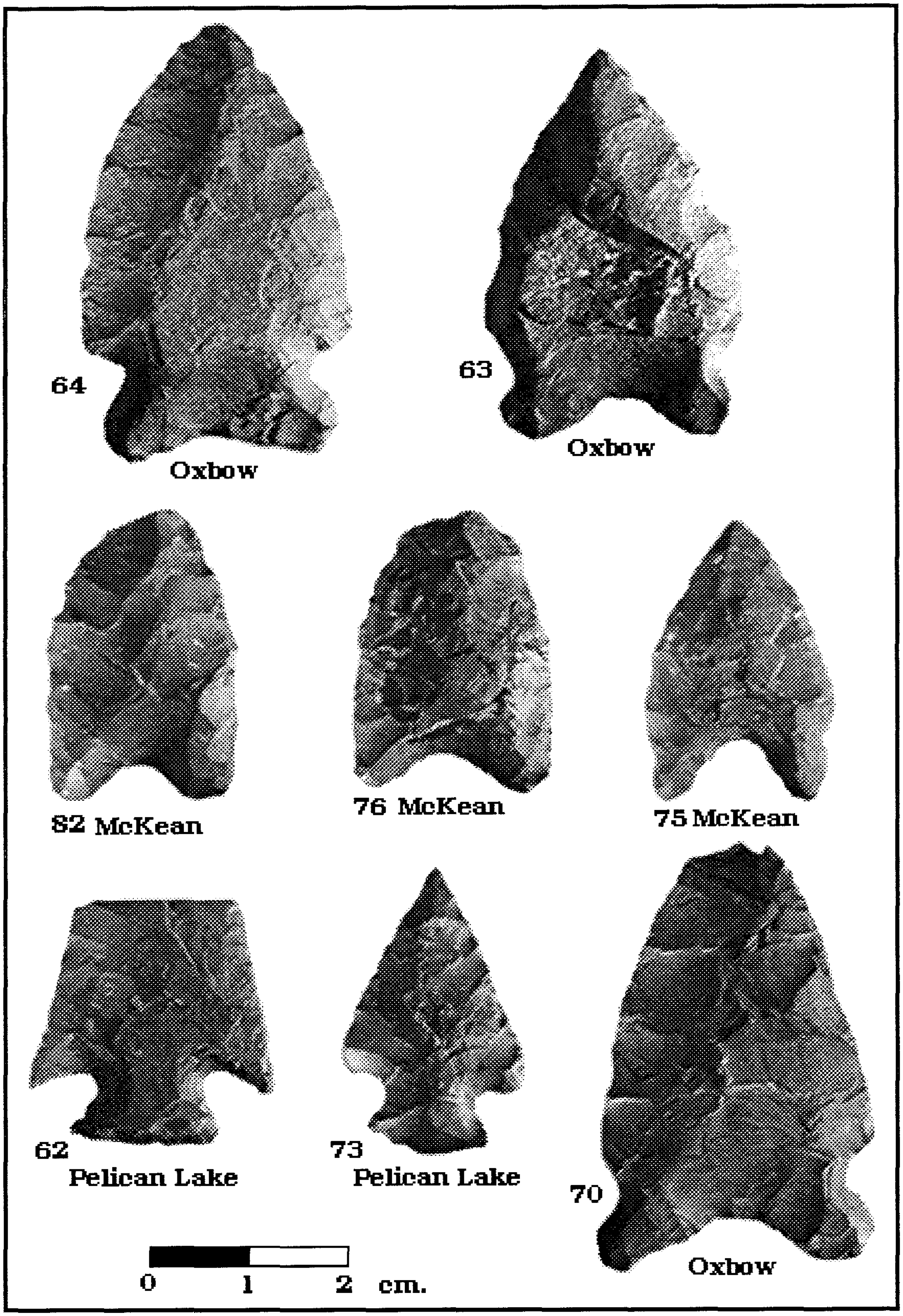

Figure 9.10. Sample of Middle/Late Middle Prehistoric period projectile points from the Marvel Houston collection.

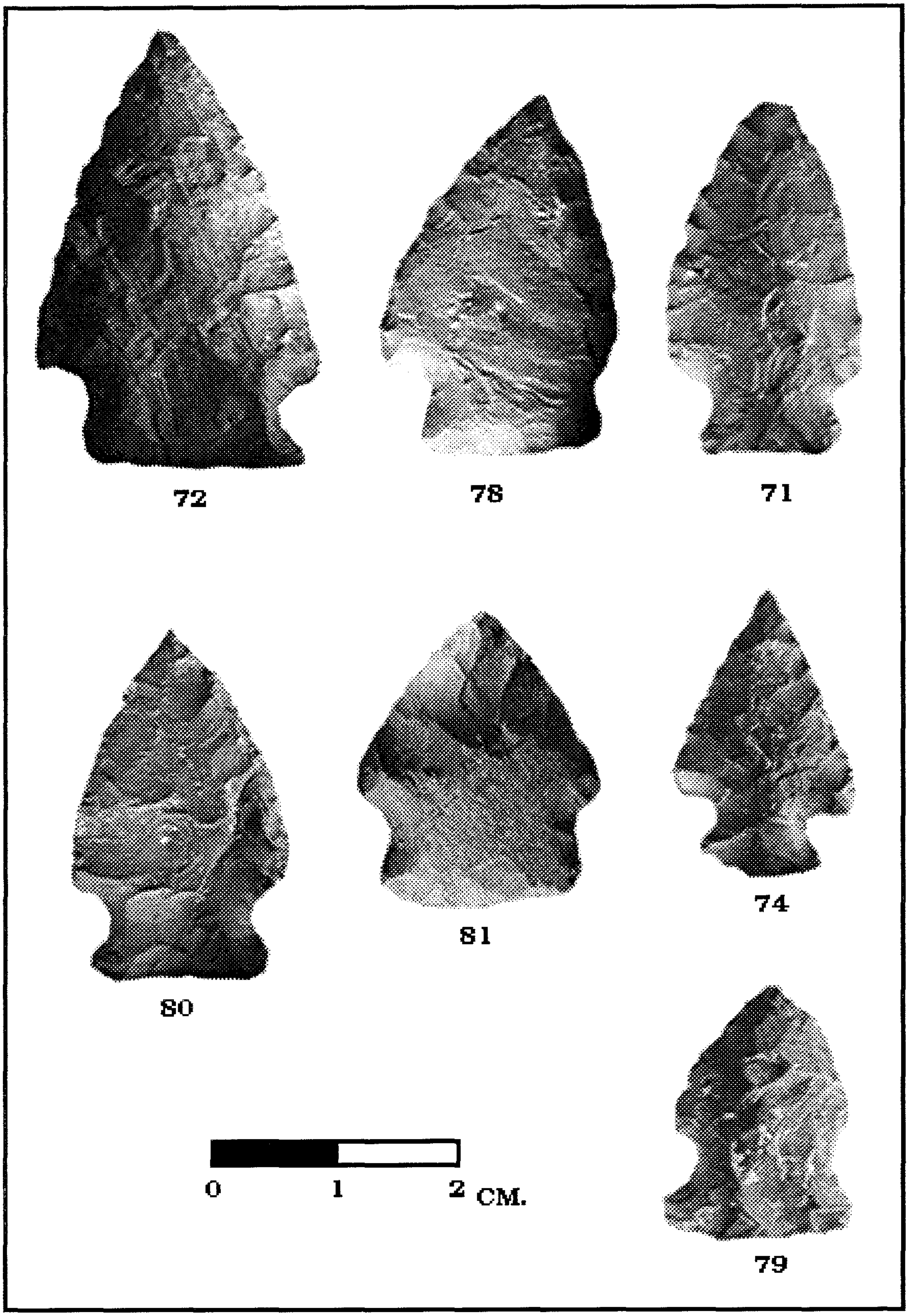

Figure 9.11. Sample of Middle/Late Middle Prehistoric period Besant projectile points from the Marvel Houston collection.

9.3 Summary

An important aspect of the above collections is that the materials demonstrate a definite time progression of the bipolar technique regarding the use of pebble stones, from east to west. The materials illustrated indicate that a movement of this technology possibly took place from the Early Middle Prehistoric period in east-central Saskatchewan, to the Middle/Late Middle Prehistoric period and into the initial Late Prehistoric period in western Saskatchewan. Also, the types of pebble stones used appears to have changed as did the application of the bipolar technique in relation to those materials. The pebble stone artifacts recovered in Manitoba are a variety of coarse cherts and quartzites that were primarily used to produce expedient tools. The Saskatchewan materials are primarily silicified siltstone pebbles that were used to produce a wide range of implements. Unlike the majority of the Manitoba materials many of the specimens in Saskatchewan including those composed of various cherts or quartzites were subjected to some degree of planning and fore-thought in their construction.

It must be noted here, that I have personally observed that silicified siltstone pebbles occur rarely and sporadically within Manitoba glacial deposits, whereas, they occur with some frequency within Saskatchewan. I should note this interpretation is based on observance and not through a quantification of the actual frequencies. This point, however, does accounts for the differences in frequencies of this material between Manitoba and

Saskatchewan archaeological assemblages. What it does not account for is the differences in the way pebble stone artifacts are manufactured between these two regions.

It is quite clear that pebble stone was becoming a major part of the technology of at least select Northern Plains groups by the Middle Prehistoric period. However, verification of this interpretation would require much more extensive study in this area, in particular, the examination of other assemblages that contain bipolar and pebble stone materials, although this would be a immense undertaking. In part, this is related to these materials not being identified within many of the past archaeological reports. For example, in a 1970 report Dyck (1970) identified two Oxbow settlements, the Moon Lake and Harder sites, from central Saskatchewan. Although he does not discuss bipolar technology or the occurrence of pebble stone materials within this report it is quite obvious from an examination of those assemblages that these materials do occur. This is significant, because the time of settlement and the geographical location of these occupations corresponds with those materials previously identified from the Gowen sites. The next section on source and collection locales continues to expand on pebble stone materials in the archaeological record.

10. PEBBLE STONE SOURCE AND COLLECTION LOCALES

10.1 Source areas of pebble stones collected for experimental replications

Several areas were selected for the collection of pebble materials used within the experimental portion of this thesis so that a cross representation of specimens from a variety of locales would be included in the data set. The source areas I sought were those locales previously recorded, or known, to contain silicified siltstone pebbles. Although other pebble materials were also collected, as I have previously noted, silicified siltstone pebbles were the main materials used and analyzed throughout the course of this research project. The following briefly describes the areas from which I collected these materials.

10.1.1. Pebble collection locale 1: North Saskatchewan River, Saskatchewan. Several areas within west-central Saskatchewan are known to contain varying frequencies of silicified siltstone pebble stones. For example Eldon Johnson (1986:83-84) has noted that this lithic material is present sparsely in west-central Saskatchewan and occurs in Cretaceous gravels.

One area were silicified siltstones occur is within the glacial drift along the South Saskatchewan river channel. Pebble stones occur sporadically and in varying degrees of frequency throughout the length of this channel. It is probable that silicified siltstone pebbles did occur with some frequency near the Gowen site locations because of the large numbers of this material with those assemblages. Although lithic source areas do not need to be in near proximity to site locations, the dominance of local materials in the Gowen sites indicates this may have been the case here.

Another area where silicified siltstone pebble stone materials occur within Saskatchewan and the area of most concern here is within the glacial gravels of the North Saskatchewan river channel. At least one locale along this channel appears to contain silicified siltstone pebble with some degree of frequency. This area is located north of North Battleford (Figure 9.1) and it is from here that the majority of specimens used in the experimental data collection portion of this thesis were gathered. The ground surface throughout this area is currently littered with pebble stone materials including silicified siltstones that have either eroded from the river bank or recently been exposed through activities within a local gravel pit. I also collected a variety of pebbles that consisted of generic cherts, quartzite, quartz and generic material.

There are no identifying landmarks or significant geographic features that make this pebble collection area along the North Saskatchewan river stand out from the surrounding landscape (as depicted in Figure 10.1., which is an illustration of this locale). In fact much of the North Saskatchewan river flows through large expanses of fairly uniform prairie grassland. Parts of the

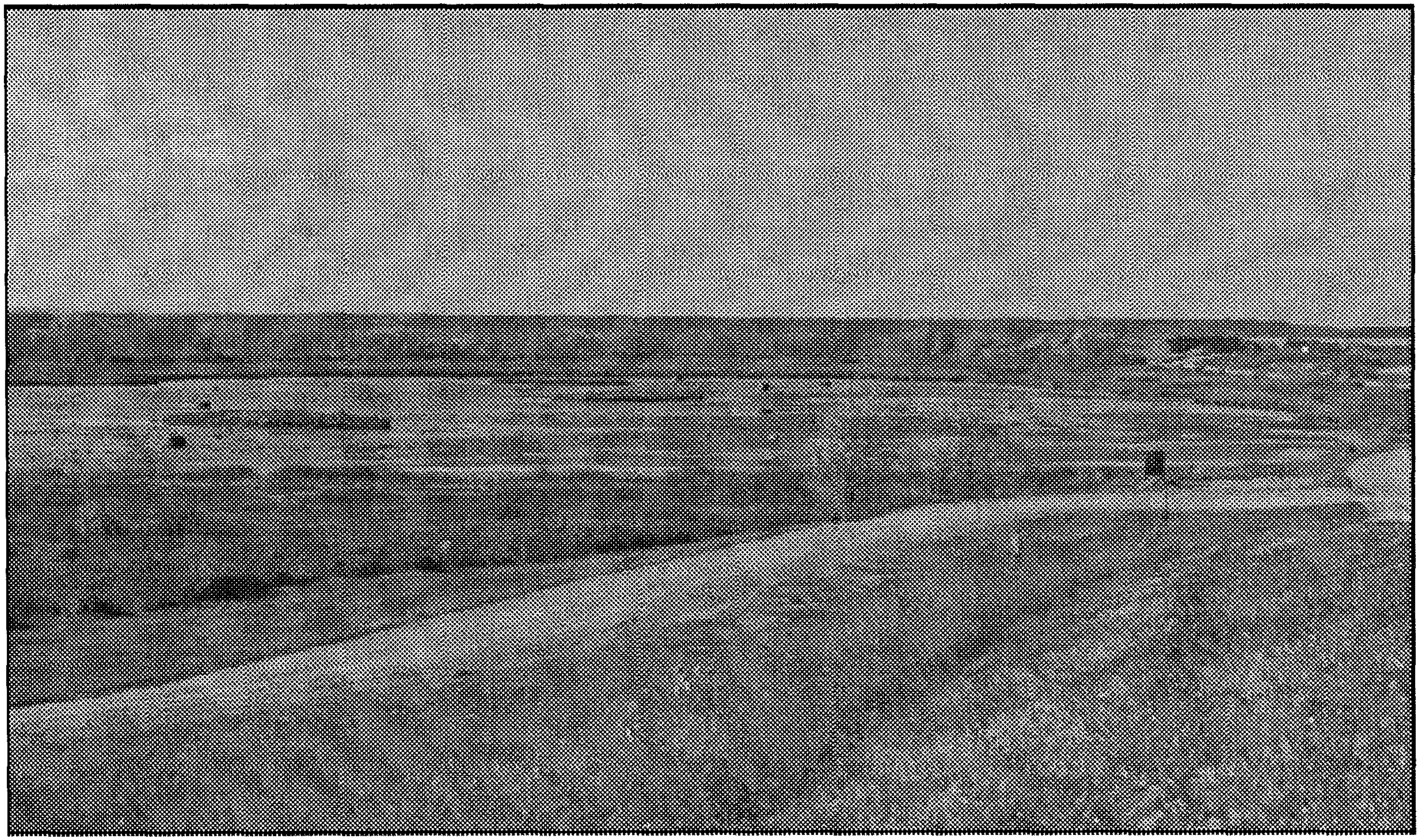

Figure 10.1. North Saskatchewan river, Saskatchewan, in background.

surrounding area does, however, consist of moraines giving the topography a hummocky appearance with lakes and sloughs common in low laying areas. Much of this region is also transected by numerous creeks. This type of topography is typical of the majority of locations where silicified siltstone pebbles occur and from where they were known to have been collected. The geomorphology of the region, as well as the abundance of glacial deposits, are the end result of Wisconsin glacial processes.

It appears that the Saskatchewan source areas for silicified siltstone pebbles were very well known to the various pre-contact groups that used them in order for this material to occur with the frequency that it does within many of the regional archaeological sites. If this is the case, then the collection of this material provides more evidence for pebble stone materials being used by some groups on a frequent basis, with frequent trips made to these collection locales, and not just because other material was not available. It also further attests to the use of the bipolar technique especially in relation to pebble stones as being a widespread and significant aspect of pre-contact lithic technology.

10.1.2. Pebble collection locale 2: Grassy Island Lake, Neutral Hills, Alberta. Quigg (1977: 58) noted that the primary lithic materials recovered during an archaeological survey of the Neutral Hills, Alberta, and the subsequent excavations of the Lazy Dog Tipi Ring site (FbOr-57) and the Buffalo Jump and Campsite (FbOv-1) in that locale, were pebble cherts. He did not separate these by type however, but rather by color. It is noteworthy, that from the illustrations he provides, and from having personally examined several areas around Grassy Island Lake, it is likely the black and grey varieties of pebble cherts he describes are silicified siltstones. If the black and grey pebble chert specimens recorded by Quigg (1977: 59) are silicified siltstone specimens then this is significant, because of the 2542 pieces of material identified 53.1% would then consist of this material. Moreover, Quigg (1977: 59) identifies another 14.6% of the materials collected as a variety of other pebble cherts and 5.7% as quartzite pebbles. In total, pebble stones comprise 73.4% of the materials that Quigg (1977: 59) recorded for the total Neutral Hills recoveries. He did note that pebble stone artifacts recovered during excavations at the Lazy Dog Tipi Ring site (FbOr-57) comprised 90% of the cultural materials (Quigg 1977: 66).

Johnson (1986: 84) observed that silicified siltstone pebbles occur with "some abundance" along the shores of Grassy Island Lake. During field reconnaissance of the Grassy Island Lake area (Figure 9.1) the materials that I noted almost exclusively consisted of silicified siltstone, although I did not find these materials in abundance (see Johnson 1986: 84). However, there is no doubt that silicified siltstone pebbles do occur in abundance throughout the glacial deposits within the Neutral Hills locale based on the recoveries of this material by Quigg (1977: 59). I did manage to collect a number of silicified siltstone pebbles from around the lake, as well as, a variety of other materials including some generic material, quartzite, quartz and generic cherts.

It is possible that the reason I did not notice silicified siltstone pebbles in abundance around Grassy Island Lake is because the shoreline of the lake has changed dramatically from its formation to its present condition. At one point this lake extended for several kilometres in all directions. Today, it is little more than a slough that almost totally dries up by the end of the summer. Moreover, much of the original shoreline around Grassy Island Lake is now grass covered and therefore it has poor ground visibility. Figure 10.2 is an illustration of Grassy Island Lake at dusk. As can be seen this area is very similar to that noted above for the pebble collection locale around the North Saskatchewan River in Saskatchewan. In fact, Neutral Hills also largely consist of fairly uniform prairie grassland interspersed with hummocky moraines, lakes and sloughs, and is frequently transected by rivers, creeks and streams. As in Saskatchewan, Wisconsin glacial processes are responsible for the abundance of glacial deposits in this region of eastern Alberta.

However, I noticed that while collecting silicified siltstone pebbles from around the lake, there were many locations that showed signs where this material had been collected and tested, based on the anvils and debris littering the ground in those locations. Johnson (1986: 84) also noted that many pebbles in this area showed signs of breakage by human action. Therefore, it is also possible that the majority of pebble materials that were exposed around this lake had been previously collected.

The frequency that pebble stones were used to manufacture stonetools within the Neutral Hills clearly illustrates that these materials, and the use of bipolar technology, was an extremely important aspect of the pre-contact human groups that occupied

Figure 10.2. Grassy Island Lake, Alberta, in backgound.

this region. Based on research conducted at the time, Quigg (1977: 58) interpreted the use of pebble stones in this locale as being an area-specific phenomenon that he identified as the Neutral Hills Pebble Industry. However, the research conducted here clearly affirms that bipolar technology and the use of pebble stone materials, especially the silicified siltstones, is not area-specific, but rather it is quite widespread across the Plains. Additionally, regarding the Neutral Hills Pebble Industry designation, Reeves (1972) had previously identified a large collection of pebble stone artifacts from the Pass Creek Valley, in Alberta, which he labeled as the Rundle Technology.

An important aspect of the Neutral Hills collections is that these materials also demonstrate a continuation of the use of bipolar technology and pebble stone by pre-contact groups from east to west; from southwestern Manitoba, across Saskatchewan and into eastern Alberta. Additionally, the time progression, noted for this technology in Manitoba and Saskatchewan appears to continue into Alberta. In his report Quigg (1977:66,71) recorded one Plains Side-notched projectile point from each of the two excavations conducted, the only lithic diagnostics recovered at the Lazy Dog Tipi Ring site (FbOr-57) and the Buffalo Jump (FbOv-1) and Campsite. Plains Side-notched materials appear in the archaeological record during the terminal Late Prehistoric period dating between 550 - 250 B.P. This is somewhat later than the pebble stone materials that are present during the Paleoindian period in Manitoba and the Middle/initial Late Prehistoric period in Saskatchewan. Quigg (1977: 72) also noted, based on ceramic recoveries, that the latest period of occupation at the Buffalo Jump (FbOv-1) and Campsite is the Old Women's phase (Reeves 1969) of the Late Prehistoric period.

10.1.3. Pebble collection locale 3: Fresno Reservoir, Montana. The final area where I collected pebble stone materials for the experimental portion of this thesis was from around the Fresno Reservoir in Montana (Figure 9.1). I choose this area based on its having been recorded to contain abundant pebble materials, including silicified siltstone. For example, Alt and Hyndman (1986:343, 377) note that stream rounded pebbles occur in the Flaxville gravels of the Eagle sandstone in late Cretaceous sedimentary formations within a variety of locations throughout Montana. Additionally, when recording source areas for silicified siltstones, Johnson (1986: 84) noted that Pierce and Hunt (1937: 244) had recorded chert pebbles within the Eagle sandstone and the Claggett shale of Montana. Therefore I thought it pertinent to visit the area for the purpose of collecting a number of pebble stones.

The district surrounding the Fresno Reservoir is very similar in topography to the areas around the North Saskatchewan river and the Neutral Hills, noted above, as illustrated in Figure 10.3. This is not especially surprising since it is also in a comparative region of the plains.

I did discover that much of the Fresno Reservoir area is littered with pebble stone materials. Unfortunately, however, the majority of the pebble stones collected here consisted of generic material with only a few specimens of silicified siltstone, generic

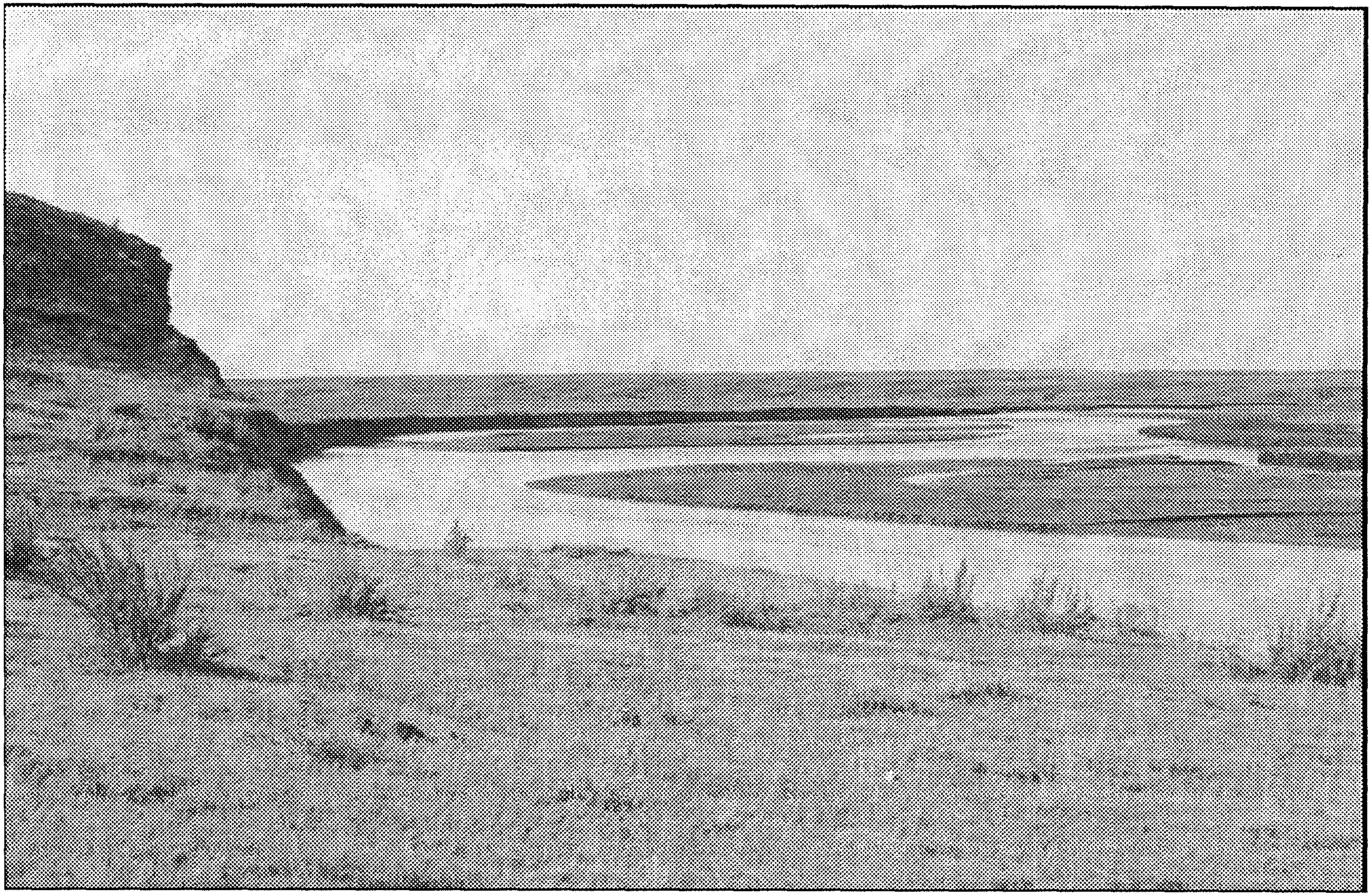

Figure 10.3. North end of Fresno Reservoir, Montana.

chert, or quartzite. The materials in this area do confirm, though, that pebble materials suitable for knapping, are geographically widespread and easily collectable.

10.2 Summary of source areas

Several common factors appear to link the above collection locales together. One is that the general topography of these areas is analogous from one locale to the other. Another, is that they are all adjacent to water sources, including lakes and rivers, and of course, that the ground surfaces in these locations are littered with pebble stone materials. In truth, frequent erosion in these areas would ensure that fresh pebble materials were always exposed on the surface, and therefore make the identification and collection of these materials a little less onerous than would quarrying for them. For example, Figure 10.4. illustrates the upper banks of the Fresno Reservoir channel and Figure 10.5. is an illustration of a low-lying area of the North Saskatchewan river. It is clearly evident that pebbles litter the ground surfaces in these locales and can be easily observed even amid the grass cover.

A final point regarding these collection locales is that they (along with the archaeological collections identified in the previous section) provide evidence for there being a time progression with bipolar technology and the use of pebble stone materials from east to west across the Northern Plains. This progression appears to begin with the Paleoindian period in Manitoba and continue into the Late Prehistoric period in Alberta.

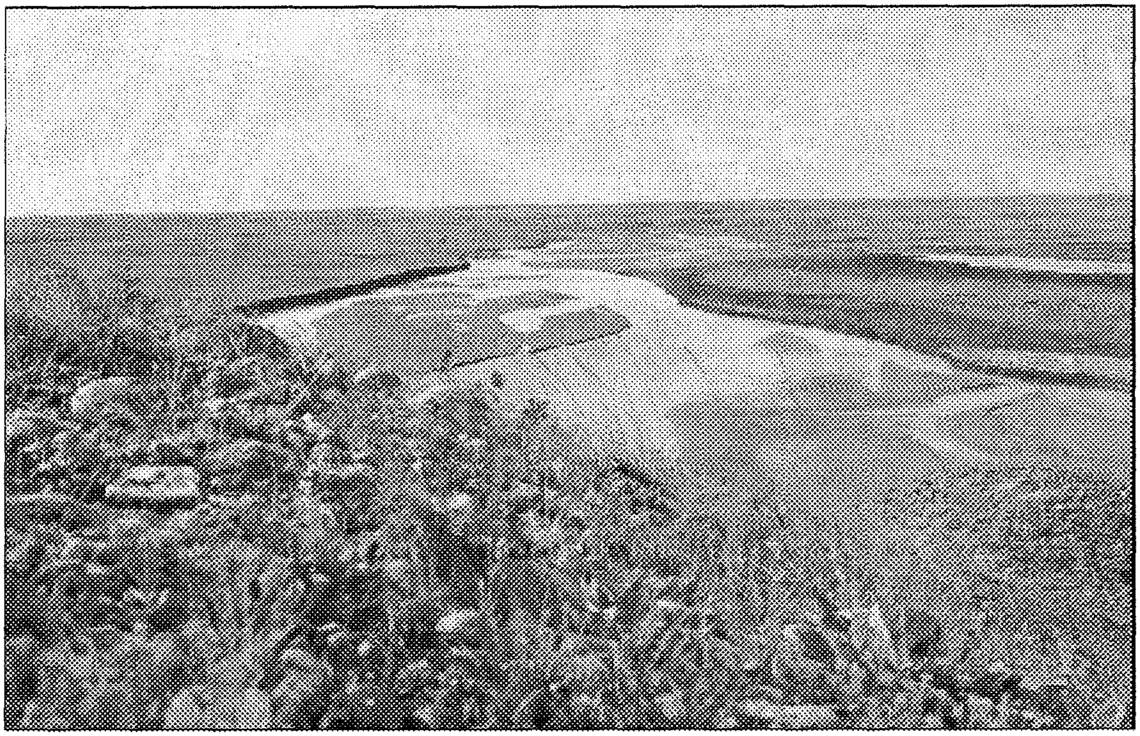

Figure 10.4. Upper channel of the Fresno Reservoir, Montana, showing pebble littered surface.

Figure 10.5. North Saskatchewan river terrace littered with pebble stones.

11. SUMMARY AND CONCLUSIONS: SIGNIFICANCE AND IMPLICATIONS OF STUDY

The examination of bipolar stone working technology within this thesis was undertaken to investigate several aspects. The first question was can bipolar technique be applied to pebble stones so that specimens would shear without crushing them into useless pieces of shatter? Second, what are the fundamental variables that essentially control this technique? Additionally, an appraisal of pebble stone materials and bipolar technology associations were examined by comparing archaeological materials with experimentally replicated specimens.

First, many researchers have noted that it is necessary to apply a forceful blow to the objective piece when using a bipolar technique. Although this is true with large cobbles, pebble stones are much more fragile. Controlled applied force is a requisite when working with small pebbles. Additional considerations regarding splitting pebbles with the bipolar technique include the types of required tools. The anvil is of special importance in this respect. The anvil stores a certain amount of applied force before it rebounds back. I discovered during experimentation that a large and dense anvil would store higher amounts of energy. The relationship of stored energy within an anvil to the frequency of successful pebble splitting attempts is essential in the success rate related to the number of attempts. When a large anvil is used only a moderate amount of downward force is needed to shear a pebble stone, since more energy is being rebounded back from the anvil. With a larger anvil a greater amount of control over the bipolar technique could be attained.

Another consideration regarding pebble stones and the bipolar method is the material, size and (especially) shape of the core. There is a strong correlation between material quality and form, such as fine grained and oblate specimens, and success rate. Another major consideration in the use of pebbles materials is their relative abundance within a given locale.

The nature of the raw lithic material available in a given area is likely a prime determinant in both in the use of pebble technology and its technological importance in pre-contact cultures. There are several factors that probably led to the selection of the silicified siltstone pebble materials over other raw materials on the Northern Plains. First, silicified siltstone pebbles are much easier to control during the knapping process. Second, although some fine grained miscellaneous pebble cherts and quartzite pebbles split well with the bipolar technique, silicified siltstone pebbles are in more abundant and are readily available for collection.

Other considerations regarding the bipolar method include the intensity of resonance that is generated by the flintknapper. This principal is related to the physics of rock fracture and fracture mechanics. That is, the variation in the shearing or shattering of a pebble stone is commensurate with the processes involved in the physics of stress waves and the fracturing of stone following impact. Furthermore, the spherical nature of wave fronts as they emanate through a specimen will have a variable outcome that is dependent on the overall body shape of the material. During the process of splitting a pebble stone using the bipolar technique I observed that the overall fracture pattern was related to the body shape of the pebble. In general, flat pebbles will split better than round ones.

The examination of existing bipolar flake and core classification systems indicated that they do not relate very well to the pebble stone materials used in the experimental analysis conducted for this study. A unique classification system was devised to accommodate the experimental sample.

Only in rare instances was proximal and distal impact crushing not visible through a hand lens. This is largely because of the stress that occurs at these points on a specimen following impact causing major alterations. With regard to proximal bulbs of percussion it was noteworthy that very few specimens displayed positive bulbs and only three specimens were identified with pronounced positive bulbs of percussion. This latter attribute is, however, frequently noted on straight percussion flakes. The most frequent proximal bulbs were negative inverted and sheared forms. It is the sheared bulbs that are of the most significance in this study. This attribute appears to be uniquely a bipolar feature and when it was identified on one section of a split pebble it was usually reproduced on the other accompanying half.

Another attribute that incontrovertibly identifies specimens as derived from bipolar technology is distal bulbs of percussion. A distal bulb of percussion can only be derived from the rebound force emanating into a pebble stone that is in contact with an anvil. Only by having opposing waves of force at both ends of the material can a distal bulb occur. Additionally, distal bulbs of percussion truncate the percussion lines in an opposing direction extending to them.

During the analysis of the pebble stones used for the experimental replications ten technological classes were developed. These materials were analyzed in Section 6 and then compared with existing bipolar classifications in Section 7. What is interesting is that they do not conform with the previously developed classifications. Moreover, although many materials could be classified by Kobayashi's (1975) bipolar flake groupings, the usefulness of that system is limited. His system does not take into account the unique technological divisions identified in this study. Compared to Kobayashi's (1975) four category lumping system this study established 10 classes.

As previously noted the various shear patterns are directly related to the physics of the force wave motion within the specimen. It is very possible, and most likely, that pre-contact groups were aware of this phenomenon. If that is the case, then the selectivity of collecting pebble stones would have slowly developed over time. Since silicified siltstone pebbles are more frequent than other raw material types, and quite thin in relation to their width, it seemed that these materials would have been much more sought after. This would account for the large numbers of these materials within bipolar pebble stone assemblages, in comparison to other pebble lithics.

During the experimental study, replicated pebbles frequently sheared transversely in two relatively uniform sections; although occasionally one split section was broken into two or more pieces often as a result of impurities within the material or resulting from the application of too much force on the material. It was also interesting that double and triple transverse splits occurred.

One of the more unique classes among the experimental materials are the Class 8 citrus-section specimens. I say this because these pieces are often recorded within archaeological assemblages. It is likely that they have been manufactured as expedient tools. Their form relates more to the shape of the pebble and not the method of the stone worker. In fact, this class of bipolar fracture is directly related to a circular pebble body form. It is also possible that pre-contact groups were aware that circular pebbles fractured in this manner and therefore, deliberately selected them to produce citrus-section materials.

Class 9 specimens are quite unusual although one consistency within this class is that the applied and rebound force did emanate from the ends of the specimen and terminated at the central point of the pebble. This caused both proximal and dorsal flakes to be detached from one half of the specimen while the other remained intact. The interesting thing with these materials is that the complete sections closely resemble pièces esquillées, a common bipolar by-product.

The appraisal of several archaeological collections provided a comparison of pebble stone materials and bipolar technology and it resulted in useful information regarding their temporal and spatial extent. For example, the Pembina Valley materials from southern Manitoba consist of a variety of pebble types that are quite distinct from the silicified siltstone materials depicted throughout the majority of this thesis. Most of these specimens indicate that they were manufactured as expedient tools used to supplement other resources and do not form a main lithic assemblage body. Alternatively, the pebble stones found throughout Saskatchewan and eastern Alberta are primarily silicified siltstones and extend from the early Middle Prehistoric period into the Late Prehistoric period.

Of note among the silicified siltstone tools identified within Saskatchewan is the wide range of products of pebble stone manufacturing. These items consist of tools that include projectile points to retouch flakes and indicates the importance and the extensive use of this material during the pre-contact period. This was quite evident by the high frequency in which silicified siltstone materials were recorded at the Gowen sites. This also provides further evidence of the extensive use of the bipolar technique on the Northern Plains.

The uniqueness of the Gowen bipolar material is largely related to the extensive use of silicified siltstone pebbles as the major lithic resource. It is quite obvious, by the amount of this material, that it was a valued lithic resource. The projectile point typologies and the dating conducted at the Gowen sites indicates that this assemblage is an Early Middle Prehistoric period occupation. The silicified siltstone materials from the Marvel Houston collection in western Saskatchewan, however, are associated with the Middle/Late Middle Prehistoric period and the initial Late Prehistoric period, although, technologically, the Marvel Houston materials are very similar to the Gowen site artifacts in that they are made from silicified siltstone pebbles with the bipolar technique.

The collection of pebble stones around Grassy Island Lake revealed the dominance of silicified siltstone. This partially explains the frequency of pebble stone tools within the Neutral Hills in Alberta, and their apparent importance. A significant aspect of the Neutral Hills bipolar pebble stone assemblages is that they also support a spatial/temporal continuation of this technology from east to west; the latest period of occupation within the pebble stone occupations of the Neutral Hills is the Old Women's phase of the Late Prehistoric period.

A very important aspect of the above Northern Plains collections is that they demonstrate a time progression of the bipolar technique regarding the use of pebble stones, from east to west from the Early Middle Prehistoric period in east-central Saskatchewan into the initial Late Prehistoric period in eastern Alberta. I previously indicated that silicified siltstones may have been used in a separate and distinct bipolar pebble stone industry within the Northern Plains during the early Middle Prehistoric period. While this is true since the Gowen site materials are obviously contained within that time frame, it is just as evident that the use of bipolar technology and pebble stones occurred during several time periods. What is even more evident is that an apparent time and geographic progression of the bipolar use of pebble stones existed across the Northern Plains from southern Manitoba to eastern Alberta.

When the high quality of tools manufactured from pebble stones is examined and the wide geographic distribution and frequency of these materials observed, it is evident that bipolar technology was thought of favorably and as useful by pre-contact groups. Although some researchers label bipolar technology as a poor lithic technique the results outlined within this thesis indicate bipolar technology is an efficient and productive method within lithic technology systems.

This study attempted to examine bipolar technology as thoroughly as possible, however, as with all research limits must be set. For one thing the geographical and temporal expanse of bipolar technology is much greater that I had originally anticipated. In spite of that I was able to make some preliminary observations in this much needed area of study. Even though, there is still much research that needs to be done regarding bipolar technology. For one, I would recommend study that examines how this technology would be represented through the use and comparison of various raw materials. Additionally, collections from other areas need to be compared. As I have previously indicated, we need to expand our localized archaeological interpretations. This can easily be accomplished by comparing similar materials from a larger geographical area, which can only provide further clarification of our own overall rationalizations.

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