

University of Montana

ScholarWorks at University of Montana

Graduate Student Theses, Dissertations, &
Professional Papers

Graduate School

2004

Introduction to the concept of a "symmetry index" for use in the assessment of biface production goals illustrated using lithic materials from the Avon site (24PW340) Powell County Montana

Raven Garvey Carper
The University of Montana

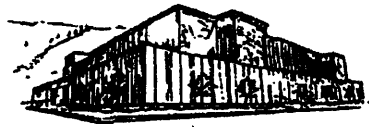
Follow this and additional works at: <https://scholarworks.umt.edu/etd>

Let us know how access to this document benefits you.

Recommended Citation

Carper, Raven Garvey, "Introduction to the concept of a "symmetry index" for use in the assessment of biface production goals illustrated using lithic materials from the Avon site (24PW340) Powell County Montana" (2004). *Graduate Student Theses, Dissertations, & Professional Papers*. 5824.
<https://scholarworks.umt.edu/etd/5824>

This Thesis is brought to you for free and open access by the Graduate School at ScholarWorks at University of Montana. It has been accepted for inclusion in Graduate Student Theses, Dissertations, & Professional Papers by an authorized administrator of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.



**Maureen and Mike
MANSFIELD LIBRARY**

The University of
Montana

Permission is granted by the author to reproduce this material in its entirety,
provided that this material is used for scholarly purposes and is properly
cited in published works and reports.

****Please check "Yes" or "No" and provide signature****

Yes, I grant permission _____

No, I do not grant permission _____

Author's Signature: *Zaven Cooper*

Date: 12/15/04

Any copying for commercial purposes or financial gain may be undertaken
only with the author's explicit consent.

AN INTRODUCTION TO THE CONCEPT OF A "SYMMETRY INDEX"
FOR USE IN THE ASSESSMENT OF BIFACE PRODUCTION GOALS,
ILLUSTRATED USING LITHIC MATERIALS FROM THE
AVON SITE (24PW340), POWELL COUNTY, MONTANA

by

Raven Garvey Carper

B.A. James Madison University, Virginia, 2000

presented in partial fulfillment of the requirements

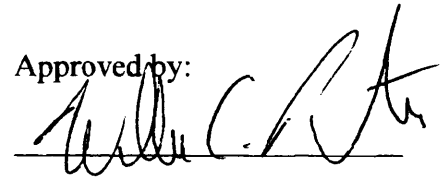
for the degree of

Master of Arts

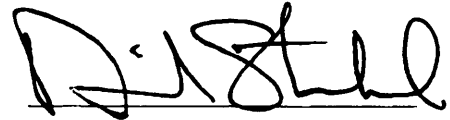
The University of Montana

December 2004

Approved by:



Chairperson



Dean, Graduate School

12-16-04

Date

UMI Number: EP36625

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



UMI EP36625

Published by ProQuest LLC (2013). Copyright in the Dissertation held by the Author.

Microform Edition © ProQuest LLC.

All rights reserved. This work is protected against
unauthorized copying under Title 17, United States Code



ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

An Introduction to the Concept of a "Symmetry Index" for Use in the Assessment of Biface Production Goals, Illustrated Using Lithic Materials from the Avon Site (24PW340), Powell County, Montana

Chairperson: William C. Prentiss



Whether or not Paleoindians were high-technology foragers, dependent on bifacial cores, is an issue that requires attention. Uncertainty regarding the role of bifaces in the Paleoindian toolkit is fueled by our inability to consistently and accurately distinguish the difference between bifacial cores and early stage preforms. I hypothesize that there are distinct and identifiable patterns among these two types of bifacial artifacts and that the amount a biface deviates from perfect bilateral symmetry may be indicative of its intended function. The concept of a "symmetry index" is introduced and used to quantify symmetry among sample groups of bifaces. Among these sample groups is a collection of artifacts from the Avon site (24PW340) in western Montana. The methods and techniques developed herein are applied to the Avon materials as a test of the hypothesis stated above. Through a symmetry index pilot study, a number of multivariate quantitative analyses, and an analysis of the Avon site debitage, it is determined that there are quantifiable differences between preforms and bifacial cores and that these may help us to better understand Paleoindian lithic technological organizations and systems of mobility.

ACKNOWLEDGEMENTS

I would like to gratefully acknowledge the advice and supervision of Dr. William Prentiss during this project. Dr. Prentiss' knowledge of lithics and many, many facets of Archaeology is profound; I learned so much from him while at The University of Montana. I thank Dr. Thomas Foor for his patient explanations of quantitative and statistical methods, and for long and fascinating discussions of symmetry, Archaeological theory and Life in general. Dr. Eric Edlund was especially helpful with aspects of the digital methods applied in this thesis. I thank Dr. Edlund also for enthusiastic discussions of the potential of the symmetry index. I am grateful to Professor Philip Hobler of Simon Fraser University for his detailed explanations regarding the 1960s excavations at the Avon site and for lending materials pertinent to this thesis. Also, many thanks to Linda McLean for all of her help with the logistics of my research and defense.

I am grateful to those of my classmates with whom I shared stimulating conversations, theoretical debates and long car rides to far away conferences. Most especially, I thank Ali Dietz for her unwavering support, great advice and all other things associated with true friendship.

Finally, I am forever indebted to my family for their love and encouragement and for letting me ramble on about all things bifacial for the last few years. And to my husband, Mark A. Carper, superb archaeologist and fellow Master's student, I extend uncounted thanks for his willingness to discuss aspects of this thesis through its many manifestations, his sound reasoning, dry-erase board explanations and infinite patience with me.

TABLE OF CONTENTS

Abstract.....	ii
Acknowledgements.....	iii
List of Tables	vi
List of Figures	viii
Chapter One, Introduction	1
The Biface Dilemma: The Nature of the Problem and the History of Past Research.....	2
The Avon Site: The Current Research Question and the History of Past Research.....	11
Thesis Outline	32
Chapter Two, Methods.....	33
Biface Analyses--Theoretical Justifications and Methods of Data Collection	34
Methods.....	37
The Symmetry Index Pilot Study	50
Quantitative Analyses	51
The Avon Debitage--Theoretical Justification and Methods of Data Collection	56
Methods.....	61
Summary.....	63
Chapter Three, Results.....	65
Biface Analyses.....	66
The Symmetry Index Pilot Study	66
Quantitative Analyses	72
The Debitage Analysis	85
Level A.....	85

Level B	93
Level C	100
Analysis of Results.....	108
Level A.....	108
Level B.....	109
Level C.....	111
Tool Analyses	113
Chapter Four, Discussions and Concluding Remarks.....	115
Summary and Discussions	116
The Symmetry Index Pilot Study and the Multivariate Quantitative Analyses	116
The Avon Debitage	119
The Avon Site (24PW340).....	126
Concluding Remarks	133
References.....	136

LIST OF TABLES

Table 2.1. Attributes of Callahan's projectile point production stages	35
Table 2.2. Number of Avon bifaces assigned to Callahan's stages based on objective and subjective criteria.....	37
Table 2.3. An example of the initial method of calculating the symmetry index, using the data collected from Avon specimen 24PW340-112.....	46
Table 2.4. Ordinally scaled variables and the designations for each value	53
Table 2.5. Ratio scaled variables and their units of measure.....	53
Table 2.6. Nominally scaled variables and their values.....	53
Table 3.1. Chi-Squared value for material type and "symmetry index value.....	73
Table 3.2. Chi-Squared value for thermally altered and "symmetry index value"	74
Table 3.3. Principal Component Analysis: initial statistics	76
Table 3.4. Principal Component Analysis: correlation matrix	76
Table 3.5. Principal Component Analysis: rotated component matrix.....	76
Table 3.6. Discriminant analysis using "symmetry index value" as the grouping variable: group statistics	80
Table 3.7. Discriminant analysis using "symmetry index value" as the grouping variable: classification results.....	81
Table 3.8. Results of student's t with 19 degrees freedom. All ratio scaled variable means for "symmetry index value" groups.....	81
Table 3.9. Discriminant analysis using "subjective value" as the grouping variable: group statistics	83
Table 3.10. Discriminant analysis using "subjective value" as the grouping variable: classification results. 77.4% of original grouped cases correctly classified	83
Table 3.11. Results of student's t with 36 degrees freedom. All ratio scaled variable means for "subjective value" groups	84

Table 3.12. Debitage raw totals and percentages.....86

Table 3.13. Debitage raw totals and percentages.....93

Table 3.14. Debitage raw totals and percentages.....101

LIST OF FIGURES

Figure 1.1. Map of the Nevada Creek Drainage	14
Figure 1.2. Detail of Antelope Hill and Rhine Point within Nevada Creek Drainage.....	15
Figure 1.3. 24PW320, Old Cabin Area, in relation to Strickland Creek	26
Figure 1.4. Feature 4 profile from Dean Wilson’s field notes, 1967	29
Figure 2.1. Correct positioning of artifacts on a polar coordinates grid	39
Figure 2.2. Biface oriented within quadrangular figure.....	43
Figure 2.3. Biface with axes of longitude and width established	43
Figure 2.4. Biface partitioned “above” break	45
Figure 2.5. Placement of measurements according to initial calculation of Symmetry Index	45
Figure 2.6. Dramatization of the potential for irregularities to cancel each other out when the index is calculated by the initial method.....	47
Figure 2.7a. Outline of a biface folded along its midline. 2.7b. Area that the two sides do not have in common are shaded. 2.7c. Area that the two sides do have in common are shaded.....	49
Figure 3.1. Descriptive statistics regarding the symmetry indices of the various study groups	67
Figure 3.2. Symmetry indices for each study group plotted on continua	69
Figure 3.3. Symmetry index values among material types from Avon	74
Figure 3.4. Dendrogram produced through Q-mode hierarchical clustering analysis using factor scores an average linkage method (between groups).....	77
Figure 3.5 Level A Debitage Material Types	86
Figure 3.6 Level A Debitage Completeness Types by Material.....	87
Figure 3.7 Level A Size Class Distribution	88

Figure 3.8 Level A Extra Large Flake Completeness Types by Material	88
Figure 3.9 Level A Large Debitage Material Types	89
Figure 3.10 Level A Large Debitage Completeness Type Distribution by Material.....	90
Figure 3.11 Level A Medium Debitage Material Types.....	91
Figure 3.12 Level A Medium Debitage Completeness Type Distribution by Material...	91
Figure 3.13 Level A Small Debitage Material Types	92
Figure 3.14 Level A Small Debitage Completeness Types by Material.....	92
Figure 3.15 Level B Debitage Material Types.....	94
Figure 3.16 Level B Debitage Completeness Types by Material	94
Figure 3.17 Level B Size Classes	95
Figure 3.18 Level B Extra Large Debitage Completeness Types by Material	96
Figure 3.19 Level B Large Debitage Material Types	97
Figure 3.20 Level B Large Debitage Completeness Types by Material.....	97
Figure 3.21 Level B Medium Material Types	98
Figure 3.22 Level B Medium Debitage Completeness Types by Material.....	98
Figure 3.23 Level B Small Debitage Material Types	99
Figure 3.24 Level B Small Debitage Completeness Types by Material.....	99
Figure 3.25 Level C Material Types	101
Figure 3.26 Level C Debitage Completeness Types by Material	102
Figure 3.27 Level C Size Classes	102
Figure 3.28 Level C Extra Large Debitage Completeness Types by Material	103
Figure 3.29 Level C Large Debitage Material Types	105
Figure 3.30 Level C Large Debitage Completeness Types by Material.....	105

Figure 3.31 Level C Medium Debitage Material Types	106
Figure 3.32 Level C Medium Debitage Completeness Types by Material.....	106
Figure 3.33 Level C Small Debitage Material Types	107
Figure 3.34 Level C Small Debitage Completeness Types by Material.....	107

Chapter One Introduction

The objective of this thesis is to address the concept of differing biface production goals among Paleoindians. I hypothesize that there are real and statistically significant differences between bifaces produced for use as portable cores and bifaces produced for use ultimately as projectile points. Our ability to discern differences between these two types has profound implications for the manner in which we interpret Paleoindian technological organizations and systems of mobility. If a thorough reevaluation of bifacial artifacts recovered from Paleoindian sites reveals that these groups relied heavily on a bifacial core technology, our agenda regarding studies of Paleoindian behavior should continue unimpeded. However, if it is found that bifacial cores were not the "centerpieces of Paleoindian technology," (Bamforth 2001:55) we will be forced to reconsider our perception of Paleoindians as high-technology foragers. The methodology described herein is offered as a tool with which to address this issue.

The research question posited here is: are there real and statistically significant differences between bifaces produced for use as cores and those produced for use ultimately as projectile points, i.e. preforms? This thesis begins with a discussion of divergent biface production goals and the implications that particular technological foci have for interpreting systems of mobility. I have developed an index of bilateral symmetry for the purpose of assessing biface production goals, and to thereby directly address the research question. In the following chapters, the "symmetry index" is introduced and applied, in conjunction with several other methods, to the lithic materials

from the Avon site (24PW340) in order to assess the nature of the production and use of bifaces at that site. Multivariate quantitative analyses are described, which were performed in order to support or refute the conclusions drawn from the pilot study of the symmetry index. The Avon data are then incorporated into a discussion of whether Paleoindians were in fact bifacial core dependent and how similar studies can contribute to a better understanding of Paleoindian mobility.

In this initial chapter, a discussion of symmetry is followed by an introduction to the Avon site (24PW340), which serves as the test case for the theories and methods put forth in this thesis. In each of the following chapters, aspects of the Avon collection are discussed, beginning with a description of the methods used to analyze the lithic material from that site. The third chapter discusses the results of those analyses and the conclusions that were drawn. The final chapter of this thesis focuses on Avon's contribution to the greater debate regarding Paleoindians as high-technology foragers.

The Biface Dilemma: The Nature of the Problem and the History of Past Research

Bifaces have long been considered a fundamental component of the Paleoindian toolkit. For the past several decades, their presence in—or absence from—Paleoindian sites has been interpreted as an indication of a particular technological organization and system of mobility. Specifically, the presence of bifaces as cores or long use-life tools within an assemblage has been interpreted as evidence of "high-technology" forager behavior. "High-technology" or "high-tech" foragers are those who employed a lithic technology that "was designed to economize raw material in the face of uncertain access to quarries by extending the use lives of tools and designing tools for multiple uses"

(Bamforth 2001:58). This was achieved through "reliance on easily flakeable stone, extension of tools' use lives by careful design and recycling, and reduction of the weight of the transported toolkit by producing tools in advance of use and relying on bifacial cores as sources of new tools for later reduction into finished tools" (Bamforth 2001:58).

Kelly (1988) highlighted the concept of alternative "roles" of bifaces in the archaeological record. Rather than viewing each biface in the archaeological record as representative of one stage in a stepwise progression towards a finished projectile point, Kelly considered the fact that bifaces could have been used in other capacities by Paleoindians. He suggests that

bifaces can be manufactured to play one or more of three different organizational roles:

- (1) as cores, although this does not preclude the biface itself from being used as a tool;
- (2) as long use-life tools, in which a tool's bifacialness is necessary to its anticipated role, which is to be resharpenable and usable for its function even if broken . . .
- (3) as a by-product of the shaping process, in which a tool's bifacialness is not an explicit intention of the maker . . . (Kelly 1988:719).

The first organizational role presented by Kelly is of primary importance to this thesis. Bifacial cores are versatile in that they can be used to perform a number of tasks, they are easy to maintain, and they provide considerable potential for a large amount of cutting edge. On this last point Kelly notes that "more usable flake edge can be produced from a biface than from a percussion core of similar weight because each flake from a biface has a high edge-to-weight ratio" and, regarding long use-life tools, "a bifacially flaked edge can have a fair amount of cutting power . . . yet the less acute angle of a biface's edge makes it more durable than an unretouched flake" (1988:718). These

assertions prompted a series of cost-benefit relationship, or optimality, studies (Elston and Raven 1990; Francis 1983; Kuhn 1994; Nelson 1987; Torrence 1989 and others), the outcome of which made a strong case for the efficiency of bifacial core use.

Efficiency, it has been argued (cf. Kelly and Todd 1988), would have been of utmost importance to highly mobile people who needed to restrict the overall weight of their toolkit, while being prepared for any possible contingency as they traversed huge and unfamiliar expanses. In this way the link between lithic technological organization and mobility strategy was made. Kelly and Todd (1988) explored this concept while considering the rapidly changing environment at the Pleistocene/Holocene transition. They argue that the Paleoindians who came to the "New World" at this time may have been the first human inhabitants of this continent. As such, they would not have had a "resident group" to consult regarding the acquisition of resources when they entered a new territory. Therefore, given the rapidly changing physical landscape, the choice to pursue game animals (which, Kelly and Todd argue [1988], are more readily identifiable and attainable than plant resources in an unfamiliar ecosystem), and the resultant frequent moves, Paleoindians had to develop what has come to be known as the high-tech forager strategy. Moving out of the theoretical realm and into the practical, Kelly (1988) argues that by looking at the proportions of bifacial cores and bifacial tools in archaeological contexts we might be able to discern the degree of residential and/or logistical mobility practiced by the group responsible for the archaeological record at a particular site.

Although Kelly states that there is "no direct correlation between mobility and the organization of technology" (1988; citing Bamforth 1986), many people have since discussed technological organization as reflective of a group's system of mobility (Bleed

1986; Nash 1996; Pecora 2001; Roth and Dibble 1998; Shott 1986). Others have considered the idea that the organization of technology is governed by subsistence strategies and latitudinal global positions, in addition to mobility systems (Bamforth 1986; Binford 1977, 1979, 1980; Bleed 1986; Boldurian 1991; Goodyear 1979; Hayden 1997; Kelly 1988; Kelly and Todd 1988; Parry and Kelly 1987; Torrence 1983; and others). Finally, Bamforth (1986) and Pecora (2001) have discussed the dependence of technological organization on the availability of raw materials. Pecora notes that "stone-working people were capable of altering raw material availability. In fact, raw material availability is greatly affected by how the stone is prepared prior to transport. Cores, for example, provide more lithic material and manufacturing flexibility than do blanks or finished tools" (2001:176).

However, despite all of the purported benefits of bifacial core use, Bamforth (2002) has called for a reevaluation of the current model of Paleoindians as high-tech foragers. He argues that bifacial cores do not appear to have been the "centerpieces of Paleoindian technology" and that the archaeological record does not strongly support the high-tech forager model (Bamforth 2002:55). Bamforth suggests that the proportions of bifacial cores in Folsom and later Paleoindian sites are not consistent with the patterns that we would expect if these Paleoindians had been bifacial core-dependent. Other lines of evidence are incongruous with this theory as well. For example, predominant use of a bifacial core technology should result in a majority of tools made on biface-struck blanks, and a relative paucity of "nonbifacial cores and debris from the reduction of such cores" (Bamforth 2002:65). Furthermore, it seems that bifaces are often poorly defined in the literature regarding Paleoindian sites, and the actual function of many bifaces found in

these contexts is suspect. Bamforth notes that "[o]ne particularly important aspect of any discussion of these issues is distinguishing between bifacial cores and unfinished blanks and preforms for bifacial knives. Standards for distinguishing between bifacial cores and bifacial tools are rarely made explicit. . ." (2002:65). While addressing each of the points mentioned above is fundamental to a proper reassessment of Paleoindian technological organization, this final point—our ability to distinguish between bifacial cores and preforms—is central to the discussion that follows.

Given the debate regarding whether or not Paleoindians were indeed bifacial core dependent, it is imperative that we devise methods by which to recognize the differences between bifaces intended ultimately for use as projectile points and those intended for use as cores when that difference is not immediately apparent. Pecora (2001) suggests patterns that we might expect to see at sites representative of core-based lithic transport "junctures." Kelly (1988) offers "archaeological consequences" of the use of bifacial cores in residential sites (largely reflected in the debitage), and Boldurian (1991) describes the surface flaking patterns and general characteristics of bifacial cores discovered at Blackwater Draw. Bamforth (2002) offers trends that we would expect to see among bifacial core-dependent groups. These and other practical discussions are helpful in assessing the "footprint" left by bifacial core use, which can then be applied to discussions of mobility strategies and other prehistoric lifeways. Yet, the continued presence of a class of artifacts associated with Paleoindian sites, generically termed "bifaces" and whose function is often ambiguous, leads me to believe that Bamforth's reference to our inability to readily distinguish between preforms and bifacial cores is especially problematic.

The following explores the hypothesis that there are real and quantifiable differences between bifaces intended ultimately for use as projectile points and bifaces intended for use as portable cores, and that a recently derived measure, the symmetry index, is a useful tool in determining these differences. This method of distinguishing between preforms and cores functions under the assumption that the former will exhibit more perfect bilateral symmetry than the latter. This assumption is based on the assertion by Callahan (1979) and others (Muto 1971; Sharrock 1966; Whittaker 1994) that successful manufacture of projectile points depends upon successful completion of a number of stages, including the achievement of a high degree of symmetry. If Callahan is correct in asserting that completion of each of these stages is requisite for the completion of subsequent stages, then we can assume that the parameters outlined for each stage would have been held as the ideal for projectile point manufacture among prehistoric stone tool producers, however subconsciously. This would be characterized in the archaeological record by higher proportions of bifaces that fit the criteria for each stage of production as defined by Callahan (1979; outlined below). Bamforth suggests that "production of a bifacial tool requires attention to plan-view and cross-sectional symmetry, regularity of edge angles, and carefully and regularly spaced flakes" (2002:65). Bifaces intended for use as cores and/or long use-life tools may have been manufactured under a less specific set of guidelines. This would likely be characterized in the archaeological record by higher proportions of bifaces with edge angle-width/thickness ratio combinations that do not comply with Callahan's definitions for each stage. They may also exhibit exaggerated thickness for their width, differential thinning, failure to edge the entire perimeter of an objective piece, and/or general asymmetry.

Additional support for the argument that finished projectile points of most temporal and cultural affiliations do exhibit a high degree of symmetry comes from studies of projectile point aerodynamics such as that performed by Christenson (1986). Christenson argues that "accuracy, flight stability, range, and killing power" are functions of stability and balance (1986). "Stability and balance are a function of symmetry and weight (Christenson 1986); that is, if a point is symmetrical in both form and weight, then the balance should be good" (Beck 1998). Thus, the more symmetrical a projectile point, the greater its ability to strike a target accurately and efficiently.

The difference between "late stage" preforms (nearly complete projectile points, often lacking only final edge retouch or hafting element) and bifacial cores is obvious and it is unlikely that the two would ever be confused. Early stage preforms, however, more closely resemble cores and these may be the source of confusion when the function of bifaces in the archaeological record is poorly defined. A measure of symmetry may be a remedy for this confusion.

Archaeologists often describe things as more or less symmetrical, but these are imprecise terms. "While it is true that an imprecise language helps in grasping complex situations and in identifying first-order trends, the danger of missing the full picture because of a vague description is always awaiting the user of the current symmetry language" (Avnir et al. 1997). Yet there is very little reference to the quantification of symmetry as it pertains to artifacts. There is a team of chemists, namely Avnir and Zabrodsky (Avnir et al. 1997; Zabrodsky and Avnir 1995), who have explored symmetry and its practical application to a wide range of fields, including Anthropology.

Zabrodsky and Avnir (1995) first outlined their methods of assessing symmetry,

or "chirality" as it pertains to molecules (the structural property or characteristic of a molecule that makes it physically impossible to superimpose an image of that molecule onto a mirror image of itself). They propose that symmetry is a "continuous rather than discrete (sic) structural property" and offer "a working tool which allows one to evaluate quantitatively, on a continuous scale, how much of any symmetry element or symmetry group exists in any configuration in any dimension" (Zabrodsky and Avnir 1995:462), and which allows the relative chirality of completely different structures to be compared. The method is explained by Saragusti et al. in the following succinct and accessible manner:

Our proposed answer (Zabrodsky and Avnir 1995) to the question 'How much of a given symmetry is there in a given structure?' has been: 'Find the minimal distances that the vertices of a shape have to undergo, in order for the shape to attain the desired symmetry.' In a formal way, given n vertices of the original configuration, located at P_i , and given a symmetry point group G , the amount, $S(G)$, of this symmetry in this configuration

$$S(G) = \frac{100}{n} \sum_{i=1}^n \|P_i - \hat{P}_i\|^2$$

where \hat{P}_i are the corresponding points in the nearest G -symmetric configuration. Equation 1 [above] is general and allows one to evaluate the symmetry measure of any shape relative to any symmetric group or element. . . . The nearest set of \hat{P}_i 's, i.e. the set of coordinates describing the nearest symmetrical shape, . . . obtained in terms of the normalized coordinates, is computed with an algorithm, described in detail in Zabrodsky and Avnir (1995) (1998:819).

Avnir et al. explain further:

Given an object to be symmetrized, it is converted to a necklace of an even number of boundary points, P_i , as dense as one wishes. . . Its center of mass is then determined and placed at the origin, and the distance from this center to the farthest P_i is scaled to 1. The aim is to find the nearest set of \hat{P}_i 's which is σ -symmetric, namely, to find that reflection line which will cause the set of P_i 's to move minimally to the set of \hat{P}_i 's (1997:321).

In a demonstration of the feasibility and versatility of symmetry studies in the field of archaeology, Saragusti et al. applied the Continuous Symmetry Measure (CSM) method, outlined above, to a collection of lower Paleolithic handaxes from Israel (1998). They argue that changes in the amount of symmetry present among bifaces representative of a number of sequential stages throughout the Acheulian Techno-complex may be reflexive of "the evolution of human cognitive, behavioural and technological capacities" (Saragusti et al. 1998:817). Though the handaxes are the immediate subject of the study, the authors themselves maintain that the "need for objective means for symmetry measurement is the main motivation for [their] study" (1998:818). In reference to this, they cite numerous occasions on which archaeologists have referred to artifacts which are *more* symmetrical, *roughly* symmetrical, or possessed of *fine* symmetry. A quantitative measure of symmetry, however, would "allow one to answer questions such as 'how much symmetry is there in a given handaxe?'; 'by how much is one handaxe more symmetrical than another?'" (Saragusti et al. 1998:818). I wholeheartedly agree with this assessment and the conclusion that the quantification of symmetry has far-reaching implications for the discipline of archaeology. I also feel, however, that the methods proposed by Avnir and Zabrodsky (Zabrodsky and Avnir 1995, Avnir et al. 1997) and applied by Saragusti et al. (1998), while apparently very effective, are highly technical, potentially very time consuming, and do not lend themselves well to standard archaeological analyses. The methods proposed here are more accessible, particularly considering the fact that many archaeologists now make use of digital cameras in the documentation of artifacts. The steps that follow digital rendering are simple and require little additional work. The "symmetry index" is outlined and applied in the following chapters.

The Avon Site: The Current Research Question and the History of Past Research

Bifaces from the Avon site (24PW340) are used to address the primary research question of this thesis: are there real and quantifiable differences between bifacial cores and projectile point preforms? The symmetry index, described in the following chapter, is applied to the Avon site bifaces and the results are used to address the larger theoretical questions regarding Paleoindian lithic technological organization and mobility strategies. This chapter provides a detailed description of the Avon site, in the context of both the Avon Valley and the greater regional interface of the Rocky Mountains and the Great Plains, and the archaeological collection recovered from the site. Subsequent chapters are devoted to the methods used to study that collection, the results of applying those methods, and the conclusions thus drawn regarding both the nature of the Avon site and its role in the discussion of whether late Paleoindians were in fact bifacial core dependent.

The Avon site is thought to have been used as a quarry workshop. Lithic materials suitable for the production of stone tools crop out in abundance less than two kilometers from the site, and basalts and non-local cherts are available in the gravels that have been down-cut by Strickland Creek, to which the site is adjacent. Quarry workshop sites offer considerable potential for insights into the lifeways of the prehistoric peoples who made use of them. At such sites we find evidence for the types of tools being produced: "[d]ebitage retains evidence of prior manufacturing steps, thus its variability must in some ways be related directly to the formal variability of intended products of manufacture" (Magne 1989:15). The lithic reduction strategies employed, the desired goals of production and the implied lithic technologies of the people who produced

workshop assemblages offer insights into that group's system of mobility. The Avon site was studied in light of these concepts.

The artifacts available for study during the production of this thesis were excavated over the course of two field seasons, in the late fall of 1966 and the spring of 1967, under the direction of Professor Philip Hobler, then of The University of Montana. The official site report contains only minimal documentation of site location and basic site type, and the majority of the information pertaining to the site was gleaned from the student journals from the 66/67 field seasons. From these sources, it was determined that eight units were placed along the banks of Strickland Creek and that at least 5927 lithic artifacts¹, 5752 of which are debitage, were recovered over the course of these two field seasons. The condition and the nature of the documentation are such that the provenience of the artifacts—both vertical and horizontal—is dubious and very little in the way of spatial analysis can be performed.

Hobler and his crew, however, were not the only ones ever to have excavated at the Avon site. In fact, the excavations performed over the course of the two field schools probably represent only a small proportion of the total time invested in the site. Yet the extent, description and results of all other investigations at the Avon site are not available. One agenda of this thesis is to interpret the nature of the Avon site, both as a Paleoindian quarry workshop and in relation to the archaeology of the northern Great Plains/Rocky Mountain interface, given the scant data available at this time.

The Avon site is located in Powell County, Montana, approximately 30 miles west

¹ One hundred and seventy-five non-debitage artifacts were present in the collection as of early 2003. The site is known to have produced a number of projectile points, which were not included in the collection when I began to study it. More on this issue follows the discussion of the Avon site projectile points.

of Helena, between the towns of Avon and Finn, along a second-order tributary of Nevada Creek. Nevada Creek, in turn, is a tributary of the Blackfoot River and is the namesake of a drainage system “located immediately west of the Continental Divide. . . It [the Nevada Creek drainage] is bordered on the southwest by the Garnet Range, and is part of the northeast-southwest trending valley [system] that make[s] up this region. Elevations range from 4300 feet on the valley floor to above 7000 feet in the adjacent Garnet Range. . .” (Cameron 1984). The Avon Valley is located in the southern portion of the Nevada Creek drainage (Figure 1.1).

The Avon Valley lies within what Malouf has referred to as the "Montana Western Region." This is the geographic region "along the Continental Divide in Montana and southern British Columbia, [which] extend[s] for two or three hundred miles on each side of the crest" (Malouf 1956:9). During the terminal Pleistocene and into the early Holocene, which is the time period of particular interest to this thesis, the vegetation of the Montana Western Region is thought to have resembled that of a modern alpine tundra. Sagebrush and grasses would have predominated and provided browse for mammoth, bison, horse, camel, mountain sheep, deer and wapiti among other, smaller game (Greiser 1984). In a personal communication with Catherine Cameron, John Taylor expressed his belief that the Nevada Creek drainage (which lies well within the Montana Western Region) would have offered a *refugium* from harsh winter conditions for animals such as bison, antelope and deer (Cameron 1984) and, potentially, the humans who pursued them. The Avon Valley may have been particularly enticing given its reliable source of water, most notably Halfway Creek and Stickland Creek (tributaries of NevadaCreek), and prominent outcrops of chert and silicified marl. Furthermore,

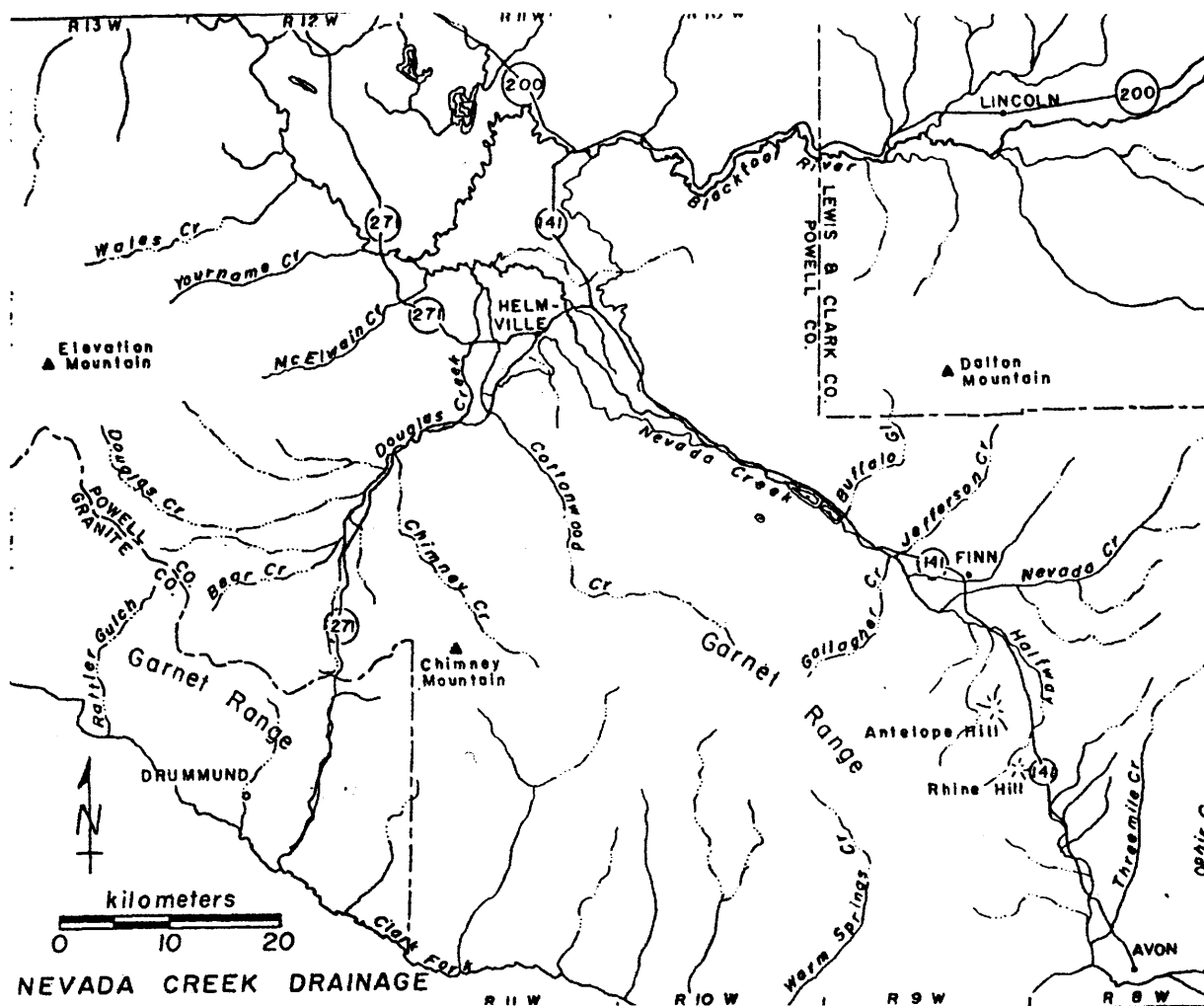


Figure 1.1. The Nevada Creek Drainage (Cameron 1984:16)

Nevada Creek located fewer than 100 miles from the Plains and "[h]istorical accounts suggest that the Nevada Creek area may have been part of or close to several major routes of [native] travel. The Clark Fork River was one of the major east-west travel routes (Choquette and Holstine 1982), and a branch of this trail led up the Blackfoot River, past the mouth of Nevada Creek" (Cameron 1984).

A comprehensive study of the Nevada Creek drainage area was conducted in 1984 that combined archaeological and geologic evidence to form a more complete picture of

the prehistory of that drainage, which includes the Avon Valley. The presence of thirty-four archaeological sites in the area drained by Nevada Creek and its tributaries was confirmed by Cameron during the 1984 survey, though she was unable to relocate twenty-two additional sites reportedly located throughout the drainage area (Cameron 1984).

The hub of the handful of recorded sites located in the Avon Valley area appears to be Antelope Hill and, to a lesser degree, Rhine Point, where materials suitable for stone tool production crop out in abundance (Figure 1.2). Cameron reports that "much of the area around [Antelope Hill and Rhine Point], especially around [Antelope Hill], appears to be a continuous distribution of cultural material" (1984:4).

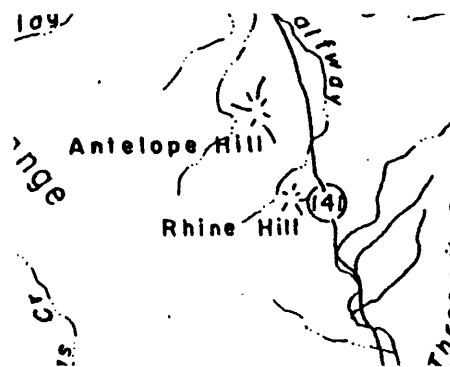


Figure 1.2. Detail of Antelope Hill and Rhine Point within Nevada Creek Drainage (Cameron 1984:16)

As part of the Nevada Creek Archaeological Project, of which Cameron's archaeological survey was a part, Fields performed a detailed geologic survey (1984) in the Nevada Creek drainage area. He found that there are two principal sources of lithic material in the Avon Valley, the Antelope Hill/Rhine Point quarries and the non-site-

specific pediment capping gravels that are being down-cut and thus exposed by the local drainages. The so-called Avon Cherts, outcrops of which are located both on Antelope Hill and Rhine Point, are actually silicified marls with cherty silica inclusions according to Fields (1984). The geologic term "marl" refers to "a mixture of clay and calcite in nearly equal parts" (Fields 1984:15). Very similar to marl is porcellanite, which is "a mixture of authogenic silica and allogenic clay, usually with some calcite as well[,] compacted into a hard rock having the luster of unglazed porcelain" (Fields 1984:15). Both lithic types are usually formed in lacustrine environments "where clay minerals and/or fine-grained volcanic material is brought into the environment of the water body" (Fields 1984:17). When aquatic organisms are present in the water body at the time of formation, they may be incorporated into the matrix. Fields goes on to note that "[i]t is difficult to distinguish a marl from a porcellanite without very detailed and sophisticated study. It is even more difficult where authogenic chert, chalcedony or opal has invaded the system via groundwater and altered the original structure. In the case of the 'Avon Chert' all of these features are present" (1984:17). The Avon Chert that crops out on Antelope Hill "is a mottled, white, gray, buff and yellow, highly altered mix of volcanically derived material (clay) and fossiliferous, calcareous, silicified marl or porcellanite in which fractures and pore space have been invaded by silica in the form of chalcedony. This has resulted in partial or complete replacement of the original material by chert (chalcedony)" (Fields 1984:18-19). This material weathers to a yellow-white or white, while a fresh break is darker tan to brown or dark brown to brownish black. "It has good to crude conchoidal fracture, luster is dull to almost earthy where the original matrix is preserved;" that is, where it has not been invaded by silica (Fields 1984:19). Where

silica has invaded the original matrix, the luster is more vitric. Very similar materials also crop out on the southern end of Antelope Hill (the South Avon Quarry Site) and on Rhine Point. However, "[f]ield data is inconclusive as to whether the Avon Quarry, the South Quarry [northern and southern ends of Antelope Hill, respectively] and the Rhine Point Site are: 1) developed in the same stratigraphic unit or 2) developed in a stratigraphically superposed set" (Fields 1984:27).

Materials other than the so-called Avon Chert are available in the Avon Valley that could have been used by prehistoric stone tool users. Stratigraphically below the Avon chert, there is a level of vitric chert which ranges in color from white to greenish- or bluish-gray with inclusions of yellow or brown material. Its luster is pearly and its fracture is irregular to conchoidal (Fields 1984:21-22). Stratigraphically above the Avon Chert is a level of calcareous siltstone. It is not clear from Fields' description whether this material would have been suitable for stone tool production and use, though he does mention that it is quite siliceous. This material is mottled white with an earthy, dull texture. There are inclusions of calcite throughout the matrix (Fields 1984:20). At the top of the stratigraphic sequence, above the calcareous siltstone, is a level of calcite limestone. This is described as a white, 98% calcite limestone, banded with tan to pink grains.

Second to these quarry sites in importance as lithic resource procurement areas are a group of non-site-specific, secondary source gravels. Much of the valley floor is composed of a pediment surface formed during late Pliocene and early Pleistocene times, which slopes from the Garnet Range to Halfway Creek. At the Pleistocene-Holocene transition, when the Blackfoot lobe of the Flathead Glacier was in a state of flux,

advancing and retreating, the pediment surface was capped with "a significant but variable thickness of water-lain cobble and pebble gravels derived from the surrounding mountains. These gravels contain clasts of Precambrian Belt rocks, andesite, basalt, rhyolite and chert" (Fields 1984:3-5). The pediment-capping gravels are

deeply dissected by Finn, Davis, Strickland and the upper reaches of Halfway creeks. Almost everywhere on the pediment and along the flanks of the drainages dissecting the pediment, gravel from the Quaternary pediment cap coat the surface. Clasts range from 0.5 to 20 cm. Chert is present and abundant in the cap gravels. Color varies from cream-white to dark chocolate brown, orange, rust-red and gray-purple. Much of it has a white to cream weathered skin (rhine [sic]). Various types of volcanic rock (mostly rhyolitic) are mixed with the chert as well as minor amounts of sedimentary cobbles (1984:12-14).

Other lithic materials would have been available to prehistoric people, and especially highly mobile people, from the Garnet Range (south of the present study area) which contains abundant nodules of chert within the Madison formation limestone there. Also, south of the Garnet Range crest, there is a thick chert lens that may have been exploited as a source of lithic material (Fields 1984).

After making a general geologic assessment of the Avon Valley materials, Fields visited what he referred to as the Napton Site (presumably 24PW340) and inspected the materials present on the surface there. Stream-transported cherts that range through shades of tan, red and purple are present at the site in both culturally-modified and non-culturally-modified forms. Pediment capping basalts and "andesite detritus" are also present as both artifacts and unmodified pebbles and cobbles. There is also North Avon Quarry, South Avon Quarry and Rhine Point material present, though Fields suggests "not in the abundance one might expect" (1984:25). Fields concludes that at 24PW340, the non-site-specific pediment capping gravels appear to be "the major source of workable

chert" (1984:30). Fields' reconnaissance was performed in 1984, however, after numerous known collection episodes were performed, to say nothing of looting activities that may have removed a significant proportion of this and other materials from the site.

Only a handful of sites have been documented in the immediate vicinity of the Antelope Hill/Rhine Point quarries: 24PW320, 24PW340, 24PW346, and 24PW1043. The following description of 24PW346 is based primarily on Cameron's work (1984), since the information provided in the official site report is limited. The "North Avon Quarry" site (24PW346; also the "Avon Quarry," the "Price Site," "Avon No. 1," and the "Antelope Hill Site" [Cameron 1984; official site form on file at Archaeological Records, The University of Montana]) is comprised of five distinct areas, covering approximately two square kilometers and centered around a number of quarry pits (N=76). These pits range in size from 4.25-30 meters in diameter and 1-3 meters in depth. In direct association with the pit features are a number of artifacts and a considerable amount of quarrying debris. Based on surficial examination, the pits themselves appear to have been the location of prehistoric quarrying activity, as there is no "evidence of tunneling or trenching" (Cameron 1984). Speculating as to the production goals at the North Avon Quarry site, Cameron notes that

. . . production at the quarry may have been geared to the manufacture of large bifaces, that could have been transported for use as cores. Several of these items were noted while examining the quarry area. A large (15 cm long) biface or preform was noted at the quarry area on [Rhine Point] and Napton (1981) mentions several of a similar size found in subsurface deposits in the Main section of 24PW340. Dr. Thomas Hester (1970 field notes) noted a group of large artifacts that he called 'cores' associated with quarry pits on a knoll at the southeast end of [Antelope Hill] (1984:6).

Other areas of the extensive 24PW346 quarry site include stone circles and lithic debris areas west of the quarry pits, a rather extensive lithic scatter near a spring located

on the northern slope of Antelope Hill, a lithic scatter west of the quarry pits, and another extensive lithic scatter along the ridge of Antelope Hill. The stone circle and lithic debris areas are of most interest here. These features are located on a relatively flat area west of the quarry pits. The circular features (N=17) range in size from 5-11.5 meters in diameter and there is little lithic debris associated with these. There are, however, concentrations of lithic debris southeast and northeast of the stone circle area. Cameron reports that these debris concentrations contain "debitage, shatter, quarry blanks, cores and unused chunks of Avon material . . . retouched flakes and utilized flakes, two bifaces and four unifaces. . . Fire-cracked rock was present in these areas" (1984:7). Given this description of features and artifacts, this area appears to represent a campsite and workshop area. One Pelican Lake point (3000 B.P. - 1500 B.P. [Frison 1991]) was located during Cameron's survey, though without subsurface investigation a secure date or range of dates cannot be assigned to this campsite.

The official site report for 24PW346 was able to add only that the site was originally recorded by George Arthur in 1961, at which time he noted very large knives and scrapers, as well as "several" projectile points in the area of the quarry. The points were neither drawn nor described in the text. Finally, there is a date of "7000 B.C." on the site form, but no clarification as to whether a ¹⁴C date was obtained or whether some diagnostic point was found that led Arthur or some subsequent investigator to make this assertion.

A number of other quarry sites and lithic scatters are described by Cameron at the southeast end of Antelope Hill and on Rhine Point. The only other of these given a trinomial designation is 24PW1043, located approximately 1700 meters west-northwest

of 24PW346 (Cameron 1984). This site consists of a "moderately dense lithic scatter. . . [that] may have been a processing area associated with the quarrys (sic) noted on these two hills [Antelope Hill and Rhine Point]" (Cameron 1984:10). The original site report, completed by Ann Johnson in 1971, contradicts the location provided by Cameron (1984), however. Johnson indicates that the site is located on a plateau "opposite" Antelope Hill, in Township 11N, Range 8W, Section 7, which is clearly *east* of Antelope Hill and 24PW346. Johnson goes on to describe the site as spanning approximately 39 square yards and containing "hunks of tarnished chert." What accounts for this discrepancy is uncertain. The most likely explanation is that Cameron simply meant to say that 24PW1043 is located 1700 meters *east-northeast* of 24PW346, which would then correspond with Johnson's legal description. A second possibility is that one of the investigators is using the site number erroneously. They do, however, appear to be describing the same site.

Johnson also recorded 24PW1045, which she describes as being very similar to 24PW1043. This site is located very close to 24PW1043 and contains large pieces of Avon Chert. No diagnostic artifacts were reported and a more specific site location could not be ascertained.

In addition to the "Avon Chert" procurement areas and associated sites mentioned above, the Nevada Creek drainage also contains a large amount of workable basalt. The basalt is generally found in the pediment-capping gravels that are being down-cut, and thus exposed, by Nevada Creek and its tributaries. It appears that prehistoric stone tool users/producers sought this basalt in addition to the local cherts/marls, as several of the above mentioned sites also contain basalt artifacts. Furthermore, north of 24PW346,

"[t]wo sites, 24PW1033 and 24PW1038, which are only 150 meters apart, consist of extensive scatters of large basalt flakes. Several large basalt bifaces were present, similar to the bifaces found at the Avon chert procurement sites" (Cameron 1984).

The "Feed Lot" site (24PW1033), "Mannix 28" (24PW1035) and "Mannix 32" (24PW1038) all appear to be in the same general area: around Nevada Lake, north of Antelope Hill. Ann Johnson recorded all three of these sites in 1971. She describes 24PW1033 as a temporary chipping station on a rise overlooking a small creek. She notes that the site is approximately 15 feet in diameter, appears to be a surface deposit only, and contains "Avon Chert debris." Of 24PW1035 she says that it, too, likely served as a temporary chipping station and perhaps a "lookout station." It is approximately 50 x 75 feet in size and contains flakes of "agate (chert)" and basalt, and "arrowheads." No descriptions or drawings of individual artifacts were provided. All three of the site forms contain only minimal information and no further reference (aside from the reference to 24PW1033 and 24PW1038 in Cameron [1984]) to any of the sites could be located.

Another site, 24PW1040, appears to be located in the general area of Nevada Lake. This site, also recorded by Johnson in 1971, extends for approximately 0.5 miles along a plateau that overlooks Finn Creek. This surface site includes agate, petrified wood, basalt and Avon Chert, presumably in the form of flakes; two projectile points (type unspecified); and "numerous" knives and scrapers. Despite the paucity of data included on the site forms for these four sites, they serve to illustrate the fact that the Avon Valley was indeed utilized by prehistoric peoples and that the so-called Avon Chert appears to have been a preferred material type.

Almost due north of Antelope Hill (approximately 3.0 kilometers) is 24PW1044.

This site was initially recorded by Johnson in 1971 and reevaluated in 2000 by HRA of Missoula, Montana. The site is described as a prehistoric campsite/food processing site. It is said to have a "fairly continuous" lithic scatter, as well as thermally affected rock and some culturally-modified trees. The site extends from the north bank of Halfway Creek approximately 500 meters north-northeast into the adjacent hills. There are three thermally altered rock concentrations, described in detail in the 2000 site report; eight projectile points, illustrated in the site report; and a number of culturally-modified trees. The HRA report suggests that the trees were scarred during cambium gathering or in order to mark a trail. The projectile point types represented seem to suggest a continuous occupation or a repeated occupation from the Paleoindian period (there is one fluted point base illustrated in the report) to the proto-historic or historic period.

In 1970, under the supervision of L. K. Napton, a field school from the University of California, Berkeley conducted a surface survey and sampling effort at 24PW320. Hester et al. (1977) describe the site as being located west of Antelope Hill. Though Hester et al. do not provide UTMs or a topographic map indicating the location of 24PW320, the general area sketch map in the publication indicates that the site is located along a small tributary of Strickland Creek, on "low knolls to the west of [the] Creek" (1977:239). During their 1970 investigations, Hester et al. performed a controlled surface collection at two artifact concentrations within 24PW320. From their examination of the materials collected, the team concluded that roughing-out or initial shaping do not appear to have been production goals at Clusters A and B, as the two artifact concentrations were called. Hester et al. propose that such early stage work was performed at "some nearby quarry-workshop" while the focus at Clusters A and B appears to have been reduction "to

produce large interior flakes to be used in implement manufacture" (1977:244). They also mention that the "debitage from Clusters A and B suggest the presence of a flake industry in which both bifacial and simple prepared cores were worked" (1977:244). Though no date was obtained for the materials recovered from 24PW320 and all of the materials considered in the analysis by Hester et al. were collected from the surface, the assertion that bifacial cores were a component of the toolkit at 24PW320, located very close to 24PW340, is an important one, as the previous section on bifaces suggests. Finally, Hester et al. conclude that there are two possible site types represented by Clusters A and B: "1) the clusters represent chipping loci subsidiary to nearby base camps; or, 2) these discrete clusters of debris represent some form of temporary occupation, perhaps related to specialized activities by persons from a nearby base camp or possibly activities of a small group passing through the area" (1977:247). They also mention that Napton had located "extensive midden deposits" nearby and suggest that perhaps the activities represented by Clusters A and B may have been performed by people belonging to whatever nearby camp is associated with the middens. No site report for such middens is on file with Archaeological Records (The University of Montana, Missoula) and no publication mentioning their location or contents has been located. Such information could provide invaluable insights into the prehistoric record of the Avon Valley.

The 1970 Hester et al. investigation (1977) focused on a portion of the site designated "Old Cabin Area" by Napton. Cameron, whose archaeological investigations were conducted in 1984, reports on a site in the Avon Valley (24PW340) that also has an area called the Old Cabin Area (Cameron 1984). Cameron's information was based on an

interim report provided to her by L. K. Napton, written in 1981 (Napton 1981). Though Hester et al. do not provide UTM coordinates or a visual representation on a topographic map of the location of 24PW320, the general area sketch map in the publication indicates that it is located along a small tributary of Strickland Creek, on "low knolls to the west of [the] Creek" (1977:239). The Avon Site (24PW340), on the other hand, appears to be located northeast of 24PW320, directly on the banks of Strickland Creek (Figure 1.3). This is likely what Hester et al. are referring to when they mention that "[t]est excavations had earlier been conducted on the floodplain by Napton, primarily in the region to the north The stream is cutting into buried archaeological deposits in that area; flakes and other lithic debris litter the bottom of the channel" (1977:239). It is unclear why both sites are reported as having subsections designated Old Cabin Area by Napton. Though the surface collections were performed by Hester et al. in 1970, the report of findings did not appear in *Plains Anthropologist* until 1977. Napton's interim report, given to Cameron, was written just four years later (1981). It seems that if the Old Cabin Area (O.C.A.) designation had been applied early-on to a portion of 24PW320 and later reapplied to a portion of 24PW340, or if the term O.C.A. refers to a period in prehistory recognized and described by Napton, that such information would have been explained in one or another of the reports. No official site form is on file at Archaeological Records (The University of Montana, Missoula) for 24PW320 and I was unable to locate a copy of Napton's interim report (1981). It does not appear, given the descriptions of each site's location, that the two reports (Hester et al. 1977; Cameron 1984) are describing the same site. The discrepancy regarding the location or nature of the O.C.A. remains unanswered.

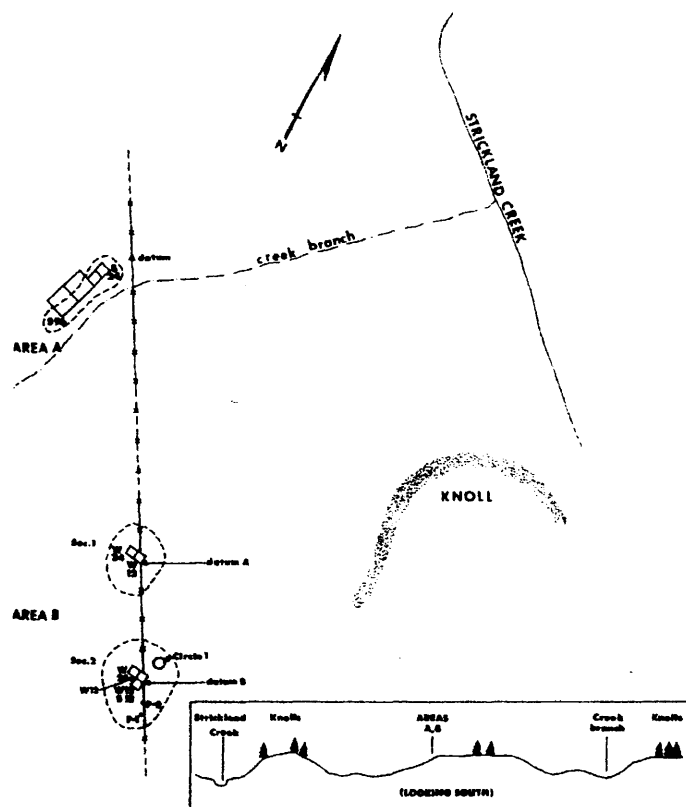


Figure 1.3. 24PW320, Old Cabin Area, in relation to Strickland Creek (Hester et al. 1977:241)

The remainder of this discussion of archaeological sites in the Avon Valley will be devoted to the Avon site (24PW340), which is the focus of this thesis and whose artifacts led to the formulation of the "symmetry index." The Avon site (24PW340) has been called by a number of names—whether as a matter of investigator whim or erroneous designation—including the Little Valley site, the Avon site, Hidden Valley and the Napton site. It will be referred to hereafter as either the Avon site or 24PW340.

The majority of the work done in the Avon Valley has been conducted by Lewis Napton and has focused on 24PW340. He is said to have begun work there in 1956 (Malouf 1985). Napton has performed numerous surveys of the Avon Valley throughout

the years, spent many summers excavating the region's sites and invited many field schools from California to participate in their excavation. Unfortunately, Napton has not published any reports of his findings.

Although his work was ongoing, Napton (1981) provided an interim report of findings concerning 24PW340 to Cameron in order to facilitate her Nevada Creek drainage study (Cameron 1984). The following information is based on the data provided to Cameron by Napton. The Avon site is located west of Antelope Hill, on the west side of Strickland Creek. Napton distinguishes two areas within this site: the Main area and the O.C.A. ("Old Cabin Area"). Radiocarbon dates were obtained from organic material in the lowest levels of the Main area, establishing that the buried soil from which the material came is approximately 9400 years old. "Diagnostic projectile points [at 24PW340] range from Agate Basin, Frederick and Lusk [late Paleoindian] to Bitterroot Side-notched, Oxbow [5,200 - 3,000 B.P.] and Besant [1900 B.P. and later] types (Napton 1981)" (Cameron 1984; parenthetical dates from Frison 1991). The majority of the Oxbow points, however, were obtained from the O.C.A., which led Napton to suggest in his interim report that this area may represent a separate, later occupation. "In general, Napton feels that this site may have been occupied during summer and autumn, as it receives heavy winter snowfall, and that functions relate to chipped stone material procurement and/or temporary occupation during journeys to the Plains" (Cameron 1984:5).

Under the direction of Professor Philip Hobler and hosted by The University of Montana, two field schools (1966-1967) were held at 24PW340. The remainder of this report, as it pertains to that site, will be based on the information obtained during that

time.

During the field seasons of 1966 and 1967, for which student field journals and limited supervisors' notes exist, a number of "features" were excavated. Though a detailed description of the dimensions and locations of these "features" could not be found, it is believed that they were units excavated back from the bank of the creek and expanded parallel to the creek as dictated by the presence of artifacts. In a personal communication with Hobler (2003), he explained that he does not clearly recall his use of the term "feature" and, while he now reserves that term for "a man-made thing such as a hearth, house pit or tipi ring," he admits that he "may have been mistakenly using the term 'feature' to refer to different excavation areas" at that "early point in [his] experience of plains archaeology." He goes on to say that the "principal excavation consisted of broadside scraping of a long arroyo bank. [They] did not cut the bank back more than 30-40 cm in this process" (Philip Hobler, personal communication, 2003).

Three broad, culture-bearing strata were identified at 24PW340. As understood from the student field journals and notes, these are as follows: "surface/topsoil" (Level A; surface to 45.72 cm [18"] below surface), white calcareous zone (Level B; 45.72 to 99.06 cm [18" to 39"] below surface), and banded brown humic zones (Level C; 99.06 cm [39"] below surface to creek level). It appears that excavations followed these natural strata and that no vertical provenience aside from general stratum was recorded for the majority of the artifacts recovered, despite the recognition of numerous substrata evident in profile drawings (Figure 1.4).

Two samples from a "black, humic deposit [within stratigraphic Level C], containing decayed vegetal material, from Hidden Valley site [one of the various names

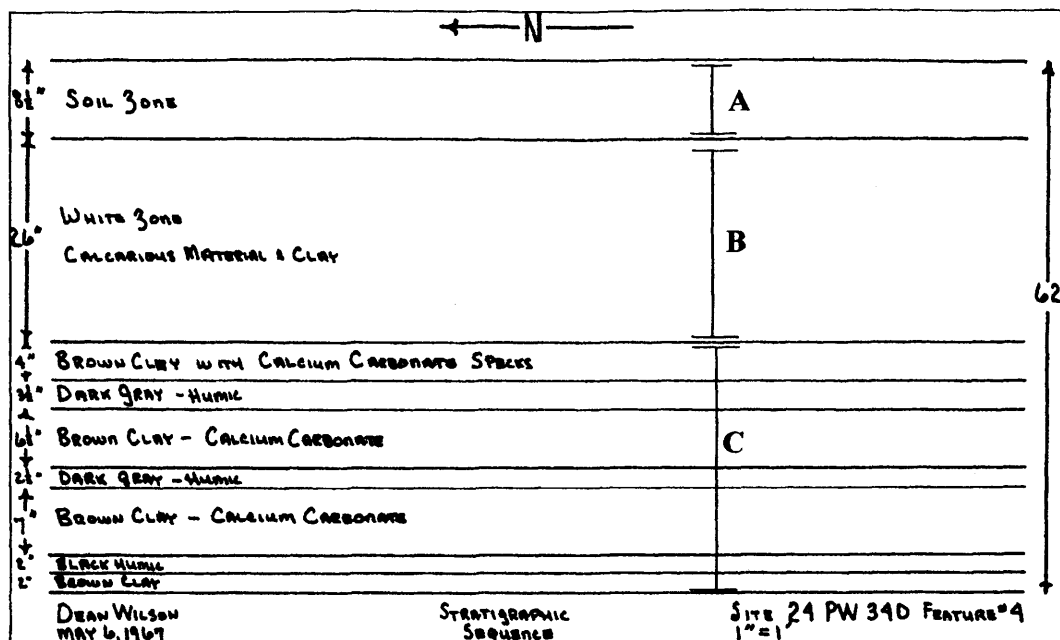


Figure 1.4. Feature 4 profile from Dean Wilson's field notes, 1967

applied to the Avon site] (24PW340)” were submitted for radiocarbon assay in 1967 (Malouf 1971). The dates obtained were 9620 ± 330 (M-1973) and 9200 ± 300 (M-1974). The depths below surface and horizontal proveniences of the dated materials were not listed in the reference from which these dates were acquired. Hobler recalls that “dark organic layers in the bank exposure [Level C] provided materials for 14-C dating” (personal communication, 2003). Doug Melton suggests, however, that a direct association between the dated organic materials and the cultural material retrieved from the Level C is questionable (personal communication, 2003).

Several projectile points were recovered during excavations at 24PW340. Their present location is unknown, however, and they cannot be observed directly. These points are discussed in correspondence between Dick Malouf and Milo McLeod in 1985.

They are described as Lusk points, though their provenience is not disclosed. Given the dates of the "black humic" level the general date range for Lusk points (northwestern Plains typology, ca. 8400 B.P.-7500 B.P.), it is unlikely that the Lusk points came from Level C. In an earlier letter between Richard Malouf and Lewis Napton (Malouf 1971), Malouf says that he is uncertain whether the projectile point discussed by Napton in a presentation of the findings from 34PW340 were from the Agate Basin or Hell Gap Complexes. Either of these two types would be more compatible with the radiocarbon dates provided for the lowest levels at Avon. Hobler recalls that "there were six projectile points. [Carling] Malouf, [Dee] Taylor and [Hobler] went over them and then [Hobler] sent them to Marie Wormington at Colorado for typing. All of them were in the collection that [Hobler] sent back to Montana a few years ago. Type names were Lusk, Frederick and Agate Basin" (personal communication, 2003). All of the point types referred to by Hobler are considered late Paleoindian. The Agate Basin Complex is thought to have been prevalent between 10,500 and 10,000 B. P. (Frison 1991), which falls squarely within the dates obtained through radiocarbon dating. The other two, Frederick and Lusk, are slightly later point types, thought to have been prevalent between 8400 and 8000 B.P (Frison 1991).

It is interesting to note that Hobler and his students conducted a refitting analysis of the Avon materials:

Surprisingly, a fair number of pieces from the lower levels could be fitted on to pieces from the upper levels. This verified that we were dealing with a single component rather than a long time span. How was it that re-fittable pieces got deposited over so much of a vertical extent? This is a good question for which I have never found a satisfactory answer. Deposition in the boggy creek side environment must have been rapid. Maybe a single flood undermined a surface site and it collapsed down the slope (Philip Hobler, personal communication, 2003).

Given the types of projectile points found during Hobler's excavations at Avon, their date ranges, and the refitting analysis discussed above, the cultural affiliation(s) of the makers of the Avon bifaces is unclear. I find it unlikely that all levels of the Avon site represent one temporal/cultural component and suggest bioturbation as the mechanism responsible for the ability to re-fit materials excavated from different strata. The characteristics of the different strata, as described by the 1966/67 field school students, are such that they appear to be discrete and not admixed, except perhaps at their interfaces.

At least 5927 lithic artifacts were recovered during the 1966/67 field seasons. Fifty-three of these are bifaces that are considered complete enough to perform a detailed study of their symmetry. This study of symmetry was developed in order to address the question of whether archaeologists can discuss goals of biface production in meaningful and quantifiable ways. As explained above, I believe that this is tantamount to a discussion of Paleoindian lithic technological organization and mobility strategies. The Avon bifaces do not exist in isolation, however. Of the lithic material recovered from Avon, 5752 specimens are debitage. Debitage can provide a considerable amount of information regarding the reduction strategies employed and, potentially, the goals of production at a site. A study of the Avon debitage is therefore performed in an attempt to elucidate the nature of the activities performed, perhaps the goals of biface production, at that site.

Thesis Outline

The following chapters are devoted in part to the study of the artifacts excavated from the Avon site during the 1966-1967 field seasons. An extensive analysis of the debitage is performed using the Modified Sullivan and Rozen Typology (Prentiss 2001) and the results of a study of small-sized debitage by Baumler and Downum (1989). The non-debitage artifacts are also examined, including a detailed study of the bifaces, which attempts to discern whether the primary technological focus at the Avon site was the production of projectile points, portable bifacial cores or some combination of the two. Another focus of this thesis is an index of bilateral symmetry that was developed as a means for interpreting biface production goals. The symmetry index methodology is described in detail and applied to a number of study groups. All of the methods described herein were chosen and formulated to address the question of whether there are significant differences between early stage projectile point preforms and bifacial cores, which, in turn, facilitates the discussion of whether Paleoindian were indeed bifacial core dependent.

Chapter Two Methods

In this chapter, the methods used to address the question "are there real and quantifiable differences between bifaces intended for use as cores and those intended for use ultimately as projectile points?" and those use to evaluate the debitage and other non-bifacial artifacts recovered from the Avon site (24PW340) are established. A thorough treatment of the subject must include both a detailed description of the empirical methods of measurement that were used and a discussion of the theories and methodologies that justify use of those particular methods. This chapter is divided into three sections: biface analyses, multivariate quantitative analyses, and debitage analyses. Each of the sections begins with a discussion of the analytical tools used to interpret the data. This is followed by a description of the empirical methods of data collection employed to address the topic of that section. The first section describes a pilot study used to investigate the utility of an index of symmetry and includes a discussion of Callahan's stages of projectile point manufacture (1979). This is followed by a description of several study collections of bifaces used in the pilot study, and the section concludes with a description of the methods used to collect data from the Avon bifaces. The second section describes the multivariate quantitative analyses used to substantiate the claims made regarding the utility of the symmetry index, and includes a discussion of what the chosen analytical tools purport to address and the methods of data collection used to perform the analyses. The final section deals with the Avon site debitage and includes a discussion of the Modified Sullivan and Rozen Typology (Prentiss 2001), observations made by Baumler

and Downum (1989) regarding small-sized debitage, and the manner in which data were collected from the Avon debitage.

Biface Analyses--Theoretical Justifications and Methods of Data Collection

The following explores the hypothesis that there are real and quantifiable differences between bifaces intended ultimately for use as projectile points and bifaces intended for use as cores, and that a recently derived measure—the symmetry index—is a useful tool in determining these differences. This method of distinguishing between what most archaeologists refer to as preforms and bifacial cores and/or long use-life tools functions under the assumption that the former will exhibit more perfect bilateral symmetry than the latter. This assumption is based on the assertion by Callahan (1979) and others (Muto 1971; Sharrock 1966; Whittaker 1994) that successful manufacture of projectile points depends upon successful completion of a number of stages, including the achievement of a high degree of symmetry. If Callahan is correct in asserting that completion of each stage of manufacture is requisite for the completion of the subsequent stages, then we can assume that the parameters outlined for each stage would have been held as the ideal for projectile point manufacture among prehistoric stone tool producers, however subconsciously. This would be characterized in the archaeological record by higher proportions of bifaces that fit the criteria for each stage of production as defined by Callahan (1979; outlined below). Bifaces intended for use as cores and/or long use-life tools may have been manufactured under a less specific set of guidelines. This would likely be characterized in the archaeological record by higher proportions of bifaces with edge angle-width/thickness ratio combinations that do not comply with Callahan's

Table 2.1. Attributes of Callahan's projectile point production stages (Adapted from Callahan 1979:30-31)

Attribute	Stage 2	Stage 3	Stage 4
1. width/thickness ratio	core reduction: 2.00-3.00+/-; flake reduction may exceed 6.00	3.00-4.00+/-	4.00-5.00+/-
2. optimum edge angle (spine plane)	55°-75°	40°-60°	25°-45°
3. nature of cross section	thick lenticular to hexagonal irregular	lenticular (bi-convex)	flattened (thin lenticular to hexagonal)
4. nature of flake scar interval	widely to variably spaced	closely to semi-regularly spaced	closely to quite regularly spaced
5. nature of flake scars	high degree of variability; extensively to moderately gouged; "hollow ground" scars	moderate degree of variability; moderately to minimally gouged	low degree of variability; minimally gouged
6. nature of opposing flake scar contact	less than 50% of biface width except at ends	50-70% of biface width; scars just contact at center	50-100% of biface width; scars undercut up to entire width
7. degree of regularity of outline (plan)	irregular outline	semi-regular	regular
8. nature of reduction emphasis	strong emphasis on lineal edge, weak to non-existent on surface and outline	strong emphasis on surface, weak on edge and outline	strong emphasis on surface, moderate on edge and outline

definitions for each stage. They may also exhibit exaggerated thickness for their width, differential thinning, failure to edge the entire perimeter of an objective piece, and/or general asymmetry. Table 2.1 highlights the stages as defined by Callahan².

The most objective and empirically measurable attributes of each stage of biface production, as defined by Callahan, are width/thickness ratio and edge angle. Callahan describes his methods of measuring these attributes thus:

² In his 1979 study, Callahan's objective was to delimit the stages of biface production from "blade flakes" to finished, fluted, Clovis-style projectile points. A principal assumption being made here is that, up to a certain point, the stages are applicable to the production of *any* finished projectile point. Justification for this assumption is that Callahan's early stages (2-4) are general and successful completion of each deals primarily with thinning, removing surface irregularities and achieving symmetry.

Width/thickness ratios were obtained by dividing the width [width at widest point, taken at 90° to length] by the thickness (thickness at center of the widest point of the biface, at the juncture of the length and the width axes, not necessarily at the thickest point) (Callahan 1979:32).

Callahan's methods of deriving edge angles and width/thickness ratios were employed during assessment of the Avon bifaces, so as to justify comparison of the Avon data set to those of Callahan's experimental collections. The edge angles and width/thickness ratios of the Avon bifaces were then used to assign the bifaces to a particular production stage as defined by Callahan. The Avon site bifaces were distributed among Callahan's stages thus: two within the parameters for stage 2, six within stage 3, and one within stage 4 (Table 2.2). These assignments were based on combinations of edge angle and width/thickness ratio, which are the two objective, quantifiable criteria provided by Callahan. Other factors, however, such as facial flaking patterns, frequency of surface irregularities and "aligned and centered" edge angles (Callahan 1979) make some of the assignments questionable. That is, four of the bifaces assigned to Callahan's stage 3 on account of edge angles sufficiently low and width/thickness ratios sufficiently high for placement into this stage, are more appropriately considered stage 2 bifaces on account of surface irregularities and "sinuous" edges. Therefore, using the more subjective of Callahan's criteria for assignment of bifaces to a stage of production, the distribution of the Avon bifaces is as follows: six within stage 2, two within stage 3 and one within stage 4 (Table 2.2). It can be said that the objective criteria provided by Callahan for the assignment of bifaces to production stages are unreliable, while the subjective criteria, though perhaps a better indicator of production stage, are precisely that—subjective—and are, therefore, also unreliable.

Table 2.2. Number of Avon bifaces assigned to Callahan's stages based on objective (edge angle and width/thickness ratio) and subjective (surface characteristics and sinuosity of edges) characteristics.

	Objective Criteria	Subjective Criteria
Stage 2	2	6
Stage 3	6	2
Stage 4	1	1

Callahan's biface reduction stages provide a useful starting point for the recognition of goals of production among the makers of bifaces in that deviation from the guidelines for these stages may indicate production without a preconceived, desired finished product in mind. As illustrated by the Avon bifaces, however, assignment of bifaces to stages of production using both the objective and subjective criteria established by Callahan can be somewhat problematic. An assessment of bilateral symmetry among bifaces may help to clarify production stages and indicate goals of production. The following is a pilot study of the utility of an index of symmetry, which I propose may aid our understanding of the goals of biface production among Paleoindians.

Methods Fifty-three bifaces were recovered from the Avon site, exclusive of finished projectile points³ and biface fragments considered too small to assess accurately. Each of the Avon bifaces was examined for the following information: material type, width, thickness, width/thickness ratio, edge angle, weight, the presence of usewear, evidence of thermal alteration, break type (if any), and symmetry index value.

The three material types recognized among the bifaces are chert/marl, basalt and

³ The projectile points were not present in the collection when I first acquired it in 2003. In correspondence with Philip Hobler, it was determined that the projectile points were with the rest of the collection when it was sent back to The University of Montana from Simon Fraser University a few years prior to my inquiry. Hobler recalls that there were six projectile points recovered during the 1966/67 field seasons (Philip Hobler, personal communication, 2003).

"other." The marls and cherts were classified together and may actually include marls, porcellanites and cherts, given the formation processes described by Fields (1984). Fields notes that "[i]t is difficult to distinguish a marl from a porcellanite without very detailed and sophisticated study. It is even more difficult where authogenic chert, chalcedony or opal has invaded the system via groundwater and altered the original structure. In the case of the 'Avon Chert' all of these features are present" (1984:17). The "other" materials consist of those things not readily identifiable and materials whose characteristics do not match those described by Fields (1984) for locally-occurring materials. Width and thickness were measured in millimeters and recorded at the landmarks provided by Callahan (1979) in order to justify the initial comparison of the two data sets. The width/thickness ratio was then calculated. Edge angle was taken as a spine plane measure on one lateral margin of each biface at a point though to be representative of the mean edge angle of the specimen. The symmetry index was calculated as described below. Weight was measured in grams and hundredths of grams. The presence of usewear and evidence of thermal alteration were noted for each artifact.

The problem of assessing symmetry in a quantitative way is not often discussed, particularly in the archaeological literature. Montet-White has discussed aspects of symmetry, though with a goal wholly different from that intended here (1973). In a study of artifacts from Le Malpas rockshelter, she discusses her use of a polar coordinates grid:

From a central point on the graph paper radiates a series of lines, the polar axes, spaced at five degree intervals. One of these axes, usually the 0/360 degree lines, constitutes the arbitrary axis of origin of the polar coordinates system. Angles are read from the axis of origin and distances are measured along the polar axis from the centroid. Data recording starts when a planar projection of the artifact to be studied is placed at the center of the polar grid. Then a series of points are marked at the intersection of polar axes with the artifact perimeter.

Descriptive points are defined by a linear and an angular measurement. . . Effectiveness of the analysis hinges on: (1) the consistent definition of the artifact centroid, (2) selection of the artifact orientation and (3) the number and placement of points (Montet-White 1973:61).

The final statement in the quote above, regarding the factors upon which effectiveness of the method is contingent, introduces a critical point in the use of a polar grid to assess symmetry: definition of the centroid and artifact orientation. This is illustrated as Montet-White describes the proper and consistent definition of the artifact centroid and the selection of artifact orientation for two artifact types: “blanks” (understood to mean flakes) and tools:

When dealing with blanks, the centroid is the midpoint of a line drawn between the butt and the tip of the artifact. . . The butt or platform is centered on the 0°-360° axis so that the tip normally coincides with the 180 axis [Figure 2.1]. . . In the case of marginally retouched tools, the centroid marks the junction of the working area with the tool haft. . . [Tools are] oriented according to working axis, with the tip or working extremity placed as if it were in contact with material to be worked. The centroid, then, is defined by drawing an arbitrary line between the lateral extremities of the line of retouch and by determining the center of that line (1973:64).

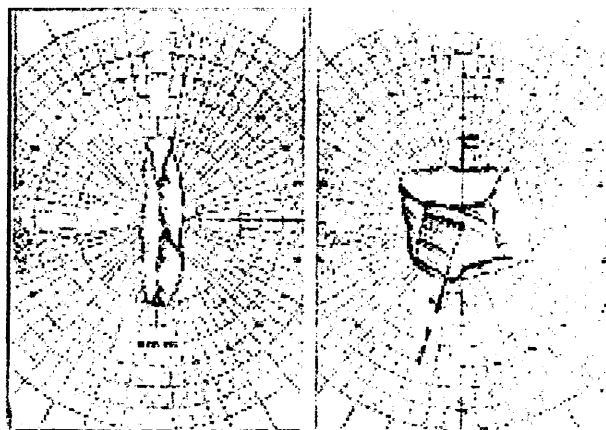


Figure 2.1. Correct positioning of artifacts on a polar coordinates grid (Montet-White 1973:64)

Neither of these orientations on the polar grid was appropriate for the Avon artifacts since no bulbar axis could be established in order to use the protocol designed to describe “blanks,” and none of the bifaces exhibit a haft area, necessary for the orientation of tools on the polar grid. Borchert experienced a similar problem when examining within-type and between-type variation among Angostura, Frederick, Lusk and James Allen points (1989). Borchert used illustrations of projectile points from a variety of archaeological collections, upon which she superimposed a polar grid. She describes her methods thus:

Most of the points illustrated were incomplete. If a proximal (basal) or distal (tip) fragment were centered on the polar grid paper, then the primary variance [between points] would be in the lengths of the fragments. This would be the case even if proximal and distal fragments were isolated in the analysis. I chose to standardize the length of the fragment and approach comparison based on width and shape. This was accomplished by taking the shortest proximal and distal fragments and establishing a set point. The shortest proximal fragment was set below the 90/270 degree axis and the set point was marked at the base of the point. This was done based on an imaginary line from one edge of the base to the other. In that way, the incurvate base center would be above the set point and the excurvate base center would be below the set point. . . . All points measured were placed according to the appropriate set point and centered on the 0/360 degree axis (1989:26).

One problem with the application of Borchert's method to the Avon artifacts is that it requires that all bifaces have either a proximal or distal end and offers no alternative method for medial fragments, as her collections did not contain any such fragments. Furthermore, she does not discuss what is meant by “centered” on a particular axis. Whether the centering of the artifacts on the 0/360 degree axis is intuitive or mathematically derived can have a profound effect on measurements of symmetry. Finally, it was discovered that even complete, finely crafted projectile points from various

archaeological collections, used in the present study to highlight use of the symmetry index (discussed below), were not always compatible with Borchert's methods. That is, the "imaginary line from one edge of the base to the other" is not always perpendicular to the longitudinal axis of the biface and thus an unsuitable axis for orientation of the bifaces on a polar grid as it would be used to assess bilateral symmetry.

The two studies discussed above were explored as potential methods for assessing symmetry on bifacial artifacts. It is understood that neither Montet-White nor Borchert was attempting to assess bilateral symmetry in the manner proposed here and that they were both, in essence, making comparisons between artifacts and artifact groups rather than between two sides of singular specimens. The discussion provided above is not intended as a criticism of their methods, but rather as an explanation of the reasons that they cannot be used to discuss intra-specimen bilateral symmetry in a reliable, quantitative manner.

An alternative to the methods described above sought to address certain shortcomings of those methods with respect to the Avon material. The following is a description of an early attempt to assess bilateral symmetry. This description is provided in order to show the evolution of the present method, thereby highlighting the benefits of the most recent version of the symmetry index.

The first step, and perhaps the most problematic, in both early and later versions of calculating symmetry is to establish the midline of a biface. Montet-White et al. discuss the proper procedures for establishing axes and measuring artifacts:

"Measurements are taken by inscribing the artifact into a quadrangular figure. The striking platform is placed at the base and the axis of percussion is perpendicular to the

base. The geometric description of an artifact is based on an analysis of the relation of the lateral and transverse edges to the longitudinal axis. The longitudinal axis is the median line drawn from the point of percussion of a flake tool, or medial point of the base of a bifacial tool. . ." (1963:10). While this method ensures consistent and accurate measurements for flakes, flake tools and bifacial tools, it requires that bifaces possess a distal tip and a complete base for accurate establishment of the longitudinal axis. Many artifacts, however, lack such landmarks and another method had to be devised to accommodate such specimens. The longitudinal axis is the focal point for this study of symmetry and thus its proper (or at very least replicable) establishment is imperative for a relevant discussion of bilateral symmetry.

During the initial attempt at quantifying symmetry, a line rendering of each biface was produced by placing the artifact on a piece of grid paper and tracing its outline very carefully and with a fine-tipped pencil. In order to "fix" the orientation of the bifaces and provide a reference by which to make axes parallel or perpendicular, each biface outline was inscribed into a quadrangular figure per Montet-White et al. (1963), clarified here to mean a four-sided figure with four right angles. Each biface was oriented within a quadrangular figure such that the farthest projection of each lateral margin touched the sides of the figure and its distal end touched the top of the figure. Thus, the dimensions of each figure were equal to the maximum dimensions of each biface (Figure 2.2).

Under normal circumstances, after the longitudinal axis is established, the axis of maximum width is drawn as a line perpendicular to the longitudinal axis through the widest part of the artifact. Given the fact that a number of the bifaces examined in this study lack proximal and/or distal ends, and given the perpendicular relationship of the

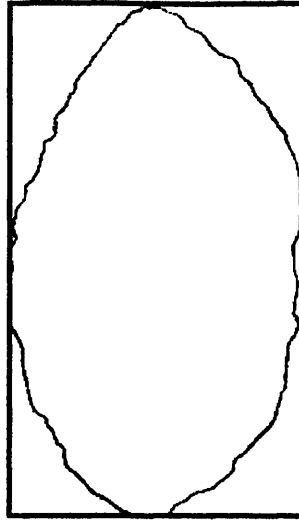


Figure 2.2. Biface oriented within quadrangular figure

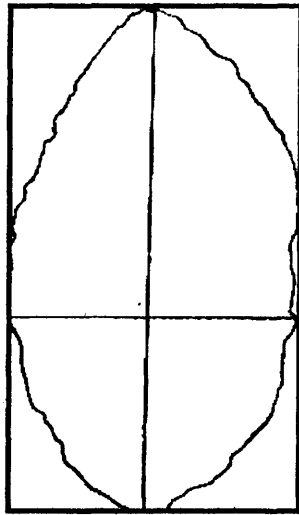


Figure 2.3. Biface with axes of longitude and width established

axes, it was reasoned that the placement of the axes could be established "backwards." That is, the axis of maximum width is established first, and then the longitudinal axis is established as a line perpendicular to the axis of maximum width at the midpoint of the latter (Figure 2.3). Consistent use of this method of determining the midlines of bifaces

regardless of whether their proximal and distal ends are intact allows for comparison of all data sets and allows for inter-observer replication. Furthermore, the validity of this method is supported by the fact that its application to 26 finished projectile points used as a comparative collection in this study resulted in a longitudinal axis identical to that which would have been drawn by more conventional methods 85% of the time. That is to say, by the method described above, 22 of 26 finished projectile points had longitudinal axes drawn from the distal tip to the midpoint of the base.

Finally, it is necessary to accommodate bifaces with breaks oblique to the midline. Not correcting for this would result in grossly elevated indices of symmetry where zero is the ideal. Broken portions of bifaces should be excluded from comparison by partitioning them with a line parallel to the base of the quadrangular figure just "above" the break (Figure 2.4). After correcting for breaks oblique to the midline, if the remaining portion of a particular biface is thought to be too small to accurately represent its symmetry, the specimen ought to be excluded from analysis. No minimum percent of total is suggested here, as the method is still in its infancy; such decisions are left to the discretion of the analyst.

After establishing the axes of maximum width and longitude and correcting for breaks oblique to the midline, the initial calculation of symmetry proceeded thus: The length of the longitudinal axis between proximal and distal ends (or between an extant proximal or distal end and the partition line for broken sections) was divided into ten equal portions. Then a straight line distance, parallel to the base of the quadrangular figure, between the midline (longitudinal axis) and the lateral margins of the biface at each of the ten points along the midline was calculated in millimeters for each side of

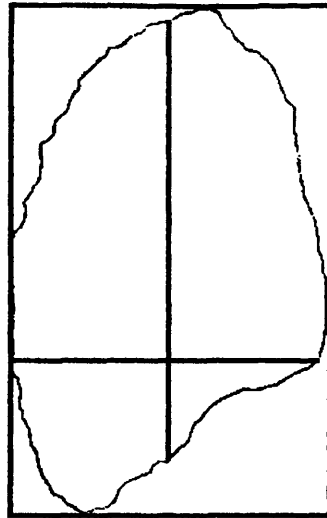


Figure 2.4. Biface partitioned "above" break

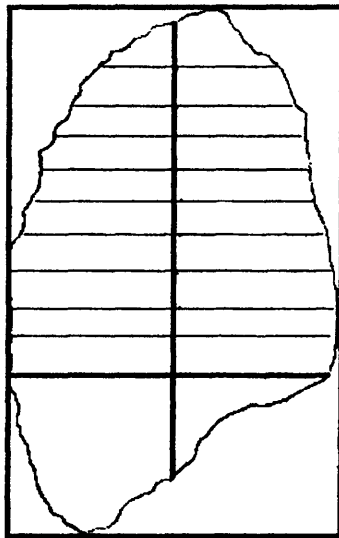


Figure 2.5. Placement of measurements according to initial calculation of Symmetry Index

the biface (Figure 2.5). Each of these distances was converted to a percent of the total width of the biface at that point in order to correct for size biases that would result from calculation of raw data. That is, large points have the potential for much higher numbers overall and thus would appear less symmetrical than smaller bifaces regardless of actual

symmetry. For each of the ten points along the midline, the percentage from one side was subtracted from the other and recorded as an absolute value. The sum of these absolute differences was then calculated and this figure represented the index of symmetry. An example of this method is provided in Table 2.3.

Table 2.3 An example of the initial method of calculating the symmetry index, using the data collected from Avon specimen 24PW340-112

"Left" Side	"Right" Side	%Left	%Right	Difference
8.5	18	32.1	67.9	/-35.8/
11.5	24	32.4	67.6	/-35.2/
22	24	47.8	52.2	/-4.4/
25	25.5	49.5	50.5	/-1/
28	27	50.9	49.1	/1.8/
27	28	49.1	50.9	/-1.8/
29.5	27	52.2	47.8	/4.4/
30	25.5	54.1	45.9	/8.2/
32	20	61.5	38.5	/23/
33	19	63.5	36.5	/27/

				Symm. Index= 142.6

By this method, the number of points along the midline could be increased or decreased as the recorder saw fit. Ten was chosen since it provides a large enough number of points for comparison so as to increase accuracy, yet not so many as to exceed a reasonable "cost-benefit" relationship. I realized, however, after calculating symmetry indices for a number of bifaces, that this method of quantifying symmetry had the potential to overlook gross irregularities on bifaces and thus produce highly inaccurate assessments of symmetry as illustrated in the dramatization in Figure 2.6. Therefore, an alternative approach was devised.

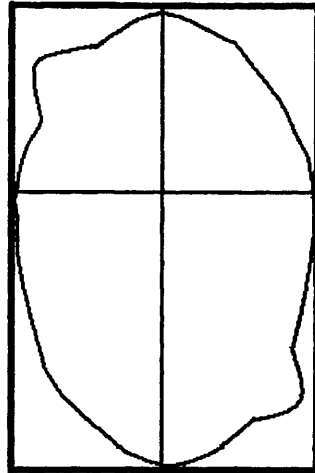


Figure 2.6. Dramatization of the potential for irregularities to cancel each other out when the index is calculated by the initial method. The symmetry of this specimen might approach 0 (perfect) despite the obvious irregularities

Symmetry in this revised version of the symmetry index is assessed according to the difference in surface area on either side of the midline of a given biface. A digital photo of each physical specimen was taken with a Canon Powershot 540, mounted on a tripod 78 cm from the floor. Each artifact was placed on a white background and lit by an overhead light source so as to diminish shadows that might skew the true outline of each biface. The photos were downloaded to a computer and each digital image was converted to a single-pixel-wide line rendering in Photoshop. The outline of each biface was inscribed into a quadrangular figure as described above, and the axes of longitude and width were established. Broken portions were excluded from analysis, also as described above. Having established the midline and corrected for breaks oblique to the midline, the next step is to fold the biface outlines along their midlines (Figure 2.7a). This is most easily achieved using a light table and a printed version of the line rendering, though a folded image can also be achieved using Photoshop or another graphics program at a

slightly higher cost in time, and for a slightly higher benefit in accuracy. For the remainder of the procedure, a digital medium is highly recommended in order to minimize error and facilitate the calculation of surface area. Images of bifaces folded along their midlines should be scanned and entered into a graphics program such as Photoshop if the light table method is used to fold the bifaces, or opened into Photoshop if a digital method is used. Most image manipulation software packages, such as Photoshop or Illustrator, have a "histogram" function that will count the total number of colored pixels in a particular image. In order for the numbers produced using the histogram function to be relevant in the calculations that follow, it is necessary to convert each image to a black and white bitmap format; grayscale images confound the black/white juxtaposition necessary to calculate the symmetry index. The symmetry index can then be calculated as follows: 1) Tally the number of pixels that comprise the outline of the folded image and any other darkened pixels that may result from imperfections on the paper being scanned or dust on the scanner bed. This number should be recorded, as it is a factor in the symmetry index equation given below. Failure to account for the outline pixel contribution will skew the end result and guarantee an inaccurate measure of symmetry. 2) The investigator should then fill in all of the area that the two sides of a given biface do *not* have in common when folded along the midline (Figure 2.7b). Then, using the histogram function, the program can be made to tally the number of black pixels; this number should be recorded⁴. 3) Next, all of the area that the two sides of the biface *do* have in common should be filled in. A histogram

⁴ In the interest of time and ease of operation, shaded areas were not un-shaded between steps 2 and 3, resulting in cumulative pixel counts. This point is a fundamental to the final equation given. The equation must be adjusted accordingly should the investigator choose to subtract the outline pixel contribution from all subsequent histogram tallies.

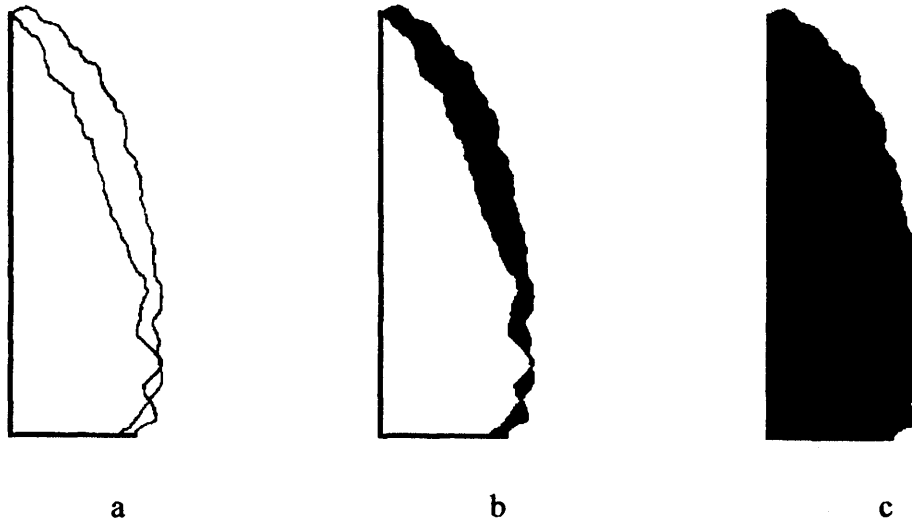


Figure 2.7a. Outline of a biface folded along its midline. 2.7b. Area that the two sides do not have in common are shaded. 2.7c. Area that the two sides do have in common are shaded.

function should be performed, and this number should be recorded (Figure 2.7c). 4) The symmetry index is then calculated as a ratio of area difference to total area, which can then be converted to a "percent difference." Therefore:

Symmetry Index = x/z

Given that: $r_2 - r_1 = x$

$r_3 - x = y$ and

$2y + x = z$

Where: r_1 = outline contribution

r_2 = area difference

r_3 = area in common

Example: Specimen 24PW340-112

r_1 (outline contribution) = 116022

r_2 (area difference) = 277246

r_3 (area in common) = 2140674

such that $x = 161224$, $y = 1979450$,

$z = 4120124$ and

symmetry index = 0.0391 (or 3.91% difference)

Calculation of the index as a ratio eliminates size effect. That is, larger bifaces have the potential for much higher numbers overall and thus would appear less symmetrical than smaller bifaces regardless of actual symmetry. As the index number approaches zero, the object is more symmetrical since the area difference makes a smaller contribution to the equation.

The Symmetry Index Pilot Study The symmetry index functions under the assumption that the makers of bifaces would not strive for perfect symmetry if the goal was to produce cores or long use-life tools, whereas bifaces produced according to a preconceived mental template and intended for use as finished projectile points would be more likely to reflect that ideal. In order to test this theory, illustrations of twenty-six finished projectile points from various sources and representative of a wide range of temporal and cultural affiliations; illustrations of ten bifaces representative of each of Callahan's stages (2, 3, and 4; taken directly from Callahan 1979); illustrations of the fifty-three Avon site bifaces, divided by stratigraphic level; and thirty-two illustrations of generically termed "bifaces" from the literature were subjected to the protocol for assessing bifacial symmetry, described above. The collection of finished projectile points includes Clovis points from the Anzick site (Frison 1991:42), Clovis points from the Fenn Cache (Frison 1991:44), Goshen points from Carter/Kerr-McGee (Frison 1991:52), Agate Basin points from the Agate Basin type site (Frison 1991:60), Hell Gap points from the Casper site (Frison 1991:61), Alberta points from the Hudson-Meng site (Frison 1991:63), Alberta-Cody points from the Horner site (Frison 1991:65), Besant points from the Muddy Creek site (Frison 1991:106), Dalton points from the central/southern Plains (Kay 1998:187), a Lecroy bifurcate point from Pennsylvania (Swope 1982:38), and a Dovetail point from Tennessee (Swope 1982:92). Ten illustrations of each of Callahan's bifacial stages (2, 3, and 4) were taken directly from Callahan's work (1979). Digital renderings of fifty-three bifaces from the Avon site were used in this study. These were recorded and analyzed according to stratigraphic level, including Levels A, B, and C, and "surface." This last category includes bifaces that were surface collected before

excavation of the units had begun as well as bifaces thought to have been surface collected from the greater Avon site area. Finally, illustrations of 32 "bifaces" were used for comparison in this pilot study. These include specimens from Vermilion Lakes, Alberta (Fedje et al. 1995); the Carter/Kerr-McGee site (Frison 1984); Frank's Folsom Campsite (Stanford and Broilo 1981); the Sims site, Tennessee (Adair 1976); Lindenmeier (Wilmsen and Roberts 1979); the Mount Jasper site (Gramly 1980); and the Horner site (Bradley and Frison 1980; Frison 1980).

The methods described above were used to calculate symmetry indices for all 141 bifaces. The indices for each study group were then plotted on continua and analyzed relative to one another in order to recognize trends among different types of bifaces. It was hypothesized that if the symmetry index is able to detect small variances in symmetry among different stages of projectile point production, it will be illustrated by the distribution of the sample groups' symmetry indices on the continua. Then descriptive statistics, including mean, median, inter-quartile range and extreme scores, were calculated for each group and compared to one another. The results of this pilot study are presented in the next chapter.

Quantitative Analyses The quantitative analyses described below were selected for three reasons: 1) to discern whether there are statistically significant differences between bifaces as preforms and bifaces as cores, 2) to determine whether the symmetry index is a useful tool in assessing those differences, and 3) to compare the validity of visual assessments of bifaces to that of assessments using quantifiable variables.

Data from fifty three bifaces from four different culture-bearing strata of the Avon

site (24PW340) were used in the quantitative analyses. Unfortunately, the other data sets used in symmetry index pilot study (preforms produced by Callahan through replicative experimentation [1979], a group of generically termed “bifaces” from the literature, and illustrations of 26 finished projectile points) had to be excluded from the present analyses since other variables considered here, such as weight, width, width/thickness ratio and edge angle, were not consistently provided in the sources from which they were drawn.

The variables considered in these analyses and coded using the SPSS statistical package (version 11.0) included material, width, thickness, width/thickness ratio, edge angle, symmetry index, weight, the presence or absence of usewear, evidence of thermal alteration, break type, symmetry index value, and subjective value. Material type was coded using an ordinal scale, where 1 equals chert (cryptocrystalline), 2 equals marl (also cryptocrystalline but not an ideal knapping material), 3 equals a mix of chert and marl (the marl that crops out near the Avon site was invaded by silica in the geologic past and some archaeological specimens contain elements of both), 4 equals basalt, and 5 equals quartzite (Table 2.4). Width, thickness and width/thickness ratio were measured in millimeters and recorded at the landmarks provided by Callahan (1979) in order to justify the initial comparison of the two data sets. Edge angle was taken as a spine plane measure on one lateral margin of each biface at a point thought to be representative of the mean edge angle of the specimen. The symmetry index was calculated as described above. Weight was measured in grams and hundredths of grams. The previous five measures were recorded as ratio scale variables (Table 2.5). Artifacts that bear evidence of utilization were coded with a 1; artifacts that were not utilized were coded with a 2; and when it could not be established whether and artifact had been utilized, the number 3

Table 2.4. Ordinally scaled variables and the designations for each value

Value	Material Type	Use Wear	Thermal Alteration	"Symm. Index Val."	"Subjective Val."
1	chert	present	present	>5.0	probable preform
2	marl	not present	not present	4.9 - 2.0	probable core
3	chert/marl	indeterminate	indeterminate	<1.9	indeterminate
4	basalt	-----	-----	-----	-----
5	quartzite	-----	-----	-----	-----

Table 2.5. Ratio scaled variables and their units of measure

Variable	Unit of Measure
Width	millimeters
Thickness	millimeters
Width/thickness ratio	width (mm)/thick (mm)
Edge angle	spine plane, degrees
Symmetry index	area difference/total area (pixels)
Weight	grams

was assigned. Artifacts that bear evidence of thermal alteration were coded with a 1; artifacts that were not thermally altered were coded with a 2; and when it could not be established whether an artifact had been thermally altered, the number 3 was assigned. Break type was recorded as a set of nominally scaled variables and includes perverse fracture, lateral snap, no break, and indeterminate (Table 2.6).

Table 2.6. Nominally scaled variables and their values

Break type	Value 1	Value 2
Break	present	absent
Perverse fracture	present	absent
Lateral snap	present	absent
Indeterminate	yes	no

Based on information derived from the symmetry index pilot study, I hypothesized that bifaces with symmetry indices above 5.0 are most likely to represent cores. Those with symmetry indices below 1.9 are almost certainly projectile points or late stage preforms, and those between 4.9 and 2.0 are indeterminate since many preforms—both early and late stage—and some probable cores fall within this range. Organizing the cases in this way permits analysis of whether these groups, specifically the probable cores versus the probable preforms, share other attributes in common. Therefore "symmetry index value" was scaled ordinally (1=symmetry index >5.0, 2=symmetry index between 4.9 and 2.0, 3=symmetry index < 1.9 (Table 2.4). Finally, the "subjective value" variable was derived by visually assessing the bifaces in the Avon collection. Those with surface features (such as flaking pattern, facial fineness, sinuosity of edges, and others) that appear to be probable projectile point preforms were assigned the number 1. Bifaces that appear to represent probable cores were assigned the number 2 and those whose probable function is indeterminate were assigned the number 3.

A number of multivariate quantitative analyses were performed on the Avon biface data using the SPSS statistical package (Version 11.0). The methods discussed below have explanatory power regarding the research questions posited here: Are there significant and discernable differences between bifaces intended ultimately for use as projectile points (preforms) and those intended for use as cores, and is symmetry a useful variable in determining these differences?

Contingency tables were calculated for sets of variables in order to discern whether the makers of the bifaces from the Avon site expressed a preference for combinations of particular attributes. The ability to recognize statistical preferences for

particular combinations of attributes potentially offers insights into knapper behavior. Understanding knapper behavior, then, allows further analyses of overall technological organization and mobility strategies. The results of the Chi-squared tests for independence are discussed in the next chapter.

A factor analysis was performed on the Avon biface data. Width, thickness, width/thickness ratio, edge angle, symmetry index and weight were entered as the variables under consideration. The extraction method used was Principal Components Analysis and the component matrix was rotated using the Varimax rotation method with Kaiser Normalization. After the factor analysis was interpreted, the factor scores were used to perform a Q-mode hierarchical clustering analysis, using an average linkage method. Q-mode analyses create a numerical taxonomy of individual cases (bifaces). That is, SPSS links the bifaces considered most similar based on the factor scores provided, and constructs a dendrogram illustrating the iterations in which bifaces and groups of bifaces were linked. Groups of linked bifaces can then be evaluated for other similarities and broad patterns of knapper behavior can be interpreted.

Discriminant function analysis is a powerful tool for assessing the effectiveness of particular variables selected in determining specimen membership in a particular group. The Avon data were subjected to two such analyses. In the first analysis, "symmetry index value" was selected as the grouping variable and the range was defined as 1 to 3 (1 = >5.0, 2 = 4.9-2.0, 3 = <1.9). The independent variables used were material, thickness, width, width/thickness ratio, edge angle, symmetry index, presence/absence of use wear, break type, weight, and presence/absence of thermal alteration. Group statistics were produced and examined, as were the casewise statistics.

Since the results provided by discriminant function analysis, which is a multivariate quantitative analysis, do not have any statistical significance as such, two-sample t-tests were performed. The means values of the >5.0 sample (probable cores) were compared to those of the <1.9 sample (probable preforms) for all of the ratio scaled variables (thickness, width, width/thickness ratio, edge angle, symmetry index, and weight) collected from the Avon bifaces. I performed these tests in order to discern whether, statistically speaking, the samples could have been drawn from the same population.

In the second discriminant function analysis, "subjective value" was selected as the grouping variable and the range was defined as 1 to 3 (1 = probable preform, 2 = probable core, 3 = indeterminate). The independent variables used were material, thickness, width, width/thickness ratio, edge angle, symmetry index, presence/absence of use wear, break type, weight, and the presence/absence of thermal alteration. Group statistics were produced and examined, as were the casewise statistics. Two-sample t-tests were performed, comparing the data from the subjectively identified probable cores to that from the probable preforms for all of the ratio scaled variables (thickness, width, width/thickness ratio, edge angle, symmetry index, and weight). The results of these analyses are presented in the following chapter.

The Avon Debitage--Theoretical Justification and Methods of Data Collection

Although the Avon biface analyses offer some valuable insights into the type of lithic technological organization employed by the producers of that collection, it is judicious to seek support of any hypothesis from multiple lines of evidence. The majority

of the artifacts recovered from the Avon site are debitage. Debitage offers the potential to understand the types reduction techniques and, potentially, the goals of production at a site. Magne (1989:15) says,

[b]eing an immediate byproduct of manufacturing activity, debitage largely escapes curative efforts (Collins 1975, Magne 1985); it is also abundant, widespread and therefore suited to statistical manipulation (Collins 1975, Magne 1985). Debitage retains evidence of prior manufacturing steps, thus its variability must in some ways be related directly to the formal variability of intended products of manufacture.

Thus, I considered a debitage analysis a useful compliment to the biface analyses, in that it could offer another line of evidence of the goal or goals of production at the Avon site. The Avon site data, then, could be offered as supporting evidence for either the high-tech forager model (Kelly 1988; Kelly and Todd 1988) or the argument that the archaeological record does not support that model strongly (Bamforth 2002).

Given the volume of debitage from the Avon site (N=5752) and the dubious nature of its provenience (see below), an exhaustive analysis of each artifact was neither practical nor worthwhile in the greater scheme of interpreting knapper behavior at the Avon site. Rather, a distinctive aggregate approach was employed. Using the Modified Sullivan and Rozen Typology (Prentiss 2001), I was able to consider the debitage from each stratigraphic level of the Avon site as a group in order to address broad patterns of behavior.

The Sullivan and Rozen Typology (1985; Sullivan 1987) and a modified version of that approach (the Modified Sullivan and Rozen Typology [MSRT]; Prentiss 2001) play a key role in the analysis of the Avon site debitage. Five flake-completeness categories are used in the following analyses: non-orientable pieces, medial-distal

fragments, split flakes, proximal fragments and complete flakes. Non-orientable pieces lack a single, identifiable interior surface. Medial-distal fragments exhibit a single ventral surface, but lack an identifiable point of applied force (initiation). Split flakes exhibit a single ventral surface and an identifiable initiation, but have a sheared axis of flaking (i.e. they are split perpendicular to the point of applied force). Proximal fragments have a single ventral surface and an identifiable point of applied force but lack an identifiable termination.

Sullivan and Rozen assert that hard hammer percussion, often associated with core reduction, will produce high percentages of complete flakes and non-orientable pieces relative to other flake types (1985). This assertion is based on the observation that hard hammer reduction tends to yield relatively thick flakes that remain complete, or else shatter under the force of the percussor, resulting in non-orientable pieces. Conversely, soft hammer percussion, often associated with biface thinning and tool production, tends to produce thinner flakes that are prone to snapping, thereby increasing the percentages of medial-distal and proximal fragments in an assemblage. Sullivan and Rozen state that “[t]he high proportion of broken flakes and flake fragments. . . is related to the mechanical failure of very thin flakes which separate into several pieces during biface or tool manufacture” (1985:769). However, Prentiss and Romanski (1989:92) assert that among their experimental data,

tool production consistently results in far more numerous complete flakes than core reduction. Moreover, almost as many proximal fragments are found in core reduction assemblages as are found in tool production assemblages. This contradicts Sullivan and Rozen’s assumption that tool assemblages should contain exceptionally high numbers of proximal fragments and low numbers of complete flakes compared to core reduction assemblages.

Furthermore, Prentiss (1998:647-648) has shown that

though reliable, the SRT [Sullivan and Rozen Typology] does not appear to be a valid measuring instrument, at least for application to highly vitreous raw materials such as obsidian and perhaps other more brittle raw material types such as vitreous basalt or perhaps some fine-grained cherts. . . While the SRT allows rapid data collection from large sized assemblages, it also collapses variability, which is typically partitioned along flake size dimensions. . . The resulting data are often homogenized to the point that 'tool' production takes on many of the characteristics of 'core' reduction and vice versa.

Prentiss went on to explore the combination of flake-completeness and flake size in debitage analyses in an attempt to remedy the collapse of variability under the SRT (2001). He established a series of size classes ("small: .64 to 4 sq cm; medium 4 to 16 sq cm; large: 16 to 64 sq cm; and extra large: >64 sq cm" [Prentiss 2001:148]) and then sorted debitage from a number of experimental assemblages, produced by various reduction techniques, according to size class and Sullivan and Rozen flake completeness type. He found that "core and tool reduction resulted in distinctively different debitage distributions. Core reduction assemblages tended to produce more numerous larger, complete, proximal and split flakes, in addition to medium medial-distal and non-orientable fragments and small non-orientable fragments. Tool production assemblages resulted in more frequent small medial-distal and proximal fragments and very few to no non-orientable fragments" (2001:171). The MSRT was used to analyze the Avon site debitage, since it combines flake-completeness and flake size and is thus a more effective tool in distinguishing core reduction from tool production.

The MSRT is indeed an effective tool in distinguishing core reduction from tool production. However, Prentiss' (1998, 2001) experimental collections were produced on Glass Butte obsidian and his observations, therefore, reflect the results of reduction

activities on a far more brittle material than that found at the Avon site. The Avon chert/marl is a tougher raw material than Glass Butte obsidian, and so we can expect slightly different proportions of flake completeness types among assemblages produced during Avon chert/marl reduction events. Logic dictates that this would be most evident in the proportion of complete flakes among the Avon debitage as compared to that of Prentiss' (1998, 2001) obsidian assemblages. The tougher Avon material is expected to produce higher proportions of complete flakes regardless of production goal than the more brittle obsidian in Prentiss' experiments. While the MSRT is still used as an analytical tool in this thesis, I found it necessary to augment that approach with another in order to assess the Avon debitage through multiple lines of evidence in an attempt to correct for any biases inherent in the Avon material type.

Small-sized debitage (following Baumlér and Downum [1989:101], "arbitrarily defined as lithic manufacturing waste between 1 and 20mm in maximum dimension") offers a unique opportunity to study lithic reduction sequences and production goals. Baumlér and Downum (1989:101) suggest that "different lithic reduction and assemblage formation processes result in variable proportions of large and small byproducts and that these differences can be useful in inferring the responsible processes." They go on to describe "an experimental study to investigate the morphological characteristics of small-sized debitage generated by two fundamental activities in lithic reduction: . . . 1) core reduction/flake production and 2) tool manufacture/retouch" (Baumlér and Downum 1989:101-102). Through these experiments, they found that "core reduction consistently produced higher percentages of shatter and lower percentages of complete flakes than scraper manufacture [tool production]" (Baumlér and Downum 1989:106). Although

Baumler and Downum focus on the debitage group between 2 and 4 mm maximum dimension, I believe that their findings are also applicable to the small size class of debitage from the Avon site. The small size class at Avon, in accordance with Prentiss' (2001) definition of that size class is 0.64-4 squared centimeters, or 8-20 mm maximum dimension. Therefore, the Avon material was also analyzed in light of these conclusions.

Methods As part of her Master's thesis research, Leslie Riley (2004) passed all of the Avon Site debitage through a series of nested screens and assigned size class labels of G1-G4 accordingly. G1, the largest screen in the series, measures 2.54 cm² (1") per aperture. G2 measures 1.27 cm² (0.5") per aperture, G3 measures 0.635 cm² (.25") and G4 measures 0.318 cm² (0.125"). Riley then sorted each size class by material type: marl/chert, basalt and "other." The marls and cherts were classified together and may actually include marls, porcellanites and cherts, given the formation processes described by Fields (1984). Fields goes on to note that "[i]t is difficult to distinguish a marl from a porcellanite without very detailed and sophisticated study. It is even more difficult where authogenic chert, chalcedony or opal has invaded the system via groundwater and altered the original structure. In the case of the 'Avon Chert' all of these features are present" (1984:17). Furthermore, it is likely that all of the cherts and silicified marls came from one of two places—the Antelope Hill/Rhine Point quarries or the pediment capping gravels along the Strickland Creek—thus making their differentiation superfluous; the source(s) of the lithic materials present at the Avon site is irrelevant to the goal of this paper. The "other" materials consist of those things not readily identifiable and materials whose characteristics do not match those described by Fields (1984) for locally-occurring materials.

In an initial analysis of the Avon site, Level C debitage, I attempted to apply Prentiss' (2001) findings to the debitage as it was size-classed by Riley (2004). During that analysis, each bag of debitage, as sorted by Riley according to stratigraphic level, size class and material type, was further sorted into five flake-completeness categories: non-orientable pieces, medial-distal fragments, split flakes, proximal fragments and complete flakes. Counts were made according to level, material type, size class and flake-completeness type. These counts were recorded, converted to percentages and graphed in bar charts. However, the size classes used by Prentiss (2001) and Riley (2004), respectively, do not correspond and the first analysis was laden with contingencies: for example, *if* size class G1 is comprised mostly of debitage that would fall into Prentiss' "large" size class, *then and only then* can it be assumed that core reduction was the primary reduction strategy at the Avon site during the Level C occupation. I was unable to draw any satisfactory conclusions regarding the technological foci of the three stratigraphic levels at Avon. Therefore, a reorganization of the Avon debitage was necessary.

In a more recent study of the Avon debitage, each stratigraphic level and material type was sorted according to the following size classes: extra large (>64 sq cm), large (16-64 sq cm), medium (4-16 sq cm) and small (0.64-4 sq cm), following Prentiss (2001). Squares of the appropriate dimensions for each size class were drawn on a piece of paper. Each piece of debitage was placed on the size class diagram with its dorsal face up and its proximal end touching the top of the square thought to best represent its size class. If any dimension of the piece exceeded the dimensions of the square, that piece was included in the next highest size class. Non-orientable and medial-distal fragments were admitted to

the next highest size class if their maximum dimension exceeded the dimensions of a particular square, regardless of orientation within the square.

Each size class was then further sorted using the Sullivan and Rozen (1985; Sullivan 1987) flake-completeness typology. Counts were made according to stratigraphic level, material type, size class and flake-completeness type. These counts were recorded, converted to percentages and graphed in bar graphs. Finally, during the sorting and counting, notations were made regarding the presence of cortex, the frequency of blade-like flakes, and the amount of debitage that shows evidence of thermal alteration. The results and analysis of this study are presented and interpreted in the following chapter.

Summary

This thesis aims to address biface production goals among prehistoric knappers. If there are real and quantifiable differences between bifaces produced for use as portable cores and bifaces produced as projectile point preforms, then by making detailed observations of these differences and applying them to archaeological contexts we might better understand Paleoindian lithic technological organization and mobility strategies. I hypothesize that symmetry plays a key role in our ability to determine these differences and I offer an index for quantifying bilateral symmetry on bifacial artifacts. Methods of employing the symmetry index were outlined in this chapter. A number of multivariate quantitative analyses were outlined as well, which are intended to substantiate the claim that the symmetry index is a useful tool. Finally, since hypotheses are strengthened by the use of multiple lines of evidence, I have also outlined the methods used to assess

production goals at the Avon site through an aggregate analysis of the debitage from that site. In the following chapter, the results produced by the methods outlined here are presented.

Chapter Three Results

The symmetry index described in the previous chapter was designed to quantify bilateral symmetry on bifaces. I believe that symmetry plays a key role in our ability to determine the difference between bifacial cores and projectile point preforms, when the difference is not readily apparent by more traditional means. While the bifaces are of primary importance to this thesis, in that I believe their level of bilateral symmetry to be a key indicator of production goals, an analysis of the debitage offers a secondary line of evidence for knapper behavior. By assessing the Avon site bifaces in conjunction with the debitage, I hope to more fully understand the goals of production at that site.

Understanding production goals among prehistoric knappers, and particularly Paleoindians, is crucial to our understanding of other patterns of behavior, such as overall technological organization and the mobility strategies that such organizations are thought to represent. The Avon site has been selected as the archaeological site with which to test the hypothesis that there are real and significant differences between bifaces produced for use as projectile points and bifaces produced for use as cores and that the degree of bilateral symmetry present among bifaces can be indicative of such differences.

The following is a presentation of the results produced when the theories and methods described in the previous chapter were applied to the Avon materials and the biface study collections.

As in previous chapters, in order to discuss each theme in as straightforward a way as possible, this chapter is divided into sections. The first section reports the results of the symmetry index pilot study. Descriptive statistics for each of the study groups are

provided and their distributions relative to one another are discussed. The results of the multivariate quantitative analyses are presented in the second section. This includes a detailed report of the results of each analysis and an interpretation of the results. The final section contains a detailed report of the classification of the debitage using the Modified Sullivan and Rozen Typology (Prentiss 2001) and Baumler and Downum's (1989) observations. This is followed by an analysis and interpretation of the distribution of flake-completeness types among the different stratigraphic levels, size classes and material types. Insofar as they are relevant to an interpretation of the Avon site and the determination of production goals at Avon, this section also includes a description of other artifacts from the site.

Biface Analyses

The Symmetry Index Pilot Study

Symmetry indices were calculated for each of the bifaces from the various study groups: illustrations of 26 finished projectile points from various sources and representative of a wide range of temporal and cultural affiliations; illustrations of ten bifaces representative of each of Callahan's stages (2, 3, and 4; taken directly from Callahan 1979); illustrations of the 53 Avon site bifaces, organized by stratigraphic level; and a sample of 32 illustrations of generically termed "bifaces" from the literature. The indices were then rendered graphically in order to interpret the results. The descriptive statistics for each group's symmetry indices show a well-defined progression through Callahan's stages and into finished projectile points (Figure 3.1). Callahan's stage 2 bifaces produced a mean symmetry index of 6.13, with a standard deviation of 1.42 and

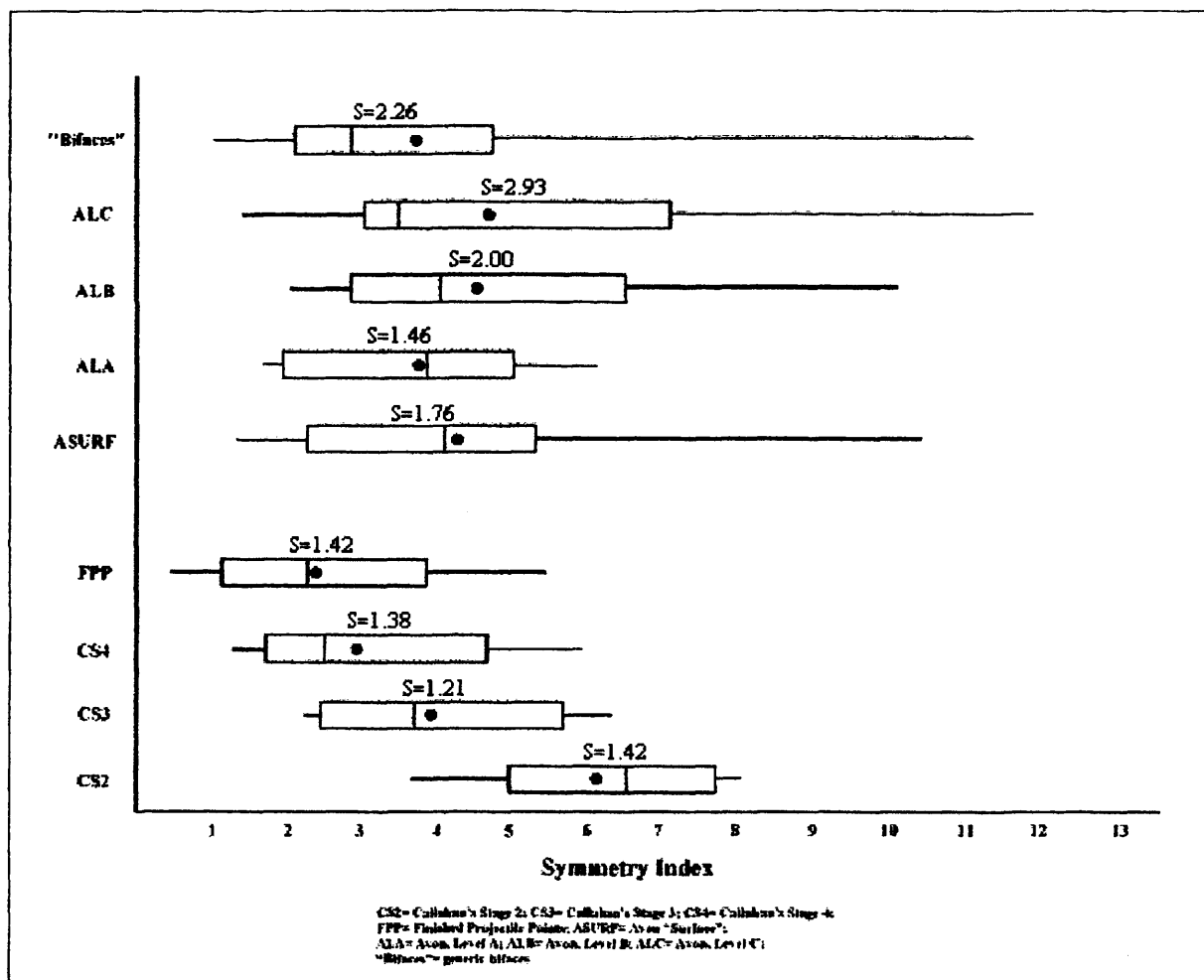


Figure 3.1. Descriptive statistics regarding the symmetry indices of the various study groups

extreme scores of 3.65 and 8.06. Callahan's stage 3 bifaces produced a mean symmetry index of 3.97, with a standard deviation of 1.21 and extreme scores of 2.31 and 6.26. Callahan's stage 4 bifaces produced a mean symmetry index of 2.85, with a standard deviation of 1.38 and extreme scores of 1.33 and 5.92. The group of finished projectile points produced a mean symmetry index of 2.37, with a standard deviation of 1.42 and extreme scores of 0.53 and 5.41.

The archaeological collections show much less pronounced patterns. The group of generically-termed "bifaces" produced a mean of 3.65, with a standard deviation of

2.26 and extreme scores of 0.98 and 11.13. The Avon site "surface" bifaces produced a mean symmetry index of 4.31, with a standard deviation of 1.76 and extreme scores of 1.39 and 10.48. The Avon site, Level A bifaces produced a mean symmetry index of 3.72, with a standard deviation of 1.46 and extreme scores of 1.67 and 6.10. The Avon site, Level B bifaces produced a mean symmetry index of 4.52, with a standard deviation of 2.00 and extreme scores of 2.08 and 10.18. The Avon site, Level C bifaces produced a mean symmetry index of 4.62, with a standard deviation of 2.93 and extreme scores of 1.44 and 11.88. The broad ranges present among the archaeological collections are harder to interpret than the progression from early stage to late stage preforms and projectile points described above. In an attempt to tease out patterns from among these data sets, the symmetry index numbers for each group were plotted singly and then compared.

The symmetry indices for each study group were plotted on continua and compared directly to one another (Figure 3.2). The distribution, where zero equals perfect symmetry, further illustrates the functional utility of the method and allows for a more informed analysis of the archaeological collections. As we would expect, the finished projectile points cluster closest to perfect symmetry, between zero and three percent difference, with a few outliers. Following these are Callahan's stage 4 bifaces, which are farthest along in the sequence of production of finished projectile points, often lacking only the fluting and finishing retouch on the lateral margins. These are grouped between 1.5 and 2.5 with some outliers. Next are the stage 3 preforms, which are slightly less finished than stage 4 preforms, and grouped between 3.0 and 4.0. And finally stage 2, with the majority of the specimens falling between 6.0 and 8.0 percent difference.

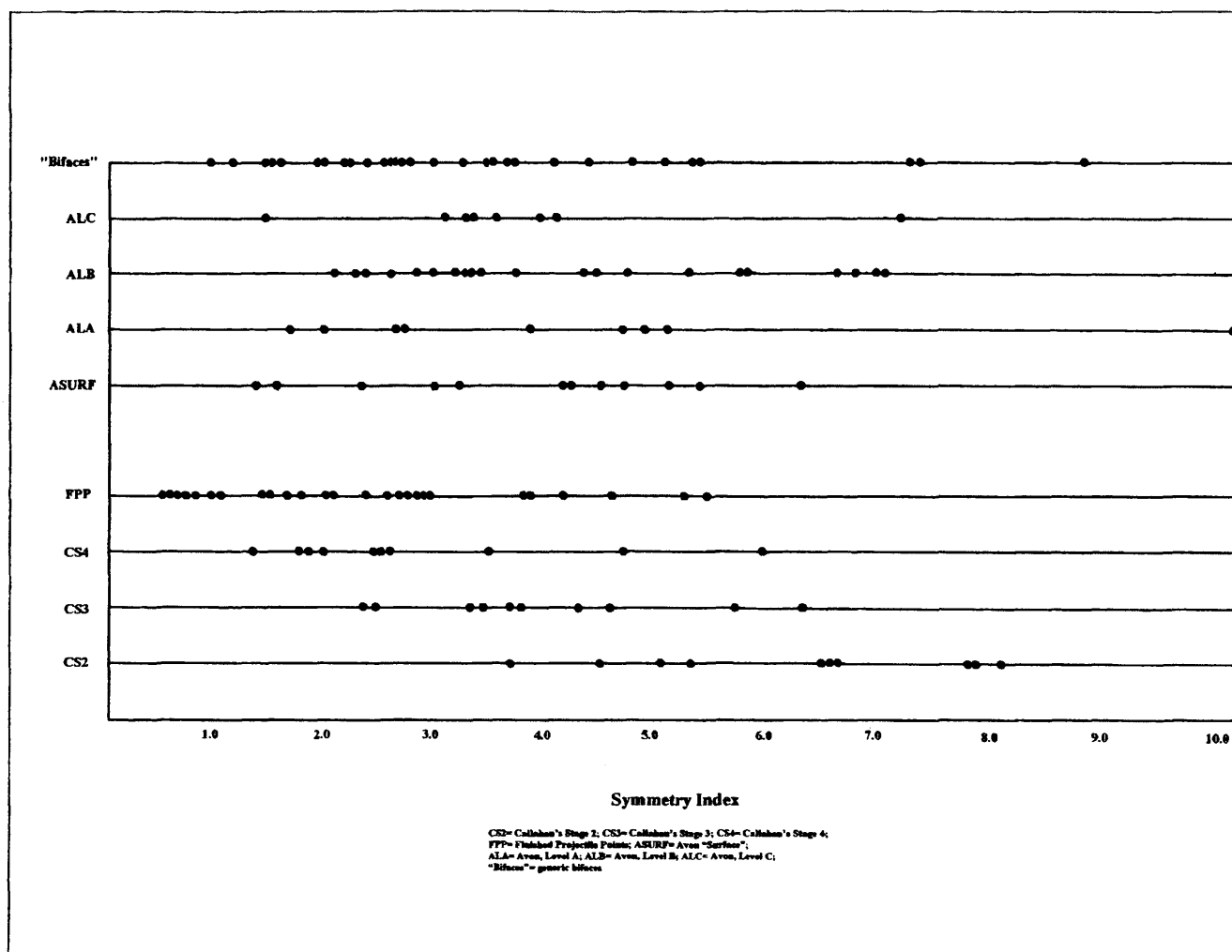


Figure 3.2. Symmetry indices for each study group plotted on continua

Given the distributions of the study collections (finished projectile points and Callahan's stages of projectile manufacture), and visual assessment of the surface characteristics of both illustrated and physical specimens, I hypothesize that bifaces with indices greater than 5.0 are most likely to represent bifacial cores, while those with indices below 2.0 almost certainly represent projectile point preforms.

By comparing them with the sample groups whose goal of production is unambiguous (i.e. finished projectile points and Callahan's experimentally produced

stages of projectile point manufacture) we can interpret the archaeological collections in a more informed way. The "surface" bifaces (N=13) seem to be most similar to Callahan's stage 2-3 preforms. Three of the surface bifaces have symmetry indices above 5.0, which may be indicative of bifacial core use in addition to the preform manufacture suggested by the majority of the bifaces from this level. The majority have indices between 3.0 and 5.0—closely resembling Callahan's stage 2-3 preforms. Four of the bifaces with indices between 3.0 and 5.0 exhibit breaks that are consistent with failure during preform thinning. Three of the "surface" bifaces have indices near 2.0, which suggests late stage preform manufacture. Though the provenience of these "surface" artifacts is vague, it appears that projectile point manufacture was the chief focus among the producers of this collection.

The bifaces from Level A of the Avon site (N=9) fall into three categories: those with indices above 5.0 (N=2), those between 3.0 and 5.0 (N=3) and those with indices just above or below 2.0 (N=4). The majority of the bifaces from this level most closely resemble Callahan's stage 3-4 bifaces, and so it appears that Level A is also dominated by the production of projectile point preforms.

Of the Level B bifaces (N=22), eight have symmetry indices in excess of 5.0 and may represent bifacial cores. Three of the Level B bifaces have indices at or just above 2.0, and these are very likely projectile point preforms. The remaining majority has indices between just under 3.0 and 5.0 and most closely resemble Callahan's stage 3.

Relatively speaking, Level B has the highest percentage (36.4%) of bifaces with high symmetry indices. Whether this level represents a period of incipient bifacial core use, or the activities of a culturally-distinct, bifacial core-using group cannot be

determined from the evidence at hand. This level not only produced the most bifaces, but it also produced the least amount of debitage. Therefore, a strong argument could not be made for increased overall activity thereby increasing the likelihood that bifaces with high symmetry indices would be discarded.

The bifaces from Level C of the Avon site are grouped between 3.0 and 4.0 percent difference, with three exceptions: one above 5.0 and two below 3.0. The majority (3 of 5) of the bifaces in the group between 3.0 and 4.0 exhibit breaks consistent with manufacturing errors during preform thinning. These correspond most closely to Callahan's stage 3. However, the asymmetrical outlier may be representative of a biface intended for use as a core. Still, similar to the other stratigraphic levels, projectile point production appears to have been the central focus of production during the Level C occupation.

The sample of bifaces derived from the literature regarding Folsom and late Paleoindian sites (N=32) was analyzed in a similar manner in order to get a sense of the types of bifaces being found in the archaeological record. For the most part these are termed simply and ambiguously "bifaces" in the references from which they were drawn, and their function is often neither stated nor implied. When we consider the way they are distributed along the continuum, we see that there is a broad range, with a concentration between 2.0 and 4.0 (N=15), but with a number of specimens whose symmetry indices exceed 5.0 as well (N=7). This suggests that this group of generically termed "bifaces" may actually be representative of both preforms and bifacial cores.

These preliminary analyses support the functional utility of the symmetry index. It appears that the symmetry index is able to detect slight differences in symmetry and

that there are recognizable differences in average symmetry indices between each of Callahan's stages and finished projectile points. In order to substantiate these claims, I performed a number of multivariate quantitative analyses using the Avon biface data. The results of these are described below.

Quantitative Analyses

The results of the quantitative analyses make a strong case for the use of an index of symmetry in the assessment of bifacial artifacts and biface production goals. The following are the results of those analyses.

Chi-squared tests of independence were performed on attributes of the Avon bifaces in order to determine whether the makers of the bifaces expressed preferences for certain combinations of attributes. The ability to recognize statistical preferences for particular combinations of attributes potentially offers insights into knapper behavior. Understanding knapper behavior, then, allows further analyses of overall technological organization and mobility strategies. Among the attribute combinations examined for the Avon bifaces, there is a significant relationship between material type and "symmetry index value" (bifaces are grouped according to whether they are >5.0 symmetry index, between 4.9 and 2.0, or <1.9 symmetry index). The Chi-squared value for the table is significant at the 0.001 level with 8 degrees of freedom (Table 3.1). That is, the calculated Chi-squared value exceeds the Chi-squared tabled value at the 99.9% confidence interval. Therefore, I reject my null hypothesis of independence and conclude that there is a relationship between material type and symmetry index value. A bar chart

Table 3.1. Chi-Squared value for material type and “symmetry index value”

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	25.579	8	.001
Likelihood Ratio	18.511	8	.018
Linear-by-Linear Association	8.783	1	.003
N of Valid Cases	53		

of the data shows that bifaces with symmetry indices above 5.0 are made exclusively of chert and marl with the exception of one basalt biface with a high symmetry index (Figure 3.3). Furthermore, there are no bifaces with symmetry indices below 1.9 produced on chert. The data suggest that the makers of these artifacts expressed a preference for large, asymmetrical bifaces made on chert and marl and fine, symmetrical bifaces of basalt and quartzite. It is possible, however, that the disparity is representative of incipient flaws in the chert and marl which caused breakage at earlier stages of projectile production resulting in a disproportionate representation of large, asymmetrical bifaces among these material types.

Other contingency tables showed significant correlations at or above the 90% confidence level. Close examination of these relationships revealed that their explanatory power was limited, however, and they were excluded from final analysis of the Avon site bifaces. For example, the correlation between symmetry index value and whether an artifact was thermally altered was significant at the 0.09 level (Table 3.2). Only a very small percent (3.8%) of the total sample (N=53) was thermally altered. Two thermally

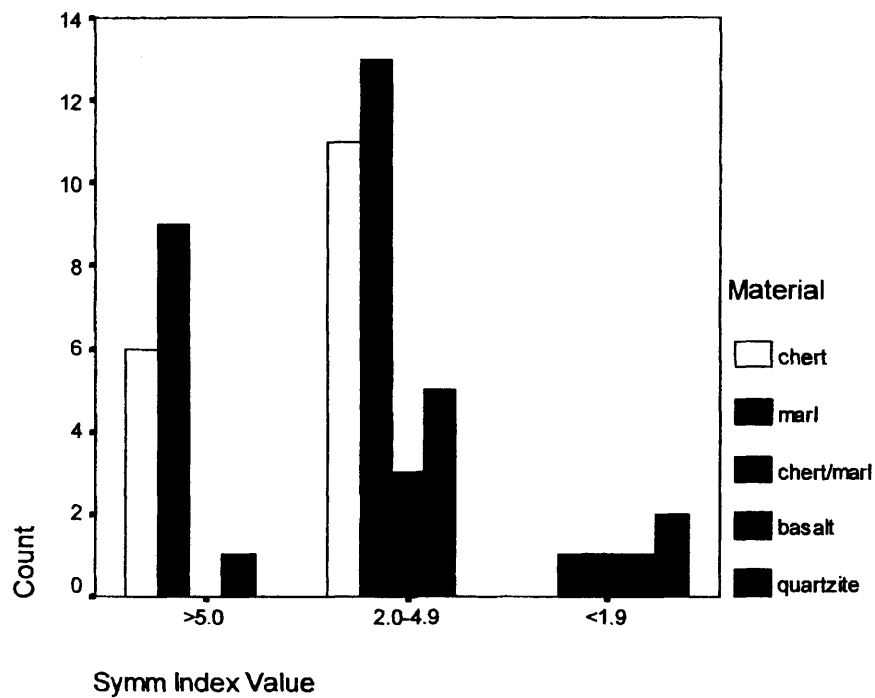


Figure 3.3. Symmetry index values among material types from Avon

Table 3.2. Chi-Squared value for thermally altered and "symmetry index value"

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.806	2	.090
Likelihood Ratio	4.975	2	.083
Linear-by-Linear Association	3.626	1	.057
N of Valid Cases	53		

altered bifaces with symmetry indices >5.0 were observed when 0.6 were expected, resulting in a Chi-squared contribution of 3.27, which accounts for the majority of the calculated Chi-squared value. This figure seems to offer little by way of explanation of whether the makers of the Avon bifaces expressed a preference for thermal alteration of asymmetrical bifaces.

The factor analysis produced some very interesting results. When width, thickness, width/thickness ratio, edge angle, symmetry index and weight were entered as the variables under consideration, greater than 72.5% of the total variance was explained by the first two factors generated, with factor one contributing 53.57% of that figure (Table 3.3). Factor one was characterized by high positive loadings on width (0.956), thickness (0.867), edge angle (0.624) and weight (0.885). I determined this to be a general size factor. Factor two was characterized by a moderate positive loading on symmetry index (0.689) and a high negative loading on width/thickness ratio (-0.814). I determined this to be a factor dealing primarily with shape, expressing an inverse relationship between the two variables (Tables 3.4-3.5). That is, as width/thickness ratio increases, symmetry index decreases. This is to be expected, since high width/thickness ratios denote broad, thin bifaces, characteristic of projectile points and late stage preforms. As symmetry index decreases, the more symmetrical the biface, and the more likely it is to be a finished projectile point or a late stage preform. These factor scores were saved as variables and subjected to a Q-mode cluster analysis. Since size is not strongly relevant to the study at hand, the first factor was not considered.

Table 3.3. Principal Component Analysis: initial statistics.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.214	53.568	53.568	3.214	53.568	53.568	2.857	47.622	47.622
2	1.143	19.054	72.623	1.143	19.054	72.623	1.500	25.000	72.623
3	.806	13.433	86.056						
4	.537	8.948	95.004						
5	.221	3.685	98.689						
6	7.866E-02	1.311	100.000						

Table 3.4. Principal Component Analysis: correlation matrix.

		Width	Thickness	W/T Ratio	Edge Angle	Symmetry Index	Weight
Correlation	Width	1.000	.807	-.031	.505	.108	.787
	Thickness	.807	1.000	-.453	.655	.273	.746
	W/T Ratio	-.031	-.453	1.000	-.320	-.216	-.203
	Edge Angle	.505	.655	-.320	1.000	.275	.453
	Symmetry Index	.108	.273	-.216	.275	1.000	.200
	Weight	.787	.746	-.203	.453	.200	1.000
	Sig. (1-tailed)	Width		.000	.414	.000	.221
Thickness		.000		.000	.000	.024	.000
W/T Ratio		.414	.000		.010	.060	.072
Edge Angle		.000	.000	.010		.023	.000
Symmetry Index		.221	.024	.060	.023		.075
Weight		.000	.000	.072	.000	.075	

Table 3.5. Principal Component Analysis: rotated component matrix. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 3 iterations.

	Component	
	1	2
Width	.956	-6.696E-02
Thickness	.867	.385
W/T Ratio	-9.998E-02	-.814
Edge Angle	.624	.449
Symmetry Index	9.226E-02	.689
Weight	.885	9.877E-02

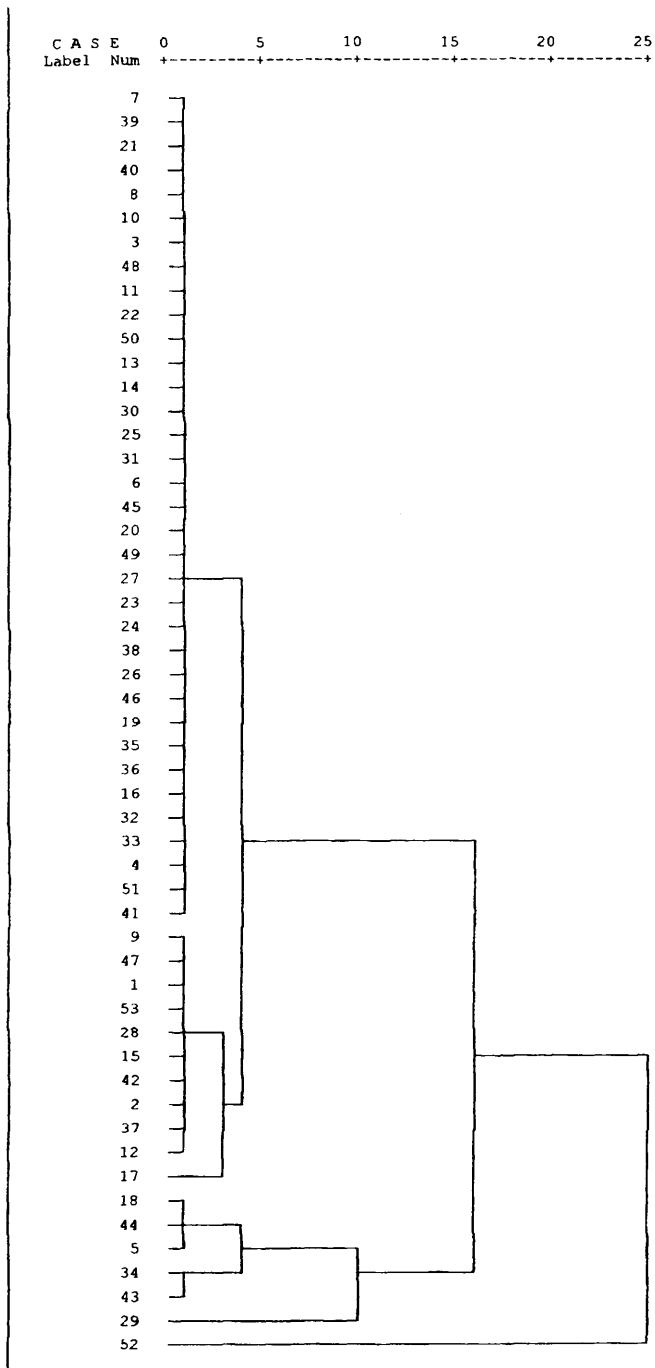


Figure 3.4. Dendrogram produced through Q-mode hierarchical clustering analysis using factor scores and an average linkage method (between groups)

Using an average linkage method, a dendrogram was generated which illustrates three general clusters of cases (Figure 3.4). Clustered in the first iteration were thirty five bifaces that share in common symmetry indices between 2.0 and 5.0, with three exceptions, and width/thickness ratios between 2.2 and 3.9. These represent the "symmetry index value" category 4.9-2.0 and likely contain both preforms and cores. Another ten bifaces were also clustered together in the first iteration based on high symmetry indices (>5.0, with one exception) and low width/thickness ratios. These represent the "symmetry index value" category >5.0, the probable cores. Six of the remaining seven bifaces were grouped together in three stages and share in common very low symmetry indices (<2.0, with one exception) and very high width/thickness ratios (>4.0). These represent the symmetry index value category <1.9, the probable preforms. This group makes up the third main cluster. A final biface, specimen 24PW340-52, was grouped last and seems to stand apart from the other bifaces in that it has an exceedingly high symmetry index (15.6).

The fact that the hierarchical clustering analysis produced groups of artifacts consistent with the "symmetry index value" groups is significant. Based on the "shape" factor produced during the factor analysis, which includes the amount of bilateral symmetry present in a given specimen, the program recognized a distinction between bifaces that are likely representative of cores and those that are likely representative of projectile point preforms. This validates use of "symmetry index value" as a grouping variable in the discriminant function analysis.

The discriminant function analyses were perhaps the most useful method of addressing whether there are significant and identifiable differences between bifaces

intended for use as projectile points and bifaces intended for use as cores. For the first analysis, "symmetry index value" was selected as the grouping variable and the range was defined as 1 to 3 (1 = >5.0, 2 = 4.9-2.0, 3 = <1.9). The independent variables used were material, thickness, width, width/thickness ratio, edge angle, symmetry index, utilized/not utilized, break type, weight, and presence/absence of thermal alteration. Regarding group statistics (Table 3.6), bifaces with symmetry index values greater than 5.0 (N=16) share in common high mean width (47.81 mm), high mean thickness (16.69 mm), low mean width/thickness ratio (3.03), high mean edge angle (49.69°), and high mean weight (56.68 g). That is, the less symmetrical a biface, the larger the overall dimensions. The middle class of bifaces (between 4.9 and 2.0; N=32) are difficult to interpret since that group is likely composed of different types of bifaces including both preforms (mostly late stage with a few early stage) and cores. The final class, (<1.9; N=5) is opposed to the first class (>5) in that it is characterized by high mean width (49.2 mm), low mean thickness (11.6 mm), high mean width/thickness ratio (4.26), low mean edge angle (39.2°), and low mean weight (40.82 g). The opposition between the first (>5.0) and final (<1.9) "symmetry index value" classes is interesting since smaller overall dimensions do not necessarily dictate more perfect symmetry, nor are larger dimensions prerequisite for asymmetry. As suggested by the symmetry index pilot study outlined above and Christenson's studies of projectile point aerodynamics (1986), a high degree of symmetry, wide width and relative thinness, and low weight seem to have been held as the ideal during projectile point manufacture. This also underscores the usefulness of the >5.0/<1.9 categories in the determination of core versus preform.

Table 3.6. Discriminant analysis using "symmetry index value" as the grouping variable: group statistics.

Symm Index Value		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
>5.0	Material	1.7500	.77460	16	16.000
	Width	47.8125	13.61112	16	16.000
	Thickness	16.6875	6.27661	16	16.000
	W/T Ratio	3.0344	.59639	16	16.000
	Edge Angle	49.6875	11.82494	16	16.000
	Symmetry Index	7.6150	2.93191	16	16.000
	Utilized	2.1875	.54391	16	16.000
	Break Type	2.7500	1.23828	16	16.000
	Weight	56.6750	40.91559	16	16.000
	Thermally Altered	1.8750	.34157	16	16.000
2.0-4.9	Material	2.0625	1.04534	32	32.000
	Width	43.6328	12.32850	32	32.000
	Thickness	13.8594	4.93708	32	32.000
	W/T Ratio	3.3775	1.01149	32	32.000
	Edge Angle	44.4375	7.58155	32	32.000
	Symmetry Index	3.4512	.79155	32	32.000
	Utilized	1.8750	.65991	32	32.000
	Break Type	1.9688	.64680	32	32.000
	Weight	42.3184	36.28803	32	32.000
	Thermally Altered	2.0000	.00000	32	32.000
<1.9	Material	3.8000	1.30384	5	5.000
	Width	49.2000	12.46295	5	5.000
	Thickness	11.6000	1.55724	5	5.000
	W/T Ratio	4.2600	.91701	5	5.000
	Edge Angle	39.2000	5.49545	5	5.000
	Symmetry Index	1.5240	.31691	5	5.000
	Utilized	2.0000	.70711	5	5.000
	Break Type	2.2000	.44721	5	5.000
	Weight	40.8160	25.34159	5	5.000
	Thermally Altered	2.0000	.00000	5	5.000

The casewise statistics show that the first discriminant function analysis only misclassified 5 of 53 cases, that is, 90.6% of the original grouped cases were correctly classified (Table 3.7). This suggests that the variables selected were very good predictors of which of the three pre-determined classes (>5.0, 4.9-2.0, <1.9) each biface would be

placed into. I am confident that using quantifiable size and shape variables to describe bifaces, archaeologists can accurately determine whether a particular bifaces was produced for use as a projectile point preform or for use as a core.

I then compared the mean values of all of the ratio scaled variables (thickness, width, width/thickness ratio, edge angle, symmetry index, and weight) of the probable cores (>5.0) to those of the probable preforms (<1.9) using Student's "t" for independent samples and 19 degrees of freedom (Table 3.8). Comparison of the mean width/thickness ratios of the two samples produced a calculated value of 6.32. Because the associated p is <0.001, I conclude that there is a significant difference between the two samples.

Table 3.7. Discriminant analysis using "symmetry index value" as the grouping variables: classification results. 90.6% of original grouped cases correctly classified.

		Predicted Group Membership			Total	
		Symm Index Value	>5.0	2.0-4.9	<1.9	
Original	Count	>5.0	14	2	0	16
		2.0-4.9	0	29	3	32
		<1.9	0	0	5	5
	%	>5.0	87.5	12.5	.0	100.0
		2.0-4.9	.0	90.6	9.4	100.0
		<1.9	.0	.0	100.0	100.0

Table 3.8. Results of student's t with 19 degrees freedom. All ratio scaled variable means for "symmetry index value" groups.

Variable	Calculated t	Associated p
Width/thickness ratio	6.32	<0.001
Symmetry index	3.41	<0.01
Thickness	1.77	<0.10
Edge angle	1.89	<0.10
Width	0.202	n/a
Weight	0.166	n/a

Comparison of the mean symmetry indices of the two samples produced a calculated value of 3.41. Therefore, I draw a similar conclusion since the associated p is < 0.01 . Regarding thickness and edge angle the associated p is < 0.10 . For all of these values, therefore, I concluded that my samples were not likely drawn from the same population, and that there is a statistically significant difference between bifaces with symmetry indices > 5.0 and those with indices < 1.9 based on the attributes described here.

"Subjective value" was used as the grouping variable during the second discriminant function analysis in order to determine whether visual assessment was a useful method for distinguishing probable cores from probable preforms. The independent variables used were material type, thickness, width, width/thickness ratio, edge angle, symmetry index, utilized/not utilized, break type, weight, and presence/absence of thermal alteration (Table 3.9). In this case, probable preforms (N=31) are characterized by a mean width of 40.36 mm, low mean thickness (11.71 mm), high mean width/thickness ratio (3.48), low mean edge angle (41.81°), low mean symmetry index (4.36), and relatively very low mean weight (33.65 g). On the other hand, the probable cores (N=7) are characterized by much higher mean width (56.64 mm), high mean thickness (19.93 mm), lower mean width/thickness ratio (3.00), high mean edge angle (55.71°), and very high mean weight (89.16 g). The classification statistics indicate that 77.4% of the originally grouped cases were classified correctly (11 misclassified cases; Table 3.10). This analysis shows that visually assessing bifaces and placing them into "probable preform" and "probable core" groups is not as effective a method of accurately classifying bifaces as quantifying symmetry and grouping bifaces according to their index numbers. Bifaces classified according to symmetry index

Table 3.9. Discriminant analysis using "subjective value" as the grouping variable: group statistics

Subjective Group		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
probable preform	Material	2.2258	1.28348	31	31.000
	Width	40.3629	12.52528	31	31.000
	Thickness	11.7097	3.66691	31	31.000
	W/T Ratio	3.4848	.49787	31	31.000
	Edge Angle	41.8065	7.32766	31	31.000
	Symmetry Index	4.3610	2.61593	31	31.000
	Utilized	1.9677	.75206	31	31.000
	Break Type	2.2581	.81518	31	31.000
	Weight	33.6494	31.40964	31	31.000
	Thermally Altered	1.9677	.17961	31	31.000
probable core	Material	2.2857	.48795	7	7.000
	Width	56.6429	11.27207	7	7.000
	Thickness	19.9286	5.00357	7	7.000
	W/T Ratio	3.0000	1.07784	7	7.000
	Edge Angle	55.7143	10.64134	7	7.000
	Symmetry Index	5.5714	4.72760	7	7.000
	Utilized	2.0000	.00000	7	7.000
	Break Type	1.7143	.48795	7	7.000
	Weight	89.1643	44.74492	7	7.000
	Thermally Altered	2.0000	.00000	7	7.000

Table 3.10. Discriminant analysis using "subjective value" as the grouping variable: classification results. 77.4% of original grouped cases correctly classified.

Original	Count	Subjective Group	Predicted Group Membership			Total
			probable preform	probable core	indeterminate	
		probable preform	26	1	4	31
		probable core	1	5	1	7
		indeterminate	3	2	10	15
	%	probable preform	83.9	3.2	12.9	100.0
		probable core	14.3	71.4	14.3	100.0
		indeterminate	20.0	13.3	66.7	100.0

numbers share more attributes in common and are therefore more easily recognized as members of a particular group by this method.

I then compared the mean values of all of the ratio scaled variables (thickness, width, width/thickness ratio, edge angle, symmetry index, and weight) of the probable cores to those of the probable preforms using Student's "t" for independent samples and 36 degrees of freedom (Table 3.11). Comparison of the mean thickness, edge angle, width and weight between the two samples produced calculated values of 5.01, 4.16, 3.79, and 3.90 respectively. Because the associated p's are <0.001 , I conclude that there is a significant difference between the two samples. Comparison of the mean width/thickness ratios of the two samples produced a calculated value of 1.31. Therefore, I draw a similar conclusion since the associated p is <0.20 . For all of these values, therefore, I concluded that my samples were not likely drawn from the same population; there appear to be significant differences between types of bifaces with respect to these characteristics when they are classified according to "subjective value."

Table 3.11. Results of student's t with 36 degrees freedom. All ratio scaled variable means for "subjective value" groups.

Variable	Calculated t	Associated p
Thickness	5.01	<0.001
Edge angle	4.16	<0.001
Width	3.79	<0.001
Weight	3.90	<0.001
Width/thickness ratio	1.31	<0.20
Symmetry index	0.95	n/a

The results of the multivariate quantitative analyses described above make a strong case for the use of an index of symmetry in the assessment of biface production goals. Both the symmetry index pilot study and the quantitative analyses suggest that the makers of the Avon collections were focusing primarily on the production of early- and middle- stage projectile point preforms. In order to strengthen this argument, an aggregate analysis of the Avon site debitage was performed, which was designed to determine the difference between core reduction and tool production.

The Debitage Analysis

When grouped according to stratigraphic level, material type, size class and Sullivan and Rozen flake-completeness type (Prentiss 2001; Sullivan and Rozen 1985; Sullivan 1987), the Avon debitage were distributed as follows:

Level A--Surface to 45.72 cm (18") below surface The debitage from Level A of the Avon site (N=2114) represents 36.8% of all of the debitage from the site (N=5752; Table 3.12). The debitage from this level can be separated into three general material types: chert/marl, basalt, and "other," which includes quartzite, obsidian, unidentifiable materials and cherts that do not fit the description of Avon Chert provided by Fields (1984). Chert/marl accounts for 90.1% of the debitage (N=1904), basalt for 9.7% (N=205) and 0.2% includes all "other" materials (N=5; Figure 3.5). Of the total chert/marl, 19.2% is non-orientable, 44.0% are medial-distal fragments, 3.5% are split flakes, 16.9% are proximal fragments and 16.4% are complete flakes. Of the basalt, 7.3% are non-orientable, 47.3% are medial-distal fragments, 10.7% are split flakes, 21.0% are proximal fragments and 13.7% are complete flakes. Of the "other" materials, 40.0% are

Table 3.12. Debitage raw totals and percentages. Total Avondebitage N=5752

Level	Raw Data	Percentage
Level A	2114	36.8
Level B	1534	26.7
Level C	2104	36.6

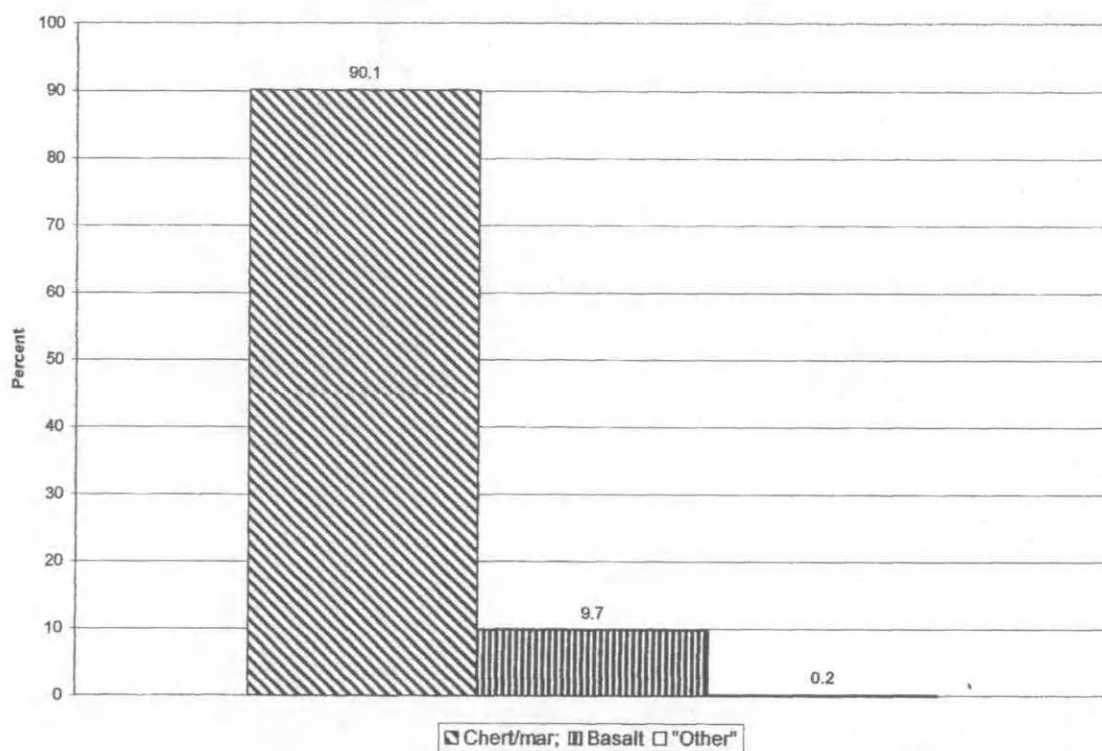


Figure 3.5 Level A Debitage Material Types

non-orientable, 40.0% are medial- distal fragments, 0.0% are split flakes, 0.0% are proximal fragments and 20.0% are complete flakes (Figure 3.6). Of the total Level A flake count, 16.5% is thermally altered. Debitage bearing any sign of cortex represents 7.5% of the total Level Adebitage.

All of the Level A debitage was sorted using Prentiss' (2001) size classes: extra large >64 sq cm, large = 16-64 sq cm, medium = 4-16 sq cm, and small = 0.64-4 sq cm. The extra large size class represents 0.2% of the total debitage from the level. The large size class represents 8.7%, medium equals 49.3%, and small accounts for 41.8% of the total debitage from Level A (Figure 3.7).

Each size class was then further broken down according to the Sullivan and Rozen flake-completeness typology (1985; Sullivan 1987). Extra large debitage (N=4) represents 0.2% of all debitage from Level A; 50.0% of that figure is chert/marl and 50.0% is basalt. Of the chert/marl in this size class, 100.0% are non-orientable pieces. Of the basalt in this size class, 100.0% are non-orientable pieces (Figure 3.8).

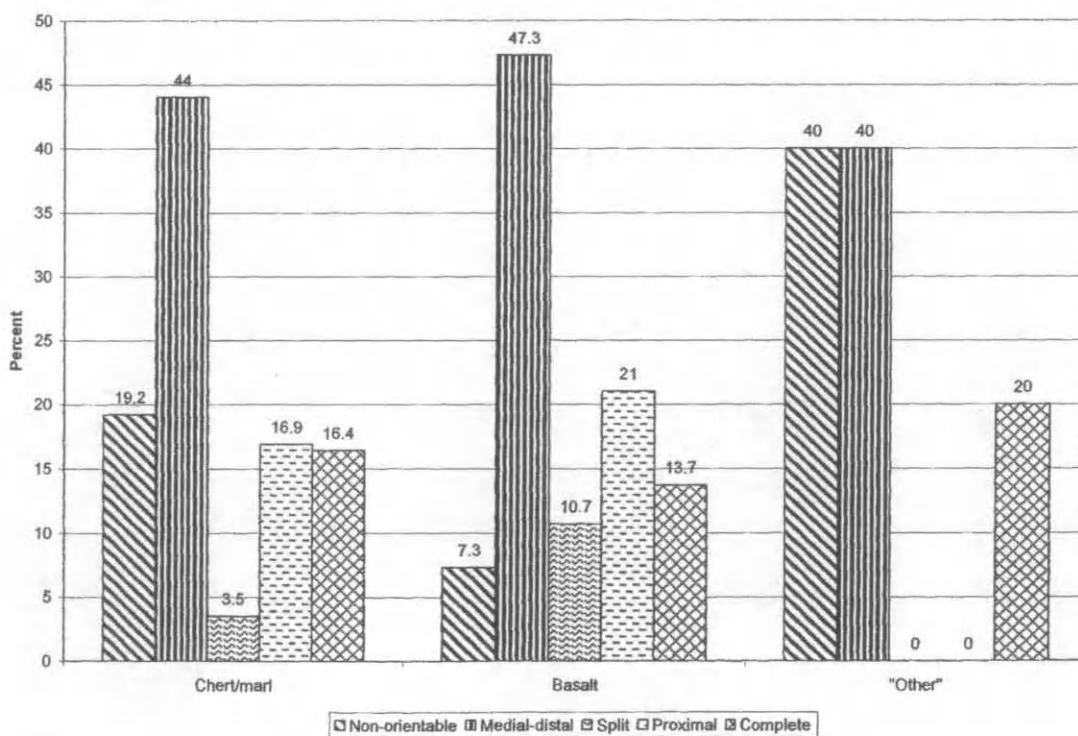


Figure 3.6 Level A Debitage Completeness Types by Material

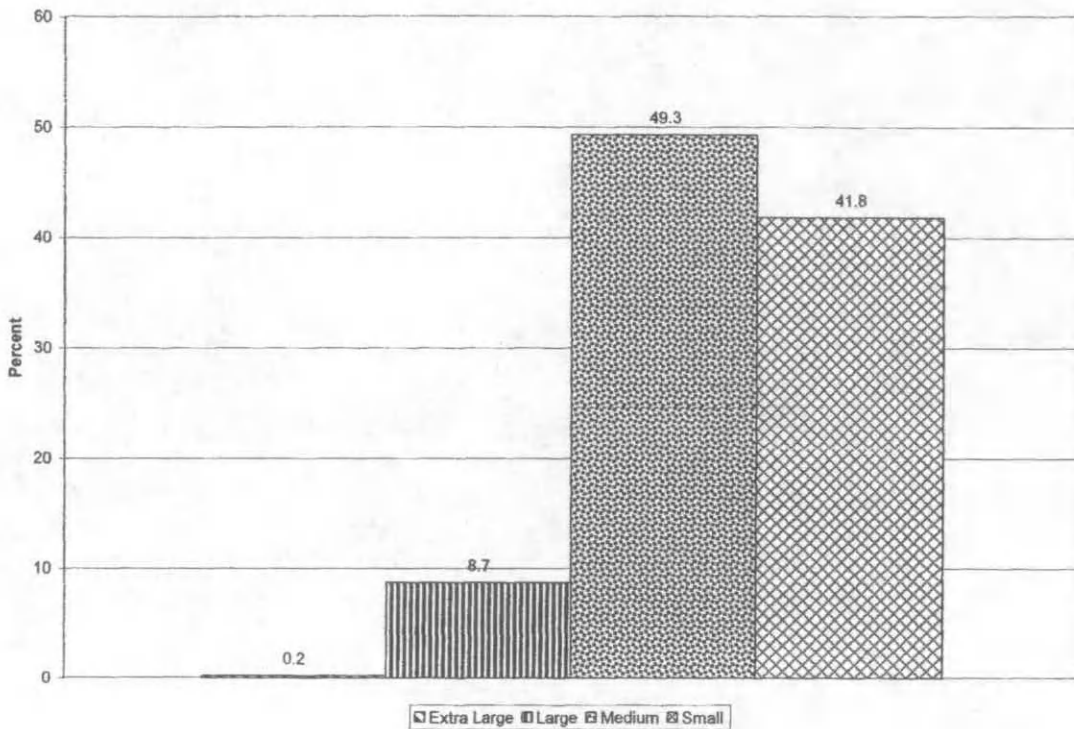


Figure 3.7 Level A Size Class Distribution

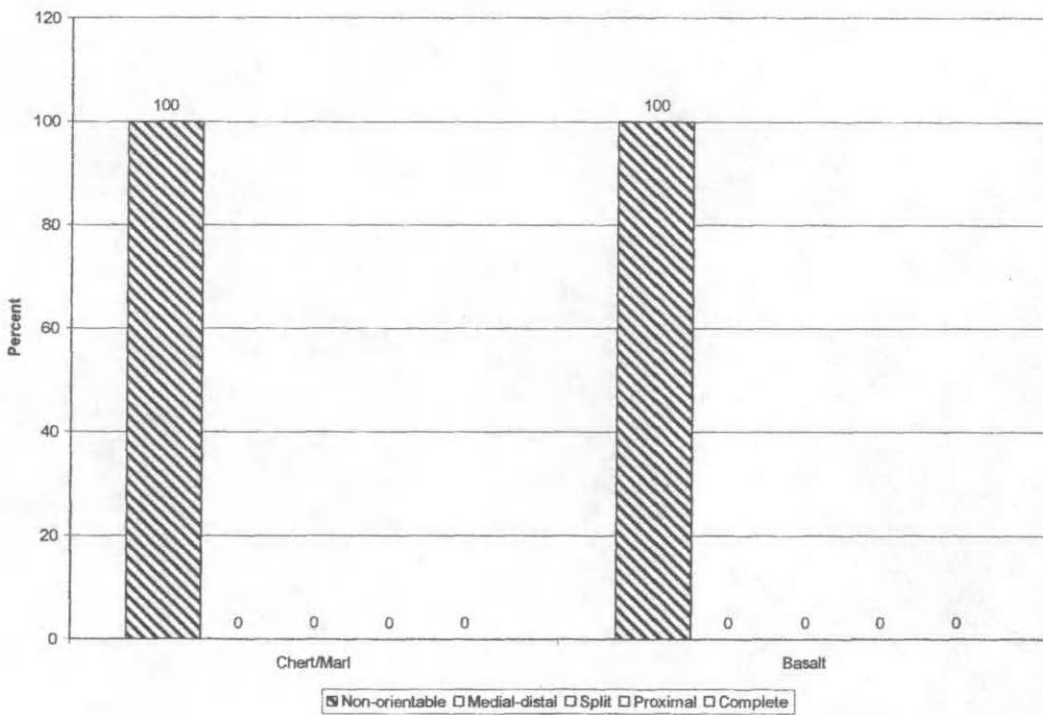


Figure 3.8 Level A Extra Large Flake Completeness Types by Material

Large debitage (N=184) represents 8.7% of all debitage from Level A; 72.8% of that figure is chert/marl (N=134), 26.6% is basalt (N=49), and 0.5% of the large debitage is made up of "other" materials (N=1; Figure 3.9). Of the chert/marl in this size class, 8.2% are non-orientable pieces, 22.4% are medial-distal fragments, 8.2% are split flakes, 17.9% are proximal fragments and 43.3% are complete flakes (Figure 3.10). Of the basalt in this size class, 4.1% consists of non-orientable pieces, 20.4% are medial-distal fragments, 24.5% are split flakes, 30.6% are proximal fragments and 20.4% are complete flakes (Figure 3.10). Of the "other" materials in this size class, 100.0% are non-orientable pieces (Figure 3.10).

The medium size class (N=1043) represents 49.3% of all debitage from Level A; 89.3% of that figure is chert/marl (N=931), 10.4% is basalt (N=108), and 0.4% of the

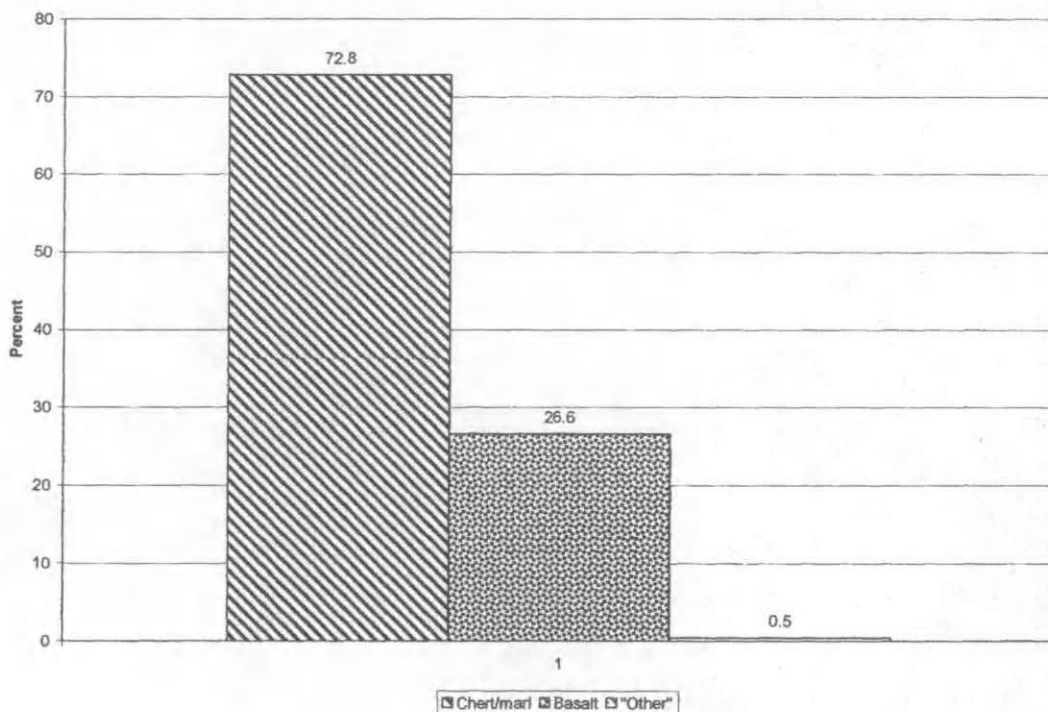


Figure 3.9 Level A Large Debitage Material Types

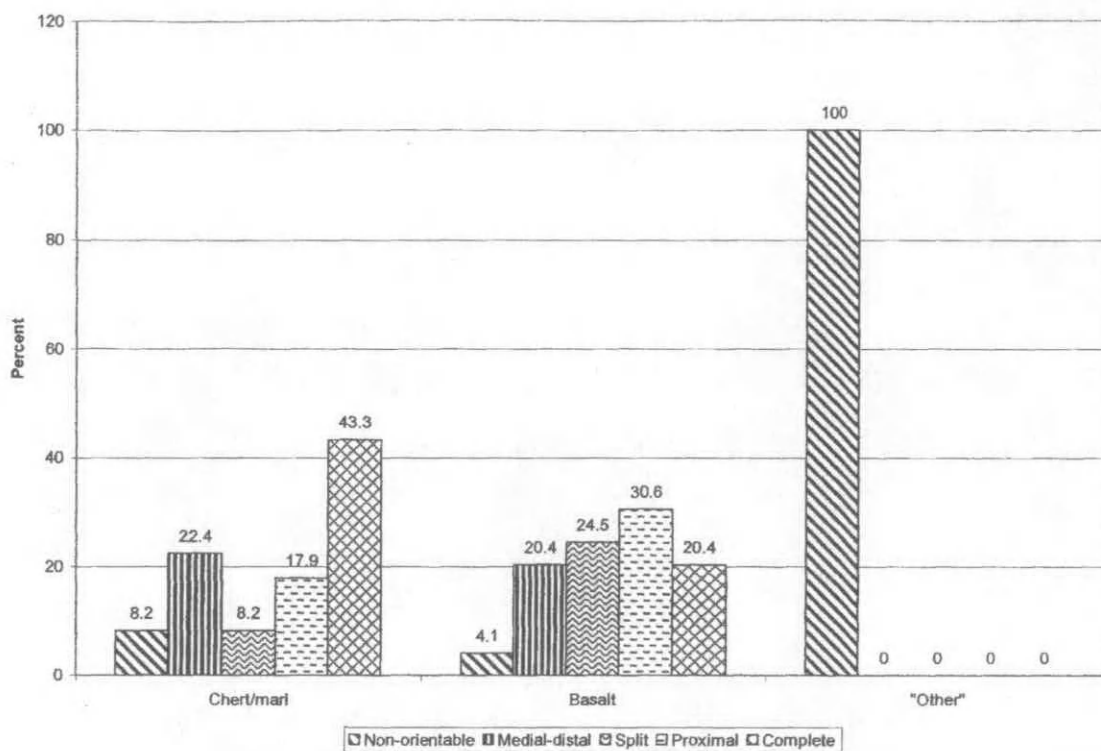


Figure 3.10 Level A Large Debitage Completeness Type Distribution by Material

medium debitage is made up of "other" materials (N=4; Figure 3.11). Of the chert/marl in this size class, 18.7% are non-orientable pieces, 38.8% are medial-distal fragments, 4.3% are split flakes, 17.8% are proximal fragments and 20.4% are complete flakes (Figure 3.12). Of the basalt in this size class, 8.3% consists of non-orientable pieces, 48.1% are medial-distal fragments, 8.3% are split flakes, 21.3% are proximal fragments and 13.9% are complete flakes (Figure 3.12). Of the "other" materials in this size class, 25.0% are non-orientable pieces, 50.0% are medial-distal fragments, 0.0% are split flakes, 0.0% are proximal fragments and 25.0% are complete flakes (Figure 3.12).

The small size class (N=883) accounts for 41.8% of the total debitage from Level A; 94.8% of that figure is chert/marl (N=837), 5.2% is basalt (N=46), and this size class

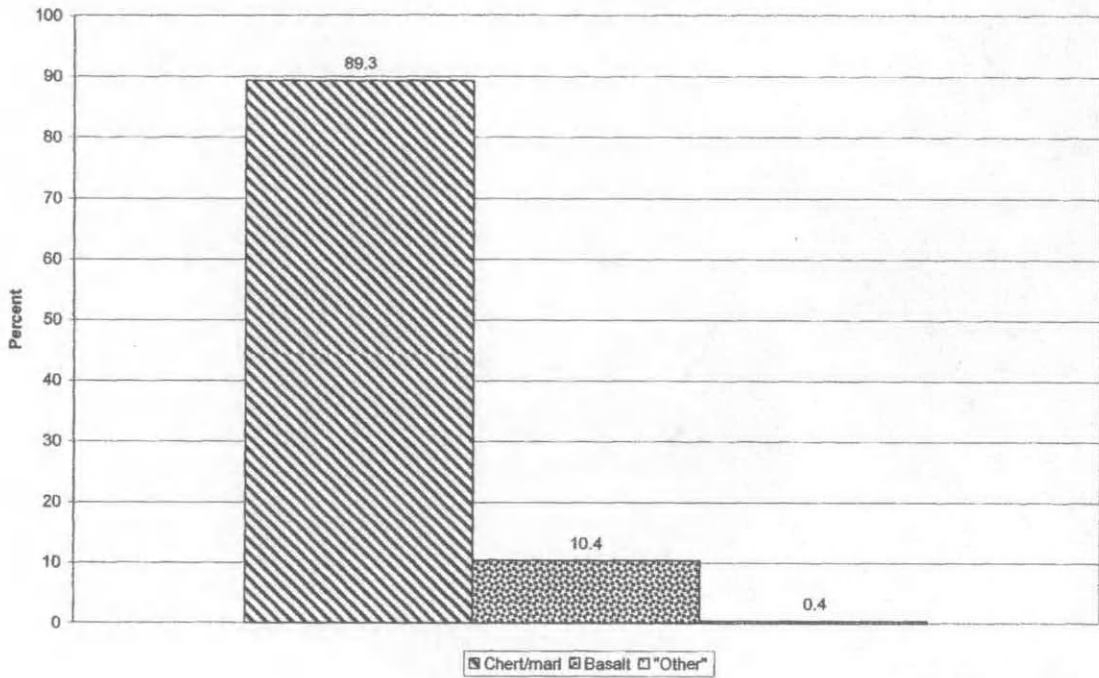


Figure 3.11 Level A Medium Debitage Material Types

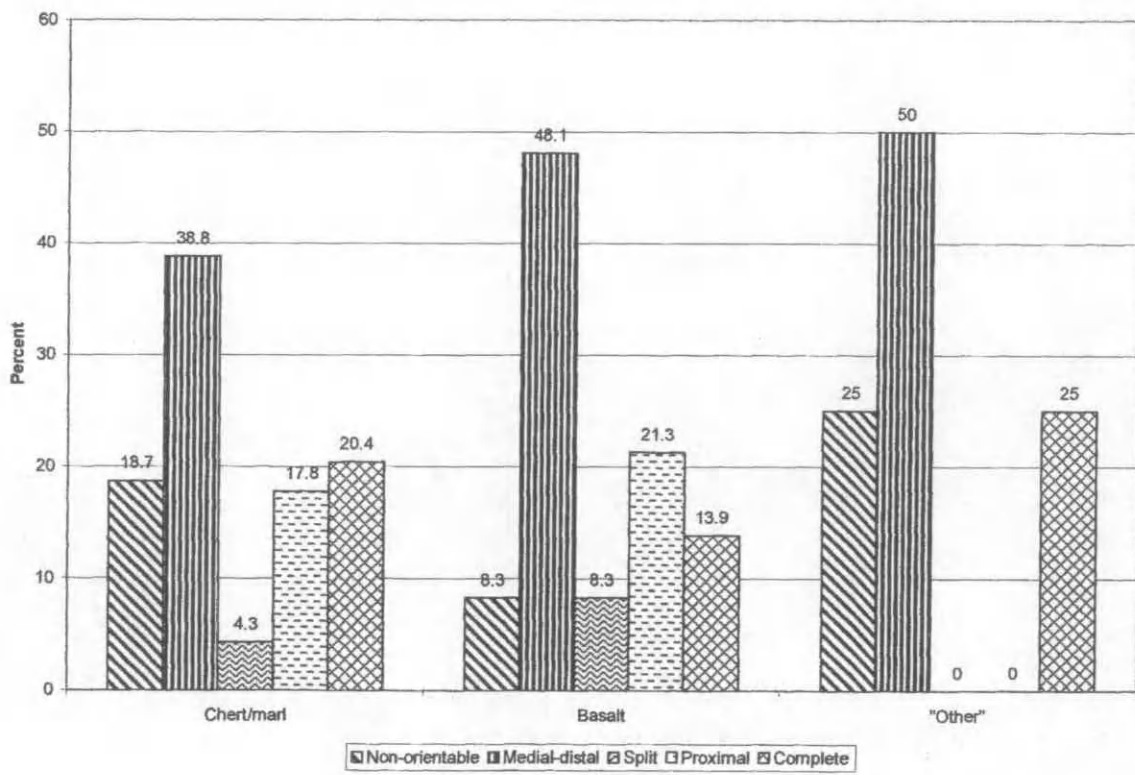


Figure 3.12 Level A Medium Debitage Completeness Type Distribution by Material

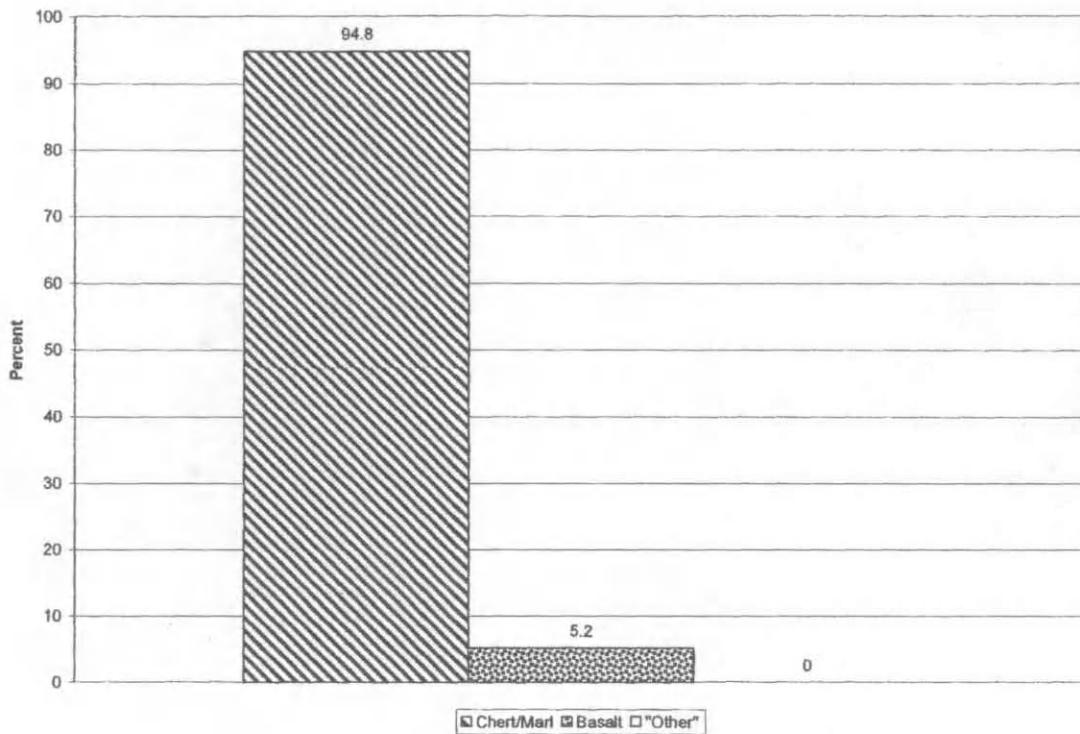


Figure 3.13 Level A Small Debitage Material Types

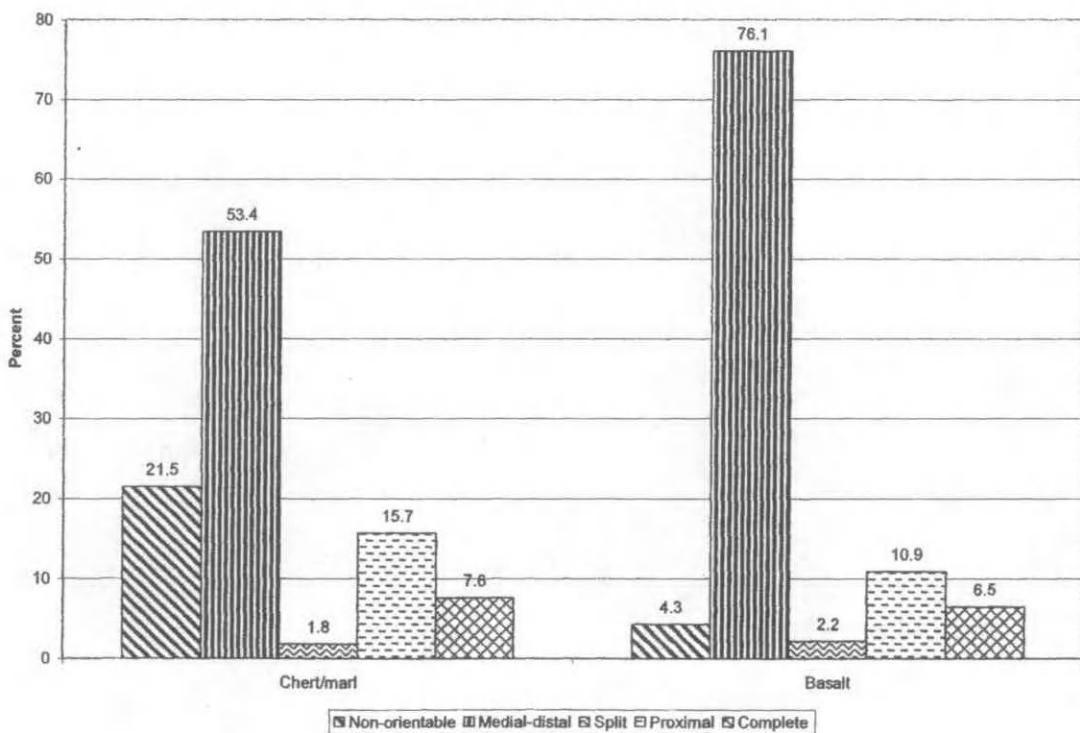


Figure 3.14 Level A Small Debitage Completeness Types by Material

contains no "other" materials (Figure 3.13). Of the chert/marl in this size class, 21.5% are non-orientable pieces, 53.4% are medial-distal fragments, 1.8% are split flakes, 15.7% are proximal fragments and 7.6% are complete flakes (Figure 3.14). Of the basalt in this size class, 4.3% consists of non-orientable pieces, 76.1% are medial-distal fragments, 2.2% are split flakes, 10.9% are proximal fragments and 6.5% are complete flakes (Figure 3.14).

Level B-- 45.72 to 99.06 cm (18" to 39") below surface The debitage from Level B of the Avon site (N=1534) represents 26.7% of all of the debitage from the site (N=5752; Table 3.13). The debitage from this level can be separated into two main material types: chert/marl and basalt. Chert/marl accounts for 96.3% of the debitage, and basalt for 3.6% (Figure 3.15). Of the total chert/marl, 10.6% is non-orientable, 50.3% are medial-distal fragments, 4.9% are split flakes, 16.4% are proximal fragments and 17.9% are complete flakes. Of the basalt, 7.3% are non-orientable, 45.5% are medial-distal fragments, 3.6% are split flakes, 25.5% are proximal fragments and 18.2% are complete flakes (Figure 3.16). Of the total Level B flake count, 20.1% is thermally altered. Debitage bearing any sign of cortex represents 17.0% of the total Level B debitage.

Table 3.13. Debitage raw totals and percentages. Total Avon debitage N=5752

Level	Raw Data	Percentage
Level A	2114	36.8
Level B	1534	26.7
Level C	2104	36.6

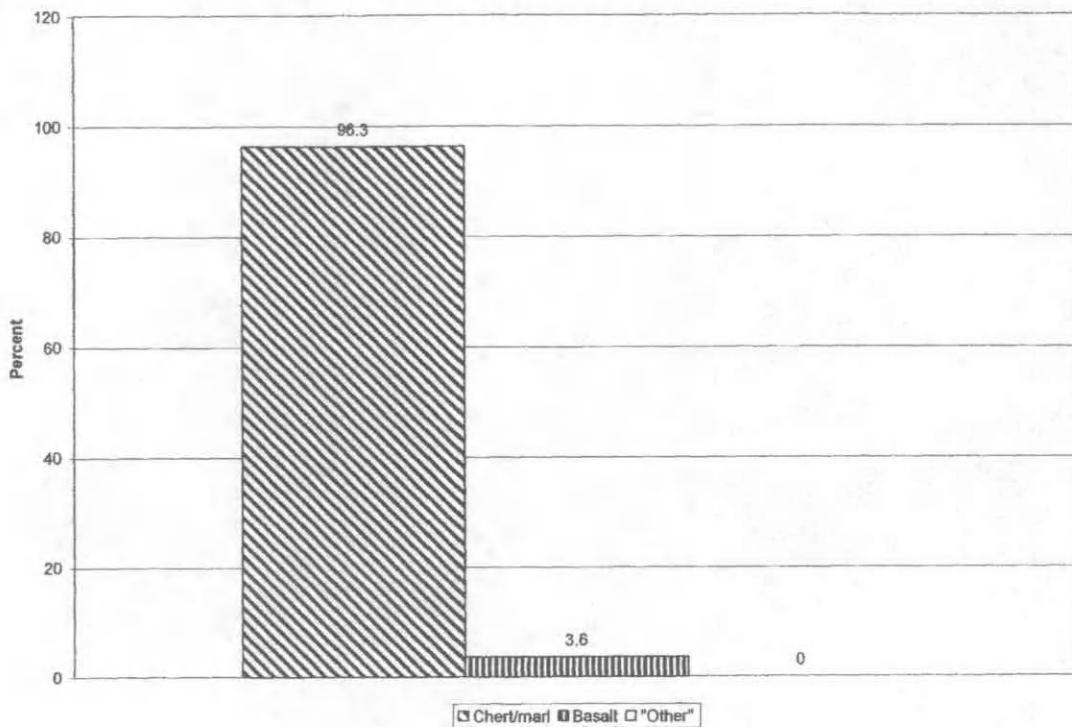


Figure 3.15 Level B Debitage Material Types

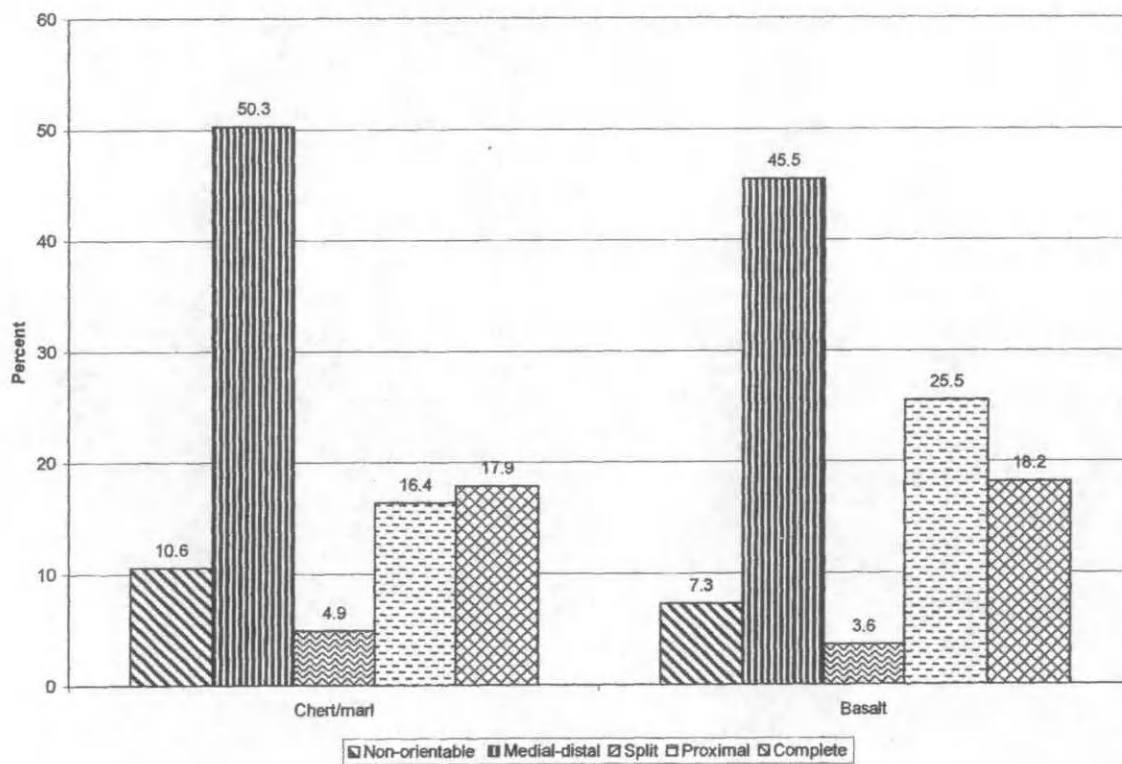


Figure 3.16 Level B Debitage Completeness Types by Material

All of the Level B debitage was sorted using Prentiss' (2001) size classes: extra large >64 sq cm, large = 16-64 sq cm, medium = 4-16 sq cm, and small = 0.64-4 sq cm. The extra large size class represents 0.1% of the total debitage from the level. The large size class represents 7.3%, medium equals 56.2%, and small accounts for 35.4% of the total debitage from Level B (Figure 3.17).

Each size class was then further broken down according to the Sullivan and Rozen flake-completeness typology (1985; Sullivan 1987). Extra large debitage (N=1) represents 0.1% of all debitage from Level B; 100.0% of that figure is chert/marl. Of the chert/marl in this size class, 100.0% are complete flakes (Figure 3.18).

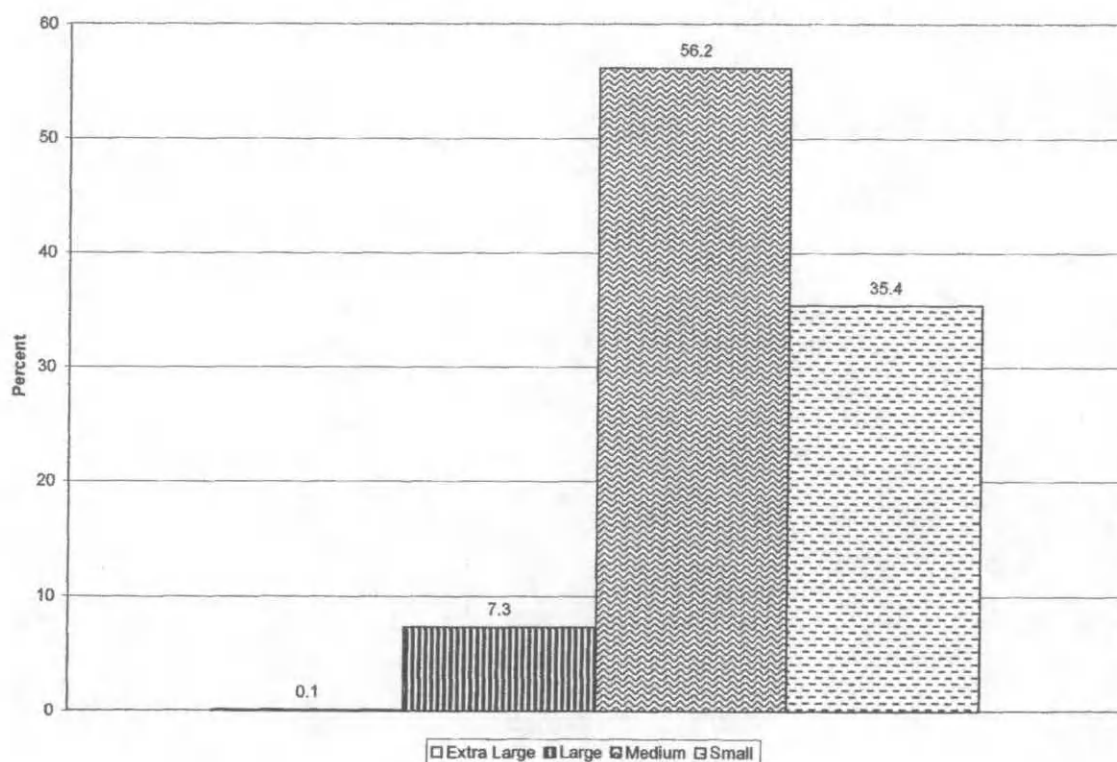


Figure 3.17 Level B Size Classes

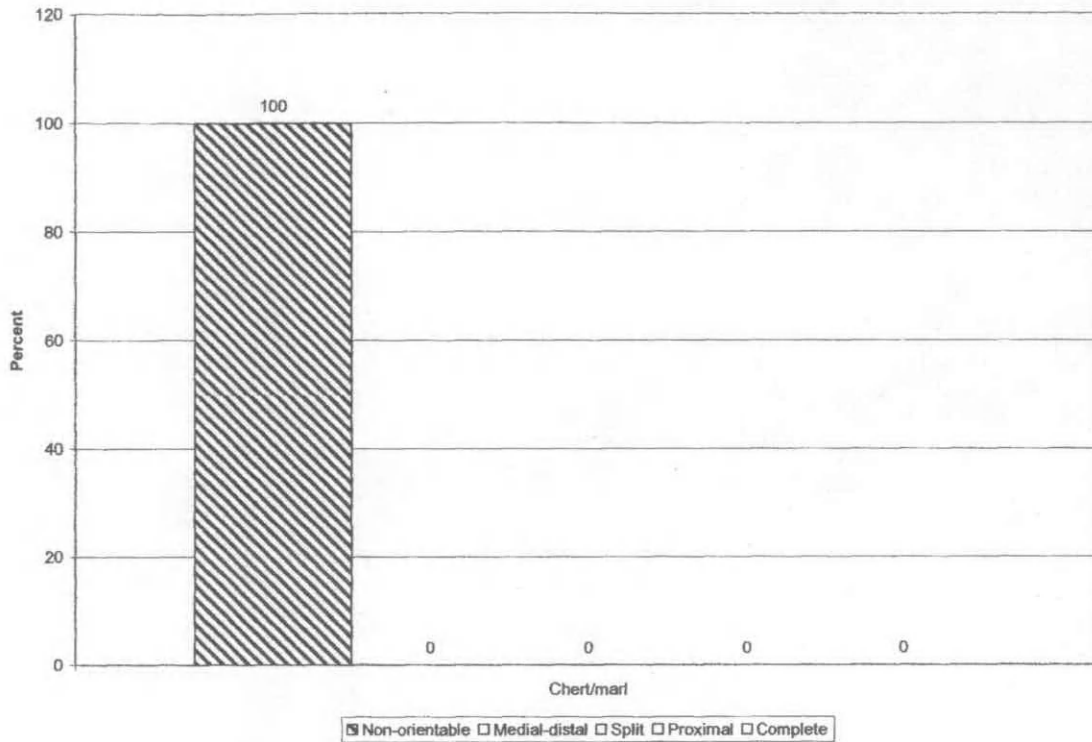


Figure 3.18 Level B Extra Large Debitage Completeness Types by Material

The large size class (N=112) represents 7.3% of all debitage from Level B; 92.9% of that figure is chert/marl (N=104), 6.3% is basalt (N=7), and 0.09% is "other" (N=1; Figure 3.19). Of the chert/marl in this size class, 7.7% are non-orientable pieces, 17.3% are medial-distal fragments, 11.5% are split flakes, 18.3% are proximal fragments and 45.2% are complete flakes (Figure 3.20). Of the basalt in this size class, 14.3% consists of non-orientable pieces, 14.3% are medial-distal fragments, 0.0% are split flakes, 14.3% are proximal fragments and 57.1% are complete flakes (Figure 3.20). Of the "other" materials in this size class, 100.0% are non-orientable pieces (Figure 3.20).

The medium size class (N=862) represents 56.2% of all debitage from Level B; 97.3% of that figure is chert/marl (N=839) and 2.7% is basalt (N=23; Figure 3.21). Of the chert/marl in this size class, 10.8% are non-orientable pieces, 45.4% are medial-distal

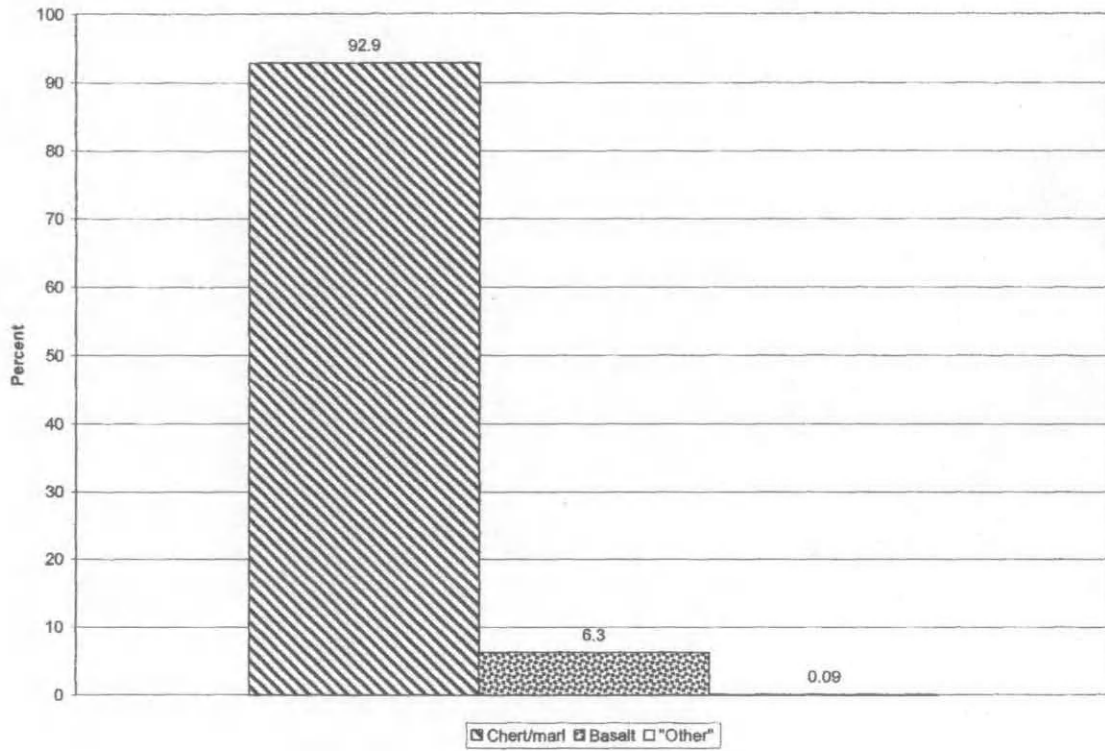


Figure 3.19 Level B Large Debitage Material Types

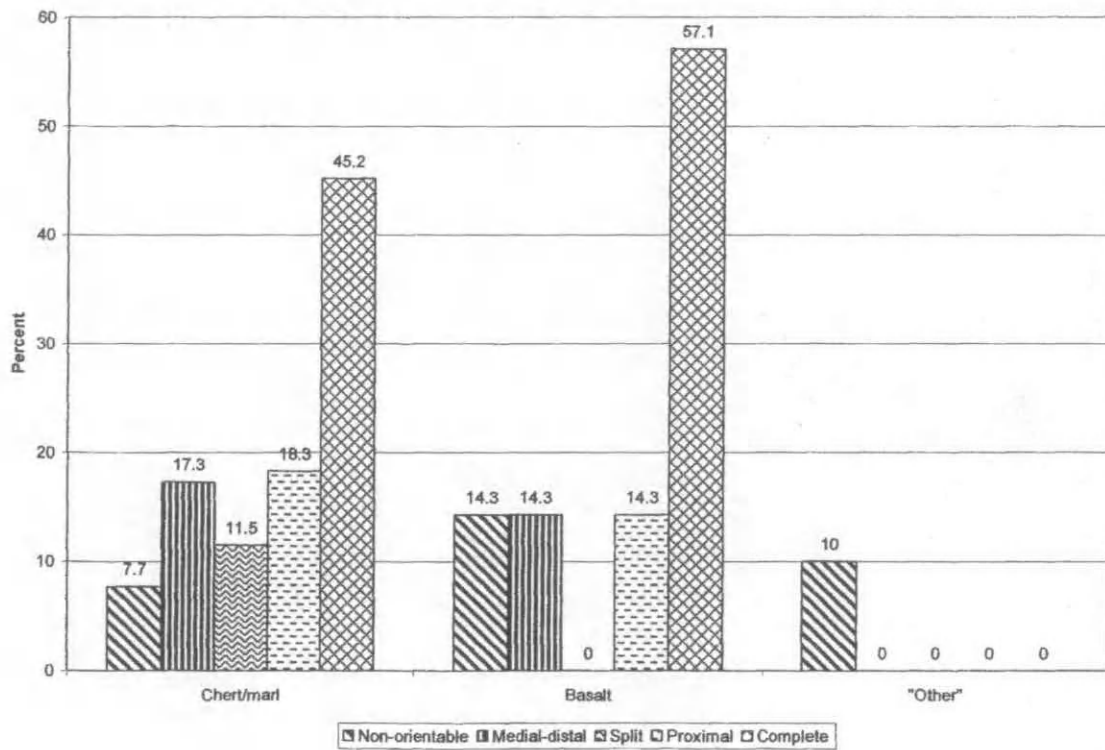


Figure 3.20 Level B Large Debitage Completeness Types by Material

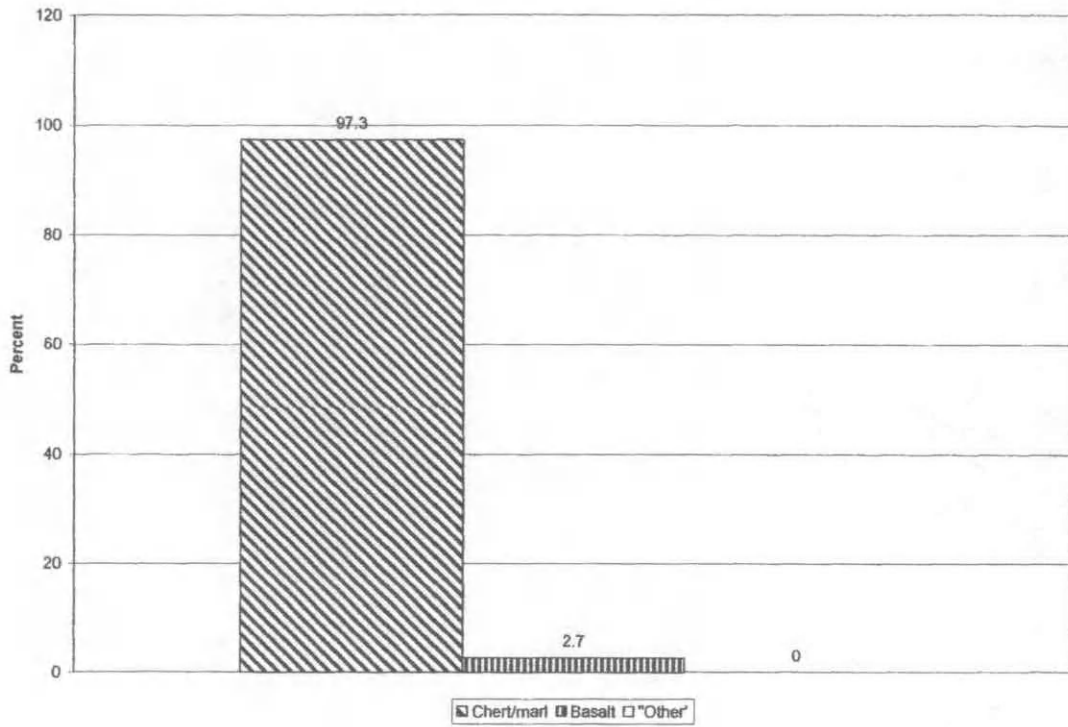


Figure 3.21 Level B Medium Material Types

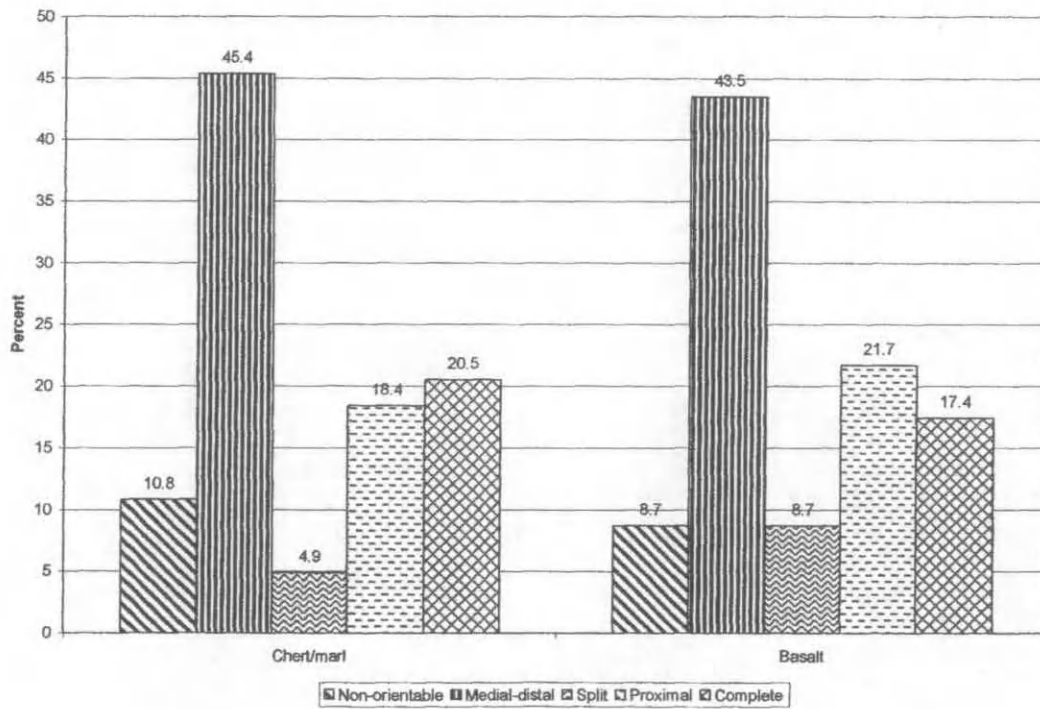


Figure 3.22 Level B Medium Debitage Completeness Types by Material

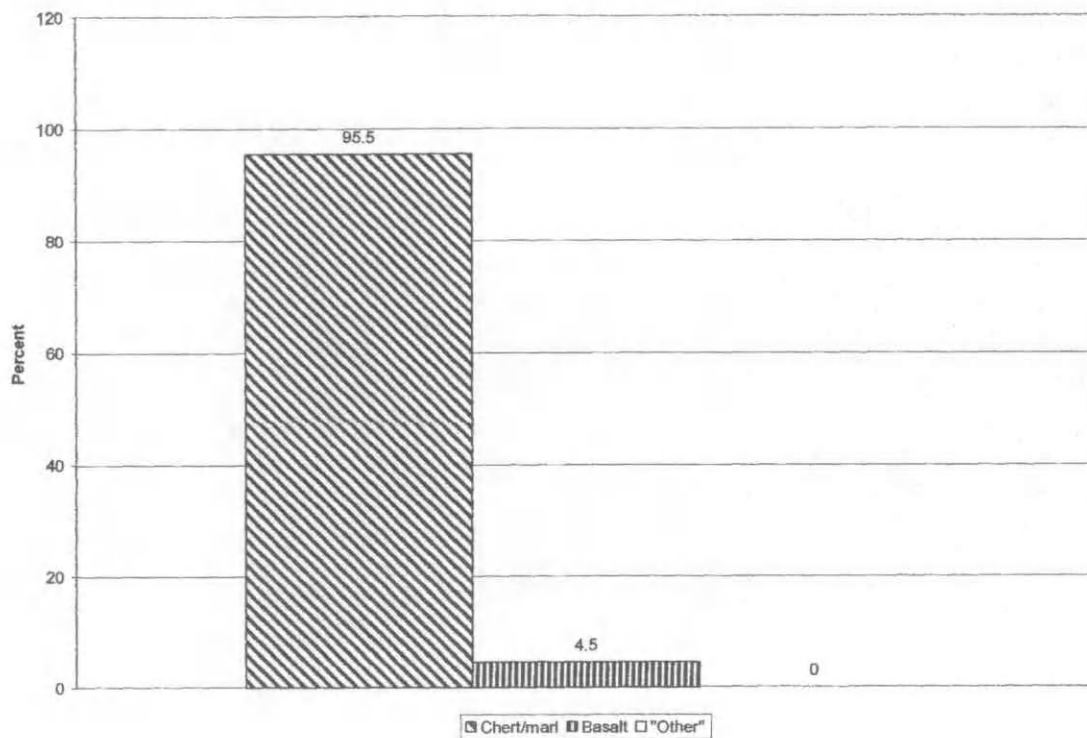


Figure 3.23 Level B Small Debitage Material Types

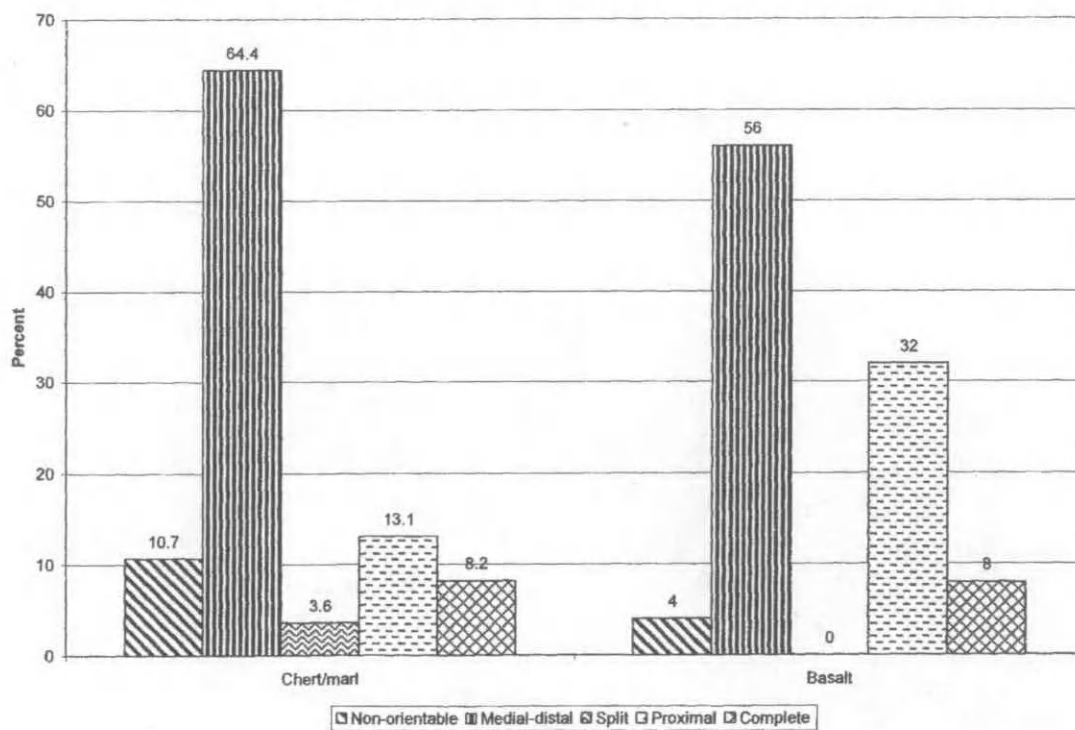


Figure 3.24 Level B Small Debitage Completeness Types by Material

fragments, 4.9% are split flakes, 18.4% are proximal fragments and 20.5% are complete flakes (Figure 3.22). Of the basalt in this size class, 8.7% consists of non-orientable pieces, 43.5% are medial-distal fragments, 8.7% are split flakes, 21.7% are proximal fragments and 17.4% are complete flakes (Figure 3.22).

The small size class (N=559) represents 36.4% of all debitage from Level B; 95.5% of that figure is chert/marl (N=534) and 4.5% is basalt (N=25; Figure 3.23). Of the chert/marl in this size class, 10.7% are non-orientable pieces, 64.4% are medial-distal fragments, 3.6% are split flakes, 13.1% are proximal fragments and 8.2% are complete flakes (Figure 3.24). Of the basalt in this size class, 4.0% consists of non-orientable pieces, 56.0% are medial-distal fragments, 0.0% are split flakes, 32.0% are proximal fragments and 8.0% are complete flakes (Figure 3.24).

Level C-- 99.06 cm (39") to creek level The debitage from Level C of the Avon site (N=2104) represents 36.6% of all of the debitage from the site (N=5752; Table 3.14). The debitage from this level can be separated into two main material types: chert/marl and basalt. Chert/marl accounts for 84.9% of the debitage and basalt for 15.1% (Figure 3.25). Of the total chert/marl within this size class, 6.9% is non-orientable, 42.6% are medial-distal fragments, 3.6% are split flakes, 19.9% are proximal fragments and 27.1% are complete flakes (Figure 3.26). Of the basalt 3.2% are non-orientable, 39.7% are medial-distal fragments, 8.2% are split flakes, 18.9% are proximal fragments and 30.0% are complete flakes (Figure 3.26). Of the total Level C debitage count, 11.7% is thermally altered. Debitage bearing any sign of cortex represents 17.1% of the total Level C debitage.

Table 3.14. Debitage raw totals and percentages. Total Avondebitage N=5752

Level	Raw Data	Percentage
Level A	2114	36.8
Level B	1534	26.7
Level C	2104	36.6

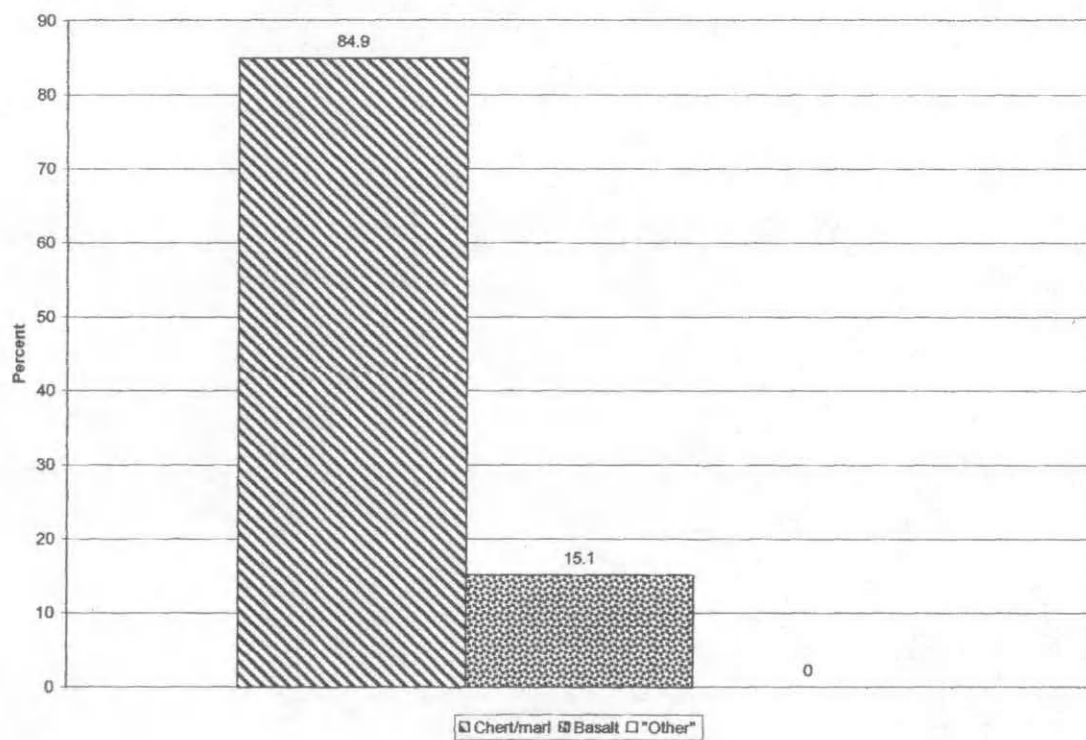


Figure 3.25 Level C Material Types

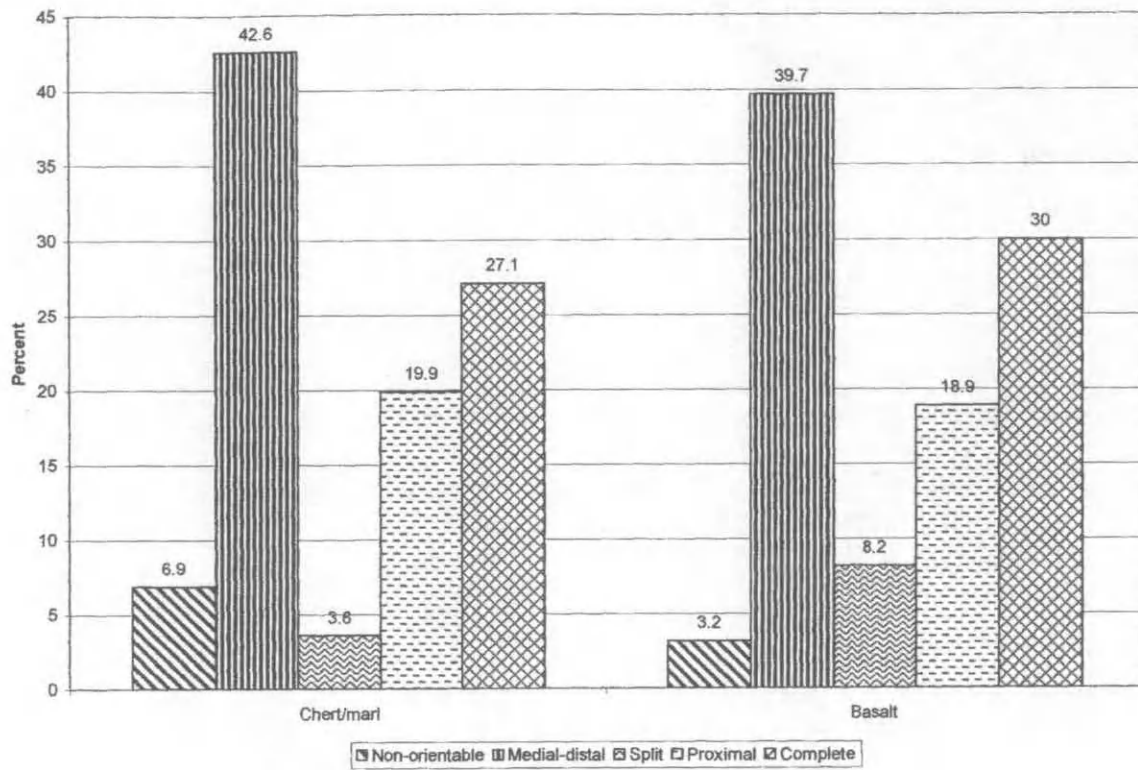


Figure 3.26 Level C Debitage Completeness Types by Material

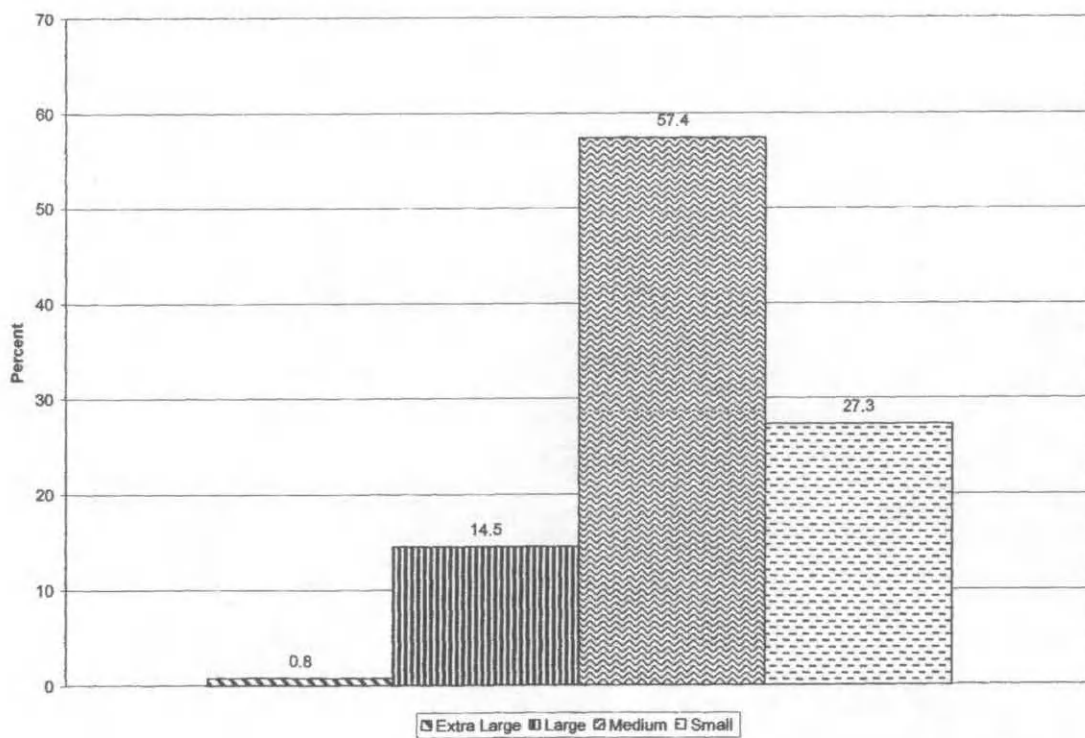


Figure 3.27 Level C Size Classes

All of the Level C debitage was sorted using Prentiss' (2001) size classes: extra large >64 sq cm, large = 16-64 sq cm, medium = 4-16 sq cm, and small = 0.64-4 sq cm. The extra large size class represents 0.8% of the total debitage from the level. The large size class represents 14.5%, medium equals 57.4%, and small accounts for 27.3% of the total debitage from Level C (Figure 3.27).

Each size class was then further broken down according to the Sullivan and Rozen flake-completeness typology (1985; Sullivan 1987). Extra large debitage (N=17) represents 0.8% of all debitage from Level C; 100.0% of that figure is basalt. Of the basalt in this size class, 0.0% are non-orientable, 23.5% are medial-distal fragments, 0.0% are split flakes, 11.8% are proximal fragments, and 64.7 are complete flakes (Figure 3.28).

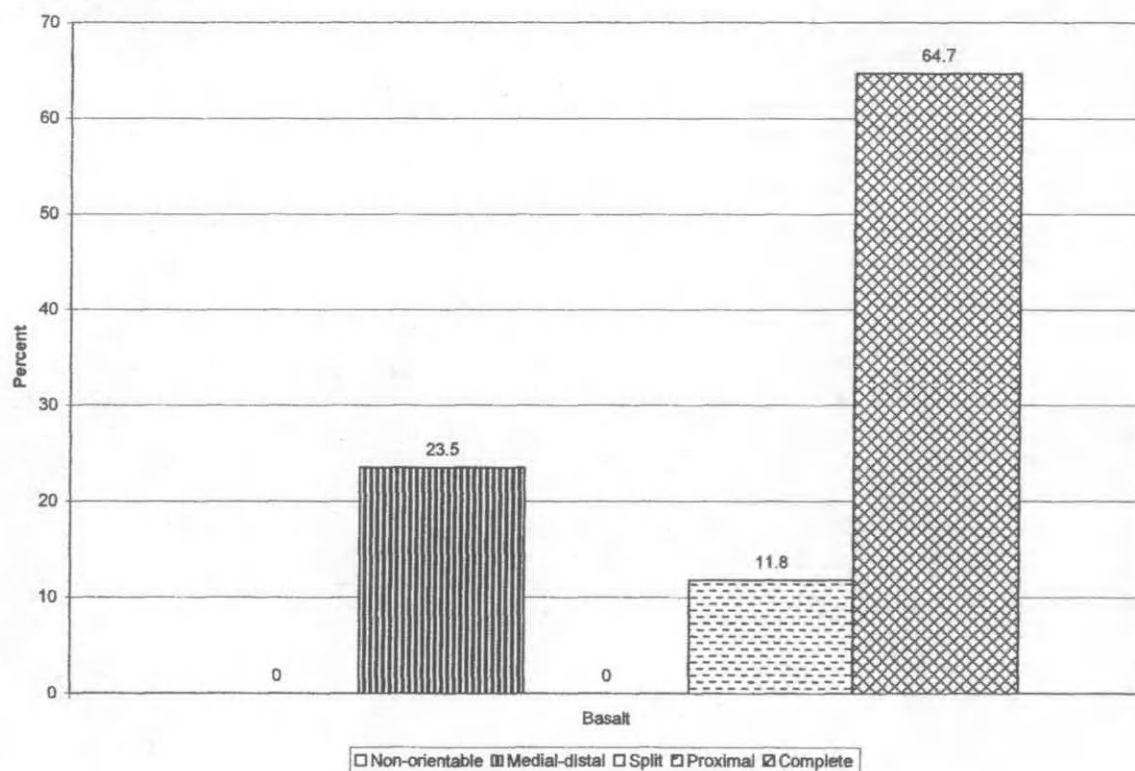


Figure 3.28 Level C Extra Large Debitage Completeness Types by Material

The large size class (N=306) represents 14.5% of the total debitage from Level C; 62.7% of that figure is chert/marl (N=192) and 37.3% is basalt (N=114; Figure 3.29). Of the chert/marl in this size class, 4.7% are non-orientable pieces, 23.4% are medial-distal fragments, 2.1% are split flakes, 22.9% are proximal fragments and 46.9% are complete flakes (Figure 3.30). Of the basalt in this size class, 0.0% consists of non-orientable pieces, 33.3% are medial-distal fragments, 10.5% are split flakes, 18.4% are proximal fragments and 37.7% are complete flakes (Figure 3.30).

The medium size class (N=1207) represents 57.4% of the total debitage from Level C; 86.5% of that figure is chert/marl (N=1044) and 13.5% is basalt (N=163; Figure 3.31). Of the chert/marl in this size class, 6.3% are non-orientable pieces, 41.5% are medial-distal fragments, 3.5% are split flakes, 20.5% are proximal fragments and 28.2% are complete flakes (Figure 3.32). Of the basalt in this size class, 4.3% consists of non-orientable pieces, 46.0% are medial-distal fragments, 8.6% are split flakes, 19.0% are proximal fragments and 22.1% are complete flakes (Figure 3.32).

The small size class (N=574) represents 27.3% of the total debitage from Level C; 96.0% of this figure is chert/marl (N=551) and 4.0% of that figure is basalt (N=23; Figure 3.33). Of the chert/marl in this size class, 8.7% are non-orientable pieces, 51.4% are medial-distal fragments, 4.2% are split flakes, 17.6% are proximal fragments and 18.1% are complete flakes (Figure 3.34). Of the basalt in this size class, 13.0% are non-orientable pieces, 39.1% are medial-distal fragments, 0.0% are split flakes, 26.1% are proximal fragments and 21.7% are complete flakes (Figure 3.34).

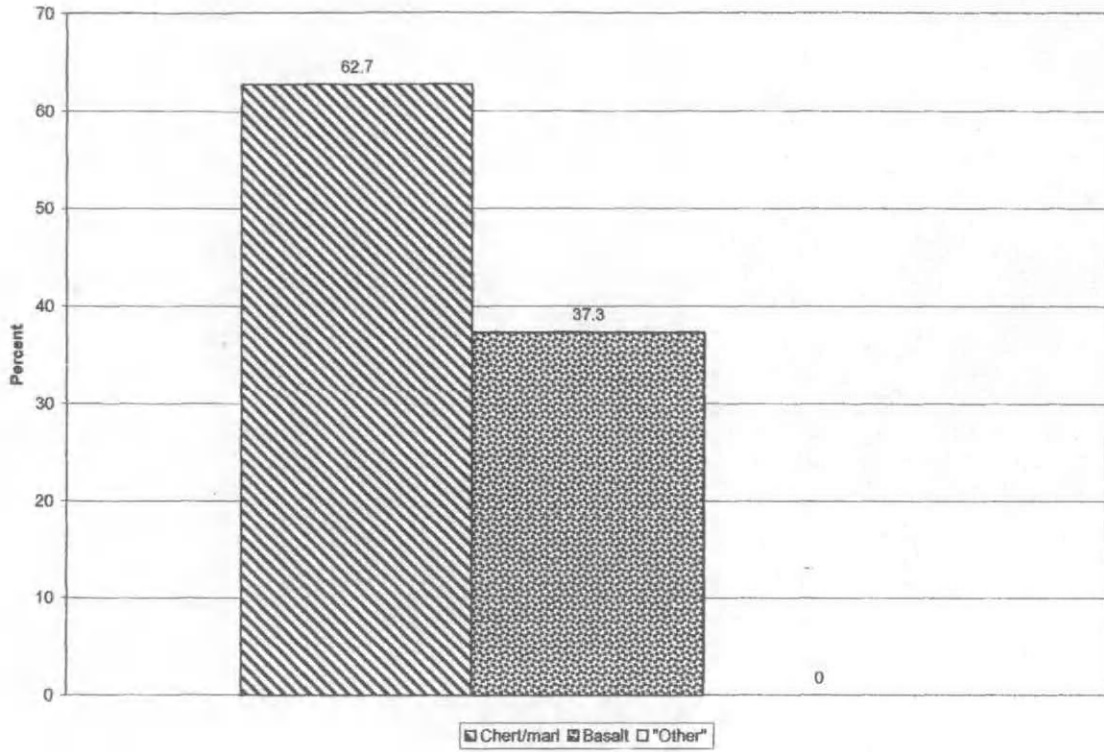


Figure 3.29 Level C Large Debitage Material Types

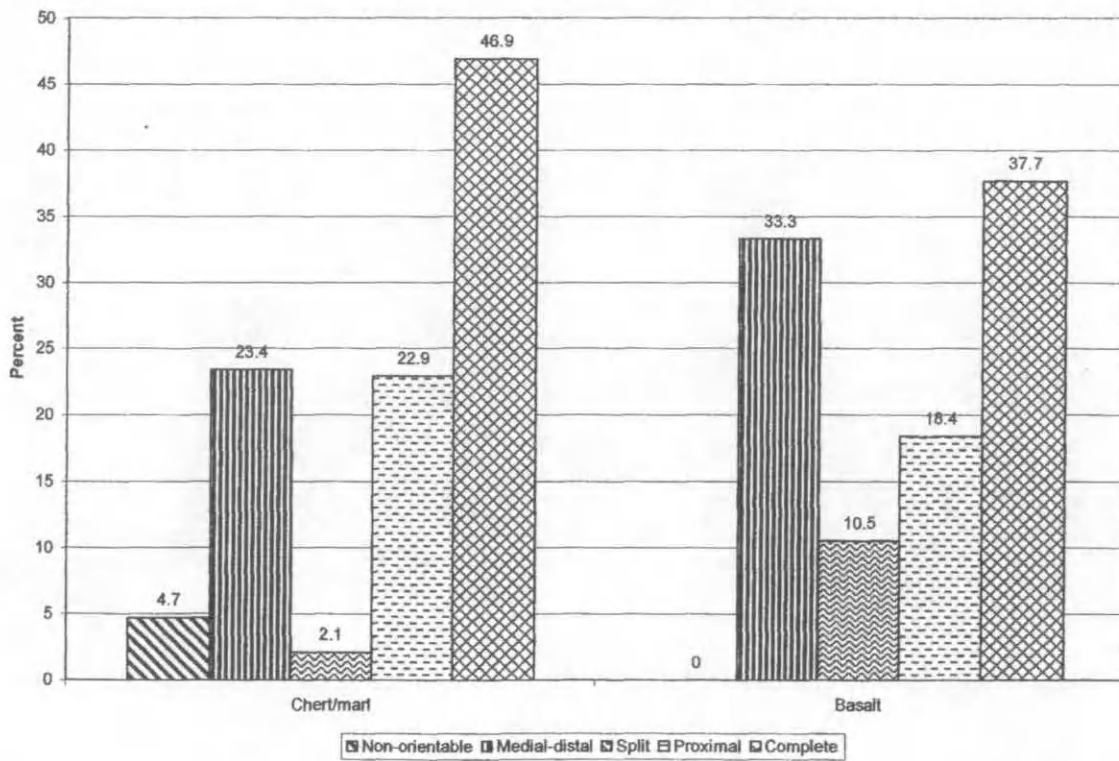


Figure 3.30 Level C Large Debitage Completeness Types by Material

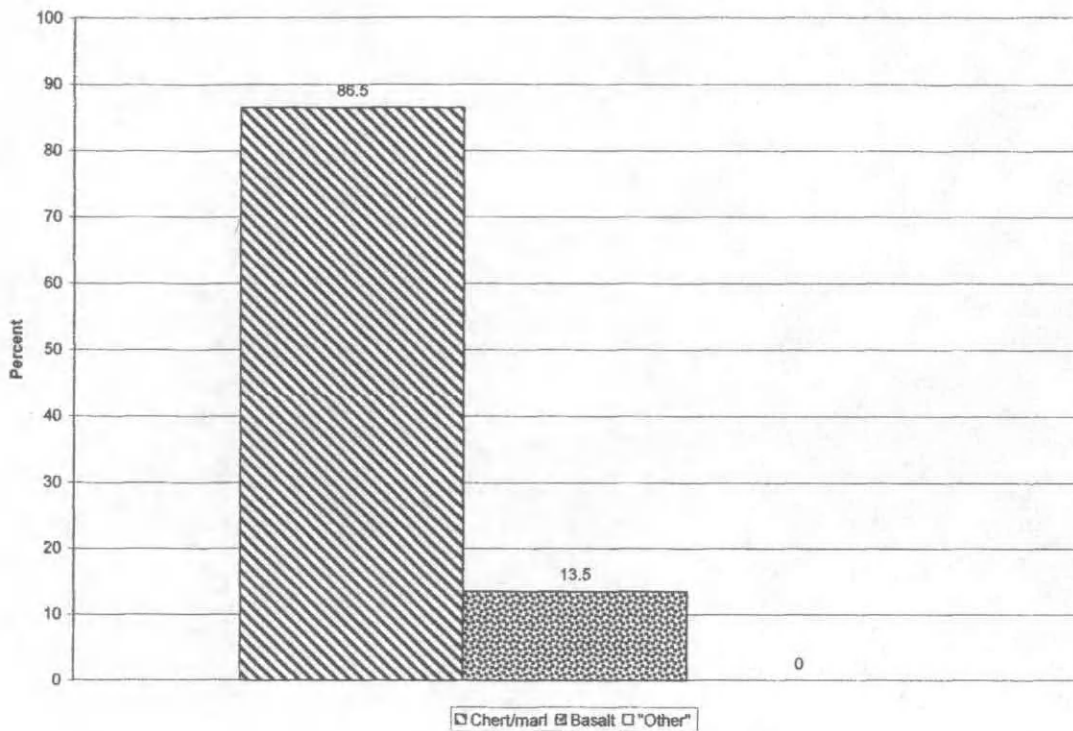


Figure 3.31 Level C Medium Debitage Material Types

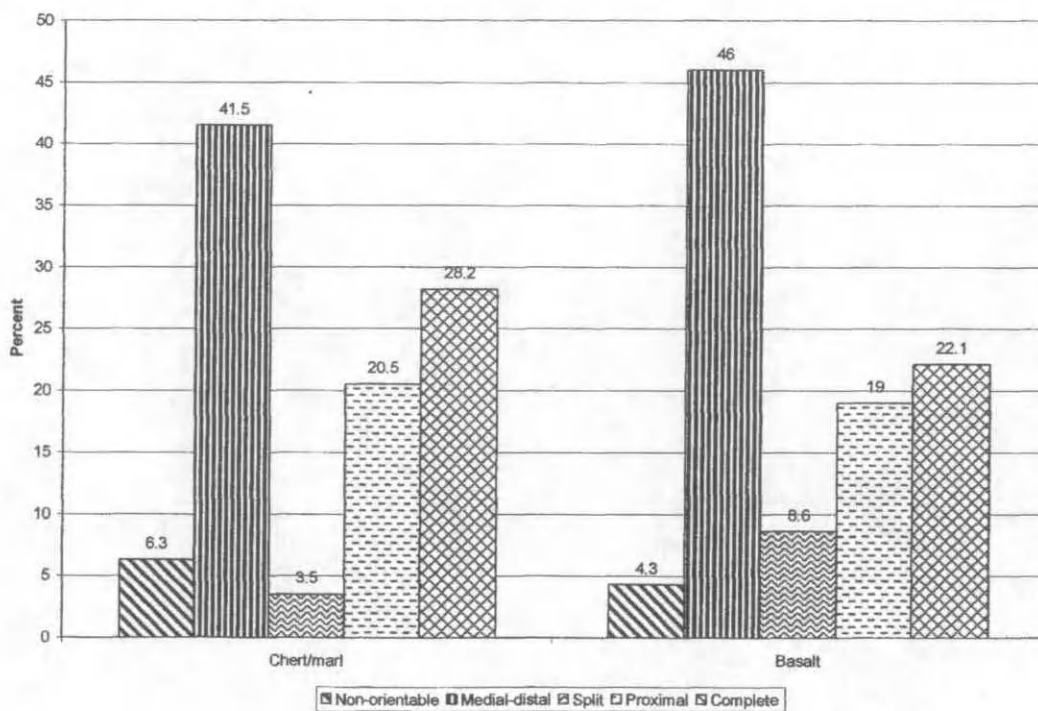


Figure 3.32 Level C Medium Debitage Completeness Types by Material

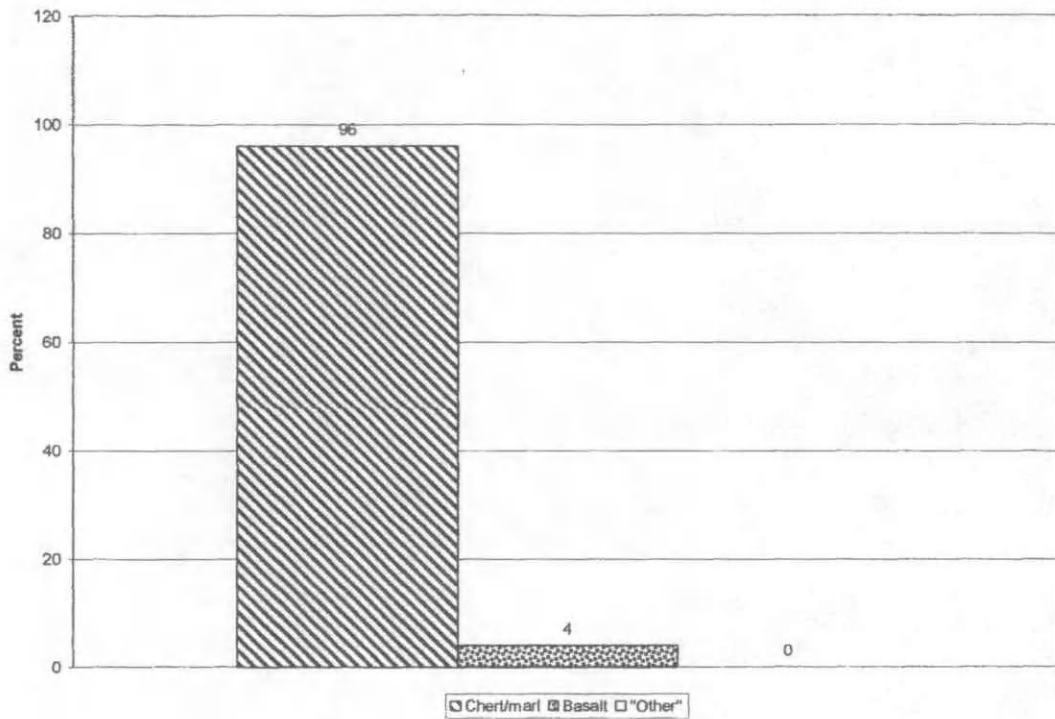


Figure 3.33 Level C Small Debitage Material Types

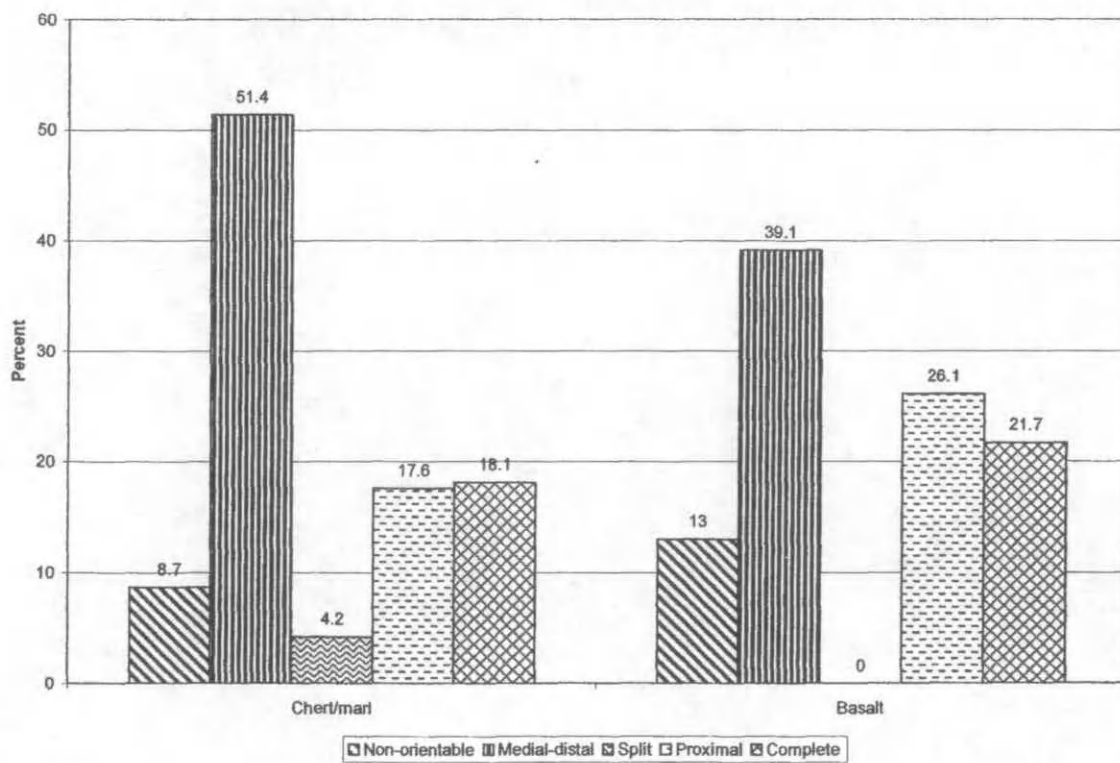


Figure 3.34 Level C Small Debitage Completeness Types by Material

Analysis of results Level A Initial analysis of the distribution of Level A chert/marl among size classes and flake-completeness types (MSRT; Prentiss 2001) suggests that the technological focus for that material type was core reduction. The Level A chert/marl is dominated by high proportions of large complete flakes (43.3% of that size class [osc]) and proximal flakes (17.9%osc); medium medial-distal fragments (38.8%osc) and non-orientable fragments (18.7%osc); and small non-orientable fragments (21.5%osc). This pattern is consistent with Prentiss' description of a size and flake-type distribution for a core reduction sequence (2001). However, the high proportion of complete flakes may actually be a factor of the toughness of the Avon chert/marl relative to the obsidian used in Prentiss' experiments (1998, 2001; Prentiss and Romanski 1989). Therefore, attention was focused on the small-sized debitage, which may actually be more representative of the production activities taking place at the Avon site.

The small size class represents a significant proportion of the Level A debitage (44.0% of chert/marl from Level A). This class is dominated by medial-distal fragments (53.4%osc) and has a relatively high proportion of proximal fragments (15.7%osc), which are traits more consistent with tool production according to Prentiss (2001). Though the larger debitage from the Level A assemblage appears to have been dominated by core reduction, given the predominance of complete flakes, it cannot be said that this was the sole technological focus at the Avon site. The small size class indicates that tool production using chert and marl was occurring during this occupation, and this size class may actually be a more accurate representation of the production activities taking place at the site.

Analysis of the basalt from Level A using the MSRT also appears to indicate the predominance of core reduction. Among the large size class, complete flakes (20.4%osc), proximal fragments (30.6%osc), and split flakes (24.5%osc) are well-represented. The medium size class is strongly dominated by medial-distal fragments (48.1%osc). Dominance of these flake-completeness types among these two size classes suggest core reduction according to Prentiss (2001). However, Prentiss also says that core reduction should include high proportions of small non-orientable fragments. The small size class is 76.1%osc medial-distal fragments, followed by proximal fragments (10.9%osc). There are very few non-orientable fragments among this size class (4.3%osc). All three of these traits are more suggestive of tool production than of core reduction according to both Prentiss (2001) and Baumler and Downum (1989), who consider small non-orientable pieces ("shatter," by their terminology) to be the hallmark of core reduction. Small size debitage represents 22.4% of all of the basalt from Level A, and this size class indicates basalt tool production taking place during this occupation.

The "other" materials in Level A (N=5), all of which are quartzite, are too few to interpret in any meaningful way. Of further note regarding the debitage from this level is the presence of four core fragments among the large chert/marl (three of which appear to be Levellois-type), and five such fragments among the medium chert/marl. There are also four and three blade-like flakes among the large and medium chert/marl, respectively. The presence of these core fragments and "blades" are discussed in the following chapter.

Level B Initial analysis of the distribution of Level B chert/marl among size classes and flake-completeness types using the MSRT suggests that core reduction was the primary technological focus for this material type. The large size class has high

proportions of complete flakes (45.2%osc), proximal fragments (18.3%osc) and split flakes (11.5%osc), while the medium size class is dominated by medial-distal fragments (45.4%osc). All of these things are considered traits of core reduction (Prentiss 2001). However, the small size class, which constitutes 36.1% of the chert/marl from Level B, is strongly dominated by medial-distal fragments (64.4%osc), has a moderate proportion of proximal fragments (13.1%osc), and a relative paucity of non-orientable fragments (10.7%osc). The small size class, then, according to both Prentiss (2001) and Baumler and Downum (1989) more accurately reflects tool production. These distributions suggest that tool production was also a focus, if not the primary focus, of chert/marl reduction during this occupation.

The basalt from Level B shows a similar pattern: a high proportion of large complete flakes (57.1%osc) and proximal fragments (14.3%osc [there are, however, only 7 specimens in this size class]), and medium medial-distal fragments (43.5%osc) indicate a focus on core reduction. However, the small size class suggests that tool production was also a focus. The small debitage is dominated by medial-distal fragments (56.0%osc) and proximal fragments (32.0%osc) with very few non-orientable pieces (4.0%osc). This distribution is representative of tool production according to both Prentiss (2001) and Baumler and Downum (1989) and, since the small size class accounts for 45.5% of the Level B basalt, it is likely that tool production was the primary technological focus for the basalt during this occupation.

The "other" materials of this level (N=1; quartzite) are too few to make a meaningful interpretation. Also of note among the debitage from this level is the presence of seven core fragments in the large size class, and five such fragments in the

medium size class, all of which are chert/marl. The majority of these appear to be amorphous cores, discarded at the point of exhaustion. There are also seven blade-like flakes among the large size class and five blade-like flakes among the medium debitage. The presence of these cores and "blades" are discussed in the following chapter.

Level C Initial analysis of the chert/marl from Level C appears to indicate a focus on core reduction. This interpretation is based on the presence of many large complete flakes (46.9%osc) and proximal fragments (22.9%osc), and many medium medial-distal fragments (41.5%osc). As with the levels and materials discussed previously, the small size debitage appears to represent a focus on tool production. The small size class accounts for 30.87% of all of the chert/marl from Level C. The small debitage is dominated by medial-distal fragments (51.4%osc), with a significant proportion of proximal fragments (17.6%osc) and very few non-orientable pieces (8.7%osc), all of which are suggestive of tool production (Baumler and Downum 1989; Prentiss 2001).

The Level C basalt follows a similar pattern. The large debitage has high proportions of complete flakes (37.7%osc) and proximal fragments (18.4%osc), and some split flakes (10.5%osc). The majority of the medium size class is medial-distal fragments (46.0%osc). These traits are indicative of a core reduction strategy (Prentiss 2001). However, the small size class suggests that tool production on basalt was also taking place during this occupation, since there are high proportions of medial-distal fragments (39.1%osc) and proximal fragments (26.1%osc), and only a moderate amount of non-orientable pieces (13.0%osc). Unlike the other cases described above, the small size class of basalt debitage from Level C account for only 7.3% of all of the basalt from that level. It is possible, therefore, that core reduction was the primary focus for basalt during this

occupation and the presence of a tool-production-like distribution among the small size class is a byproduct of core reduction, since core reduction produces some amount of small medial-distal and proximal fragments each time it is performed.

No "other" materials were recovered from Level C of the Avon site. Also of note among this level's debitage is the presence of three core fragments within the large chert/marl category. There is also one blade-like flake in the large basalt, and three such flakes in the medium chert/marl debitage. The presence of these cores and "blades" is discussed in the following chapter.

Using a strict interpretation of the MSRT (Prentiss 2001), the debitage from all three levels of the Avon site appear to represent a primary focus on core reduction. However, the experimental collections that led to the formulation of the MSRT (Prentiss 1998, 2001) were produced on Glass Butte obsidian. The Avon chert/marl is a tougher raw material than Glass Butte obsidian, and so we can expect different proportions of flake completeness types among assemblages produced during Avon chert/marl reduction events (Prentiss and Romanski 1989). Logic dictates that this would be most evident in the proportion of complete flakes among the Avon debitage as compared to that of Prentiss' (1998, 2001) obsidian assemblages. The tougher Avon material is expected to produce higher proportions of complete flakes regardless of production goal than the more brittle obsidian in Prentiss' experiments. Therefore, the small size class is considered the size class least susceptible to material-type biases and most sensitive to actual production goals. Among both the chert/marl and the basalt material types for all three stratigraphic levels, the small size class debitage is indicative of a primary focus on tool production. This is supported by the evidence provided by both Prentiss (2001) and

Baumler and Downum (1989). Given the high proportions of small size debitage among the total debitage counts for all three levels, and the sensitivity of small-sized debitage to actual production goals, tool production appears to have been the primary technological focus as the Avon site.

Tool Analyses

Insofar as they are useful in drawing conclusions regarding production goals at the Avon site, descriptions of others of the artifacts from the site are provided here. A total of 175 non-debitage artifacts were included in the collection as of 2003. Of these, 87 are bifaces and biface fragments. Eight of that number are made on basalt. Some of the fragments mend to make complete or nearly complete bifaces, which were used in the symmetry index pilot study. A total of 53 bifaces from the Avon collection, including those that were mended, were considered complete enough to be used in the symmetry study. The rest of these were catalogued and described in detail on the catalog sheet, now housed with the artifacts.

There are forty-two cores, core fragments and core reduction flakes, all but one of which are chert/marl. All of the cores appear to be amorphous, with three exceptions, which are tabular. There are three core-rejuvenation flakes (one basalt), which appear to be inconsistent with the predominance of amorphous cores. Three of the cores exhibit bipolar reduction.

There are forty flake tools in the Avon collection. Among these are a convergent scraper, scrapers with bifacial retouch, notches, denticulates, a concave/convex scraper with alternating retouch, an L-shaped tool, tools with both abrupt and invasive retouch, a

graver and a corner-notched scraper. Eleven of these flake tools are basalt. All of the flake tools appear to have been made on flake-struck blanks. It is not believed that any of them were made on bifacial core-struck blanks.

When the non-debitage artifacts are considered as a whole, 88.0% are chert/marl and 12% are basalt. The implications of these notes on the non-debitage artifacts from Avon are discussed in the following chapter.

Chapter Four

Discussions and Concluding Remarks

The methods and results described in the previous chapters indicate that the Avon site (24PW340) was used as a quarry workshop for the production of early- to middle-stage bifaces (preforms) and tools, and that an index of symmetry is a useful tool in addressing goals of biface production. Understanding the goal or goals of biface production among Paleoindian groups vastly improves our ability to understand their lithic technological organization. Particular technological organizations, in turn, are thought to be indicative of particular mobility strategies. In light of the recent debate regarding the previously unchallenged "high-technology" forager model (Kelly 1988; Kelly and Todd 1988) and Bamforth's (2002) call for a reevaluation of that model, a methodology was devised to address this issue directly. Quantifying the amount of bilateral symmetry present among bifaces from archaeological contexts and comparing these numbers to numbers produced by collections from known reduction trajectories (i.e. Callahan's stages of projectile point manufacture [1979] and finished projectile points) can be indicative of the intended production goals represented by archaeological specimens. This method was applied to the bifaces from the Avon site (ca. 9300 BP), and the results suggested that bifaces were being produced for use as projectile points at that site. This conclusion was supported by an aggregate analysis of the Avon debitage, which suggested that the primary technological focus at the site was tool and preform production. These results support Bamforth's argument that the high-tech forager model and the supposition that many, if not most, Paleoindian groups relied on a bifacial core technology is not strongly supported by the archaeological evidence.

This chapter draws this thesis to a close by summarizing the results described in the previous chapter and offering some discussions and concluding remarks. The first part of this chapter is organized according to the three main themes that have run throughout the thesis: the symmetry index as a useful tool in discussing goals of biface production, and the application of that method to the bifaces from the Avon site; the multivariate quantitative analyses and their support of the symmetry index as a powerful and accessible tool in the assessment of biface production goals; and the Avon site debitage and its ability to shed light on the goals of production at that site. All of this is then synthesized in a final discussion of the research questions posed here: 1) are there real and discernable differences between bifaces produced for use ultimately as projectile points (i.e. preforms) and those produced for use as cores or long use-life tools; 2) can these differences be used to address the debate regarding Paleoindians as bifacial core-dependent versus some alternative hypothesis; and 3) does the data from the Avon site support one or the other side of said debate? Finally, suggestions for future research are provided and some final concluding remarks are offered.

Summary and Discussions

The Symmetry Index Pilot Study and the Multivariate Quantitative Analyses

The symmetry index pilot study and the multivariate quantitative analyses both indicate that the symmetry index is a useful tool in the quantification of symmetry among bifaces. The pilot study indicates that there *is* a pattern of increasing symmetry among preforms and finished projectile points: the more finished a biface intended ultimately for use as a projectile point, the more symmetrical that biface tends to be. The pilot study

also suggests that the symmetry index is capable of identifying subtle differences in symmetry that an observer may be unable to detect with the eye. Admittedly, the continua displaying the symmetry index distributions for the different study groups (Figure 3.2) also shows that each group displays a *range* of indices and that there is overlap between stages of production. Nonetheless, I am confident that calculating indices on a larger number of specimens of each type and conducting a more comprehensive study of bilateral symmetry on bifaces will help to identify a more discrete range for each type. These ranges, then, and the bifaces that produce them could be held as the standard. Quantifiable attributes of bifaces from archaeological contexts could be compared to those of the "standard" collections in order to draw conclusions about intended goals of production, just as a zooarchaeologist might use a comparative collection of faunal remains.

The results of the multivariate quantitative analyses performed on the Avon biface data suggest that there are real and significant differences between bifaces intended ultimately for use as projectile points and bifaces intended for use as cores, and that the symmetry index is a useful measure in determining these differences. This conclusion is inferred from several lines of evidence. The factor analysis performed on the Avon data produced a "shape" factor, which was based on an inverse relationship between symmetry index and width/thickness ratio and which explained a significant portion of the total variance. When the factor scores were plugged into a hierarchical clustering analysis, they produced a dendrogram that separated the 53 Avon bifaces into groups consistent with the "symmetry index value" groups, i.e. probable cores and probable preforms. This indicates that thickness relative to width and symmetry index are important variables in

the determination of whether a particular biface represents a preform or a core, and that the difference between the two types is knowable.

The two discriminant function analyses provide what is perhaps the most convincing evidence for the assertion that there are discernable differences between preforms and cores, and that the symmetry index is a useful tool in the placement of a given biface into one or the other of these categories. The group statistics produced when "symmetry index value" and then "subjective value" were entered as the grouping variable illustrated the differences between the mean dimensions, mean edge angles, and mean weights of probable preforms versus probable cores. In the first discriminant function analysis, where "symmetry index value" was used as the grouping variable, the casewise statistics show that only five of the fifty-three cases were misclassified. That is, 90.6% of the original grouped cases were correctly classified. This suggests that the variables selected were very good predictors of which of the three pre-determined classes (symmetry indices >5.0 , $4.9-2.0$, or <1.9) each biface would be placed into. Conversely, visually assessed group membership ("subjective value") was only correctly classified 77.4% of the time.

The Student's "t" tests performed on the data for the two grouping variables shows that there are statistically significant differences between preforms and cores. By comparing the mean values for a number of attributes between the "symmetry index value" of >5 (probable cores) and that of <1.9 (probable preforms), it was determined that there are significant differences in width/thickness, symmetry index, thickness and edge angle.

Having discussed the utility of the symmetry index and the strength of the

arguments afforded by the quantitative analyses, it is necessary to point out some of the shortcomings of the materials and methods used here and to make suggestions for future research. Perhaps the greatest shortcoming of the present study is the limited number of specimens used. Given the success rate of the test sample (76%), the acceptable margin of error (5%), and the desired 95% confidence level, 290 bifaces would have to be tested in order to make the present assertions reliable. Furthermore, as was done during the initial pilot study for the utility of the symmetry index, parametric data should be collected from a number of known sample groups such as finished projectile points, bifacial cores, and preforms made through replicative experimentation, and similar multivariate quantitative analyses should be performed in order to strengthen the arguments made here. Finally, it is critical that a study collection of bifaces known to have been used as cores be obtained. In light of the current controversy regarding the true function of many bifaces in the archaeological record (Bamforth 2002), it may be necessary to reproduce such a collection from ethnographic accounts. Without a collection of bifacial cores, assertions regarding the attributes of core-like bifaces are merely informed conjecture. Nonetheless, the information provided above makes a strong case for the hypotheses that there are real and significant differences between bifaces intended ultimately for use as projectile points (preforms) and bifaces intended for use as cores, and that the symmetry index is a useful tool in determining these differences. I believe that additional studies can only strengthen this argument.

The Avon Debitage

Although the large and middle size classes ofdebitage from all three stratigraphic

levels of the Avon site appear to represent a primary technological focus on core reduction (Prentiss 2001), other lines of evidence suggest otherwise. That is, the small size class debitage from all three stratigraphic levels is consistent with tool and preform production (Baumler and Downum 1989; Prentiss 2001). When we consider the fact that Prentiss' experiments were performed using Glass Butte obsidian, which is considerably more brittle than Avon chert/marl, the large numbers of complete flakes among the larger size classes is not surprising. Smaller debitage may actually be less susceptible to material type fracture biases, and so attention was focused on this size class for the purpose of determining production goals at the Avon site. Small debitage constitutes a considerable portion of most material types/stratigraphic levels at Avon, and the distributions of flake-completeness types among this size class are consistent with the pattern described by Prentiss (2001) for tool production. This includes high proportions of medial-distal and proximal fragments, and very few to no non-orientable pieces. The small debitage is also consistent with Baumler and Downum's (1989) observations for core reduction versus tool production. That is, core reduction assemblages produce much higher percentages of shatter (non-orientable pieces) than tool production assemblages, and the small Avon debitage has relatively few non-orientable pieces in all material types and stratigraphic levels. Therefore, it is concluded that tool and preform production were the primary technological foci at the Avon site, based on the debitage distributions.

Another interesting point to consider regarding the Avon site debitage is the proportion of pieces that exhibit thermal alteration. Callahan devised a scale of lithic material workability and notes that exposure to heat "seems to raise most amenable materials .5 to 1.0 higher in the scale. A 1.5 raising may be possible under optimum

conditions" (1979:16). Thermal alteration may have been used to increase the ease of workability of the cherts and marls at the Avon site. Of the Level A chert/marl, 16.5% exhibit thermal alteration. Of the Level B chert/marl, 20.1% is thermally altered, and of the Level C chert/marl, 11.7% of the debitage bears evidence of thermal alteration. When considered as a whole, 15.7% of the Avon site debitage has been affected by exposure to heat.

The counts for burned material among the Avon debitage were made according to incontrovertible signs of thermal alteration: reddening, textural changes, charring, potlidding and crazing. The counts, therefore, may actually be fairly conservative. It is also interesting to note that very few cortical flakes showed signs of heat treatment. Many flakes exhibit potlidding on interior flake surfaces and could, therefore, only have been heated after having been removed from an objective piece. This latter phenomenon may actually be representative of lithic reduction activities taking place in front of a fire and the pieces being burned unintentionally, or some other incidental exposure to heat as opposed to deliberate thermal alteration. The fact that a significant proportion of the collection has been thermally altered, however, leads me to believe that at least some of the time the materials were being heat treated intentionally.

Also of note are the twenty-six blade-like flakes observed among the debitage (0.5% of total debitage). All of these flakes are of the large and medium size classes, and all but one are chert/marl. Hester et al. (1977) note the presence of a small number of blades at the nearby site 24PW320. However, they say that these do not suggest the "presence of a core blade technology" and that they probably represent unintentional "byproducts of a flake industry" (1977:245). This calls to the fore the question of what

constitutes a significant percentage of blades in a debitage assemblage for the possibility of a blade technology and the implied mutual exclusion of flake-based and blade-based technologies. Is it not possible that one culture made supplemental use of a blade technology when a flake technology was the dominant method, for example? I am not suggesting that the occupants of Avon were using a blade technology, supplementally or otherwise, as less than one percent of the debitage resembles blades. This question is mentioned here merely as point for future consideration and as commentary on the discipline-wide tendency to view technologies in isolation.

The percentage of cortical pieces among the Avon site debitage (13.5%) was calculated as a point of interest. It has been suggested that the presence of cortex tells us little more than whether a piece was decorticated on site (Mauldin and Amick 1989). In the case of the Avon site, it is suspected that some of the materials being worked were taken from the secondary-source gravels exposed in Strickland Creek. These would have been decorticated in the process of reduction and thus would leave cortical flakes among the debitage. The percentage of cortical flakes may, therefore, offer insights into the degree to which the gravel deposits were utilized as sources of raw material. Future studies might benefit from such an inquiry.

Having made these observations and drawn conclusions regarding the Avon site debitage, it is necessary to point out some of the shortcomings and potentially insurmountable obstacles regarding use of the Avon debitage to interpret that site in a meaningful way. During the 1966/67 excavations, debitage was collected only according to vertical provenience, that is, without horizontal control. Any meaningful distribution of the debitage across the site cannot be assessed due to insufficient provenience. Nor

was a precise method of collection described in the field notes from the 1966/67 field seasons. It seems that each unit was excavated according to natural stratigraphy, which diminished the control afforded by the introduction of smaller, arbitrary levels.

Furthermore, the precise dimensions of each unit were not provided. References in student field journals indicate that some of the units became quite large over the course of the two field seasons, and so a reasonable reconstruction of even the general provenience of the debitage was not possible. Finally, the bags containing the debitage were labeled simply "Level A," "Level B," and "Level C." It appears that the debitage from all units' Level A is included together, for example. Therefore, the levels are taken to represent a very broad stratigraphic sequence across the entire site.

The lack of horizontal provenience severely limits the potential to interpret the distribution of activity areas and the use of space within the site. Examination of all of the Level A debitage from across the site collapses the variability that may be present in the horizontal plane. It may have been the case, for example, that different tasks were being performed in different locales across the site. Add to this the dimension of time—the fact that different locales could have been used to perform different tasks during different seasons or separate visits to the site—and the lack of provenience is all the more confounding. That is, it is also quite possible that more than one, if not many, cultural levels of occupation were collapsed through the use of broad, natural strata to guide excavations.

It is unclear whether all of the debitage encountered during the excavations was collected or whether some sampling method was employed. Furthermore, essentially untrained field school students may not have recognized all of the lithic debitage as such.

Non-orientable pieces, for example, may not have been recognized as having been culturally modified. And, finally, there are the phenomena of scavenging and culling by prehistoric peoples (Prentiss 1993) and "relic hunting" in the far more recent past which may have altered the debitage assemblage.

Post-excavation methods of handling the Avon material may also be partially responsible for a certain amount of skewness of the Avon debitage data. Some of the Avon debitage shows signs of "bag-wear." That is, many pieces have been chipped or broken over the course of nearly forty years of bag-in-box transport. No count was made of all such pieces with relatively recent chips or breaks and it is suspected that the number would not dramatically alter the outcome of the MSRT study. Complete flakes were the most prevalent type in the large size class regardless of the potential exclusion of flakes that were broken post-excavation. Such breakage may also have skewed the size classifications slightly. It is unclear how much of the debitage would have been included in a larger size class before the effects of bag-wear.

On a similar note, several of the pieces in the debitage collection exhibit "nibbling." These were examined under a 40x microscope and determined to be the products of bag-wear or trampling, prehistoric or otherwise. The chips and breaks are inconsistent with established patterns of wear produced by cutting or scraping (Flenniken and Haggerty 1979; McBrearty et al. 1998; Nielsen 1991; Pryor 1988).

The shortcomings mentioned above are in no way intended as criticisms of the work performed during the 1966-1967 field seasons. It is well understood that the goals of those investigations differ from the goals of the present thesis. Hobler stated in no uncertain terms that "[t]he sole purpose of our work was to obtain a sample of early

materials from an intact archaeological context which would permit assessment of association and direct dating, both of which we succeeded in doing" (personal communication, 2003). The points considered above are mentioned merely as a cautionary note for those seeking a better understanding of the Avon site through the debitage.

At the end of the last chapter, I introduced some of the other tools present in the Avon collection. These were mentioned because aspects of their nature and presence are relevant to the arguments being made here. It is of interest that only 12% of the non-debitage assemblage is basalt. This is concurrent with the fact that just 10.0% of all of the Avon site debitage is basalt. Thus, it is apparent that basalt was a less desirable lithic material than the locally available chert/marl.

The presence of forty flake tools, including scrapers, graters and notches, suggest a few possible scenarios. It is possible that the tools found at the Avon site were discarded because they were exhausted and new tools were being made to replace them. It may also be the case that the tools were made at the site, used in "gearing up" activities (shaft straightening and manipulation for projectile point fitting, etc.), and discarded on site. It is possible that domestic activities were being performed at the site in conjunction with lithic reduction activities, i.e. a temporary encampment at the resource site. It may also be that these tools are part of the toolkit of a more permanent encampment near the quarries. Hester et al. (1977) note that Napton had located extensive midden deposits in the general vicinity of 24PW320, which is also quite close to the Avon site, 24PW340. Unfortunately, no further reference to these middens has been located and their precise location is not known.

Future work with the Avon debitage should include a distinctive artifact approach. Counting dorsal facets and platform scars, assessing fracture initiations and terminations might give a much more precise picture of the type or types of reduction taking place at the Avon site. Such a detailed analysis might also strive to distinguish differences in fracture mechanics inherent to the cherts, marls and porcellanites of the Avon Valley. This might provide insights into preferences expressed in coupling particular material types with particular tool types. This same study might also seek to augment the MSRT by performing similar experiments using Avon chert.

Furthermore, I recommend a detailed records search for the presence of the Avon chert/marl in other sites throughout the region. Cameron states that "[a]rchaeological distribution of the Avon material also indicates that populations exploiting this material covered a wide area. Reeves (1972) reports large quantities of Avon chert in the Waterton Lakes area of Canada, approximately 300 miles north of Nevada Creek" (1984:13). Other studies of this kind could be used to address the concern expressed by Bamforth (2002) that many of the assumptions that we have made about the Paleoindian lifestyle, including the transport of lithic raw materials over very large distances to reduce the risk of not having materials available in the next location, are not well-supported by the archaeological record.

The Avon Site (24PW340)

Analyses of both the Avon bifaces and the Avon site debitage suggest that the site was used as a quarry workshop for the production of early- to middle-stage bifaces (preforms) and tools. It appears that quarry blanks were being roughed out at the nearby

Antelope Hill and Rhine Point Quarries and transported to the Avon site for further reduction into these types of tools. Avon is located on a relatively flat floodplain on the Avon Valley floor, adjacent to running water, which would have been a draw for both people and game animals. The area would have been ideal for a seasonal, repeated occupation base camp. Evidence for this hypothesis is drawn from the biface and debitage analyses, as well as the following supplemental data derived from various sources. The purpose the analyses applied to the Avon material was to determine whether the makers of the Avon collections employed a bifacial core technology and to infer from such a conclusion the nature of the Avon peoples' mobility strategies. Determining these traits contributes to the present discussion regarding the nature of Paleoindian technological organization and mobility strategies (cf. Bamforth 2002; Kelly 1988; Kelly and Todd 19688).

Given the limited nature of the excavations performed at the Avon site during the 1966/67 field seasons, and given the fact that the materials and data from those two field seasons form the basis of this thesis, it could not be determined whether the site contains evidence of logistical or residential encampment. Hester et al. note that the debitage and tools from 24PW320, just south of the Avon site, suggest that the site was either a workshop near a base camp or a logistical camp for a small group procuring lithic materials. They state that, superficially, the site appears to be a logistical "chipping station" but that Napton's work in the greater Avon Valley revealed extensive middens nearby, which suggests a repeated occupation base camp (Hester et al. 1977). The contents and location of these middens remains unavailable to researchers, however. Still, it may be possible to infer the nature of occupation at Avon using other lines of evidence. Callahan

notes that:

if the workshop (that area where quarried rock was reduced to transportable form) were near the quarry and both areas were at a distance from the home base, it may have been that the chunks, nodules or cores were carried, as extracted, to the workshop area after preliminary testing. At the workshop, spalling and preliminary shaping, Stages 1 through 3 or 4 might have been performed prior to transportation to the home base. But if the workshop was also the base camp. . .then it may have been that the blocked-out quarry cores were carried 'home' and the entire sequence of manufacture performed there (1979:40).

If Callahan's generalizations are correct, it appears that the latter is more likely the case at the Avon site. The debitage analysis indicates that the primary technological focus at the workshop was preform manufacture and tool production, which suggests that this workshop may have been close to—essentially an activity area within—the base camp. Hobler states that, during the 1966/67 field seasons, “principal excavation consisted of broadside scraping of a long arroyo bank. [They] did not cut the bank back more than 30–40 cm in this process” (Philip Hobler, personal communication, 2003). Field journals from the 1966/67 field seasons suggest that units were excavated back from the bank of the creek and expanded parallel to the creek as dictated by the presence of artifacts. These descriptions imply that excavations were not designed to locate specific activity areas on the living surface. However, the debitage analyses and the reported presence of extensive middens in the area suggest that the Avon site is located close to, or is indeed part of, a base camp.

The Avon site debitage analyses indicate that the primary technological focus at the site was tool production. Other lines of evidence presented in this thesis allow us to expand upon that inference in an attempt to form a more complete picture of the Avon site. Hester et al. (1977) note that at 24PW320, which is located just south of the Avon

site, debitage patterns suggest that "roughed-out" pieces were being brought from nearby Antelope Hill to the site and further "reduced to produce. . . flakes to be used in implement manufacture" (1977:244). Their conclusion was drawn from an analysis of cortical flake percentages and the presence of "interior and biface thinning flakes" (1977:244). High percentages of such flakes suggest a focus on tool production, as was the case at 24PW320. A more detailed analysis of 24PW320 would benefit from a debitage analysis incorporating Prentiss' MSRT (2001) and Baumler and Downum's (1989) findings regarding small-sized debitage. Since 24PW320 is located just south of 24PW340 (the Avon site), perhaps separated only by a few tens of meters, such an analysis would aid our interpretation of the prehistory of the Avon Valley.

Hester et al.'s (1977) broad conclusions regarding a core-and-flake industry at 24PW320 is interesting nonetheless. Bamforth states that among bifacial core-dependent groups, "nonbifacial cores and debris from the reduction of such cores should be rare or absent" (2002:65). Hester et al. mention the presence of "chunks [that] were especially numerous in Section 2 and many of these probably represent core fragments" (1977:244). Though they do not describe these potential core fragments in detail, reference to them as "chunks" suggests that perhaps they were amorphous. Among the non-debitage artifacts at Avon, there are thirty-six cores and core fragments, the majority of which are amorphous. If Bamforth (2002) is correct in his assertion that groups dependent on a bifacial core technology would not have employed amorphous cores, then the presence of amorphous cores at 24PW320 and the Avon site suggest that the people responsible for these assemblages were not bifacial core dependent.

It is interesting to note that two bifaces with symmetry indices greater than 5.0

showed signs of thermal alteration. Thermal alteration is generally considered a method employed in order to make an objective piece more easily workable (cf. Callahan 1979). While it is possible that heat treating such large pieces was intended to make the flakes generated from those pieces more easily workable into smaller tools, it is more likely that such heating was being performed in order to make the larger piece more workable in itself. This is further evidence for the production of projectile point preforms rather than for bifacial cores.

The intended production goals for the numerous bifaces found at the Avon site and surrounding areas has been the subject of some debate. Hobler, who conducted excavations at the Avon site between 1966 and 1967, believes that the Avon site

represents a secondary lithic reduction site. That is, there were lots of large bifaces resulting from the reduction of materials quarried elsewhere. These bifaces were probably on their way to becoming points. . . . I have come to believe that the production of bifaces to serve as 'blanks' for later reduction into points might have been an end in itself. Avon might have been a factory location for the manufacture of 'blanks' . . . (personal communication, 2003).

While this scenario seems likely in light everything we know of the Avon site thus far, it is not unreasonable to conclude that different types of bifaces, or bifaces with different intended functions, were being manufactured at this quarry workshop site. Speculating as to the production goals at the North Avon Quarry site, Cameron notes that

. . . production at the quarry may have been geared to the manufacture of large bifaces, that could have been transported for use as cores. Several of these items were noted while examining the quarry area. A large (15 cm long) biface or preform was noted at the quarry area on [Rhine Point] and Napton (1981) mentions several of a similar size found in subsurface deposits in the Main section of 24PW340. Dr. Thomas Hester (1970 field notes) noted a group of large artifacts that he called 'cores' associated with quarry pits on a knoll at the southeast end of [Antelope Hill] (1984:6).

Bamforth (2002:55) suggests that bifacial cores were not the "centerpieces of Paleoindian technology," as many prior reports had claimed them to be (cf. Kelly 1988; Boldurian and Hubinsky 1994). He goes on to suggest that "[u]se of bifaces first as cores and subsequently as blanks for tools also implies that many tools should be made on biface-struck blanks. In addition, nonbifacial cores and debris from the reduction of such cores should be rare or absent" (Bamforth 2002:65). The cores and debitage from the Avon site fail to meet these criteria. That is, there are a number of amorphous cores in the collection, the majority of the debitage appears to have been struck from such cores (though the method used to analyze the debitage was not a distinctive artifact approach), and none of the flake tools appear to have been produced on biface-struck blanks. While it may be the case that bifacial core use did not play the central role that it has been purported to have played, Bamforth himself admits that most Paleoindian sites on the Great Plains have not been examined in light of this hypothesis. His predictions as to what a bifacial core-based technology ought to look like in the archaeological record are based on informed logic and reexamination of a handful of Paleoindian assemblages. Furthermore, while Bamforth acknowledges the fact that Paleoindian technological organization was probably not uniform across time or space, he does not address the possibility that the two technologies could have coexisted.

The people responsible for the Avon assemblage were clearly making projectile point preforms. However, there is additional, quantitative evidence supporting prior claims that the makers of the Avon bifaces may have been producing bifacial cores as well. There are a number of bifaces with indices in excess of 5.0 (N=16). The

multivariate quantitative analyses described in this thesis suggest that bifaces with elevated indices of symmetry share other quantifiable traits in common. Comparing the mean values of these traits among bifaces with elevated symmetry indices to the mean values of these traits among bifaces with lower indices indicates a very low probability that individual bifaces from either of these two categories could mistakenly be placed in to the opposite category. These lines of reasoning suggest that some of the large, asymmetrical bifaces, most especially those that do not exhibit breaks consistent with failure during thinning and whose indices exceed 5.0, may actually represent bifacial cores. Though the Avon material appears to have been dominated by the production of projectile point preforms and tools, and despite Bamforth's claim that bifacial core using groups would leave very little evidence of non-bifacial core use, there is no convincing evidence to date that these two technologies—core-and-flake-based and bifacial core-based—could not have coexisted.

Understanding the goals of biface production among Paleoindian groups vastly improves our ability to understand their lithic technological organization. Particular technological organizations, in turn, are thought to be indicative of particular mobility strategies. Given the recent debate regarding the integrity of the "high-tech" forager model (Kelly 1988; Kelly and Todd 1988) versus Bamforth's (2002) call for a reevaluation of that model, our ability to determine the difference between bifaces produced for use as cores and those produced for use as projectile points is vitally important.

Bamforth (2002:55) has argued that the archaeological record does not strongly support the notion that bifacial cores were the "centerpieces of Paleoindian technology."

If it is determined that Paleoindians were not bifacial core-dependent, as we have come to believe that they were, we may be forced to reconsider everything that we have come to believe about Paleoindian lifeways. Faced with this debate, it was necessary to develop a means for interpreting a collection of bifaces from a late Paleoindian context (the Avon site) to enable direct observation of the presence or absence of bifacial core use at that site. Bifaces are often poorly defined in the literature regarding Paleoindian sites, and the actual function of many bifaces found in these contexts is suspect. Bamforth notes that "[o]ne particularly important aspect of any discussion of these issues is distinguishing between bifacial cores and unfinished blanks and preforms for bifacial knives. Standards for distinguishing between bifacial cores and bifacial tools are rarely made explicit. . ." (2002:65). In this thesis, I outlined a method for distinguishing the difference between these two types of bifacial artifacts. I then applied these methods to the bifaces from the Avon site and establish that, not only do the data from the Avon site support Bamforth's (2002) argument that the archaeological record does not strongly support the "high-tech" forager model, but also that the symmetry index used to arrive at this conclusion could be applied to bifaces from other sites in order to address Bamforth's concerns and, potentially, to reevaluate Paleoindian lithic technological organization and mobility strategies.

Concluding Remarks

The symmetry index described and applied herein was developed as a means for interpreting the Avon site bifaces in light of the present debate surrounding the lithic technological organizations and mobility strategies of Paleoindians. Specifically, the

procedures outlined in this thesis were designed to explore the use of bilateral symmetry in determining differences between bifacial cores and early stage projectile point preforms. It is well understood that there remains a rather ambiguous group of artifacts among the bifaces considered in these analyses and that so, too, would there be such a group if this method were to be applied to other archaeological collections without further refinement. The sample groups used were small. The evidence, however, does seem to be in favor of the functional utility of the method, and the quantitative analyses makes a strong case for the hypotheses that there are real and significant differences between bifaces intended ultimately for use as projectile points (preforms) and bifaces intended for use as cores, and that the symmetry index is a useful tool in determining these differences. This thesis provides basic, quantifiable guidelines for discerning the difference between preforms and bifacial cores when that difference is not readily apparent by traditional means. It also provides a common vocabulary through which we may begin to reduce the ambiguity inherent in the present literature regarding "bifaces." That is, if we include symmetry indices in our reports, we eliminate the imprecision of terms like "less symmetrical" and allow for alternative interpretations by our peers. Finally, this method can only become more widely applicable and accurate through additional testing of larger and more diverse sample groups which I believe will result in more refined ranges of indices for particular control groups of bifaces.

Callahan and others assert that successful completion of each of a number of identified stages in projectile point manufacture is requisite for the successful completion of each subsequent stage. If this is correct, we can assume that the parameters outlined for each stage would have been held as the ideal during projectile point manufacture

among prehistoric knappers, however subconsciously. The study of symmetry outlined here attempts to identify a range of indices among different types of bifaces, and to support the theory that symmetry does play a significant role in the determination of whether a particular biface was intended for use as a core or as a preform. Deviation from perfect symmetry may be an additional "footprint" left by bifacial core-using people and systematic inclusion of measures such as the symmetry index in our analyses may aid our understanding of Paleoindian lifeways. Those things intended ultimately for use as projectile points do show a trend towards more perfect bilateral symmetry with each sequential stage. Conversely, those things labeled "bifaces" in the literature likely represent a range of production goals—some resembling projectile point preforms and some more likely representative of bifacial cores, which are highly portable, highly flexible sources of raw material that could have been used as tools in their own right by highly mobile people. If we are to better understand Paleoindian lifeways, we need to identify the techno-functional role of individual bifaces in the archaeological record. The potential to clarify the use of bifaces in the archaeological record through the incorporation of a readily accessible study of symmetry into our routine analyses of bifaces from archaeological sites may prove to be a valuable tool in determining how a particular group organized their lithic technology and, potentially, their system of mobility.

REFERENCES

Adair, L.

1976 The Sims Site: Implication for Paleoindian Occupation. *American Antiquity* 41:325-334.

Avnir, D., O. Katzenelson, S. Keinan, M. Pinsky, Y. Pinto, Y. Salomon and H. Zabrodsky

1997 The Measure of Symmetry and Chirality: Conceptual Aspects. In *Concepts in Chemistry: A Contemporary Challenge*, edited by D. H. Rouvray, pp. 283-324. Research Studies Press, Ltd., Taunton, Somerset, England.

Bamforth, D. B.

1986 Technological Efficiency and Tool Curation. *American Antiquity* 43:38-50.

2002 High-Tech Foragers? Folsom and Later Paleoindian Technology on the Great Plains. *Journal of World Prehistory* 16(1):55-98.

Baumler, M. F. and C. E. Downum

1989 Between Micro and Macro: A Study in the Interpretations of Small-Sized Debitage. In *Experiments in Lithic Technology*, edited by D. S. Amick and R. P. Mauldin, pp. 101-116. BAR International Series 528.

Beck, C.

1998 Projectile Point Types as Valid Chronological Units. In *Unit Issues in Archaeology*, edited by A. Ramenofsky and S. Steffen, pp. 21-40. University of Utah Press, Salt Lake City.

Binford, L. R.

1977 Forty-Seven Trips. In *Contributions to Anthropology: The Interior Peoples of Northern Alaska*, edited by E.S. Hall, Jr., pp. 299-351. National Museum of Man Mercury Series, Archaeological Survey of Canada Paper No. 49. National Museums of Canada, Ottawa.

1979 Organization and Formation Processes: Looking at Curated Technologies. *Journal of Anthropological Research* 35:255-273.

1980 Willow Smoke and Dog's Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45:4-20.

Bleed, P.

1986 The Optimal Design of Hunting Weapons: Maintainability and Reliability. *American Antiquity* 51:737-747.

Boldurian, A. T.

1990 Lithic Technology at the Mitchell Locality of Blackwater Draw: A Stratified Folsom Site in Eastern New Mexico. *Plains Anthropologist* 35(130): memoir 24.

1991 Folsom Mobility and Organization of Lithic Technology: A View from Blackwater Draw, New Mexico. *Plains Anthropologist* 36(137):281-295.

Boldurian, A. T. and S. M. Hubinsky

1994 Preforms in Folsom Lithic Technology: A View from Blackwater Draw, New Mexico. *Plains Anthropologist* 39:445-464.

Borchert, J. L.

1989 Parallel-Oblique Flakes Projectile Points: Angostura, Lusk, Frederick, James Allen? Unpublished Master's Thesis, Department of Anthropology, The University of Montana.

Bradley, B.A. and G.C. Frison

1980 Projectile Points and Specialized Bifaces. In *The Horner Site: The Type Site of the Cody Cultural Complex* edited by G. C. Frison and L. C. Todd, pp.199-231. Academic Press, Orlando.

Callahan, E.

1979 The Basics of Biface Knapping in the Eastern Fluted Point Tradition: A Manual for Flintknappers and Lithic Analysts. *Archaeology of Eastern North America* 7(1):1-180.

Cameron, C. M.

1984 Chipped Stone Procurement and the Archeology of the Nevada Creek Drainage. Report on file, Archaeological Records, The University of Montana.

Choquette, W. and C. Holstine

1982 An archaeological and historical overview of the Bonneville Power Administration's proposed Garrison-Spokane transmission line corridor, western Montana, northern Idaho and eastern Washington. Bonneville Cultural Resource Group Report Number 100-20. Eastern Washington University Reports in Archaeology and History, Cheney, Washington.

Christenson, S. L.

1986 Projectile Point Size and Projectile Aerodynamics: An Exploratory Study. *Plains Anthropologist* 31:109-128.

Collins, M.

1975 Lithic Technology as a Means of Processual Inferences. In *Lithic Technology: Making and Using Stone Tools*, edited by E.H. Swanson, pp. 15-34. Aldine, Chicago.

- Crompton, R. and J. Gowlett
1993 Allometry and Multidimensional Form in Acheulean Bifaces from Kilombe, Kenya. *Journal of Human Evolution* 25:175-199.
- Elston, B. and C. Raven
1990 Archaeological Investigations at Tosawihi, a Great Basin Quarry, Part 2: The Periphery. 2 vols. Intermountain Research, Silver City, Nevada.
- Fedje, D., J. White, M. Wilson, D.E. Nelson, J. Vogel and J. Southon
1995 Vermilion Lakes Site: Adaptations and Environments in the Canadian Rockies During the Latest Pleistocene and Early Holocene. *American Antiquity* 60:81-108.
- Fields, R. C.
1984 Nevada Creek Basin Archaeological Project, Western Montana, Powell County Montana: Geological Reconnaissance Report. Report on file, The University of Montana, Missoula.
- Flenniken, J., and J. Haggerty
1979 Trampling as an Agent in the Formation of Edge Damage: An Experiment in Lithic Technology. *Northwest Anthropological Research Notes* 13:208-214.
- Francis, J.
1983 Procurement and Utilization of Chipped Stone Raw Materials: A Case Study from the Bighorn Mountains and Basin of North-Central Wyoming. Ph.D. dissertation, Department of Anthropology, Arizona State University.
- Frison, G. C.
1980 The Tool Assemblage, Unfinished Bifaces, and Stone Flaking Material Sources. In *The Horner Site: The Type Site of the Cody Cultural Complex* edited by G. C. Frison and L. C. Todd, pp. 233-278. Academic Press, Orlando.

1984 The Carter/Kerr-McGee Paleoindian Site: Cultural Resource Management and Archaeological Research. *American Antiquity* 49:288-314.

1991 *Prehistoric Hunters of the High Plains*. Academic Press, California.
- Frison, G. C. and B. A. Bradley
1980 *Folsom Tools and Technology at the Hanson Site, Wyoming*. University of New Mexico Press, Albuquerque.
- Frison, G. C. and L. C. Todd
1987 *The Horner Site: The Type Site of the Cody Cultural Complex*. Academic Press, Orlando.

- Glennan, W. S.
1972 The Manix Lake Lithic Industry: Early Lithic Tradition of Workshop Refuse? Paper read at the 37th S.A.A. Conference. 32pp.
- Goodyear, A. C.
1979 *A Hypothesis for the Use of Cryptocrystalline Raw Materials among Paleoindian Groups of North America*. Research Manuscript Series 156. South Carolina Institute of Archaeology and Anthropology, University of South Carolina, Columbia.
- Gramly, R. M.
1980 Raw Material Source Areas and "Curated" Tool Assemblages. *American Antiquity* 45:823-833.
- Greiser, S.
1984 Projectile Point Chronologies of Southwestern Montana. *Archaeology in Montana* 25:35-51.
- Hayden, B.
1997 *The Pithouses of Keatley Creek*. Harcourt Brace College Publishers, Fort Worth.
- Hester, T. R., A. D. Albee, and C. Willer
1977 Lithic Analysis of a Controlled Surface Collection from a Site in Western Montana. *Plains Anthropologist* 22(77):239-249.
- Kay, M.
1998 The Central and Southern Plains Archaic. In *Archaeology on the Great Plains*, edited by W. R. Wood, pp. 173-200. University Press of Kansas, Lawrence.
- Kelly, R. L.
1983 Hunter-Gatherer Mobility Strategies. *Journal of Anthropological Research* 39:277-306.

1988 The Three Sides of a Biface. *American Antiquity* 53:717-734.
- Kelly, R. L., and L. C. Todd
1998 Coming into the Country: Early Paleoindian Hunting and Mobility. *American Antiquity* 53:231-244.
- Kuhn, S. L.
1994 A Formal Approach to the Design and Assembly of Mobile Toolkits. *American Antiquity* 59:426-442.

- McBrearty, S., L. Bishop, T. Plummer, R. Dewar, and N. Conard
1998 Tools Underfoot: Human Trampling as an Agent of Lithic Artifact Edge Modification. *American Antiquity* 63:108-129.
- Magne, M.
1985 *Lithics and Livelihood: Stone Tool Technologies of Central and Southern Interior British Columbia*. Mercury Series No. 133. National Museum of Man, Ottawa.

1989 Lithic Reduction Stages and Assemblage Formation Processes. In *Experiments in Lithic Technology*, edited by D. S. Amick and R. P. Mauldin, pp. 15-31. BAR International Series 528. British Archaeological Reports, Oxford, UK. Utah Press, Salt Lake City.
- Malouf, C.
1952 Economy and land use by the Indians of western Montana. Manuscript prepared and mimeographed for the plaintiffs, case #61, U.S. Land Claims Commission. Copy on file at the University of Montana library, Missoula.

1956 Cultural Connections Between the Prehistoric Inhabitants of the Upper Missouri and Columbia. Unpublished doctoral dissertation, Columbia University.
- Malouf, R. T.
1967 Personal letter to Phillip Hobler, 11/21/1967. On file, The University of Montana.

1971 Personal letter to Lewis Napton, 5/24/1971. On file, The University of Montana.

1985 Personal letter to Milo McLeod, 10/18/1985. On file, The University of Montana.
- Mauldin, R. P. and D. S. Amick
1989 Investigating Patterning in Debitage from Experimental Bifacial Core Reduciton. In *Experiments in Lithic Technology*, edited by D. S. Amick and R. P. Mauldin, pp. 67-88. BAR International Series 528. British Archaeological Reports, Oxford, UK. Utah Press, Salt Lake City.
- Melton, D. A.
1983 Report Review: Archaeological Investigations in the Avon Valley, by Lewis Kyle Napton. *Archaeology in Montana* 24(2):153-155.

Melton, J. A.

n.d. A Preliminary Functional Analysis of the Flint Run Paleo-Indian Complex Bifaces. Unpublished Master's Thesis, Catholic University of America, Washington, D.C.

Montet-White, A.

1973 Le Malpas Rockshelter. University of Kansas Publications in Anthropology, No. 4. The University of Kansas, Lawrence.

Montet-White, A., R. L. Binford, and M. L. Papworth

1963 Miscellaneous Studies in Typology and Classification. Museum of Anthropology, The University of Michigan Anthropological Papers No. 19. The University of Michigan, Ann Arbor.

Muto, G. R.

1971 A Technological Analysis of the Early Stages in the Manufacture of Lithic Artifacts. Master's Thesis, Washington State University.

Nash, S. E.

1996 Is Curation Useful or Heuristic? In *Stone tools: Theoretical Insights into Human Prehistory*, edited by G. H. Odell, pp. 81-99. Plenum Press, New York.

Nami, H. G.

1999 The Folsom Biface Reduction Sequence: Evidence from the Lindenmeier Collection. In *Folsom Lithic Technology: Explorations in Structure and Variation*, edited by D. S. Amick, pp. 82-97. International Monographs in Prehistory Archaeological Series 12, Ann Arbor, Michigan.

Napton, L.K.

1981 Archaeological investigations in the Avon Valley. Institute for Archaeological Research, California State College, Stanislaus, Turlock, California.

Nelson, M. C.

1987 Site Content and Structure: Metate Quarries and Workshops in the Maya Highlands. In *Lithic Studies Among the Contemporary Maya*, edited by B. Hayden, pp. 120-147. The University of Arizona Press, Tucson.

Nielsen, A. E.

1991 Trampling the Archaeological Record: An Experimental Study. *American Antiquity* 56:483-503.

Parry, W. J., and R. L. Kelly

1987 Expedient Core Technology and Sedentism. In *The Organization of Core Technology*, edited by J. K. Johnson and C. A. Morrow, pp. 285-304. Westview Press, Boulder, Colorado.

Pecora, A. M.

2001 Chipped Stone Tool Production Strategies and Lithic Debitage Patterns. In *Lithic Debitage: Context, Form, Meaning*, edited by William Andrefsky Jr., pp. 173-190. The University of Utah Press, Salt Lake City.

Prentiss, W. C.

1993 Hunter-Gatherer Economics and the Formation of a Housepit Floor Lithic Assemblage. Ph.D. dissertation, Department of Archaeology, Simon Fraser University, Burnaby, British Columbia.

1998 The Reliability and Validity of a Lithic Debitage Typology: Implications for Archaeological Interpretation. *American Antiquity* 63:635-650.

2001 Reliability and Validity of a "Distinctive Assemblage" Typology: Integrating Flake Size and Completeness. In *Lithic Debitage: Context, Form, Meaning*, edited by W. Andrefsky, pp.147-172. The University of Utah Press, Salt Lake City.

Prentiss, W. C., and E. J. Romanski

1989 Experimental Evaluation of Sullivan and Rozen's Debitage Typology. In *Experiments in Lithic Technology*, edited by D. S. Amick and R. P. Mauldin, pp. 89-100. BAR International Series 528. British Archaeological Reports, Oxford, UK. Utah Press, Salt Lake City.

Pryor, J. H.

1988 The Effects of Human Trample Damage on Lithics: A Model of Crucial Variables. *Lithic Technology* 17:45-50.

Reeves, B.O.K.

1972 The archaeology of Pass Creek Valley, Waterton Lakes National Park. National and Historic Parks Branch manuscript report No. 61.

Riley, L.

2004 Analysis of Artifacts from Avon Valley, Montana. Unpublished Master's Thesis. On file at the University of Montana, Department of Anthropology.

Roth, B. J., and H. L. Dibble

1998 Production and Transport of Blanks and Tools at the French Middle Paleolithic Site of Combe-Capelle Bas. *American Antiquity* 63:47-62.

- Saragusti, I., I. Sharon, O. Katzenelson and D. Avnir
1998 Quantitative Analysis of the Symmetry of Artefacts: Lower Paleolithic Handaxes. *Journal of Archaeological Science* 25:817-825.
- Sharrock, F. W.
1966 Prehistoric Occupation Patterns in S.W. Wyoming and Cultural Relationships with the Great Basin and Plains Culture Areas. University of Utah, Department of Anthropology. *Anthropology Papers*, No. 77.
- Shott, M. J.
1986 Technological Organization and Settlement Mobility: An Ethnographic Examination. *Journal of Anthropological Research* 42:15-51.

1989 On Tool-class Use Lives and the Formation of Archaeological Assemblages. *American Antiquity* 54:9-30.
- Stanford, D. and F. Broilo
1981 Frank's Folsom Campsite. *The Artifacts* 19(3&4):1-11.
- Sullivan, A. P.
1987 Probing the Sources of Variability: A Regional Case Study near Homolovi Ruins, Arizona. *North American Archaeologist* 8(1):41-71.
- Sullivan, A. P., and K. C. Rozen
1985 Debitage Analysis and Archaeological Interpretation. *American Antiquity* 50: 755-779.
- Swope, R.
1982 *Indian Artifacts of the East and South: An Identification Guide*. By the author, York, Pennsylvania.
- Torrence, R.
1983 Time Budgeting and Hunter-Gatherer Technology. In *Hunter-Gatherer Economy in Prehistory*, edited by G. N. Bailey, pp. 11-22. Cambridge University Press, Cambridge, U. K.

1989 Retooling: Towards a Behavioral Theory of Lithic Procurement. In *Time, Energy and Stone Tools*, edited by R. Torrence, pp. 57-66. Cambridge University Press, Cambridge.
- Whittaker, J. C.
1994 *Flintknapping: Making and Understanding Stone Tools*. University of Texas Press, Austin.

Wilmsen, E. N. and F. H. Roberts, Jr.

1978 Lindenmeier, 1934-1974: Concluding Report on Investigations. *Smithsonian Contributions to Anthropology* No. 24. Smithsonian Institution Press, Washington, D.C.

Zabrodsky, H. and D. Avnir

1995 Continuous Symmetry Measures. 4. Chirality. *Journal of the American Chemical Society* 117:462-473.