Graduate Student Theses, Dissertations, & Professional Papers

Graduate School

2000

Cost-benefit relationships at South Everson Creek quarries

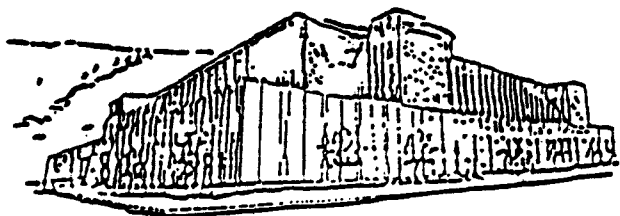Christina E. Kelly
The University of Montana

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 _Christina E. Kjell_____

Date ___12-18-00_____

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

Cost-Benefit Relationships at
South Everson Creek Quarries

By
Christina E. Kelly

B.A. Northern Kentucky University – Highland Heights, 1996

Presented in partial fulfillment of the requirements

for the degree of

Master of Arts Anthropology

University of Montana

2000

Approved by

_____
Chairman, Board of Examiners

_____
Dean, Graduate School

12-20-00
_____
Date

UMI Number: EP36324

UMI®

Dissertation Publishing

UMI EP36324

ProQuest®

Kelly, Christina Elizabeth. M.A., December 2000   Anthropology

Cost-Benefit Relationships at South Everson Creek Quarries

Director: William Prentiss

The manner by which lithic raw materials have been procured and used has been a topic of inquiry and debate in the archaeological literature since W.H. Holmes' article in 1890. Using a model developed by Elston (1992) which examines the risks and benefits associated with acquiring toolstone and quarry procurement strategies devised by Francis (1983), this thesis will examine the procurement of lithic resources at South Everson Creek.

It is hypothesized that groups exploiting the lithic resources at South Everson Creek were attempting to maximize their net value which is the total benefit they receive from tool procurement minus the cost of procurement. To examine the manner in which raw materials were procured and the subsequent lithic reduction of this toolstone for export, a data set compiled from excavations at South Everson Creek was investigated to determine if the data corresponds to Elston's (1992) model and to examine if there is change over time in quarry strategies.

The data from South Everson Creek seems to correspond to the cost-benefit model suggested by Elston (1992). It would appear that the people exploiting this resource responded or were motivated and/or influenced by costs, benefits, and risk through the manipulation of production technology. Production costs can be managed by changing behaviors such as mobility patterns, procurement techniques, organization of labor and activities, extending tool use life, creating technological systems that are multifunctional, maintainable and/or reliable, through the use of scheduling, and monitoring demand and output.

Table of Contents

List of Figures

List of Tables

Chapter 1 - Introduction

The manner by which lithic raw materials have been procured and used has been a topic of inquiry and debate in the archaeological literature since W.H. Holmes' article in 1890. As the methods and theoretical perspectives of archaeologists have changed over the past century, so too have the questions posed and the ways by which lithic raw materials have been examined. Theoretical perspectives borrowed from such diverse fields as ecology and risk management have been adopted by archaeologists and applied to the study of the archaeological record. Using a model developed by Elston (1992) and quarry procurement strategies devised by Francis (1983), this thesis will examine the procurement of lithic resources at South Everson Creek. This model examines the risks and benefits associated with acquiring toolstone. It is my hypothesis that groups exploiting the lithic resources at South Everson Creek were attempting to maximize their net value, the total benefit they receive from tool procurement minus the cost of procurement. I will use a data set compiled from excavations conducted at South Everson Creek to examine the manner by which raw materials were procured and the subsequent lithic reduction of this toolstone for export to investigate if the data corresponds to Elston's model and to examine if there is change over time in quarry strategies.

A given society's technology includes among other factors, the way that stone tools are acquired, used and discarded. Although this thesis focuses on the acquisition of toolstone, it may be helpful to have a working definition of technology itself. Nelson (1991:57) defines organization of technology as:

The study of the selection and integration of strategies for making, using, transporting and discarding tools and the materials needed for their manufacture and maintenance. Studies of the organization of technology consider economic and social variables that influence those strategies.

Technology can be seen as a means to solve problems posed by both the physical and social environment (Binford 1977, 1978; Nelson 1991; Torrence 1989a) since particular environmental conditions will favor choosing and organizing one technological strategy or combination of strategies over others (Bleed and Bleed 1987). The ultimate goal of studying technological organization is to determine "how technological changes reflect large scale behavioral changes in prehistoric societies" (Kelly 1988:717). The Mammoth Meadow site at South Everson Creek Quarry is a multicomponent site spanning from the Paleo-Indian times to the Late Prehistoric. It contains the potential to investigate if or how technological changes, may or may not have occurred concurrently with changes in behavior represented at this site as changes in quarry strategies. Bamforth (1991:217) however reminds us that:

> Specific technological strategies are not determined by any single characteristic of a society's way of life, but by the interactions between many factors and the environment that society inhabits.

Technological strategies are shaped by lithic resource availability, settlement pattern, and other structural characteristics of the society in question (Bamforth 1986:40). Technology is structured by the requirements of an activity or set of activities that constrain variation in all aspects of tool manufacture and use. An efficient technology fulfills these requirements with a minimum effort, meaning that time and energy spent on technological activities would ideally not be so consuming that these actions would result in losses to productivity in other areas such as food procurement. Efficient activity

2

scheduling and time-efficient procurement and production are subsumed by this definition because tool manufacture and use are integrated into cultural behavior as a whole (Bamforth 1986:39).

The costs of locating, acquiring, and processing a resource depend upon the technology and labor organization available to a society and can change rapidly and profoundly when useful innovations in either of these become available through inventions or diffusions (Bamforth 1988:27). Raw material distribution, one aspect of the environment, is considered a necessary component in the studies of technological organization. Kelly (1992) also acknowledges that other variables, such as tool function and risk, interact with technology and affect how it is organized.

This study relies heavily on work done at the Tosawihi Quarries by Elston and Raven (1991-1992), the Bighorn Mountains by Francis (1983), and investigations carried out at the South Everson Creek Quarries by Bonnichsen et al. (1986; 1989), Douglas (1991), and MacWilliams (1991). Following these researchers' lead, I attempt to identify how certain factors relate to the cost-benefit aspect of the procurement of resources. These components include fixed costs, which remain constant and are fixed over the entire production period and variable costs that vary with production. Overhead costs, supply, demand, costs of labor and product determination also are related to cost minimization. Manipulating these variable costs can increase or decrease access to resources, the effective availability of resources, search and handling time, and opportunity costs associated with procurement of lithic raw materials.

In examining South Everson Creek I will address the following questions:

1.) Does the economic model developed by Elston and Raven (1991-1992) explain the pattern of behavior revealed in the archaeological record at South Everson Creek as it relates to the manipulation of production processes by people in an attempt to minimize risk and maximize benefits?

2.) Does the archaeological record at South Everson Creek reflect the hypotheses outlined by Francis (1983) regarding procurement strategies based upon lithic material type and curation practices - specifically are different types and quality of stone procured and used in different manners?

3.) And finally, Kelly (1988) suggests that mobile hunter-gatherers could benefit from the use of bifaces in their toolkits as portable cores; whereas, Kuhn (1994) suggests that a toolkit composed of small, specialized tools would be more efficient. Are either of these patterns reflected by the data found at South Everson Creek?

Theoretical Perspective

Any analysis of how people obtain and use stone inherently involves the consideration of technological organization. Technology is viewed as a means to solve problems posed by both the physical and social environment (Binford 1977, 1978; Scott 1986; Lurie 1989; Torrrence 1989; Bamforth 1991; Nelson 1991; Kuhn 1992). One of the first questions to address in a study of technological organization is - what resources are available? What is the effective supply?

Raw materials to manufacture stone tools were obtained from three different types of geological sources: cobbles in unconsolidated sediments, bedrock exposures, and subsurface bedrock deposits. Francis (1983:23-24) distinguishes between casual

4

procurement, the gathering of raw materials for immediate and situational needs during the course of pursuing other activities, and deliberate procurement meaning the gathering of materials for anticipated future needs either via a trip to the resource (deliberate direct procurement), or in conjunction with other activities (deliberate indirect procurement). Elston (1992:38-39) uses the category designations of encounter technique, the acquisition of toolstone by people as they move across the landscape; surface collection, which is a more intensive process of the encounter technique; quarrying, which is the extraction of raw materials from subsurface or bedrock sources; and retrieval, acquiring toolstone that has been accumulated by overproduction at the quarry and cached for use at a later time. Francis suggests that these procurement strategies will leave different patterns of debitage at raw material source sites.

Aspects of optimal foraging theory such as time-stress (Torrence 1983; Ellis 1989) and cost-benefit determination (Reidhead 1979; Winterhalter and Smith 1981; Jochim 1989; Lurie 1989; Odell 1996) can be useful in investigating how variable costs are manipulated in the exploitation of lithic resources. Geological and geographical processes limit distribution, frequency of geological formation, and occurrence, which in turn limits the accessibility of the resource. Seasonality and mobility of populations also need to be considered when examining procurement strategies. Bamforth (1988:17) defines a "resource structure" as the spatial and temporal patterns of resource availability in a particular region. "Availability" refers to either the abundance or scarcity of a given resource and the accessibility of that resource to humans given their technology and the organization within which they use that technology (Bamforth 1988:17.). Optimization strategies can be applied to the way by which humans operate within these set parameters

in examining technological organization (Jochim 1983; Keene 1983; Findlow and Bolgnese 1984; Odell 1996). Hayden (1996) also suggests that we need to consider design criteria and reliability in raw materials as limiting factors related to maintainability and multifunctionablity of the tool created.

The Mammoth Meadow I site in the South Everson Creek quarry was suggested for use by Mark Baumler of the Montana State Historical Preservation Office since it had been studied in detail and was likely to contain the data necessary to conduct this study. It is a multicomponent site containing hearths and associated diagnostic artifacts, which provide a temporal aspect to the site. This data has been substantiated with radiocarbon dates that correspond to identified occupation levels. In deciding to work with quarry data, the problem of temporal control has been an issue. Quarries represent activity areas that may have been used over and over again with no way to identify when one period of use ends and another begins. The nature of quarries as a short-term limited activity area used by people to acquire a specific raw material and then move on, generally results in a lack of datable materials present at these types of sites. Mammoth Meadow I however, does possess intact stratigraphic levels with deposits that contain diagnostic artifacts and corresponding radio-carbon dates so it may be possible to make observations regarding how different occupations levels relate to one another or if there are discernible changes occurring over time. To facilitate this discussion, this thesis is organized into five chapters: Introduction, Literature Review, Economic Implications of Lithic Procurement, Statistical Analysis of the Model, and Discussion.

Chapter 2 - Literature Review

The study of quarries has a long history beginning with W. H. Holmes in 1890, and continuing to the present day. In 1935, Clarke discussed the gunflint industry in Brandon, England. Bryan, in 1950, reviewed the work done by Holmes and suggested that Native Americans used quarries like "factories" to produce items for trade. He also hypothesized that the flake tools associated with quarries were finished products in and of themselves and were employed in the same manner as formal tools.

A sample of the more recent work regarding quarries includes Gramley's 1980, article about the Mt. Jasper quarry in New Hampshire. He discussed the absence or presence of "exotic" materials and how this relates to the concept of retooling. In 1984, Gramley again discusses Mt. Jasper in association with quarry procurement activities on an individual versus a group level. Singer (1984) conjectured that the relationship of quarry ownership and associated debitage found at quarries and surrounding sites within a 63-kilometer radius produced identifiable patterns in the archaeological record. Torrence (1984) and Renfrew (1975) investigate quarrying on an industrial level in the Old World. Alher (1985) conducted extensive research with Knife River Flint of North Dakota, identifying the material based upon its physical properties and using size grading to distinguish between hard and soft hammer percussion during the reduction process. Larson (1994) examines minimum analytical nodule analysis as a method to employ in sourcing materials from different quarries.

Anthropologists, studying technological strategies of different cultures, have also written a great deal about quarries and lithic procurement. Gould, Koster, and Sontz (1971) describe the lithic assemblage of the Australian Aborigines which consists of a

chipped stone tool assemblage with some implements intended for everyday use and others that have secret uses and are hidden by the user until needed. They further indicate that certain colors of stone are preferred based upon totemic ties to different regions. White and Thomas (1972) compare stylistic variation of stone tools recognized by contemporary New Guineans to those noted by Euro-American archaeologists. Binford in his 1976 investigation of the Nunamiut introduced the concept of personal gear, curation strategies, and embeddedness. Binford noticed that some items are used and discarded in their place of manufacture (situational gear) whereas others are carried transported from place to place (personal gear). He found that personal gear was more likely than situational gear to be curated and that the Nunamiut embedded the procurement of toolstone into other activities such as hunting. Gould and Saggers (1985) apply Binford's concept of embeddedness in Australia and conclude that there are other factors involved in obtaining lithic raw materials. The Aborigines engage in special purpose trips to procure resources that cannot be embedded into other economic activities. In Ethiopia, Gallager (1977) studied the acquisition of obsidian. Stone is quarried with iron tipped digging sticks, reduced into blanks on site and then transported back to the village for finishing.

One of the foremost experts in the field of lithic reproduction and reduction studies, Donald Crabtree, wrote in 1967, about the toolmaker's criteria for identifying good lithic raw materials: texture, luster, surface character, cortex, color, transparency, flexibility, sharpness of removed flakes, and the necessary force required to detach a flake. He further discusses, in the same article, the attributes as applied to specific rocks such as obsidian, chert, chalcedony, etc. Barbara Luedtke (1992) also wrote about the

8

characteristics of chert and flint. She describes the mineralogical characteristics of different materials focusing on the chemical and physical properties of different stones.

Numerous authors have also discussed the subject of source availability and access. As the cost of procurement increases, technological improvements or substitution can occur. Bamforth (1986, 1991) hypothesizes that the availability of raw materials is closely related to the practices of tool maintenance and recycling and is a response to raw material shortages. If source availability is low, people will tend to be more conservative in their use of that source and this will be reflected in the archaeological record through tools that show evidence of repeated resharpening and/or the recycling of broken tools into other items to extend the use life of the tool. Blanton (1985) suggests that lithic procurement is based upon accessibility of the resource through social relations, technological demands upon a given resource, and geological patterning of the resource. Amick (1994) discusses the forager vs. collector distinction as it relates to subsistence strategies based on resource availability and time stresses. Since mobility patterns differ between foragers and collectors this in turns affects the availability of a resource and the time frame in which it can be procured.

Hayden, Franco, and Spafford (1996) discuss raw materials and technological organization through the consideration of design theory. Different reduction strategies such as expedient block, biface, quarried bipolar, and others vary in efficiency and constraints. The concepts of maintainability, reliability, and multifunctionability are discussed here and by other authors such as Bleed (1986) and Nelson (1991). While definitions of the concepts vary slightly between authors, they agree that these factors should be taken into consideration when questions are asked regarding technology.

Leudtke (1979, 1984) also identifies toolstone demand as a factor in technological studies of stone tools. She created a mathematical formula to determine demand based upon activities that require the use of stone tools, the number of tools needed to perform the tasks, and the amount of materials needed to make the tools to carry out the tasks.

Various authors (e.g. Jeske 1989; Torrence 1989; Odell 1996) hypothesized that the procurement of lithic raw materials can be seen as comprising a cost-benefit type of relationship. These researchers examine optimization of returns, risk management, and time as currency. The application of optimal foraging theory and evolutionary ecology to lithic resource studies has opened up new areas of research (Keene, 1983; Jochim, 1983, 1989, Torrence 1989). Researchers have even suggested that lithic raw materials are similar to other resources such as plants or animals because the nature and distribution fundamentally condition the manner in which all can be exploited (Bamforth 1986; Hayden 1989). Torrence (1983) introduces the concept of time as currency meaning that time is a limiting factor for hunter-gathers in the exploitation of resources. Some items are only available seasonally and time spent engaged in one activity, is time not spent engaged in an alternate activity. Findlow and Bolognese (1984) and Wiant and Hassen (1985) discuss the importance of scheduling in the obtainment of resources. This ties into the concept of seasonality as a factor in the procurement of lithic raw materials (Ammerman 1974; Odell 1980; Bamforth 1988).

Mobility strategies and transportation costs have also been examined as they relate to the procurement of toolstone. Whether a group is considered collectors, foragers, or a combination of both, affects how they move across the landscape and what resources are available for them to exploit (Kelly 1983; Kelly and Todd 1989; Torrence 1983; Ellis,

10

1989; Kuhn 1989, 1994; Lurie, 1989; Carr 1994). The amount of goods and materials

that can be transported by people has also been a topic of consideration in lithic studies

(Metcalf and Barrow 1992). They suggest that the decision to transport a resource is

partly a function of its proportional utility. Proportional utility is defined as the ratio of

usable to non-usable material contained within that resource.

Another area of inquiry has been the question what would constitute the most

efficient toolkit - many small specialized tools or a collection of blanks, bifaces, and

cores that can be manufactured into tools at a later time (Kelly 1988; Kuhn 1994). Kelly

(1988) suggests that bifaces can be used both as a tool in and of themselves and also as a

portable core to be manufactured into other items. Kuhn (1994) proposes that researchers

need to investigate whether it is more efficient for mobile hunter-gatherers to carry

toolkits that contain many small-specialized items or larger heavier blanks and cores.

Julie Francis (1983) wrote her Ph.D. Dissertation about lithic sources in the Big

Horn Mountains of Wyoming. She hypothesized that each type of toolstone source – .

cobbles in unconsolidated sediments, bedrock outcrop and bedrock in consolidated

sediments - would exhibit different methods of procurement. These procurement

methods would be related to the desirability of a given type of source in manufacturing

items for either expedient use or for use as curated items. These sources were studied to

determine if they were exploited in a deliberate or causal fashion and if the items

produced from the source were expedient tools or curated tools. She felt that quarries,

which she defined as subsurface deposits of materials in a consolidated matrix, would

exhibit the highest frequency of curation and they would be exploited in the most

deliberate fashion. Secondary sources, defined as cobbles deposited by alluvial or

colluvial actions would be the most casually procured and would be manufactured into expedient tools. While her results for some materials were slightly different than she originally anticipated, they did provide support for her initial hypothesis that different source materials were used in different fashions.

Elston and Raven (1991-1992) investigated the Tosawihi quarry in Nevada. They proposed that a model could be built based on cost-benefit relationships between fixed and indirect costs as related to the procurement of lithic resources. Some of the questions posed by the researches included: could the season(s) that the quarry was used be determined; how had the resource been exploited - was it visited by large groups or by small work detail parties? They also used this model to posit what types of items visitors to the quarry may have been producing, whether it was blanks for transport, cores or finished tools. The researchers at Tosawihi also conducted experimental archaeology on quarrying behavior examining how long it took to perform such tasks as overburden removal, manufacturing different stage bifaces, and how heat treatment affected Tosawihi opalite.

Several different researchers have investigated the South Everson Creek quarries. As part of a mitigation plan for the construction of a cattleguard at a fence crossing, the site was originally examined by Dr. Les Davis (Montana State University) in 1978 and excavated again in 1981. Davis, Smith and Foor wrote the report on South Everson Creek in 1997. During the summer of 1985, Dr. Robson Bonnichsen (University of Maine) conducted fieldwork to obtain archaeological and paleoenvironmental data. The team was exploring how human adaptive strategies in the area, particularly lithic procurement strategies, changed over time from the terminal Pleistocene through the early

Holocene. Several of Dr. Bonnichsen's students wrote their Master's Theses on South

Everson Creek. A. C. Macwilliams (1991) examined flexibility in quarrying activity, use

life of the quarries, the identification of activity areas in the quarry, and the identification

of South Everson Creek materials based upon macroscopic, microscopic, and atomic

criteria. Diane Douglas (1991) considered the features present at the quarry and how the

artifact distribution varies by level, whether artifact form and technology differs between

levels, the relationship between artifacts and floor structures, and the relationship of each

assemblage to the regional record.

Chapter 3 – Economic Implications of Lithic Procurement

The analysis of the quarry and its workshops provides primary data to determine extraction technology, raw material selection processes, knapping behavior, reduction technology, production rates, changes in technology, material productions and the systematic stability of production, technology, and exchange over time (Ericson 1984:4). Production is seen as a process of material modification with intent to form a particular object. A lithic production system can be defined as the total of synchronous activities and locations involved in the utilization and modification of a single source-specific lithic material for stone tool manufacture and use in a larger social system (Ericson 1982). A lithic production system contains variables such as: the structure of the regional lithic resource base, labor investment, modes of transport, the mode of production, social distances between knappers and consumers, social organization and technology. According to Blanton (1985:16) lithic raw material procurement and use behavior is regarded as a response to:

1. demands of a particular technology
2. physical patterning of raw material in the natural environment
3. accessibility as determined by social relations

Optimization

In procurement strategies, hunter-gatherers act to minimize costs and maximize their returns by obtaining more products for the time and energy they invest. Several components are involved in accomplishing this goal: mobility patterns; scheduling; labor organization; technology; and procurement techniques. A particular lithic procurement strategy is assumed to have been used by people to manipulate these variables in order to maximize some rate, such as time available for processing and quarrying (Elston

1992:33). It is also assumed that hunter-gatherers minimize indirect costs, such as water, food, travel time, and lost opportunity when on excursions to lithic raw material sources (Elston 1992:33). The benefit of the toolstone is in its future use as a tool to increase productivity in procuring and processing food and materials to make shelter, clothing and other non-lithic items. According to Elston (1992:33) the minimization of these indirect costs should result in patterns of archaeological variation observable in site placement, activity segmentation, and assemblage content.

Managing Risk

According to Elston, there are two types of risk associated with lithic procurement strategies: venture and contingency risk. Risk itself is not quantifiable, but is used to illustrate the goal of various procurement strategies. Venture risk relates to the probability that procurement and opportunity costs in the acquisition of toolstone will exceed the benefits of any lithic resource gained (Elston 1990). Since venture risk is present for the entire procurement expedition, it increases in proportion to time, energy, and opportunity costs, all of which vary during different phases of the procurement process; therefore, it is assumed that venture risk rises swiftly to unity during extraction and stays there until processing commences. With adequate return, venture risk then declines quickly during processing and falls to zero when processed toolstone is in hand (Elston 1992:33) (Fig. 1).

Consuming toolstone increases contingency risk, which refers to the probability of having insufficient toolstone to meet subsistence needs (Elston 1990). Contingency risk is present for the time that it takes to deplete a supply of toolstone. In Figure 2 the cost of toolstone is held constant for simplicity. As a supply of toolstone is exhausted, the

15

capacity to fulfill subsistence demands becomes increasingly more at risk. When

toolstone supplies fall low enough, but have not been exhausted, the decision to acquire

toolstone is triggered. At this point, the potential costs of insufficiency start to

approximate the costs of procurement. Since contingency risk increases from the moment

toolstone is acquired; it seems reasonable to assume the usefulness of monitoring and

managing lithic consumption to avoid shortages (Elston 1992:35).
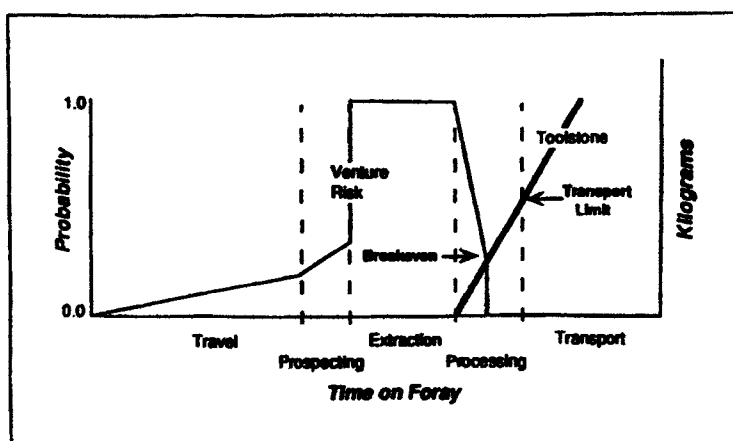
Figure 1. (From Elston 1992)
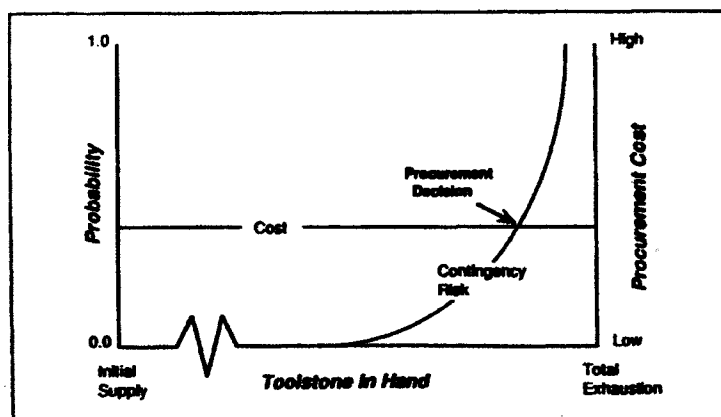
Figure 2. (From Elston 1992)

Fixed Cost Factors

Some of the costs connected with lithic procurement among hunter-gatherers are

restrained by external factors controlling the nature of toolstone, while other costs are

guided by choice among components of lithic production strategies such as mobility,

organization and technology. External factors include the quality, abundance, distribution and manner of occurrence of lithic raw material in the landscape. Since these factors can not be manipulated by human behavior, Elston (1992) considers them to be fixed costs. In economics, a fixed cost is one that does not change over the production process. Once the cost is incurred, it is paid regardless of the level of extraction or tool production. Using this definition, the costs of exploration could be considered fixed costs. However, to facilitate examination of Elston's (1992) model, the factors he identifies will be discussed under the category of fixed costs.

Toolstone Quality

Toolstone quality has an effect upon product determination. According to Crabtree (1967:9), a toolmaker's criteria for identifying good lithic raw materials are: texture, luster, surface character, cortex, color, transparency, flexibility, sharpness of removed flakes and the necessary force required to detach a flake. Using a brittle, isotropic medium or cryptocrystalline or microcrystalline silicate stone produces the most controlled and efficient flintknapping. Examples of high quality stones include obsidian, cherts, flints, jaspers, chalcedonies, and opalites. Lesser quality stones such as fine-grained basalts, argellites, andeosites and other vitreous rocks can be manufactured into tools but the toolmaker has less control during the reduction phase and the resultant tool has reduced efficiency and durability. Using high quality toolstone is a guideline in tool design that endeavors to prolong tool use-life (Goodyear 1979; Kelly 1988; Parry and Kelly 1987; Kelly and Todd 1988).

Lithic Landscape and Absolute Toolstone Availability

Geological and environmental factors dictate the distribution of toolstone in a given area. As defined by Gould (1980:132) a lithic landscape is the dispersion of toolstone in a particular region. Usually higher quality raw materials are less abundant than lower quality stones, however, some lithic landscapes are considered "richer" than others based upon the manner of toolstone occurrence, abundance and distribution (Gould 1980:132).

In certain situations, availability and accessibility of resources are suggested as principle factors that affect procurement strategies (Francis 1983:19). It is assumed that people will behave in a more or less economic, rational manner toward resources in their environment, and that in certain cases, humans will tend to make the most of those resources (Francis 1983:20). In accordance with Francis (1983:20), it is also assumed here that humans exploit resources much differently if those resources are perceived as being unlimited or readily available, rather than limited in supply. The more scarce a resource is the more valuable it is. Bamforth (1988:17) defines the "resources structure" as referring to spatial and temporal patterns of resource availability in a particular region; the temporal portion of this definition refers both to seasonal and annual changes in availability. "Availability" is further defined as referring to both the abundance or scarcity of a given resource and the accessibility of that resource to humans given their technology, and the organization within which they use that technology (Bamforth 1988:17). Nelson (1987:145) defines accessibility as the time needed to get to the resource and the time needed to procure the resource. It can be managed in several ways: organization of procurement activities, organization of reduction stages, and

18

reorganization of other resource acquisition. Shiffer (1975:269) concurs with Bamforth's

interpretation regarding availability of lithic resources:

> ...in an environment with widely dispersed and abundant sources of raw material
> that there would be a greater amount of functional specificity of tools, hence a
> greater variety of tools, and proportionally less curate behavior (holding constant
> mobility and variety of tasks).

The physical presence and distribution in the landscape controls the absolute

availability of toolstone which itself is resource specific. If the region contains no

obsidian, then obsidian is simply not available in that landscape. At the scale of annual

range, the absolute availability of raw materials is high in a landscape that contains good

quality lithic materials within the foraging radius of most residential camps and would be

ranked as a rich area. An area that contains only one source of average quality materials

characterizes a poor landscape with a low absolute availability of toolstone (Fig. 3).

Since the effort required to locate lithic sources is also a fixed cost, the first example

would allow people to move through their annual range with little regard to the

scheduling of lithic procurement and tool maintenance since the costs of production

would be about the same everywhere. The second example would necessitate the careful

planning of lithic procurement over much of the annual range so that sufficient toolstone

could be ensured throughout the year (Elston 1992:36).

a. Rich Lithic Terrane   b. Poor Lithic Terrane

Lithic Source   Winter Base W   Summer Foraging   Diurnal Radius
Camp
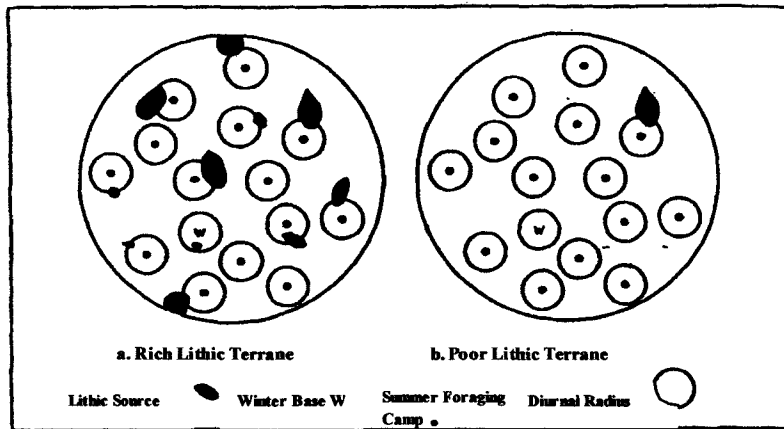
Figure 3. (From Elston 1992)

Variable Costs of Lithic Procurement

Following Elston (1992:35), this section assumes that integral variables such as

mobility pattern, labor organization, and procurement techniques can be manipulated to

vary access, effective availability, search and handling time, and opportunity cost since

the choice of toolstone procurement strategies affects the cost in time and effort that must

be spent acquiring stone tools.

Effective Toolstone Availability

By modifying procurement strategies, the effective availability of toolstone can be

manipulated. Expanding or reducing residential mobility, changing the size and shape of

the annual range to include or exclude sources, or planning to be in the vicinity of sources

when the need for toolstone is highest can affect toolstone availability considerably and

result in differences in the intensity of exploitation at different sources (Goodyear 1979;

Elston 1990). Effective availability can also be influenced through engaging in more

intensive extraction techniques as illustrated by Elston and Raven (1991-1992) at the

Tosawihi quarries.

Toolstone Access

The need for economizing behavior would be directly affected by social and political constraints over access to raw materials as well as by the distance traveled to procure supplies (Jeske 1989:35). For some geographic areas the concept of ownership applies to quarries. Clark (1935:44) noted that the practice of mining among the Brandon flintworkers is restricted to a few families. In some areas of California, the control of quarries is described as "tribal", but related and nearby groups had the right to quarry either freely or on the payment of small gifts. Wars resulted from attempts by distant groups to use a quarry without payment (Bryant 1930:34). In his excavations at Keatley Creek, B.C., Hayden (1992) and Hayden et al. (1996) also found evidence of quarry ownership or at least control of quarries by certain groups. Gould et al. (1971) gave no indication of any concept of ownership among Australian aborigines. In fact they mentioned that the chipping of stone tools is regard as an art of little importance. If a group is restricted to a resource poor area, costs are incurred through the expenditure of time and energy to maintain social ties and/or accumulating surplus goods for trade.

Procurement and Opportunity Costs

Search and handling time is included in the procurement of lithic raw materials (Stephens and Krebs 1986:13-14). Search time consists of the time spent traveling to the source or patch, finding the items in the patch, and inspection and testing of likely toolstone items. Handling time includes the time spent for extraction, processing, transporting, and maintaining. Search time can be modified via changes in mobility patterns and prospecting techniques while extraction and processing time are functions of quarrying, processing technology, and tool design (Elston 1992:37). Transport costs vary

directly with distance and weight of the load (Jones and Madsen 1989) and can be lessened by putting the manufactured object into use as soon as possible. While search and handling can be considered direct costs, opportunity or indirect costs are also involved in acquiring toolstone. This refers to the fact that time spent obtaining toolstone is equal to time that is not spent engaged in other sorts of activities.

Procurement Techniques

There are three strategies involved in the procurement of lithic resources: casual, direct and indirect. Casual lithic procurement can be found in areas where chert or other raw materials deposits occur over widespread areas such as gravels, glacial deposits or desert pavements. Direct lithic procurement is defined as a special trip to a source to obtain materials for a particular task or for future use. Indirect lithic procurement occurs through mediation of some other individual or social group, therefore falling within the realm of exchange and interaction systems (Leudtke 1976:26-27).

There are four techniques used to acquire toolstone: encounter, surface collection, quarrying, and retrieval. Encounter technique involves obtaining lithic resources by collecting suitable materials as people move across the landscape. This technique has the lowest procurement cost as it can be embedded into other activities (Binford 1979). Search and handling costs are low and this method incurs the least venture risk. When such strategies are embedded within subsistence strategies, there are not necessarily direct costs associated with lithic procurement, but as mentioned previously, there are opportunity costs involved. Procurement strategies can be embedded in other aspects of the subsistence system and appear very casual, but there is a direct, deliberate and planned effort involved to obtain those raw materials. Procurement, manufacture and

maintenance tasks can be fitted into small time slots, which occur within the contexts of

other activities. The rate at which lithic use is embedded in general subsistence

strategies will vary among hunter-gatherers depending upon the relative availability of

lithic and food resources. It thus becomes important to know both the accessibility of raw

materials as well as a group's strategies for subsistence and settlement (Jeske 1989:36).

Surface collection indicates a more intensive process than encounter procurement.

It is likely to occur in areas where toolstone cobbles are adequately abundant and

localized to provide a positive return for the investment of search and handling time

which is higher than encounter technique (Elston 1992:38). Surface and encounter

procurement produces materials that are of lower quality as they have been exposed to

environmental factors such as weathering and frost fracturing requiring that more material

be inspected, tested and processed to obtain a good return. Quarrying refers to the

procurement of toolstone by extracting raw materials from subsurface or bedrock sources.

This method entails the greatest search, handling and opportunity costs as well as the

greatest venture risks, but can pay off in the procurement of large amounts of high quality

toolstone (Elston 1992:39). The retrieval strategy depends on the overproduction of more

toolstone at the source than is transported. The surplus can be cached for retrieval at a

later time which exchanges the energy cost of overproduction for a reduction in

transportation costs and a minimization of future labor and opportunity costs. Returns are

certain and venture risk is eliminated (Elston 1992:39). Figure 4 illustrates the

relationship between net toolstone return and the time needed for procurement of

toolstone using the methods described above.
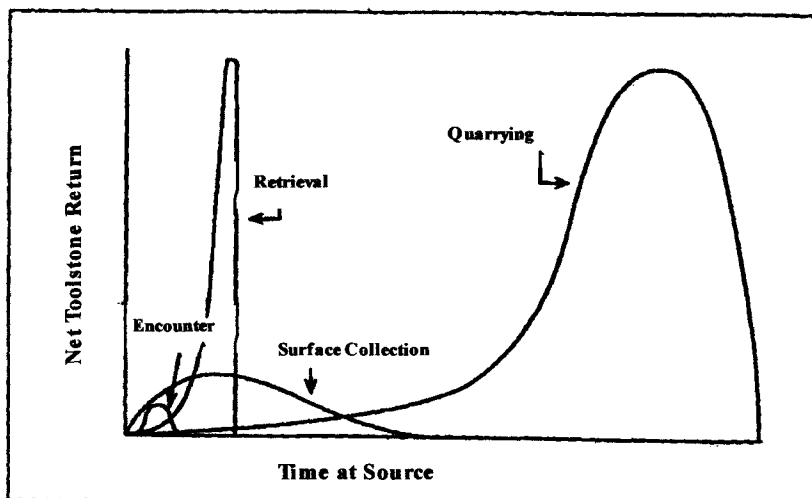
Figure 4. (From Elston 1992)

Extending Tool Use Life

Technology is organized as an adaptive response to geographic and temporal

variation in lithic and biotic resources and is designed to minimize tool costs (Wiant and

Hassen 1985:105). Tools operate alongside and in conjunction with a number of different

strategies to ensure the continuity of the social group as a whole (Torrence 1983). Tactics

for obtaining the most from tools are essential to procurement cost minimization and

guide the basic determination of what toolstone to procure and direct procurement and

processing techniques.

Strategies for lengthening tool life involve using high quality toolstone, large tool

size, symmetry of design, concurrent use of bifaces as both tools and cores, and standard

techniques for maintenance and recycling (Goodyear 1979; Kelly 1988). According to

Bamforth (1986:40) maintenance and recycling are closely related to raw material

availability and not directly or solely to settlement organization or the time limits on the

activities for which tools are used. The use of heat-treatment on toolstone can improve

workability and sharpness but there can be associated loss of durability and increased risk

24

of failure during the manufacturing phase. Since many of these methods require costlier

forms of lithic procurement this suggests that people are willing to bear increased venture

risk in return for decreased contingency risk (Elston 1992:40). The extension of tool life

employed in the technological system can theoretically be gauged through such measures

as the ratio of flake tools to biface tools, of resharpended edges to total used edges, of

bipolar reduced tools to total number and tools and others (Zeier and Elston 1986; Elston

and Budy 1990; Elston 1990; Kelly 1985).

Reliability

The nature and distribution of lithic resources critically affect technological

efficiency. Shortages result from regional geographic conditions and from behavior

patterns that restrict access to raw materials in certain conditions (Bamforth 1986:38).

The classic design theory constraints that have been investigated include materials

available and their relative costs, technologies available, adequate task performance, and

the economics of various production and use alternatives, including relative use-lives and

repair costs (Hayden et al. 1996:10). Following Nelson (1991:66), Hayden et al.

(1996:12) identifies design considerations as including longevity, maintainability,

versatility, and flexibility.

Reliability is seen as perhaps the most central concept as it has been related to

high-risk conditions and seems to have material design implication (Hayden et al.

1996:12). Reliability qualifies as a design consideration because the craftsman

additionally and intentionally emphasizes aspects such as thickness, care in manufacture,

and sturdiness (Hayden et al. 1996:12). Reliable systems have discontinuous use that is

scheduled and predictable. They operate below capacity and are made up of

overdesigned, extremely strong components and include numerous redundant parallel

parts that function as a backup in case any part of the system fails (Bleed 1986).

Employing a reliable strategy involves a higher cost than the maintainable system as

repair, manufacture, and use in maintainable systems are carried out continuously;

whereas when reliable systems employ these activities they are carefully differentiated,

scheduled separately, and each may be carried out by different personnel (Torrence

1983:62). Torrence (1983:63) sees reliability as a response to the severity of the risk

whereas the timing of risk determines the need for maintainability.

Maintainability

Bleed (1986:739-741) identifies eight criteria for the concept of maintainability of

lithic tools: modular or serial design, simple design, lightness and probability; easy

maintenance by people with low levels of lithic skills; use in a range of functions; and

possibly the occurrence of repair or maintenance during use. Maintainable designs are

supposed to be useful under task conditions that are more or less continuous but

somewhat unpredictable, or where size and weight constraints are important; therefore,

they are thought to characterize foragers rather than collectors (Hayden et al. 1996:13).

Maintainable technologies respond to a pattern of use, which is either continuos or

unpredictable and designed so that the tool is always ready for use (Torrence 1983:62). If

people attempt to create a maintainable technology, then they will need materials that can

easily be repaired or recycled into another tool (Torrence 1983:64). The resulting choice

will probably be homogeneous, highly siliceous stones which may be fairly rare within

the environment and therefore costly to obtain if located outside the areas where they

might be procured as part of normal subsistence activities (Binford 1979; Goodyear 1979).

Multifunctionability

Hayden et al. (1996) introduces the concept of multifunctionability, tools that are designed to perform multiple functions. Multifunctionability is included in design consideration because it can certainly be a deliberate function of tool manufacturing. The occurrence of different uses on the same flake can simply be the opportunistic use of available or scavenged flakes for immediate needs not involving any real design considerations (Hayden et al. 1996:13). Schott (1986) and Bleed (1986) agree that multiple functions of tools should characterize tools in which portability, resulting from mobility, is an important consideration (Hayden et al. 1996:13). Hayden et al. (1996:14) suggests that "flexibility" in Nelson's sense is more appropriately dealt with in terms of a procurement and resharpening strategy. In regards to design considerations, the important aspect is the intentional choice of flake size and shapes, as well as materials and resharpening techniques.

Manipulating Cost Through Technological Process

Following Elston and Raven (1991-1992), I have identified costs of lithic procurement and will now address methods in which costs can be manipulated assuming that the final goal is one of net value maximization.

Mobility Patterns

Mobility refers to the approaches used by people to position themselves in relation to resources, specifically food, water, and shelter (Binford 1980, 1982; Kelly 1983; Thomas 1983, 1988). These patterns are designed to handle variable temporal and spatial

accessibility of subsistence means. Supply is driven by demand and human beings obtain

needed resources while foraging; material for clothing, shelter, and tools and other artifact

manufacturing...the need for materials such as these, must also enter into the foraging

decision (Bamforth 1988:27).

Binford (1980) distinguishes between "foragers" who move consumers to

resources and "collectors" who move resources to consumers. Foragers exercising

residential mobility move as a group to resources at appropriate times, exploited those

resources and then moved as a group to a new location. Collectors exercising logistical

mobility tend to establish multi-purpose base camps in areas from which they send out

task forces to exploit specific resources. Their base camps could be expected to have

been relatively sedentary, at least on a seasonal basis (Binford 1979; Lurie 1989).

According to Kuhn (1989:33) most hunter-gatherers probably employ a combination of

both mobility strategies, the mix being determined largely by the spatial and temporal

distribution of resources. Over time environmental conditions or technological

innovations could also effect mobility strategies.

Residentially mobile forgers seem to be constantly at work repairing or making

something using free time where and when they find it. In contrast, logistically hunters

have periods of reduced subsistence activity, which are used to gear up for future

episodes (Kuhn 1989:35). This affects the evaluation of "scarcity" or "cost" to raw

materials because different mobility strategies result in varying patterns of landscape use

making simple geographic distance an ineffective measure (Kuhn 1989:35). Raw

material distribution may be a significant factor if the distance between discrete resources

exceeds the normal foraging of logistical radii in regions where raw materials occur in

locations unsuited for other uses (Kuhn 1989:39). According to Torrence (1983:62), it is clear that collectors probably travel, on average, many more miles per hunter per day in pursuit of food than do foragers. Both the pattern and severity of risk play a role in determining the character of how raw material procurement, tool manufacture, repair and caching are organized according to a daily or yearly schedule and how tasks are allocated among individuals.

Mobility is certainly a consideration for prehistoric hunter-gatherers in choosing a technological strategy, but this consideration is made within the context of raw material variability as well as other factors (Carr 1994:36). According to Goodyear (1979) the focus of Paleoindian groups upon cryptochrystaline materials follow a principle of cost minimization. This focus was a response to the need for a highly portable and flexible toolkit under conditions of a highly mobile lifeway. He feels that these high-grade materials allowed for the creation and maintenance of a more flexible and portable tool kit than one based on other kinds of materials. Gramley's (1984:20) study of the Mount Jasper quarry in New Hampshire revealed variation in the procurement strategies over time as a result of differing mobility strategies:

> With their canoes Ceramic Period hunters were not tied down to a few lithic sources. They could range widely and remain away from quarries for longer periods. On the other hand, by staying on the hunt for extended periods, more stone had to be extracted for toolmaking when they camped at a lithic workshop. Their entire toolkit, and not just a few elements of it, needed replacing.

He further asserts that the mining operation and tool production may vary from period to period and within a single cultural period, from visit to visit. This is dependent upon the transportation available to miners and perhaps the season when a resource was exploited (Gramley 1984:21).

Most likely there is a balance struck between production and transportation costs, as transportation costs are reduced, raw material or products tend to be transported longer distances. In simple societies, direct access, ad hoc production by the occasional knapper and, at times, the creation of a no-man's land around the quarry appear to be recurrent patterns in many regions for many millennium (Ericson 1984:7).

Organization of Labor and Activities

Changing the organization of labor and activities should affect procurement costs (Elston 1992:43). Optimal group task size is expected to be connected to mobility patterns and method of procurement. Division of labor by sex, age, or ability might augment acquisition efficiency, especially on longer journeys where opportunity costs associated with quarrying can be reduced by local foraging.

High mobility throughout a large annual range can make a greater number of raw material sources available. Although choices can be made among the highest quality sources, groups may not be capable of predicting, accurately, when they will be in the neighborhood of any specific source and are limited by the amount of lithic raw material that they can transport from source to source (Elston 1992:43). Contingency risk is a significant factor as considerable time may pass between visits to the premium sources.

Low residential mobility with established residential base camps allow resources in the foraging radius to be exploited, but the larger area is accessible via special task groups formed to acquire a specific resource or group of resources. These groups travel from the base camp and set up temporary field camps to procure and process the desired items and then return with the commodities. Because human load carrying capacity is limited (Jones and Madsen 1989), resources are generally processed at or near their

source to reduce mass and weight. Storage can also be used to tackle seasonal shortages

and transportation limits. Caching can provide a means to store items at the main camp,

field camp, and points in-between for retrieval at a later time.

Scheduling

To minimize opportunity costs of food resources it is important to schedule lithic

procurement. The degree of time stress will mainly condition the quantity of the

responses whereas the type of stress will determine the quality of adaptive technological

behavior (Torrance 1983:23). If the amount of time available is limited, tools which

increase the speed at which the activity is carried out will be employed, or where there is

sufficient time available it may still be necessary to schedule certain activities in order to

avoid competition among behaviors for particular periods of time (Torrence 1983:12).

The length of time during the year in which resources can be exploited as well as the

nature of the resource being exploited also needs to be examined (Torrence 1983:14).

In discussing predictability with regard to seasonal cycles of production, Colwell

(1974) points out that there are two distinct components with the concept: constancy and

contingency. A resource is completely constant if it does not vary in time or space. The

availability of a resource is completely contingent if it can be predicted with certainty on

the basis of the state of some other aspect of the environment (Bamforth 1988:19).

Perfect predictability can derive from perfect constancy or perfect contingency or a

combination of the two. Both aspects of predictability can be assessed either through

time, particularly in terms of seasons, or through space, in terms of location (Bamforth

1988:19). Local patterns of productivity are described by the degree of patchiness of a

resource distribution and the fluctuation in resource availability with a patch. Lithic

materials are resources in the somewhat similar to plants and animals. Its nature and

distribution fundamentally condition the fashion in which it can be exploited (Bamforth

1986:40).

Limitations in the time available to complete a task are a key variable in

explaining differences in the structure of the hunter-gatherer tool kits as well as in the

patterns of procurement, manufacture and discard of an artifact (Torrence 1983:12). If

optimum use of time can be assumed to lead ultimately to increased productivity, it seems

reasonable to assume that technology will reflect the areas where time budgeting will take

place. The concept of scheduling encompasses differences in the temporal availability of

biotic resources and need to procure lithic resources. Even though chert is available,

accessibility may be limited by other demands on procurement time (Waint and Hassen

1985:104). Specific technical responses are the result of an adaptive interaction

involving the structure of the biotic environment and the strategic and technological

potential of a society (Wiant and Hassen 1985:105).

Figure 5 (from Elston 1992) illustrates the interaction between seasonality,

productivity, and food patch variance for the Towsohaii quarries. During winter both

productivity and food patch variance are low so the need for lithic resources are also low.

As spring appraches, productivity increases dramatically resulting in an increasing need

for lithic resources so that adequate raw materials will be on hand when food path

varience peakes during autum. Productivity declines gradually over autumn as plant and

animal resouces become less available. According to this model, mid spring to mid

summer would be the most likely time to acquire toolstone if the goal is to decrease costs

and increase benefits.

32

Figure 5. (From Elston 1992)
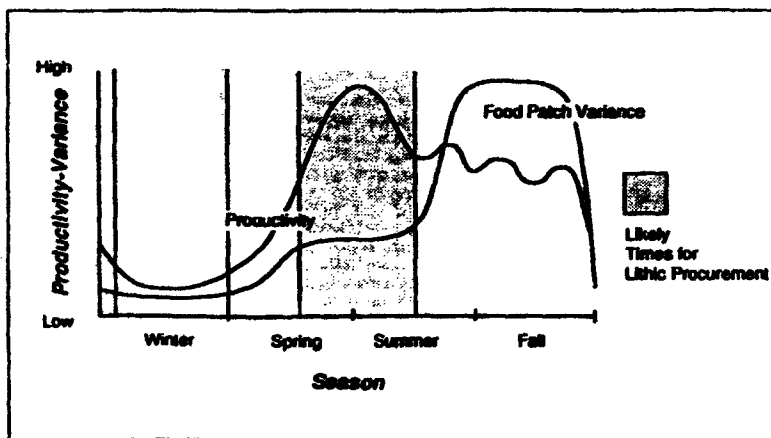
Demand and Output

Leudtke (1984) identifies demand as also being a factor in lithic procurement

strategies. Derived demand is demand that gives rise to supply. Demand is thus defined

as essentially a function of two aspects of a cultures's technology: the number and

frequency of activities requiring stone tools and stone tool efficiency. Production and

supply are affected by the tool production techniques. All other factors being equal, the

demand for stone should increase as the number of tasks requiring stone tools increases

(Leudtke 1984:65). The more "wasteful" the production technique used, the more raw

material will be needed. If the average tool lifespan is short, the demand for raw material

over time will be greater (Leudtke 1984:66). Hayden et al. (1996) also suggest that

demand will increase depending on the intensity of the tasks being performed. These

tasks also effect the resharpening tactics used by groups. A task that rates high in

intensity may result in high demand for raw materials. If edges of tools become dulled

quickly during task performance, tools will become exhasted quickly through extensive

33

resharpening and will need to be replaced on a regular basis. This leads to the assumption

that lithic procurment strategies will respond to different costs and levels of demand via

changes in output of toolstone produced.

Elston (Fig 6: 1992:46) illustrates the seasonal variation in toolstone procurement

costs and contingency risk. During the winter, procurement costs are the highest while

contingency risk is held constant. This assumes that an adequate supply of toolstone was

on hand and is slowing being depleted during the months when accessiblity to the raw

material source is limited. Procurement costs begin to decline around mid-spring before

reaching a low heading into the summer season. Contingency risk, however peaks at the

end of spring and drops drastically right before the summer season. This means that there

is less posssiblity that sufficient toolstone is on hand coming out of winter. A new supply

will probably be needed before summer so that material present will be of a quantity

adequate to deal with the increased productivity and the increasing food patch varience as

illustrated in Figure 5 (Elstone 1992:46). According to Elston's model, procuement costs

continue to decline over the summer and fall before beginning to increase along with the

coming winter. Contingency risk remains relatively constant with slight peaks over

summer and fall. The time frame that corresponds to the lowest costs and least risk is late

spring to early summer. If the goal is to have low cost and low risk, this then would be

the time of the year that toolstone would likely be acquired.

He identifies mobility and relaxed tool design parameters, or lower quality

materials, as methods to decrease cost associated with supply (1992:46). If a group is

very mobile, there are more sources of raw materials available to them on a regular basis

and less materials are produced on a quarry visit to satisfy demand. Less mobile groups

who do not choose to lower material quality standards or relax tool design parameters may need to focus on several specific sources which are available within their range. The use of lower quality materials may actually increase demand as more toolstone is needed to produce the same amount of goods.

Figure 6. (From Elston1992)

High

Procurement Cost

Cost - Risk

Contingency Risk

Low

Winter   Spring   Summer   Fall

Season
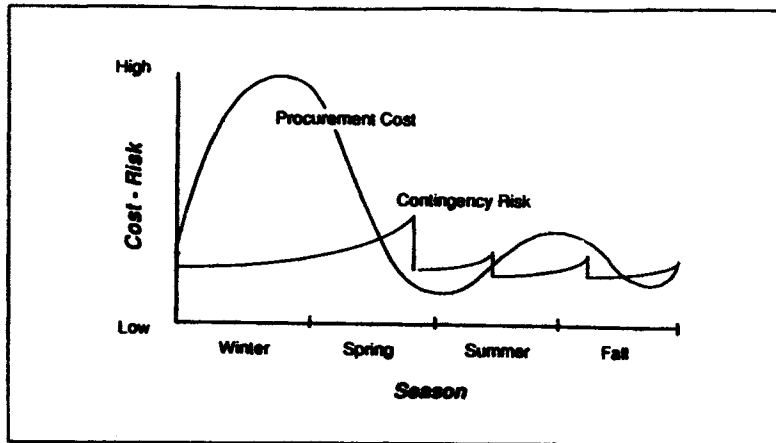
Implications of Elston's Model

The factors identified previously attempt to illustrate how costs can be manipulated by hunter gatherers to minimize cost and avoid risk when engaged in lithic procurment strategies. This model suggests that the economics of procurment strategies can be an important aspect of hunter-gatherer adaptation. Although embeddedness is not thought to be very common according to this model, this strategy can lessen some procurement costs and increase the probability of success. Nevertheless, opportunity costs are still present. Like the Tosawihi Shoshone, it is expected that the people at South Everson Creek used different strategies of lithic procurement based upon position, seasonality, and scheduling demands related to the procurement of other resources (Elston 1992:46-47).

35

Procurement Strategies

There is a range of variation involved in lithic procurement strategies with casual direct procurement involving the least amount of planned effort as tools made out of materials procured in this manner are designed only to meet immediate needs (Francis 1983:23). These items are termed situational gear by Binford (1979). Exploitation can only occur in those materials that are readily available and easily accessible. If not readily available, recycling and reuse of immediately available items will be done (Francis 1983:24).

Deliberate direct procurement involves more fixed costs as materials are obtained in anticipation of future needs. It may occur in situations where raw material sources are not widely available or where source locations are highly localized. This type of procurement strategy may also occur if particular sources are valued for their high quality of flaking characteristics or if for some reason there is not always ready access to these sources (Francis 1983:24).

Items termed personal gear (Binford 1979) are more likely to be made out of materials procured in a deliberate manner. There are not necessarily any direct costs or planned effort involved with direct procurement. Items or raw materials may be obtained through interaction systems, ritual, gift giving behavior or even caching. Methods of indirect procurement may be the most organizationally complex and may be used to obtain non-local or rare items (Francis 1983:24).

Variation in procurement strategies will ultimately be related to the overall availability, abundance, and access to resources as well as to the intended use or role of the items (Francis 1983:24-25). Where raw materials are widely available and easily

accessed at all times there is much less anticipation and planning needed to obtain these

resources (Francis 1983:25). Procurement will most likely be done in a casual manner.

Where materials are not widely available or access is limited for whatever reason

(seasonality, ownership, etc.) future planning is necessitated and raw materials are

procured in a more deliberate manner (Francis 1983:25).

Curation

Curation relates to the benefits of a good that has characteristics of duration or

longevity. The concept of a curated technology was introduced by Binford (1973:242-

244) and involves transportation, preservation of tools for future use, and efficiency.

Used here it refers to tools that are likely to be transported site to site as part of one's

personal gear and should consist principally of small, lightweight formal tools. These

items are seldom discarded when worn out, rather, if possible, they are recycled into

usable items. Ebert (1979:68) states that curated tools have a high degree of recycling,

they are likely smaller items since they are made to be carried around. Bamforth

(1986:39) classifies curation into five different aspects: "the production of implements in

advance of use, design of implements for mutiple uses, transport of implements from

location to location, maintenance, and recycling."

Expedient tools compose the other end of the spectrum. These items are designed

for immediate or short term use and are generally found within a short distance from the

raw material sources. They are most likely discarded in the area of use and can be found

in both habitation and limited activity sites. Reuse and recycling of expedient tools is

expected to be low with very few resharpened or reworked items (Binford 1976?).

According to Ebert (1979:68), these items should be larger than their curated

37

counterparts. Tools used for food-getting are carried around on a daily basis so their portability is not only a consideration when moving camp (Torrence 1983:62). Binford links curation to subsistence-settlement organization (1979:35). Torrence links it to the problem of scheduling different activities around one another which he refers to as "time-stress" (1983:11-13). Bamforth (1986) has argued that tool raw material availability is closely related to curation practices and that two components of curation; maintenance and recycling, were often responses to shortages of raw materials rather than a manifestation of curatorial behavior. Wiant and Hassen (1986:104) have suggested that it is possible that the physical characteristics of lithic tool assemblages from resource rich environments will be similar to those from resource poor areas if scheduling pressure limits accessibilty to those resources.

Francis (1983:25-26) suggestes that importance and degree of curation may be related to the following factors and indicates that there is a relationship between procurement strategy and degree of curation of artifacts based upon the availability of the material, costs of obtaining the material, and anticipated needs of the material. As availability decreases, cost and anticipated needs increase. Planned efforts to obtain the material would be practiced and the degree of curation would be high. Where availability is unlimited, costs of procurement are negliable and anticipation of future needs is also low. Planned efforts are unnecessary and procurement would be casual and the degree of curation would be low (Francis 1983:26). The types of resources for which an artifact is used play an important role in determing the raw material selected, the energy invested in tool manufacturing, the artifact's use-life and discard rates (Jeske 1983:35).

This leads to the following propositions outlined by Francis (1983:26-27):

38

Causual direct procurement would be practiced in situations where availability of resources are not limited and these tools would show little or no evidence of curation; deliberate direct procurment and indirect procuremnt would be practiced in situations where availability is limited and anticipated needs are high, tools made from these materials would tend to be curated; and as distance to the source increases and the amount of manufacturing debris of the material decreases, the likelihood of indirect procurement or other costs mediating strategies such as embedding increases.

There also seems to be a direct relationship between the amount of labor invested in manufacturing a tool, the amount of planned effort required to obtain the raw material and the degree of curation. Binford (1979:266) and Gould (1980:124) found that tool design was limited and intentional modification was minimal for situational gear or expedient tools that had been procured in a casual manner. Binford (1979:269) established that personal gear tool design was much more complex and the function of these tools may cross-cut different aspects of tool design.

To determine how tool design relates to the principles of procurement and curation several terms will be defined here (Francis 1983:27-28). Formal tools are defined as items which show deliberate shaping of the tool into a desired form. Secondary or tertiary retouch is present over all or one or both margins. This category includes projectile points, bifacial knives, many types of end scrapers and can be considered personal gear. Retouched flakes are defined as tools on which only the use edge(s) are shaped to a desired form. Intentional modification occurs only along the edge. These items were likely used as both personal and situational gear. Utilized flakes are defined as flakes which were used

but not intentionally retouched. Edges are modified only as a result of use and were likely used in situational contexts.

Lithic reduction strategies

Hayden et al. (1996:16-22) identify several lithic strategies employed by prehistoric people at the Keatley Creek site. While his results are site specific, they may help to provide insight into reduction strategies used in other locals. For the purposes of this paper only expedient block core strategy and biface strategy will be examined in detail. Expedient block core strategy uses cores kept at the habitation site. Flakes are removed and modified according to immediate needs and are usually discarded after the present task is completed, unless large still usable flakes are involved. Core material is obtained from the most easily available resources and generally there is not a need for especially durable materials.

According to Haydon et al. (1996:22) the biface design strategy makes the most sense in the context of high mobility, as tools used in traveling to seasonal camps, and where there are high constraints on the amount of stone material that can be transported by such tribes. Advantages associated with this strategy include multifunctionability, economic use of raw materials and the potential utility of resharpening flakes.

Hayden et al. (1996:38) suggests that the expedient reduction of block cores is the most efficient use of raw material in terms of procurement, reduction, and the employment of minimal amounts of raw material in any given task. Nash (1996:88) also assumes that prepared core reduction strategies are characteristic of curated technology, while ad hoc core reduction strategies are characteristic of expedient technologies. Ebert (1996) argues that the energy required to fabricate a new tool is greater that that associated with keeping a

useful tool in a tool kit. This explanation allows room for curated items even in areas of raw material abundance (Larson 1994:65). Kuhn (1994:435-436) found that the best overall strategy for maximizing utility per unit mass is to carry many small flake tools. Bifacial reduction may be ideal for making transported artifacts simply because it allows one to most closely approach the optimal weight/utility ratios. However, ethnographic and archaeological observations indicate that at least some cores were regulary transported as part of mobile populations in a variety of contexts (Binford 1979:276; Holev 1991; Kelly 1988; Smyth 1878:132).

Figure 7 (Elston 1992) illstrates a possible biface trajectory for raw materials obtained from bedrock sources. A bedrock source might be quarried into blocks or flakes. The quarried flaked would most likely be further processed into a Stage 2 biface, characterized as possessing prepared edges but thinning of the tool has not yet begun. The quarried block is manufactured into a core from which flakes are struck and further processed or the block itself is reduced to produce a biface blank. Raw materials found in cobble form also follow this trajectory and are formed into blanks or cores. Once the initial reduction of the biface occurs, the biface may be further thinned and refined or the tool may be used "as it" (export form). After manufacturing, the biface is used, resharpened, and finally discarded. Figure 8 (Elston 1992) shows how raw materials could be reduced to produce a variety of items, including bifaces. According to this senario, cobbles are generally used to create bifaces or cores, these cores are then further reduced to produce bifaces or other items. Blocks can be used to make cores or bifaces which both can be reduced into flake blanks and further processed.

Figure 7 (From Elston 1992)

Bedrock

Cobble   Quarried Block   Quarried Flake   (Stage 1)

Core

Blank Prepped
Biface   Flake Blank   (Stage 1)

(Stage 2)

Edge Prepped
Biface   (Stage 2)

Secondary Trajectories   Export Form

Primarily
Thinned Biface   (Stage 3)

Secondarily
Thinned Biface   (Stage 4)

Bifacial Tool   (Stage 5)

Life

Resharpening

Discard

42
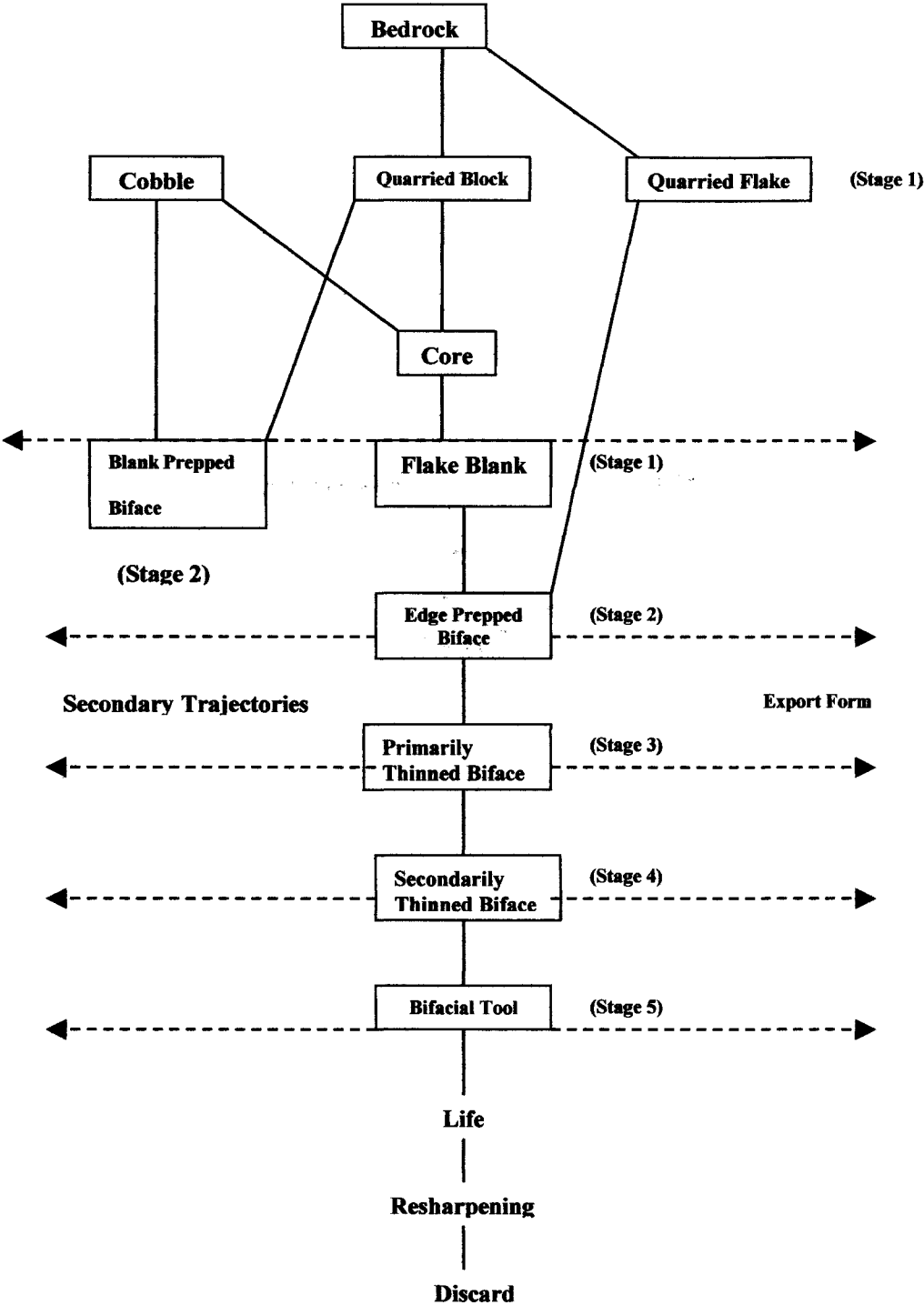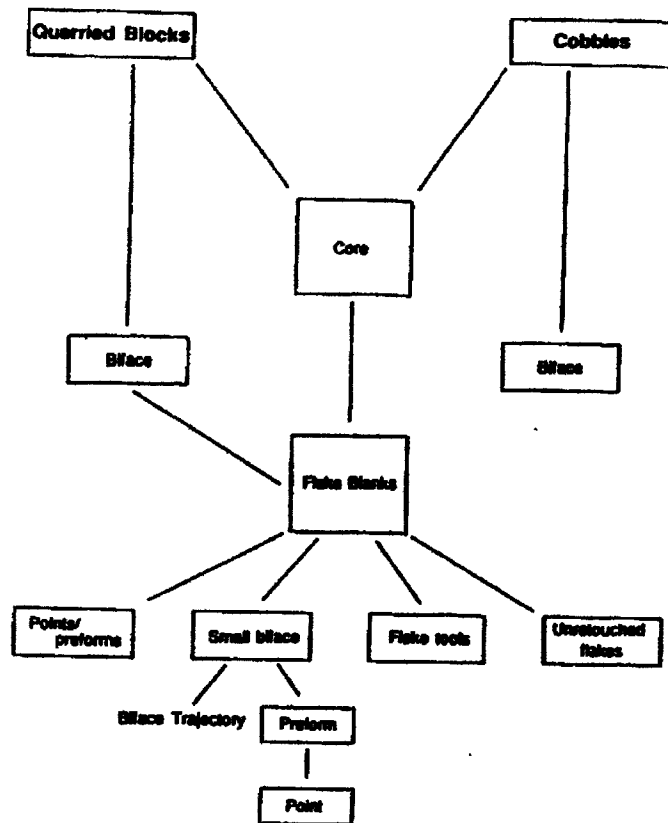
Figure 8. (From Elston 1992)

Kuhn (1994:426) discusses design technology for mobile toolkits. Since they are designed to maximize durability and fuctional versality while minimizing weight, would cores and blanks or small artifacts be a more efficient toolkit? The greatest limitation on mobile toolkits is portability, the gear must be sufficient to cope with a broad changeable set of circumstances. Items must last until there is an opportunity to replace them. Strategies should tend to minimize their potential usefulness relative to weight which is the primary determinate of transport costs (Kuhn 1994:427). Interelations between artifact size, transport cost, and potential utility can be approached as a problem in optimization with beneficial increases in portability having potentiall detrimental implications for artifact use lives and functional versatility (and

vice versa)(Kuhn 1994:428). The optimal artifact design is one which produces the

greatest utility relative to the cost of transporting it (Kuhn 1994:429).

Combining these principles, the following propositions are hypothesized regarding

tool type, raw material procurement straegy, and degree of curation on items transported

by people from location to location (Francis 1983:28):

1. Tools made out of direct casually procured materials will primarily tend to be
   utilized flakes. Some retouch flakes may also be made out of casually procured
   materials. Such tools will not show evidence of curation.

2. Tools made out of direct deliberately procured materials will tend to be formal
   tools and will be curated. Retouch flakes may also be made out of deliberately
   procured materials.

3. Tools made out of indirect procured materials will tend to be formal tools and
   will be highly curated.

Analysis of artifactual remains on lithic procurement sites should provide evidence of

particular procurement strategies, and flaking debris on source locations should differ

between casual and deliberate procurement strategies (Francis 1983:28). Characteristics of

casual procurement reflect a low cost and low curation. Reduction strategies are designed

for the production of immediately usable tools requiring little modification for use. Cores

may be reduced only minimally and reduction may be done in an unsystematic fashion.

There should be little or no production of blanks or preforms for personal gear. The

debitage should consist primarily of initial core reduction debris rather than tool

manufacturing flakes reflected by many primary flakes and few bifacial thinning flakes

(Francis 1983:29).

Characteristics of deliberate procurement should reflect high cost and high degrees of

curation. The quality of the good is higher so there is greater value added to the good.

Deliberate procurement is designed to meet future needs. Reduction strategies are geared to the production of easily transportable cores from which flakes can be detached and also to the production of blanks for personal gear. There should be a higher incidence of prepared cores with numerous flake scars. There should be discarded blanks or broken preforms in the initial states of manufacture. Debitage should consist of core reduction debris as well as tool manufacturing debris (Francis 1983:29).

Evidence for indirect procurement is not expected to be found on lithic source sites, but is more likely present in habitations or camps so it will not be dealt with extensively in this paper. Evidence would consist of the presence of "exotic" or non-local materials occurring primarily as blanks or finished tools in extremely low frequencies relative to locally available materials. There may be no debitage associated with indirectly procured materials, if it is present, it is most likely due to final finishing or resharpening of tools (Francis 1983:29).

Lithic procurement strategies should vary with the availability, accessibility, and the planned effort involved to effectively exploit a particular resource. Where there is a high availability and accessibility, one should find evidence of casual procurement. Exploitation strategies would be designed for the production of immediately usable implements. Tools would tend to consist of utilized flakes and would be discarded in an expedient fashion. They would be discarded at the place of use, found in all different site types, and evidence of recycling would be low. It is also expected that there will be extremely rapid fall-off rates from source locations (Francis 1983:32).

In areas of low availablity and accessiblity, one would expect to find evidence of personal gear. There should be a high frequency of formal tools from deliberately procured

materials and a high degree of curated tools with the highest frequency found in habitation

sites. There will be a high degree of recycling and artifacts would only be discarded when

worn out or broken beyond repair. Curated tools made from deliberately procured materials

should show more even fall-of rates and give wide spatial distributions from source

locations (Francis 1983:33).

In order to examine these suppositions in detail, it is necessary to relate them to the

specific raw material resources within a given area and deduce specific hypothesis and test

implications regarding the procurment and application of a specific set of raw material

resources (Francis 1983:54). There are three types of lithic procurment sites: secondary

sources; surface exposures or outcrops within a particular geologic formation; and quarry

sites where actual mining of raw materials occured (also rank ordered based on abundance

and accessiblity) (Francis 1983:73).

Following Francis (1983:74-75) once again, the ensuing propositions regarding lithic

procurment sites are proposed:

> Quarry sites: are ranked as lowest with regard to abundance and accessiblity. Many
> occur in the extremely high elevations where access is limited to summer and fall.
> Abundance is generally low. Suitable exposures occur in limited areas and may have
> required special trips or scheduling with other activities. The effort involved in actual
> mining of materials from subsurface deposits also serves to decrease the overall
> availablity.

This then leads to the following hypotheses and test implications, again after Francis

(1983:75-76).

> Hypothesis: Quarry sites should be exploited in a highly deliberate manner.

> Test implications pertaining to the artifactual assemblages on these sites and include:

> 1. High relative frequencies of decortication debris.
> 2. Moderate relative frequencies of core trimming and preparation debris.

3. High relative frequencies of bifacial reduction and tool manufacture debris.
4. High frequncies of prepared cores.
5. High frequencies of broken and discarded blanks and preforms.

As abundance and accessiblity increase, the degree of planned effort decreases and casual procurment strategies would be practiced. As abundance and accessibility decreases, the degree of planned effort increases and deliberate procurment strategies would be practiced (Francis 1983:78). According to Francis (1983:85) there is a direct relationship between the amount of planned effort involved with raw material procurment and the degree of curation of tools made from the different raw materials. The more deliberate the procurment, the greater the rate of curation. The most widely available and accessible secondary sources are hypothesized to have been procured in a highly casual fashion. Employment and use of these materials should be the most expedient (Francis 1983:85).

Casual and direct procurement strategies are characterized by the differences in the amount of planned effort involved to obtain lithic raw materials (Francis 1983:115). Casual procurement involved the least amount of planned effort and can only occur in situations where raw materials are redily available and highly accessible. Deliberate procurement involves a greater amount of planned effort and can only occur in situations where raw materials are not widely available or readily accessible; therefore, abundance and accessiblity of resources are suggested as the primary factors producing variation in lithic procurement strategies (Francis 1983:116).

Different indicators are logical consequences of the differences in planned effort. Casual procurement is designed to produce immediate usable tools that require little modification. Deliberate procurement is designed to meet future needs. The reduction strategies are geared toward the production of easily transported cores and to the production

47

of blanks or preforms (Francis 1983:116). This leads to the formation of two sets of hypotheses regarding lithic procurment strategies. The first pertains to the procurment strategy used to exploit each individual raw material and the second pertains to the strategies used to exploit the different types of lithic procurment sites.

Chapter 4 – Applying a Cost-Benefit Model to South Everson Creek

Site Description

Mammoth Meadow I is a open air, multi-component site located in southwestern Montana, Beaverhead County at 44.53 north latitude and 113.20 west longitude, in Section 3, Township 11S, Range 14W. Topographic map coverage is provided by the United States Geological Service 7.5 minute series 24 Quadrangle, 1965. There is also aerial photo coverage furnished by the United States Bureau of Land Management and United States Forest Service at 1:20,000 scale. Drs. E.J. Zellar and G. Dreshoff have prepared large-scale aerial photo coverage as part of the South Everson Creek project (Zellar et al. 1987). The South Everson Creek workshop/habitation site is situated approximately 7 km east of the Continental Divide on the north bank of the South Fork of Everson Creek. The continental divide runs along the crest of the Beaverhead Mountains. The site is located at an elevation circa 2092 m (6800 feet) above mean sea level (msl), 85km (50 miles) southwest of Dillon, Montana. Mammoth Meadow I is part of the South Everson Creek complex, which contains almost 200 known quarries spread over a variety of landforms and covering approximately 1,000 ha.

The northwest southeast trending Beaverhead Mountains are part of the Bitterroot Range, a component of the northern Rocky Mountains. Many small valleys, one of which is the South Fork of Everson Creek drainage valley, intersect the eastern slope of the Beaverhead Range. South Everson Creek is a tributary of Horse Prairie Creek, which flows northeast to the Beaverhead River, a tributary of the Missouri River.

Geological Background

Although the geology of the Everson Creek Quadrangle has not been published, recent geologic observations made in conjunction with the South Everson Creek Project were obtainable by project scientists (MacWilliams 1990; Turner et al 1988), and geologic maps of adjacent quadrangles to the west indicate that this quadrangle contains metamorphosed sandstones and siltstones of the Late Precambrian Belt series (Sharp and Cavender 1962; Staatz 1973 and 1979). Terrestrial and lacustrine sediments of Tertiary age, overlie these Precambrian Belt Supergroup quartzites (Bonnichsen et al. 1989).

Tertiary faulting episodes intensely fractured the Precambrian Belt quartzites, and Tertiary deposits. Hydrothermal solutions ascending along these fault zones during the Tertiary were rich in discolored silica that supplanted the original rock with fine-grained, and crytocrystalline quartz (chalcedony) (Bonnichsen et al. 1989). Discontinuous silicification of the basalt and Tertiary sediments adjacent to the fracture zone resulted in the formation of an assortment of siliceous (chalcedonic) rock types, including:

> silicified basalt; basalt with multicolored opal amygdules; silicified basalt breccia;
> white opal; white porcelainite; clear, white, tan brown, chocolate brown, and
> black chalcedony; jasper of various colors; silicified lake bed limestone; oolitic
> limestone; and sandstone (Bonnichsen et al. 1989:16).

The highest percentage of stone tools excavated at Mammoth Meadow I are comprised of chalcedonic materials. Also occurring are artifacts made from basalt, opal, porcelainite, silicified limestone, and meta-sandstone.

Geomorphology

There is a differing and discontinuous range of silicification of the basalt and Tertiary sediments along the South Fork of Everson Creek resulting in differential erosion

occurring at the site complex. Unsilicified Tertiary and Quaternary sediments "south of South Everson Creek have been deflated to a desert pavement of artifacts and small cobbles" (Bonnichsen et al. 1989:15). This desert pavement, and silicified materials adjacent to the fracture zone south of Everson Creek, acts as a barrier to further wind and water erosion (Bonnichsen et al. 1989:15). These resistant surfaces, shallow bedrock, and erosive processes result in a steep gradient on the southeastern slope of the valley (MacWilliams 1990). In contrast, the valley's northwestern slope is primarily composed of unsilicified materials. Aeolian, alluvial, fluvial, and glacial deposits are largely eroded and form moderate gradient.

Alluvial fans on the valley's northwestern slope were deposited flow down to the lowest terrace of the South Fork of Everson Creek. Mammoth Meadow I is located on this first terrace, which lies around 1 m above the bottom of the modern Creek. The terrace begins roughly 0.5 km west of the site, at about 2,192-m elevation, and continues downstream on both sides of the creek for approximately 1.5-km, terminating at an elevation of about 2050-m (Bonnichsen et al. 1989).

Glacial Geology

Extensive weathering and overgrowth of cirques and moraines in the Beaverhead Range show that this region was not glaciated during the past 100,000 years (Turner et al. 1987; Alden 1953). Considerable weathering of glacial deposits at the head of the South Fork Everson Creek signifies that no glaciers ever flowed down this valley. In contrast, cirques and moraines at the head of Black Canyon Creek, to the south of South Fork Everson Creek, and Trail Creek, located to the north, indicate that glaciation occurred at these higher elevations during Bull Lake time (Turner et al. 1988a, 1988b, 1987).

In addition to alpine glaciation, glacial deposits along upper Horse Prairie Creek and on Bannock Pass indicate that lobes of a "continental ice sheet advanced repeatedly from the north during the early to middle Pleistocene" (Bonichsen et al. 1988:16). Staatz (1974) recognized comparable glacial deposits immediately west of South Fork Everson Creek in the Lemhi Pass Quadrangle. Geomorphic evidence indicates that South Fork Everson Creek remained ice-free during much of this period. At least once in the early Pleistocene, one of these ice lobes encompassed what is now the Everson Creek area. Turner, et al. (1987, 1989) presume that the ice may have blocked South Fork Everson Creek's mouth, possibly resulting in an ice-dammed lake that heightened lateral erosion, and allowed deposition of the lateral terraces.

Holocene Climate in Southwestern Montana

Mehringer et al. (1977) describe the Holocene climate as slightly cooler than present up to around 7000 years ago at which time the weather conditions were slightly warmer than present. By about 4000 years ago the climate began cooling toward modern conditions. Probably, the greatest consequence of climatic fluctuations would be a lowering of the tree line into the quarry area. This, in turn, would have had an impact on selecting quarry locations. The diversity of point typologies found at the site suggest that the climate did not alter conditions at South Everson Creek in any manner that constrained its use for long intervals during the Holocene.

Modern Flora

The present vegetational assemblages of the South Everson Creek section are perhaps best characterized by a willow-covered riparian community in the valley bottom, a sagebrush-grass community at roughly 2000-2200 m, Douglas fir cover on northern

52

exposures between 2200-2400 m, and finally spruce-pinyon above 2400 m. The

vegetation immediately surrounding the site area falls within the sagebrush-grass zone.

Willows (*Salix* sp.) and quaking aspen (*Populus* sp.) flank South Everson Creek.

Dominant grasses in the site area include:

> Canada bluegrass (*Poa canadensis*), Idaho fescue (*Festuca idahoensis*),
> Bluebunch wheatgrass (*Agropyron spicatum*), Prairie junegrass (*Koeleria critata*),
> green needlegrass (*Stipa viridula*), and Western wheatgrass (*A. smithii*).
> Flowering grasses include yallow (*Achillea millefolium*), sedges (*Carex* sp.), and
> lupine (*Lupinus* sp.) (Bonnichsen et al. 1989:29).

Shrubs growing along the creek and lower terraces include sagebrush (*Artemesia*

tridentata vaseyana), wild rose (*Rosa* sp.), currant species (*Ribes* sp.), and an alder-like

shrub (ibid.)

Modern Fauna

The dominant animal in the area today is domestic cow (*Bostarus*), however, a

multitude of wild animal life resides in or near the site area. Antelope (*Antilocarpa*

americana), white tail deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*),

elk (*Cervus canadensis*), and moose (*Alces alces*) live in the area. Other inhabitants

include badger (*Taxidea taxis*), Richardson's ground squirrel (*Spermophilus*

richardsonii), deer mouse (*Peromyscus maniculatus*), cottontail (*Sylvilaugus nuttallii*),

jack rabbit (*Lepus americanus*), coyote (*Canis latrans*), fox (*Vulpes vulpes*), wolf (*Canis*

lupus), and black bear (*Ursas americanus*).

Excavation of Mammoth Meadow I

As mentioned previously, Montana State University (Davis 1981) initially

investigated Mammoth Meadow. Subsequent research was conducted by crews from the

University of Maine and Earthwatch volunteers which led to the documentation of

hundreds of quarry pits, varying in size and depth, along terraces and uplands of the

South Fork of Everson Creek and Black Canyon Creek (Davis, Smith and Foor 1997;

MacWilliams 1990; MacWilliams and Bonnichsen 1989; MacWilliams 1991; Douglas

1991; Bonnichsen et al. 1992). Workshop-habitation loci are consolidated along springs,

streams and in deeply stratified terrace deposits of Holocene and late Pleistocene age.

Mammoth Meadow I, so named for a fragment of mammoth bone recovered from a

badger backdirt pile, is located on Terrace I on the northwest side of the South Fork of

Everson Creek. It consists of a cultural sequence of settlement, subsistence, and lithic

procurement information that extends in time from the Paleoindian period through

European contact (Bonnichsen et al. 1992).

Standard excavation procedures were used at Mammoth Meadow consisting of

2x2 meter excavation units divided into four 1x1-meter quadrants. Levels were dug by

arbitrary 10-cm designations to an average depth of 130 cm. Artifacts were then

backplotted to the stratigraphic units from which they were excavated. Sediments were

screened through ¼ inch hardware cloth (Douglas 1991:16-17; Bonnichsen et al.

1992:295).

Radiocarbon Dating

Charcoal samples were collected from Mammoth Meadow I and submitted for

radio carbon dating. Dates were obtained from levels Ic, II, and III (corresponding to

assemblages 3,7, and 8 respectively). The sample from Ic was recovered from a hearth in

excavation unit 10N36E which intrudes from level Ib (assemblage 2) and produced a date

of 490 ± 50 BP (Beta 37608). It is believed to be associated with level Ib (assemblage 2)

(Douglas 1991:37). The boundary of Levels Ie and If (assemblages 5 and 6) yielded

samples producing dates of 2750 ± 310 BP (GX-16409) and 2885 ± 65 BP (GX-16409-AMS). A charcoal sample obtained at the boundary of Levels If and II (assemblages 6 and 7) produced a date of 3035 ± 220 BP Level III (assemblage 8) furnished a date of 8620 ± 140 BP (GX-16293-AMS) at 97 cmbd and at 110 cmbd 9390 ± 90 BP (TO-1876) (Douglas 1991:37-38).

Diagnostic Artifacts

All category classifications referred to in this section are following those designated by Douglas to maintain consistency of the data. Recovered in Level Ia (Assemblage 1) were Broad Corner-notched, Desert Side-notched and Cottonwood Triangular points associated with the Protohistoric and Late Prehistoric Period dating from 100 BP to 1500 B.P (Swanson et al. 1964; Lahren 1976; Thomas 1983). Level Ib (Assemblage 2) contained Sharply Barbed Corner-notched and Cottonwood Triangular points also associated with the Late Prehistoric dating from 100 B.P to 3000 BP (Swanson et al. 1964; Ranere 1971; Lahren 1976; Thomas 1983; Reeves 1990). Assemblage 3 associated with Level Ic contained Cottonwood Triangular, Black Rock Concave Base, Sharply Barbed Corner-Notched, Broad Corner Notched, Old Woman's, McKean and Avonlea points. These types of points are affiliated with Late Prehistoric and Late Archaic dating 100 BP to 4800 B.P, McKean representing the earlier dates (Swanson et al. 1964; Lahren 1976; Thomas 1983; Reeves 1990). Level Id, Assemblage 4, is a Late Archaic component with Cottonwood Triangular, Sharply Barbed Corner-Notched, Broad Corner-Notched and Oxbow projectile points dated 100 BP to 3450 ± 350 BP (Swanson et al. 1964; Lahren 1976; Thomas 1983; Greiser et al. 1985). Sharply Barbed Corner-Notched, Oxbow, Duncan, Hanna, and Leaf Shaped were recovered in

Level Ie, representing the Late to Middle Archaic 3000 B.P to 8000 B.P (Lanning 1963;

Frison 1978; Greiser et al. 1985). Level If which contains Assemblage 6, produced

Sharply Barbed Corner-Notched and Triangular Lanceolate points. These date ca. 7500

BP to ca. 1000 BP representing a Middle to Late Archaic component (Swanson 1972,

Lahren 1976; Reeves 1990). Assemblage 7 contained in Level II provided Triangular

Lanceolate, Intermountain Lancelate, Bitterroot Side-Notched, Cody, Eden and

Scottsbluff points which are dated 3400 B.P to ca. 10,000 BP representing the Early

Archaic and PaleoIndian component of the Mammoth Meadow site (Swanson 1972;

Lahren 1976; Frison 1978, 1982). Level III, Assemblage 8, contained Intermountain

Lanceolate, Broad Corner-Notched Lanceolate, Cody, and Eden projectile points. These

too are representative of a PaleoIndian Component dating ca. 8000 BP to 10,000 BP

(Swanson 1972; Frison 1978, 1982). These diagnostic artifacts, in conjunction with the

radiocarbon dates, show a temporal span of nearly 9000 years from the oldest occupation

to the most recent.

When the results of radiocarbon dating are combined with the diagnostic artifacts,

it appears that the data can be classified into PaleoIndian, Archaic, and Late Prehistoric

categories. The PaleoIndian component is represented by Assemblage 8, the Archaic

component by Assemblage 5 and Assemblage 6, and the Late Prehistoric by Assemblages

1 and 2. The remaining Assemblages (3, 4, and 7) contain mixed dates and artifacts that

could not be designated to a specific time period. To facilitate examining changes in

quarry behavior over time, these Assemblages were not included in the tests of lithic

reduction strategies that will be presented in this chapter.

FIXED COSTS AT MAMMOTH MEADOW I

As previously discussed, it is expected that hunter-gatherers act to optimize net value by obtaining more products for the time and energy they invest. This process involves fixed costs, variable costs, and opportunity costs. I will use the model provided by Elston and applying it to the data recovered from Mammoth Meadow I at South Everson Creek to test whether quarry visitors were engaged in efficient production of tools. Costs are related to supply and production whereas benefits are related to demand. Fixed costs of raw material procurement under Elston's model include toolstone quality, and absolute availability.

Toolstone Quality

The lithic raw material found at Mammoth Meadow is a chalcedony. Douglas (1991:106-111) classified the material into 74 varieties distinguished by dominant and secondary colors, inclusions such as gastropods, oolites, plant fossils, vuggs, and petrified wood. Additional characteristics such as zoning, mottling, zoning and mottling, seams and clouds or breccia were also noted.

Chalcedony is probably the purest form of cryptochrystalline silica. It is found in many and varied textures that relate to the fineness or coarseness of crystallization. According to Crabtree (1967:12) the type with the finest micro-crystal structure has all the attributes desirable for stone flaking, particularly precision pressure flaking. As such, chalcedony can be considered a high quality material. It has been suggested that manufacturing items from high quality materials provides a better return for time and energy expended than low quality materials (Goodyear 1979; Ellis 1989).

Ellis (1989:139) in writing about the Northeast, found that Paleoindian groups focused on the use of the highest flakable grades of fine-grained raw materials. There was emphasis on the use of bedrock rather than secondary deposits. Goodyear (1979) argues that this behavior allowed for the creation and maintenance of a more flexible and portable tool kit than one based on other kinds of materials. Excavations at the South Everson Creek quarries seem to follow the patterns described by Ellis (1989) and Goodyear (1979). The material present is of a high quality and it was extracted from bedrock, although surface cobbles exist and were probably used as well. There is evidence of raw material procurement occurring at the site over a long period of time. This suggests that hunter-gatherers in the area were aware of the presence of a high quality material source at South Everson Creek and exploited this resource through time.

Elston's (1992) model proposes that by using high quality raw materials, cost and risk are both decreased as the material allows the user better control in constructing and maintaining a toolkit. Better stone should have a longer uselife than inferior stone resulting in lower replacement costs and less time devoted to sustaining an adequate supply of toolstone. These characteristics affect demand which defines the product. If the goal of the quarrier is to decrease cost and risk, then mining chalcedony at South Everson Creek seems to support Elston's model.

Lithic Landscape and Absolute Availability

Exploration for lithic materials is a fixed cost, it is incurred regardless of production. South Everson Creek is located in what could be termed a "rich" landscape according to Gould's definition (1980:132). According to MacWilliams (1991:168), dozens of lithic sources are scattered throughout this region of southwestern Montana. In

this respect, South Everson Creek resembles lithic terrane "a" in Figure 3. Elston

(1992:36) suggests that this type of landscape would allow people to move through their

annual range with relatively little attention to the scheduling of lithic procurement or tool

maintenance since the cost of lithic procurement and toolstone utility would be about the

same everywhere.

Absolute availability refers to the types of raw material resources present in the

region. Since there are numerous toolstone sources present, including chalcedony and

cherts, the South Everson Creek area can be seen as possessing a relatively high absolute

availability. Where there is a good quality lithic source within the foraging radius of most

residential camps, at the scale of annual range, the absolute availability of toolstone is

high in a given lithic landscape (Elston 1992:35). This scenario also contributes to the

ability of people to move across their annual range with scant attention to the scheduling

of lithic procurement or tool maintenance. Once again, the costs of lithic procurement

and toolstone utility would not vary significantly within a given annual range.

Contingency risk can be considered low since the availability of multiple raw material

sources means that people would rarely be restricted to an area with no obtainable

toolstone nearby. Overall, Mammoth Meadow I and South Everson Creek contain no

fixed costs since there is a high quality material present in a rich lithic landscape with a

relatively high absolute availability but fixed costs would still be present for exploration

of lithic resources.

VARIABLE COSTS AT MAMMOTH MEADOW I

Costs vary with extraction and production. The variable costs associated with the

procurement of toolstone include mobility pattern, labor organization, and procurement

59

techniques. Manipulation of these variables by groups can vary access, search and

handling time, effective availability of resources, and opportunity costs. People can affect

the cost in time and energy spent in obtaining lithic raw materials through their choice of

toolstone procurement strategies.

Effective Toolstone Availability

Effective toolstone availability is related to the technological requirements to

extract and procure. The technology will affect the cost and the availability affects the

technology that affects cost. Effective availability of toolstone refers to the manner by

which groups modify procurement strategies to increase returns. It includes factors such

as expanding or reducing residential mobility, changing the size and shape of a given

annual range to include or exclude sources or advance planning to be in the vicinity of

sources when the need for toolstone is highest. Intensification of extraction techniques at

raw material source locals can also influence effective availability. It cannot be

determined whether visitors to the South Everson Creek area engaged in practices such as

expanding or reducing their residential mobility, changing the size and shape of their

annual range to affect source access. Advance planning to be in the vicinity of toolstone

sources may have been practiced. We can hypothesize that hunter-gathers were engaged

in advance planning as it relates to the availability of plant and animal resources, and this

probably would have extended to their needs for toolstone as well.

At the South Everson Creek quarry, MacWilliams (1991:165-166) recovered

antler tools and rib shafts that he identified as digging implements. Surface cobbles are

present at the site and were probably used by prehistoric visitors, but there is also

evidence of people engaging in more extensive extraction methods. Pits were dug to

obtain subsurface materials with fill and debitage dispersed around much of the perimeters. Shafts were not dug vertically but rather occurred along a horizontal plane. This strategy would enable workers access to the materials without the need to hoist loads of dirt and rock to the surface but rather fill could be deposited along the sides during excavation. This method does require excavation of a larger area to expose the bedrock. The cost of energy expended in regard to this quarry strategy is probably not significantly less than the vertical method since more dirt would need to be moved horizontally. Both methods however, result in the increased benefit of obtaining subsurface materials that have not been exposed to weathering or other environmental factors.

Toolstone Access/Travel Costs

Access used here refers to the concept of ownership and distance traveled to obtain resources (Jeske 1983:35). There does not appear to be any evidence of quarry ownership associated with South Everson Creek. Quarry visitors might have had particular spots that were their "favorites" in much the same manner as one may have a favorite camping spot that is returned to when visiting the area. However, the concept of "ownership" applied to that situation is not the same as "ownership" as it is used here. Ericson (1984:7) notes that there is a recurrent pattern in hunter-gatherer societies of direct access and a creation of a no-man's land around the quarry in many regions.

The projectile points recovered from the South Everson Creek sites include category classifications associated with the Plains, Great Basin, and the Intermountain which would seem to indicate that people from several regions used the site to obtain raw material resources. The site is located within an afternoon's walk from two major passes, Lemhi Pass and Bannock Pass, which would increase the availability of access to

groups in the area. Water and game are assumed to have been readily accessible based on soil analysis and recovered faunal remains. Groups could have camped in the immediate vicinity and made daily excursions to the quarry to obtain toolstone resulting in a lower cost of time and energy expended with a concurrent higher return on their investment. Venture risk and opportunity costs would be reduced since subsistence needs and toolstone needs could be satisfied in the same area.

Procurement Techniques

The South Everson Creek sites contain toolstone in cobble form and bedrock sources. The area in which this material is located covers a relatively large stretch of land. Surface cobbles could potentially have been obtained in an indirect manner as people moved across the landscape. However, given the evidence of subsurface extraction it would appear that South Everson Creek materials were obtained in a direct manner involving a special trip to the source. Francis (1983) suggests that deliberate direct procurement would be practiced at sources desired for their high quality of flaking characteristics.

Data obtained at the site seems to demonstrate that quarry visitors used both the surface collection and quarrying techniques referred to by Elston (1992:38-39). Cobbles show evidence of testing and the presence of pits indicates extraction of subsurface materials. While no caches have yet been recovered, the retrieval technique cannot be ruled out as an additional procurement technique employed by hunter gather groups present at the site.

Surface collection results in a low cost for search time since it has the potential to be embedded into other activities. There are nevertheless higher costs associated with

testing materials to obtain good quality toolstone because of exposure to environmental factors such as weathering. Quarrying entails the greatest cost in search and handling time as well as venture risks which increases in proportion to time, energy, and opportunity costs associated with the procurement process. There is, however, a high return since large amounts of high quality toolstone can be procured.

Extending Tool Use Life

Strategies associated with extending tool use life include the use of high quality toolstone, large tool size, symmetry of design, concurrent use of bifaces as both tools and cores, and standard techniques for maintenance and recycling (Goodyear 1979; Kelly 1988). The use of heat-treatment on toolstone can also improve workability and sharpness at the expense of loss of durability and increased risk of failure during manufacture (Elston 1992:40). Several researchers (Zeier and Elston 1986; Elston and Budy 1990; Elston 1990; Kelly 1985) have suggested that such measures as the ratio of flake tools to biface tools, of resharpened edges to total used edges, and of bipolar reduced tools to total number of tools can theoretically gauge the extension of tool life.

As discussed previously, the material present at South Everson Creek is of high quality. Both MacWilliams (1991) and Douglas (1991) report evidence of heat-treatment being applied to the materials. MacWilliams (1991:167) identified debitage associated with the use of bipolar reduction occurring in Quarry 12 but states that it may be affiliated with the practicality of breaking open cobbles to examine the quality of the stone, rather than specifically to the tool manufacture processes. From the data set contained within Douglas's (1991) work, the ratio of biface tools to flake tools around 2:1. The data from Mammoth Meadow I implies that one of the primary activities engaged in at this site was

biface manufacture. The procurement of the high quality materials at South Everson

Creek, heat-treatment of the material, and the manufacture of bifaces may suggest that

these people were practicing strategies that would extend the use-life of their tools. It

also seems that they are following the pattern suggested by Elston (1992:40) of engaging

in costlier forms of lithic procurement connected with increased venture risk resulting in

a return of decreased contingency risk.

Reliability, Maintainability, and Multifunctionablity

Reliable systems have discontinuous use, which is scheduled and predictable.

They operate below capacity and are made up of overdesigned, extremely strong

components and include numerous redundant parallel parts that function as a backup in

case any part of the system fails (Torrence 1983:62). Maintainable systems are supposed

to be useful under task conditions that are more or less continuous but somewhat

unpredictable or where size and weight constraints are important. They respond to a

pattern of use which is either continuous or unpredictable and designed so that the tool is

always ready for use (Torrence 1983:62). Schott (1986:19) and Bleed (1986:741) suggest

that multiple functions of tools should characterize tools where portability is an important

consideration.

Torrence (1983:64) proposes that people attempting to create a maintainable

technology will need materials that can be easily repaired or recycled into another tool,

preferably homogeneous, highly siliceous stones. Binford (1979) relates the reliability of

systems to the ecological zone in which a group resides. The Nanumuit possess a reliable

system in regard to their hunting equipment. Items are overdesigned, consist of multiple

backup pieces, and maintenance of the items occurs during scheduled downtime, rather

than being performed on a more or less continuous basis. The harsh conditions present in the Nanumuit environment contribute to the necessity of a reliable system, the margin of error in the system is relatively if any component should fail.

While mobility patterns will be discussed under a separate heading, it can be assumed that groups inhabiting the region around South Everson Creek were relatively mobile. Weight consideration of their gear would have been a concern since human carrying capacity is limited. If visitors to Mammoth Meadow I were producing bifaces for export, it might be suggestive of the desire to create a portable toolkit that could be used for multiple functions. While it does not appear that hunter-gatherers at South Everson Creek had the need for a completely reliable system, they did engage in behavior that suggests a maintainable and multifunctional one through the use of homogenous, highly siliceous stones and the manufacture of bifaces. This too fits the pattern of increased costs to obtain the materials and process them with the associated higher venture risks and the resulting increased return and concurrent decreased contingency risks.

Mobility Patterns

While we cannot assume that patterns of behavior observed in historic times reflect practices present prior to contact, we can attempt to make inferences based on the data present in the archaeological record. As mentioned previously, most hunter-gatherer groups employ a combination of both the forager and collector mobility strategies (Kuhn 1989:33). Based upon spatial and temporal distribution of resources, they exercise both residential mobility, moving as a group to the resource then moving on and logistical mobility setting up base camps and detaching task forces to exploit various resources.

Thwaites (1904(2):372) reports on the travels of the Lemhi Shoshoni to the upper

Columbia drainage to obtain salmon, Big Camas Prairie for roots and to the Three Forks

area in Montana for major bison hunts using the nearby Lehmi pass. The seasonality of

these resources would necessitate the scheduling of activities so that all subsistence needs

could be met. Historic bands in the Helena/Deerlodge National Forest, north of South

Everson Creek, gathered in the river valleys in the winter and in the spring they would

disperse to obtain roots and game, moving into the higher elevations to follow

sequentially maturing plant resources. The highest elevations would have been reached

by late summer and after berrying expeditions in August and September, the families

would gradually return to the river basins and plains for autumn bison hunting (Knight

1989:20-23). Although we cannot be certain about prehistoric groups, the historic

residents of the South Everson Creek area exhibit the pattern suggested by Kuhn

(1989:33) of employing both residential and logistical mobility.

Residentially mobile foragers, using brief, daily episodes of downtime, seem to be

engaged in repairing or making gear continuously throughout the year. Logistically

mobile hunters have periods of reduced subsistence activity that can be used to gear up

for future episodes (Kuhn 1989:35). These factors can then be seen as relating to the

reliability, maintainability, and multifunctionability factors mentioned previously. If one

is engaged in more or less daily maintenance of an item, the item does not necessarily

need to have as high a degree of maintainability or reliability as it would if maintenance

time were limited seasonally. Using high quality stone increases the maintainability of a

technology since broken items can be more easily repaired or recycled. Mobility also

affects a group's access to resources. It is suggested that residentially mobile groups

cover more ground than logistically mobile groups as a whole but the use of special task forces by logistically mobile groups would allow them to exploit resources outside their immediate vicinity.

Since the region around South Everson Creek contains numerous raw material sources and from the faunal remains recovered, it would appear that there was a general availability of subsistence resources nearby. It is hypothesized that if a group were using the site as a base camp, they would not need to be concerned with the conservation of stone. Parry and Kelly (1987:300) suggest groups in transit, which include task groups, would leave assemblages that are more reflective of preparation for curation. Binford (1979) states that highly mobile groups tend to "gear up" with new tools when they encounter a high quality toolstone source and leave their old tools behind. Numerous projectile points and other items manufactured from non-local materials were recovered at Mammoth Meadow I. Douglas (1991:359) suggests that the artifacts from Assemblage 3, associated with Level IC, consisting of a diverse core technology and projectile point styles representative of Plain, Basin, and Intermountain, support the "gearing up" hypothesis.

Organization of Labor and Activities

Organization of labor and activities is related to a group's mobility pattern. Division of labor by age, sex, or ability could augment acquisition efficiency, especially on longer excursions where the opportunity costs associated with quarrying could be reduced by local foraging. While high mobility can make a greater number of raw material resources available, groups may not be able to predict accurately when they will be close to any specific resource. Groups exercising low residential mobility can increase

their foraging radius through the use of special task groups that set up temporary field camps to procure and process goods before returning to the base camp. People are also limited by the amount of material that they can carry (Elston 1992:43). Because of this limitation, resources are generally processed at or near their source to reduce mass and weight prior to transport.

To date there does not appear to be evidence of the establishment of base camps at South Everson Creek. It has been suggested (Douglas 1991:350-351) that base camps may have been located nearby and have not yet been identified. Mammoth Meadow I contains hearth features but the archaeological record seems to indicate that visits were short-term rather than reflecting an extended occupation. This could imply short-term use by a residentially mobile group or by a special task group. As mentioned previously, if the presence of water and adequate subsistence resources in the area existed through time, this could lend support to this hypothesis. The use of special task groups reduces opportunity costs associated with quarrying as other group members could be involved in subsistence activities simultaneously. Both strategies attempt to decrease venture risk and increase returns for time and energy expended.

Scheduling

Torrence (1983) suggests that time can be considered as a form of currency in cost-benefit models. Scheduling may be necessary to avoid competition between behaviors for a given period of time. The length of time when a resource is available in addition to the nature of the resource, are also factors associated with scheduling. The elevation at South Everson Creek is 2092 m (6800 ft). Snow would be a limiting factor for access in the winter months. Currently at the upper elevations it can start to snow by

late September and the snow pack may not be completely gone until summer. Even though chert may be available, accessibility may be limited by other demands on procurement time (Wiant and Hassen 1985:104). As such, opportunity costs would be dependent upon scheduling. High opportunity costs could result from poor scheduling decisions.

If prehistoric groups in the South Everson Creek area participated in the same types of seasonal rounds associated with historic groups, procurement of lithic resources would need to be scheduled around these subsistence activities. Douglas (1991:359) suggests that groups may have visited the quarry site on their way to the fall bison hunts. This would have provided them with the opportunity to gear up for the hunt, acquire surplus supplies for even exchange or trade, and stock up for the winter when access to this particular raw material source would have been limited. Further analysis and investigation of the faunal remains recovered at the Mammoth Meadow I site could provide insights into the seasonality of the site's use. However, it does seem reasonable to accept that groups obtaining raw materials from South Everson Creek were probably there in the spring, summer or fall rather than the winter when there would be maximum returns for energy and time invested as well as decreased risk.

Demand and Output

Elston (1992:46) identifies mobility and relaxed tool design parameters or the use of lower quality materials as methods to decrease cost associated with supply. If a group is very mobile, they have potentially more sources of raw material available to them on a regular basis and subsequently, produce fewer materials per quarry visit to satisfy demand. Relaxing tool design parameters to make the good more durable serves to

decrease demand over time. If one makes the good less durable, the amount of production decreases and demand increases over time for replacements. Less mobile groups who do not choose to adopt either of the aforementioned practices may focus their efforts on several specific sources that are available within their range. Using lower quality materials could actually increase demand since more toolstone would be needed to produce the same quantity of goods.

Groups, as a strategy to control demand costs, could use the high quality material present at South Everson Creek. It has been previously hypothesized that these groups employed both residential and logistical mobility based on seasonal variation. While engaged in a strategy of increased mobility, people had access to the numerous sources in the area and may have engaged in quarrying strategies that produced fewer materials per visit. According to Leudtke (1984:65), engaging in less "wasteful" production techniques will decrease demand. If bifaces were being produced at Mammoth Meadow I this may indicate a production technique that conserves material which results in increased benefits and lower contingency risk associated with demand exceeding supply.

Lithic Reduction Strategies

According to Hayden et al. (1996:22), the biface design strategy would be the most efficient in the context of high mobility, as tools used in traveling to seasonal camps and where there are high constraints on the amounts of stone material that can be transported by such tribes. As mentioned previously a biface strategy would decrease costs and increase benefits while decreasing risks under the variables: extension of tool use life, reliability, maintainability, multifunctionablity, mobility patterns, demand and output. Kuhn (1994:427) however, suggests that small tools may be more efficient than

cores and blanks for a mobile toolkit. Using data compiled by Douglas (1991) from

Mammoth Meadow I, I have investigated if it can be determined which, if either, of these

strategies was used at South Everson Creek.

Following Elston (1992:640) bifaces were classified into the following categories,

Douglas' (1991) categories are in parenthesis:

Stage 1 Blank Procurement/Production
Stage 2 Blank/Edge Preparation (roughout)
Stage 3 Primary Thinning (percussion)
Stage 4 Secondary Thinning (percussion/pressure)
Stage 5 Fininishing (pressure)

Stage 1 bifaces potentially include any flake blanks that may be further reduced to

produce a biface. Elston et al. (1992:641) states that it is difficult to correctly categorize

flake blanks into Stage 1 at a quarry as they cannot always be distinguished from quarry

debris. Since Douglas' (1991) first biface designation was "roughout", I corresponded

this to Stage 2 rather than Stage 1. While the exclusion of the Stage 1 designation may

introduce some bias into the data, the results of the data still fit within the expected

trajectory for biface reduction (Fig. 9). As mentioned previously, only the Assemblages

that correspond to a specific time period were examined in this data set so that change

over time could be discussed. Assemblages 1 and 2 represent the Late Prehistoric,

Assemblages 5 and 6 contain Archaic deposits, and Assemblage 8 corresponds to the

PaleoIndian time frame.

The chi-square test determines, within a degree of error, whether or not there is a

statistical dependence between two characteristics of a sample population (Weiss and

Hassett 1987:473). Two hypotheses are devised for each research question, the first

states that a statistical dependence exists and a null hypothesis, which states that the

distributions are random with regard to these variables. The chi-square independence test is a method used to determine whether or not to reject the null hypothesis. Using the designations stated previously, the following chart depicts the results of chi-square analysis for bifaces recovered from Mammoth Meadow I. Degrees of freedom (df) were determined using the formula $(c-1)(r-1)$, c representing column and r representing row. The tests were conducted at the .05 significance level (α), which furnishes a cutoff point in deciding when the null hypothesis should be rejected.

Test 1

This test was designed to address the stages of biface manufacture present at Mammoth Meadow. The research hypothesis states that biface manufacture was the primary activity engaged in by visitors to Mammoth Meadow I. If bifaces are being reduced for export there should be a significant relationship between the stages of reduction; otherwise the distribution would be random. The result of the chi-square test score is greater than the critical value for α at the .05 significance level with 12 degrees of freedom, so the null hypothesis is rejected and the research hypothesis of a significant relationship existing between the stages of reduction is accepted. Some of the values are rather low so not all of the relationships are equally strong. Changing the significance level could produce different results. The .05 significance level was used since it would be adequate to examine the variables, although using a lower significance level would introduce less error.

It is hypothesized that the majority of the bifaces should fall into the Stage 3 and Stage 4 category with smaller numbers of bifaces corresponding to Stage 2 and Stage 5 classifications. It is further hypothesized that that the Mammoth Meadow I site was

72

used to manufacture bifaces rather than expedient tools following the pattern of behavior

suggested by Kelly (1988) rather than that of Kuhn (1994). If the toolstone from South

Everson Creek was being processed into bifaces for export, fewer Stage 5 items should be

present since these represent goods close to finishing or are themselves finished products.

Table 1

	Stage 2	Stage 3	Stage 4	Stage 5	Totals	
LATE PREHISTORIC						
Assemblage 1						
Observed	4(14%)	2(7%)	12(41%)	11(38%)	29	
Expected	3.140	9.873	9.253	6.734	29	
(O-E)2/E	.236	6.278	.816	2.703	10.038	
Assemblage 2						
Observed	13(17%)	27(36%)	17(22%)	19(25%)	76	
Expected	8.228	25.874	24.251	17.647	76	
(O-E)2/E	2.768	.049	2.168	.104	5.089	
ARCHIAC						
Assemblage 5						
Observed	22(13%)	65(40%)	42(26%)	35(21%)	164	
Expected	17.755	55.835	52.330	38.080	164	
(O-E)2/E	1.015	1.504	2.039	.249	4.807	
Assemblage 6						
Observed	9(5%)	70(38%)	68(36%)	40(21%)	187	
Expected	20.245	63.665	59.670	43.420	187	
(O-E)2/E	6.246	.630	1.163	.269	8.308	
PALEOINDIAN						
Assemblage 8						
Observed	28(11%)	75(30%)	85(35%)	58(24%)	246	
Expected	26.632	83.752	78.496	57.120	246	
(O-E)2/E	.070	.915	.539	.014	1.538	
Totals	76	239	224	163	702	
df=12		a=.05		X2=29.775		Critical Value=21.0261

X2>critical value = reject null hypothesis

Only 20%(252 of 1257) of the bifaces recovered by Douglas (1991) were complete

indicating that broken items were probably being left behind, and completed items were

carried off-site. Douglas (ibid.) attributes the rate of breakage to the manufacturing
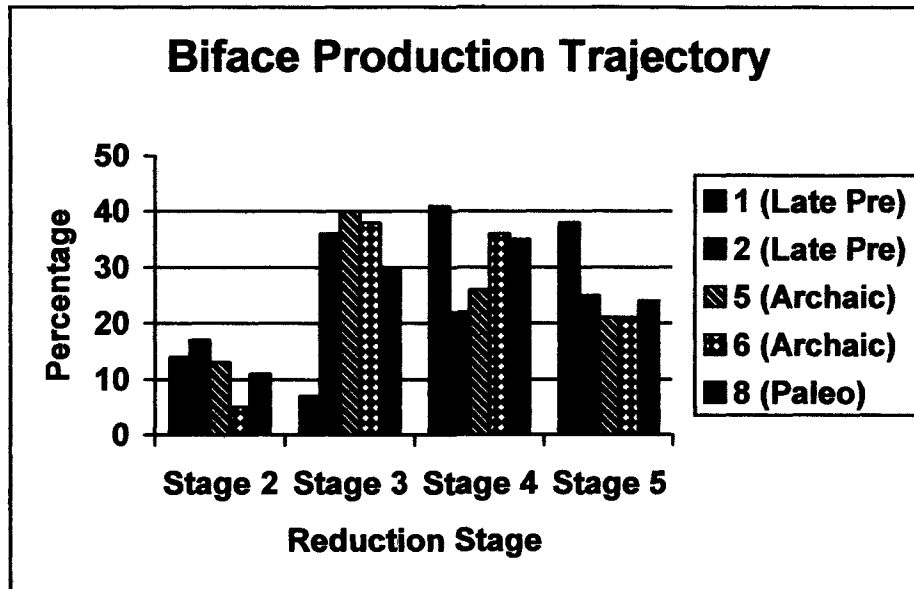
process itself.

Biface Production Trajectory

Figure 9 illustrates the biface production trajectory by assemblage. If quarry

visitors to Mammoth Meadow I were manufacturing bifaces for export, the Biface

Production Trajectory is expected to resemble a bell curve. The majority of the bifaces

should fall into the Stage 3 and Stage 4 categories and Stage 2 and Stage 5 bifaces would

be represented in smaller quantities. The assemblages depicted in Figure 9 appear to

follow the expected pattern of discarded items. There are fewer Stage 2 and Stage 5

bifaces than Stage 3 and Stage 4, except for Assemblage 1, a Late Prehistoric component.

This assemblage contains more Stage 4 and Stage 5 bifaces. This may indicate that

quarry visitors were engaging in different behavior patterns during the Late Prehistoric.

There may have been a change in technology or mobility which would have decreased the

carried off-site. Douglas (ibid.) attributes the rate of breakage to the manufacturing

process itself.

Figure 9

Figure 9 illustrates the biface production trajectory by assemblage. If quarry

visitors to Mammoth Meadow I were manufacturing bifaces for export, the Biface

Production Trajectory is expected to resemble a bell curve. The majority of the bifaces

should fall into the Stage 3 and Stage 4 categories and Stage 2 and Stage 5 bifaces would

be represented in smaller quantities. The assemblages depicted in Figure 9 appear to

follow the expected pattern of discarded items. There are fewer Stage 2 and Stage 5

bifaces than Stage 3 and Stage 4, except for Assemblage 1, a Late Prehistoric component.

This assemblage contains more Stage 4 and Stage 5 bifaces. This may indicate that

quarry visitors were engaging in different behavior patterns during the Late Prehistoric.

There may have been a change in technology or mobility which would have decreased the

costs associated with a quarry trip or a change in manufacturing techniques which resulted in an increased rate of breakage.

Overall, the pattern depicted by Figure 9 seems to support the hypothesis that bifaces were being reduced on site for export. The fall off rate from Stage 4 to Stage 5 is not very abrupt which may indicate that there was a high incidence of breakage associated with the manufacturing process, as suggested by Douglas (1991). Since people were at the source it might be more efficient and cost effective to discard broken items and start over rather than recycling broken items into something else.

Test 2

The next categories of tools examined were Flake Tools and Formal Tools. Flake tools are composed of items exhibiting little to no additional reduction work. Flake tools are generally used in an expedient fashion and discarded when worn out. The flake tool can be used "as is" when struck off the core or some finishing might be done, for example, smoothing an edge for ease in handling. Formal tools exhibit extensive modification through shaping and thinning to produce the desired pattern in the tool. It has been suggested that these items would be more highly curated than expedient tools. Francis (1983) hypothesizes that tools made from direct deliberately procured materials will tend to consist of formal tools that will be curated after they are exported from the quarry.

A chi-square test was also conducted on the flake tools recovered from Mammoth Meadow to see if there was a significant relationship present between flake and formal tools, or if the distribution was random. This test was designed to investigate Kuhn's hypothesis regarding the efficiency of many small tools versus bifaces. Once again

	Formal Tools	Flake Tools	Totals
LATE PREHISTORIC			
Assemblage 1			
Observed	32(71%)	13(29%)	45
Expected	31.175	13.825	45
$(O-E)^2/E$	0.022	0.049	0.071
Assemblage 2			
Observed	88(70%)	38(30%)	126
Expected	87.291	38.709	126
$(O-E)^2/E$	0.006	0.013	0.019
ARCHAIC			
Assemblage 5			
Observed	187(77%)	56(23%)	243
Expected	168.347	74.653	243
$(O-E)^2/E$	2.067	4.661	6.728
Assemblage 6			
Observed	202(68%)	95(32%)	297
Expected	205.758	91.242	297
$(O-E)^2/E$	0.069	0.155	0.224
PALEOINDIAN			
Assemblage 8			
Observed	269(65%)	143(35%)	412
Expected	285.428	126.572	412
$(O-E)^2/E$	0.946	2.132	3.078
Totals	778	345	1123

df = 4 $a = .05$ $X^2 = 10.12$ Critical Value = 9.488

X^2 › critical value = reject null hypothesis

Table 2

degrees of freedom were determined using $(c-1)(r-1)$ and the test was conducted at the .05

significance level (α). Douglas (1991) designated tools into scrapers and flake tools,

items placed into these categories correspond to formal tools and flake tools as defined

previously. I also included the bifaces discussed previously in the formal tool category.

It has been hypothesized that Mammoth Meadow I was primarily used to produce bifaces

and that flake tools should not represent the bulk of the assemblages

As the chi-square for this test is greater than the critical value for α at the .05 significance level with 4 degrees of freedom, the null hypothesis is rejected and the research hypothesis is accepted which states that there is a significant relationship between formal tools and flake tools. Some of the values are rather low with the strongest relationships occurring in Assemblage 5 (Archaic) and Assemblage 8 (PaleoIndian). Changing the significance level could produce different results. The .05 significance level was used since it would be adequate to examine the variables, although using a lower significance level would introduce less error. This pattern may reflect the low cost of using toolstone on hand to satisfy immediate needs. The low incidence of formal tools with the presence of finishing debitage (illustrated in the following section) seems to indicate that finished items were being exported from Mammoth Meadow I for use elsewhere.

Figure 10 illustrates the distribution of flake to formal tools recovered at Mammoth Meadow. Discarded formal tools compose 69.28% of the assemblages examined in this table. The remaining 30.72% is composed of flake tools. The majority of these flake tools exhibit evidence of use-wear. They were apparently used for a certain task at hand, discarded and were not curated. Francis (1983) hypothesized that materials procured in a deliberately direct fashion would be highly curated and materials obtained in an indirect fashion would be used expediently. Toolstone was being used on site in an expedient fashion but it occurs at a much lower frequency than formal tools. The high
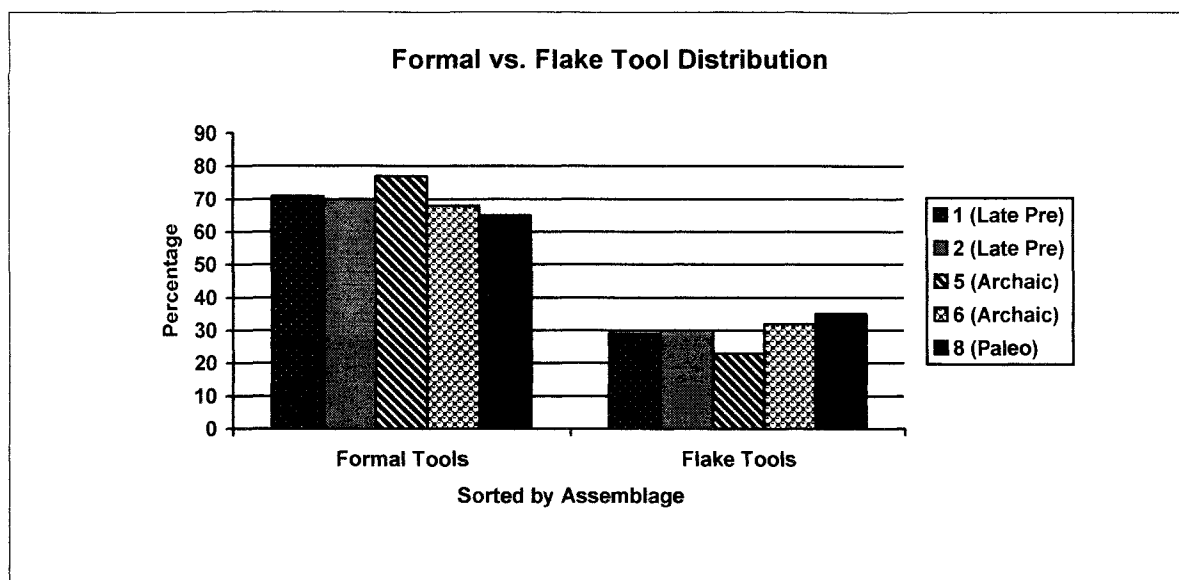
Formal vs. Flake Tool Distribution

Figure 10

percentage of formal tools present at Mammoth Meadow I, particularly since the majority

of these consist of broken tools, tend to support Francis' hypothesis. It would appear that

finished items were being exported from the site while broken items were being discarded

on site. With so much potential toolstone on hand, it would be cost-effective to use the

material for expedient tools as needed while engaging in quarrying activities. As depicted

in Figure 10, this pattern does not appear to have changed over time. All the assemblages

contain at least a 2:1 ratio of formal to flake tools. If, as Kuhn (1994) suggests, it would

be more efficient to carry many small tools in a toolkit, it would seem that the ratio of

flake tools to formal tools should be opposite of what was found at Mammoth Meadow I.

Formal tools would be less represented since production activities would target

manufacturing small flake tools rather than blanks or cores for export.

Test 3

A third chi-square test was conducted to examine the hypotheses outlined by

Francis (1983). Once again degrees of freedom were determined using $(c-1)(r-1)$ and the

test was conducted at the .05 significance level (α). Francis states that quarry sites should be exploited in a highly deliberate manner. Test implications pertaining to the artifactual assemblages on these sites and include:

1. High relative frequencies of decortication debris.
2. Moderate relative frequencies of core trimming and preparation debris.
3. High relative frequencies of bifacial reduction and tool manufacture debris.
4. High frequncies of prepared cores.
5. High frequencies of broken and discarded blanks and preforms.

It is hypothesized that there should be a significant relationship present between primary, secondary, tertiary, and thinning flakes which reflects the use of the quarry to produce items that would be highly curated. Following the definitions used by Douglas (1991) to categorize debitage, primary flakes are flakes exhibiting 90% or more cortex; secondary flakes exhibit roughly 50% cortex; tertiary flakes do not exhibit any cortex; and thinning flakes are identified by their size and shape, lipping of the platform, and diffuse bulb of percussion. Since quarrying involves the greatest effort in time and energy, it is expected that items obtained by this procurement method would consist of greater percentages of formal tools to percentages of expedient tools reflected in a high percentage of finishing debitage.

As the chi-square for this test is greater than the critical value for α at the .05 significance level with 12 degrees of freedom, the null hypothesis is rejected and the research hypothesis is accepted which states that there is a significant relationship between the number of primary, tertiary, secondary, and thinning flakes. Some of the values are rather low so not all of the relationships are equally strong. Changing the significance level could produce different results. The .05 significance level was used since it would be adequate to examine the variables, although using a lower significance

	Primary	Secondary	Tertiary	Thinning	Total
LATE PREHISTORIC					
Assemblage 1					
Observed	6(.9%)	0	38(55%)	25(36%)	69
Expected	3.063	13.692	27.384	24.861	69
(O-E)²/E	2.816	13.692	4.116	0.001	20.625
Assemblage 2					
Observed	5(5%)	20(22%)	51(55%)	17(18%)	93
Expected	4.128	18.454	36.909	33.509	93
(O-E)²/E	0.184	0.130	5.380	8.134	13.828
ARCHAIC					
Assemblage 5					
Observed	3(3%)	22(24%)	29(31%)	39(42%)	93
Expected	4.128	18.454	36.909	33.509	93
(O-E)²/E	0.308	0.681	1.695	0.9	3.584
Assemblage 6					
Observed	0	11(13%)	27(32%)	47(55%)	85
Expected	3.773	16.867	33.734	30.626	85
(O-E)²/E	3.773	2.041	1.344	8.754	15.912
PALEOINDIAN					
Assemblage 8					
Observed	3(7%)	23(54%)	7(16%)	10(23%)	43
Expected	1.909	8.533	17.065	15.493	43
(O-E)²/E	0.624	24.528	5.936	1.948	33.036
Totals	17	76	152	138	383

df=12 a =.05 X^2=86.985   Critical Value = 21.0261

X^2 › critical value = reject null hypothesis

Table 3

level would introduce less error.

Douglas' (1991) data set was not set up to examine prepared vs. unprepared cores. The categories that she examined were focused upon change in manufacturing techniques over time. The data were broken down into a fashion that make it difficult, if not impossible, to only use the category designations of prepared vs. unprepared, since the

evidence of the manufacturing technique, not the cores themselves, were tabulated. One core could have multiple evidence of shaping or multiple cores could have had one incident of shaping; only the evidence of shaping was counted, not which core had shaping evidenced on it. The manufacturing techniques investigated tend to suggest that there was more rather than less preparation of cores occurring but I could not extract raw numbers other than total number of cores recovered in each assemblage. There is a high percentage (80%) of broken and discarded blanks and preforms however, which does fit into Francis' model.

Figure 11 depicts the frequency of primary, secondary, tertiary, and thinning debitage recovered at Mammoth Meadow I. It appears to support Francis' hypothesis regarding materials procured by quarrying. There are relatively low frequencies of primary and secondary debitage, which is associated with initial core reduction, and high frequencies of tertiary and thinning debitage associated with tool production. Assemblage 8, representing the PaleoIndian component exhibits a pattern which differs from the expected trajectory. The majority of the assemblage is composed of secondary flakes. This seems to indicate that quarry behavior was different during PaleoIndian times and that the focus was on initial reduction of materials rather than later stages of reduction. If the South Everson Creek Quarries were being used in an expedient fashion, it is expected that the percentages of primary and secondary debitage would be greater. This may have been the case in PaleoIndian times. However, since it is thought that Mammoth Meadow I is a workshop area, so perhaps quarry visitors were conducting some initial reduction were they were extracting the raw materials and performing the finishing work at Mammoth Meadow I. The overall pattern suggests that the materials

procured at South Everson Creek were being manufactured into items that could be
exported as evidenced by the presence of high percentages of finishing debitage.
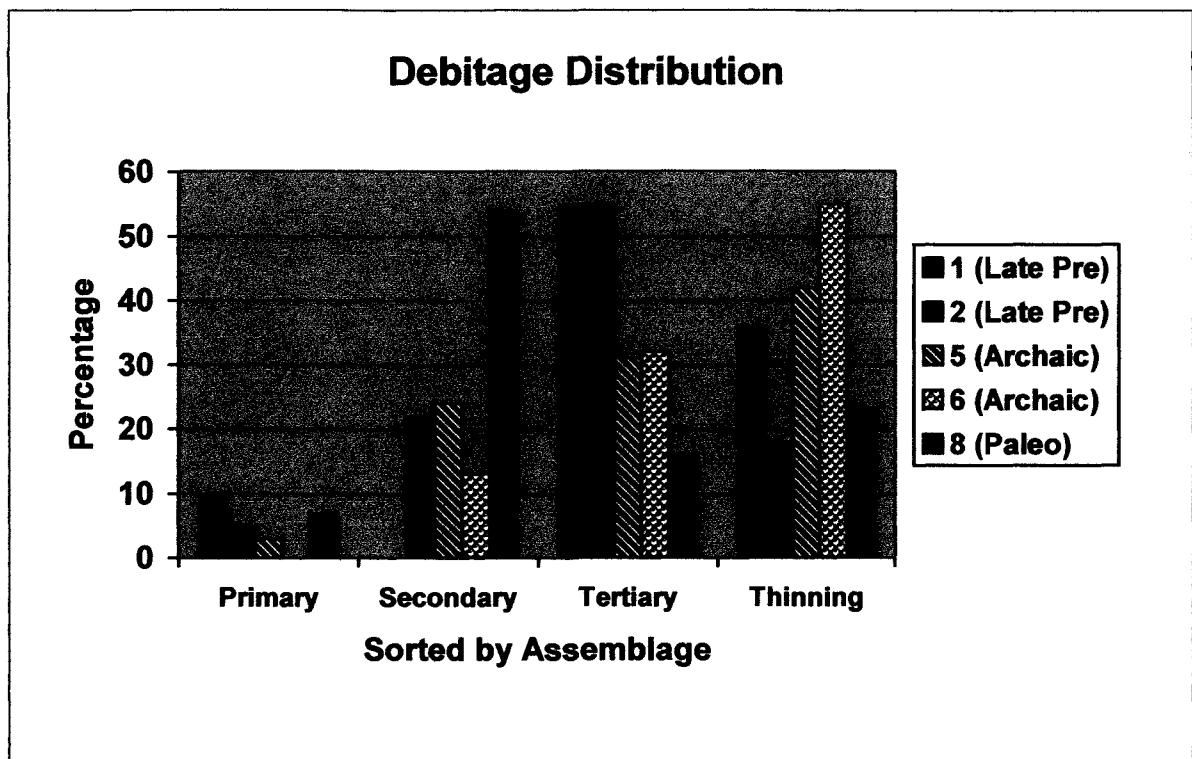
Debitage Distribution

Figure 11

These data seem to support Francis' (1983) assertion that quarry sites would be
exploited in a highly deliberate fashion. She also suggests that items manufactured from
these types of sources would be highly curated. While it appears that visitors to the South
Everson Creek area were engaged in processing material into bifaces for export, they also
used the toolstone to produce many expedient tools as well.

Chapter 5 – Summary and Conclusion

The South Everson Creek Quarries and Mammoth Meadow I provide a unique opportunity for researchers to investigate lithic procurement strategies over a long time range. The chalcedony present at South Everson Creek is a high quality material with good flaking characteristics. The numerous quarries in the area and the time depth present seem to indicate that South Everson Creek toolstone was probably a highly desirable material to obtain. MacWilliams (1991) concluded that some quarry pits might have only been exploited for short periods of time, perhaps during a single visit, while other pits indicate that they were used consecutively. Elston and Raven's (1991-1992) model provides an opportunity to examine the costs associated with lithic procurement and behaviors that people could engage in to reduce these costs and risks while increasing benefits.

Using a high quality lithic raw material is cost effective since less material would be needed to satisfy demand, less energy would need to be invested to reduce it into usable goods, and it allows for the creation and maintenance of a more flexible and portable tool kit. Additionally, using high quality toolstone can also extend tool use life. While extracting materials from bedrock requires a substantial investment of time and energy in the extraction process, the resulting long-term payoffs seem to defray the initial costs. The presence of adequate materials to satisfy subsistence needs, in the South Everson Creek region contribute to its desirability as a resource area since venture risk would be reduced. If a group visited the quarry when engaged in residential mobility, opportunity costs would be low as labor could be divided so that both toolstone and subsistence needs could be satisfied at the same time.

The rich lithic landscape in which South Everson Creek is located in also serves

to defray costs and risks. Contingency risk, associated with exceeding supply of

available toolstone, can be considered low. Groups moving through this area would

potentially have lithic raw material available to them at almost any time. If a certain

source were not accessible due to weather or other constraints, another source could be

exploited. Modifying mobility patterns to include or exclude sources or the use of

scheduling to be in source areas when demand for toolstone is high could have been used

by people in the South Everson Creek area. Projectile points recovered at Mammoth

Meadow I include types common to the Plain, Great Basin, and Intermountain which

seems to indicate that groups from several regions knew about and exploited this

resource.

Material at South Everson Creek is found in both cobble and bedrock forms. The

use of digging implements and quarry pits can be interpreted as techniques that would

have increased the effective availability of toolstone. This behavior also fits into the cost

benefit model proposed by Elston (1992) as increased benefits from better quality

subsurface materials rather than using cobbles which were exposed on the surface and

subjected to weathering which can cause fracturing of the material. Subsurface

extraction of materials corresponds to Francis' (1983) hypothesis regarding acquisition of

toolstone through the practice of deliberate direct procurement. The higher cost in time,

energy, and venture risks associated with quarrying activities does however produce a

high return in terms of the large amounts of high quality toolstone that can be procured.

It is suggested that people in the South Everson Creek region practiced both

residential and logistical mobility patterns based on seasonal exploitation of resources.

The proximity of the site to two major passes, Lemhi and Bannock, would have probably contributed to its desirability as a source of lithic materials. As suggested by Douglas (1991), the location of South Everson Creek would have enabled groups to "gear up" prior to heading east for bison hunting. The assemblage at Mammoth Meadow I supports Parry and Kelly's (1987) supposition that groups in transit, including task groups, would leave assemblages that are more reflective of preparation for curation, such as evidence of biface manufacture and prepared cores.

As shown in the previous chapter, there is a significant relationship between the stages of biface reduction which lend support to the hypothesis that biface production was an important activity at Mammoth Meadow I. The presence of large amounts of finishing debitage and lack of unbroken finished bifaces indicate that quarry visitors engaged in reduction activity on site to create finished products for export. This pattern appears to be present over most of the time span represented at Mammoth Meadow I. Assemblage 1, representing the Late Prehistoric, has a biface trajectory that differs from the other assemblages. There are more late stage reduction bifaces represented than were found in other assemblages. This may indicate that visitors to Mammoth Meadow I during this time period were engaging in a different strategy of lithic procurement.

This trend corresponds to Kelly's (1988) use of bifaces as portable cores for a technology that has limiting factors such as mobility and portability. It has been suggested that the use of bifaces as portable cores is a method of reducing cost and risks. Bifaces can extend tool use life since they can serve as cores, tools, and be recycled into other items. Reliability, maintainability, and multifunctionability can all be satisfied through the use of bifaces. Associated transport costs and limitations can be reduced in a

toolkit that contains bifaces. Bifaces also serve to conserve material and lower
contingency risk associated with demand exceeding supply.

Flake and formal tools also compose a large part of the assemblage at Mammoth
Meadow I. Francis' (1983) hypothesis that materials procured in a direct deliberate
manner would tend to be manufactured into formal tools for curation. The flake tools
exhibit extensive evidence of use-wear indicating that quarry visitors used the materials
at hand to make expedient tools as well. This could be interpreted as cost effective
behavior. Kuhn (1994) suggests that it is more efficient to carry a toolkit comprised of
many small flake tools than bifaces. While not conclusive, the data at Mammoth
Meadow I seem to indicate that visitors were not opposed to using either, they were
manufacturing both numerous bifaces and flake tools. Discarded tools tended to consist
of "exotic" materials which also support Douglas' (1991) contention that Mammoth
Meadow I was a place for people to "gear up".

The debitage present at Mammoth Meadow I supports Francis' hypothesis
regarding the exploitation of quarry sites. There is a relatively low frequency of
decortication debris. There is also expected to be a moderate relative frequency of core
trimming and preparation debris, high relative frequencies of bifacial reduction and tool
manufacturing debris, high frequencies of prepared cores, and high frequencies of broken
and discarded blanks and preforms. While core data could not be extracted from
Douglas's data set, the high percentage of bifacial reduction and tool manufacturing
debris and the high frequencies of discarded blanks and performs was found to be present
at Mammoth Meadow I. Since quarrying subsurface toolstone involves the greatest effort
in time and energy it is expected that items obtained by this procurement method would

consist of greater percentages of formal tools than expedient tools reflected by a high percentage of finishing debitage. Overall, this does appear to be the situation at Mammoth Meadow I.

South Everson Creek and Mammoth Meadow I seem to correspond to the cost-benefit model suggested by Elston (1992). The people that exploited this resource responded or were motivated and/or influenced by costs, benefits, and risk through the manipulation of production technology. Production costs can be managed by changing behaviors such as mobility patterns, procurement techniques, organization of labor and activities, extending tool use-life, creating technological systems that are multifunctional, maintainable and/or reliable, through the use of scheduling, and monitoring demand and output.

Suggestions for Future Research

Quarries can provide information on a range of topics including technological, social, and political organization. South Everson Creek and Mammoth Meadow I were used from PaleoIndian to the Late Prehistoric era. The potential exists to investigate change over time in many different subjects at these sites. South Everson Creek and Mammoth Meadow I also contain information that is applicable to investigations of interactions between regions. People inhabiting the Plain, the Basin, and Intermountain visited the sites. This leads to questions regarding topics such as how land-use between and among groups inhabiting different regions, how technology is organized in different environmental zones, and interactions between groups from various regions.

References Cited

Ahler, S. A. and J. Vannest
1985 Temporal Changes in KRF Reduction Strategies. In Lithic Resource
Procurement: Proceedings from the Second Conference on Prehistoric Chert
Exploitation, edited by S. C. Vehik, pp. 192-198. Southern Illinois University,
Center for Archaeological Investigations, Occasional Papers No. 4.

Alden, W. C.
1953 Physiography and Glacial Geology of Western Montana and Adjacent
Areas. United States Geological Survey Professional Paper 231, Washington, DC

Amick, D. S.
1994 Technological Organization and the Structure of Inference in Lithic
Analysis: an Examination of Folsom Hunting Behavior in the American
Southwest. In The Organization of North American Chipped Stone Tool
Technologies, edited by P. J. Carr, pp. 9-34. International Monographs in
Prehistory, Ann Arbor, MI.

Ammerman, A. J. and W. J. Andrefsky
1982 Reduction Sequences and the Exchange of Obsidian in Neolithic Calabria.
In Contexts of Prehistoric Exchange, edited by J. Ericson and T. K. Earle, pp.
149-172. Academic Press, New York.

Bamforth, D. B.
1986 Technological efficiency and Tool Curation. American Antiquity 51:38-50.

1988 Ecology and Human Organization on the Great Plains. Plenum Press, New
York.

1991 Technological Organization and Hunter Gatherer Land Use. American
Antiquity 56:216-235.

Binford, L. R.
1973 Interassembledge Variability – the Mousterian and the "Functional"
Argument. In Explanations of Culture Change, edited by C. Renfrew, pp. 227-
254. Duckworth, London.

1977 Forty-seven Trips: A Case Study in the Character of Some Formation
Processes of the Archaeological Record. In Contributions to Anthropology: The
Interior Peoples of Northern Alaska, edited by E. S. Hall, pp. 299-351.
Archaeological Survey of Canada Paper no. 49. National Museum of Canada,
Ottawa.

1978 Dimensional Analysis of Behavior and Site Structure: Learning From an Eskimo Hunting Stand. American Antiquity 43:330-361.

1979 Organization and Formation Process: Looking at Curated Technologies. Journal of Anthropological Research 23(3):225-273.

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

Blanton, D.
1985 Lithic Raw Material Procurement and Use During the Morrow Mountain Phase in Southern Carolina. In Lithic Resource Procurement: Proceedings from the Second Conference on Prehistoric Chert Exploitation, edited by S. Vehik, pp. 115-132. Southern Illinois University at Carbondale, Center for Archaeological Investigations Occasional Papers No. 4.

Bleed, P.
1986 The Optimal Design of Hunting Weapons: Maintainability or Reliability. American Antiquity 51:737-747.

Bonnichsen R., M. D. Turner, J. Taylor, B. Bump, R. Reinhardt, J. C. Turner
1986 Pleistocene Peoples of Southwestern Montana: Reconnaissance and Testing Project, 1985, South Everson Creek and Black Canyon. Report submitted to the Bureau of Land Management for work undertaken on a cooperative agreement No. MT950-CA6-012 with the University of Maine.

Bonnichsen, R., M. Beatty, E. Grimm, M. D. Turner, J. C. Turner, D. Douglas, A. MacWilliams, R. Reinhart, T. Turnmire
1989 Archaeological and Geological Investigations in the Vicinity of the South Fork of Everson Creek and Black Canyon Creek, Southwestern Montana: 1987-1988 Interim Progress Report. Unpublished.

Bonnichsen, R., M. Beaty, M. D. Turner, J. C. Turner, D. Douglas
1992 Paleoindian Lithic Procurement at the South Fork of Everson Creek, Southwestern Montana: A Preliminary Statement. In Ice Age Hunters of the Rockies, edited by D. J. Stanford and J. S. Day, pp. 285-321. Denver Museum of Natural History and University Press of Colorado, Niwot, Colorado.

Bryan, K.
1950 Flint Quarries – the Sources of Tools and at the Same Time, the Factories of the American Indian. Harvard University, Peabody Museum Papers XVII (3) Cambridge, MA.

Carr, P. J.
    1994 Technological Organization and Prehistoric Hunter-Gatherer Mobility:
Examination of the Hayes Site. In The Organization of North American Chipped
Stone Tools Technologies, edited by P. J. Carr, pp. 35-44. International
Monographs in Prehistory, Ann Arbor, Michigan.

Clarke, R.
    1935 The Flintknapping Industry at Brandon. Antiquity 9:38-56.

Crabtree, D. E.
    1967 Notes on Experiments in Flintknapping: 3, The Flintknapper's Raw
Materials. Tebiwa 10:8-24.

Douglas, D. L.
    1991 Cultural Variability and Lithic Technology: A Detailed Study of Stone
Tools From the Mammoth Meadow Locus, Southwestern Montana. Unpublished
MA thesis, University of Maine.

Ebert, J. I.
    1979 An Ethnoarchaeological Approach to Reassessing the Meaning of
Variability in Stone Tool Assemblages. In Ethno-Archaeology: Implications of
Ethnography for Archaeology, edited by C. Kramer, pp. 59-74. Columbia
University Press, New York.

Ellis, C. J.
    1989 The Explanation of Northeastern Paleoindian Lithic Procurement Patterns
in Eastern Paleoindian Lithic Resource Use, edited by C. J. Ellis and J. C.
Lothrup, pp. 139-164. Westview Press, Boulder, Colorado.

Elston, R. G., and C. Raven (editors)
    1990 Archaeological Investigations at Tosawihi, a Great Basin Quarry, Part 1:
The Periphery. 2 vols. Intermountain Research, Silver City, Nevada. Submitted
to Ivanhoe Gold Company, Winnemucca, Nevada.

    1992 Archaeological Investigations at Tosawihi, a Great Basin Quarry, Part 3: A
Perspective from Locality 36. Intermountain Research, Silver City, Nevada.
Submitted to Ivanhoe Gold Company, Winnemucca, Nevada.

Ericson, J. E.
    1982 Contexts of Prehistoric Exchange. Academic Press, New York.

    1984 Toward the Analysis of Lithic Production Systems. In Prehistoric Quarries
and Lithic Procurement, edited by J. E. Ericson and B. A. Purdy, pp. 1-9.
Cambridge University Press, Cambridge.

Findlow, F. J. and M. Bolognese
    1984 Economic Aspects of Prehistoric Quarry Use: A Case Study in the
    American Southwest. In Prehistoric Quarries and Lithic Procurement, edited by J.
    E. Ericson and B. A. Purdy, pp. 77-82. Cambridge University Press, Cambridge.

Francis, J. E.
    1983 Procurement and Utilization of Chipped Stone Raw Materials: A Case
    Study from the Bighorn Mountains and Basin of North Central Wyoming.
    Unpublished Ph.D. dissertation, Arizona State University.

Frison, G. C.
    1978 Prehistoric Hunters of the High Plains. Academic Press, New York.

Frison, G. C. and D. J. Stanford
    1982 Agate Basin Components. In The Agate Basin Site: A Record of the
    PaleoIndian Occupation of the Northwestern High Plains, edited by G. C. Frison
    and D. J. Stanford, pp. 76-133. Academic Press, New York.

Gallagher, J. P.
    1977 Contemporary Stone Tools in Ethiopia: Implications for Archaeology.
    Journal of Field Archaeology 4:407-414.

Goodyear, A. C.
    1979 A Hypothesis for the use of Cryptochrystalline Raw Materials Among
    Paleo-Indian Groups of North America. The Institute, Columbia, SC.

Gould, R. A.
    1980 Living Archaeology. Cambridge University Press, Cambridge.

Gould, R. A., D. A. Koster, and A. H. L. Sontz
    1971 The Lithic Assemblage of the Western Desert Aborigines of Australia.
    American Antiquity 36(3):149-169.

Gould, R. A. and S. Saggers
    1985 Lithic Procurement in Central Australia: A Closer Look at Binford's
    Embeddedness in Archaeology. American Antiquity 50:117-136.

Gramley, R. M.
    1980 Raw Material Source Areas and "Curated" Tool Assemblages. American
    Antiquity 45:823-833.

    1984 Mount Jasper: A Direct Access Lithic Source Area in the White Mountains
    of New Hampshire. In Prehistoric Quarries and Lithic Procurement, edited by J.
    E. Ericson and B. A. Purdy, pp. 11-21. Cambridge University Press, Cambridge.

Greiser, S. T., T. W. Greiser, and S. M. Vetter
    1985 Middle Prehistoric Adaptations and Paleoenvironments in the Northwestern
        Plains. American Antiquity 50:849-877.

Hayden, B.
    1989 From Chopper to Celt: the Evolution of Resharpening. In Time, Energy,
    and Stone Tools, edited by R. Torrence, pp. 7-16. Cambridge University Press,
    Cambridge.

Hayden, B, N. Franco and J. Spafford
    1996 Evaluating Lithic Strategies and Design Criteria. In Stone Tools:
    Theoretical Insights in Human Prehistory, edited by G. Odell. Plenum Press, New
    York.

Holmes, W. H.
    1890 A Quarry Workshop of Flaked Stone Implement Makers in the District of
    Columbia. American Anthropologist 3:1-26.

Jeske, R.
    1989 Economies in Raw Material Use by Prehistoric Hunter Gatherers. In Time,
    Energy and Stone Tools, edited by R. Torrence, pp. 34-45. Cambridge University
    Press, Cambridge.

Jochim, M.
    1983 Optimization Models in Context. In Archaeological Hammers and
    Theories, edited by J. A. Moore and A. S. Keene, pp. 157-172. Academic Press,
    New York.

    1989 Optimization and Stone Tool Studies: Problems and Potential. In Time,
    Energy, and Stone Tools, edited by R. Torrence, pp. 106-111, Cambridge.

Keene, A. S.
    1983 Biology, Behavior and Borrowing: A Critical Examination of Optimal
    Foraging Theory in Archaeology. In Archaeological Hammers and Theories,
    edited by J. A. Moore and A. S. Keene, pp. 137-155. Academic Press, New York.

Kelly, R.A.
    1983 Hunter-Gatherer Mobility Strategies. Journal of Anthropological Research
    39:277-306.

    1988 The 3 Sides of a Biface. American Antiquity 53:717-734.

Kelly, R. A. and L. Todd
    1987Coming into the Country: Early Paleoindian Hunting and Mobility.
    American Antiquity 53:231-244.

Knight, George (editor)
1989 Overview : Ecological and Cultural Prehistory of the Helena and
Deerlodge National Forests, Montana.

Kuhn, S. L.
1989 Hunter Gatherer Foraging Organization and Strategies of Artifact
Replacement and Discard. In Experiments in Lithic Technology, edited by D. S.
Amick and R. P. Mauldin, pp. 33-48. BAR International Series 528.

1992 On Planning and Curated Technologies in the Middle Paleolithic. Journal
of Anthropological Research 48:185-214.

1994 A Formal Approach to the Design and Assembly of Mobile Toolkits.
American Antiquity 59:426-442.

Lahren, L.
1976 The Meyers-Hindman Site: An Exploratory Study of Human Occupation
Patterns in the Upper Yellowstone Valley From 7000 BC to AD 1200. Ph.D.
Dissertation. Anthropologos Researches International Incorporated. Livingston,
Montana.

Larson, M. L.
1994 Toward a Holistic Analysis of Chipped Stone Assemblages. In The
Organization of North American Chipped Stone Tool Technologies, edited by P.
J. Carr, pp. 57-69. International Monographs in Prehistory, Ann Arbor, MI.

Lanning, E. P.
1963 Archaeology of the Rose Spring Site INY-372. University of California
Press, Berkeley.

Luedtke, B. E.
1976 Lithic Material Distributions and Interaction Patterns During the Late
Woodland Period in Michigan. Unpublished Ph.D. Dissertation, University
Microfilms, Ann Arbor.

1980 Quarrying and Quantification: Estimates of Lithic Demand.
Midcontinental Journal of Archaeology 4:255-266.

1984 Lithic Material Demand and Quarry Production. In Prehistoric Quarries
and Lithic Procurement, edited by J. E. Ericson and B. A. Purdy, pp. 65-76.
Cambridge University Press, Cambridge.

1992 Archaeologist's Guide to Chert and Flint. University of California, Los
Angeles.

Lurie, R.
1989 Lithic Technology and Mobility Strategy: The Koster Site Middle Archaic. In Time, Energy, and Stone Tools, edited by R. Torrence, pp. 46-56. Cambridge University Press, Cambridge.

MacWilliams, A. C.
1991 Analysis of Two Prehistoric Quarries at South Ford of Everson Creek, Southwest Montana. Unpublished MA thesis, University of Maine.

Mendenhall, W.
1983 Introduction to Probability and Statistics. Duxbury Press, Boston.

Metcalfe, D. and R. K. Barrow
1991 Model for Exploring the Optimal Tradeoff Between Field Processing and Transport. American Anthropologist 94:340-356.

Nash, S. E.
1980 Is Curation a Useful Heuristic? In Stone Tools Theoretical Insights into Human Prehistory, edited by G. Odell, pp. 81-99. Plenum Press, New York.

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.

1991 The Study of Technological Organization. In Archaeological Method and Theory Volume 3, edited by M. B. Schiffer, pp. 57-100. University of Arizona Press, Tucson.

Odell, G.
1980 Toward a More Behavioral Approach to Archaeological Lithic Concentrations. American Antiquity 45:404-431.

1996 Economizing Behavior and the Concept of Curation. In Stone Tools: Theoretical Insights into Human Prehistory, edited by G. Odell, pp. 51-80. Plenum Press, New York.

Ranere, A. J.
1971 Birch Creek Papers No. 4 Stratigraphy and Stone Tools from Meadow Canyon, Eastern Idaho. Occasional Papers of the Idaho State University Museum Number 27, Idaho.

Reeves, B. O. K.
1990 Communal Bison Hunters of the Northern Plains. In Hunters of the Recent Past, edited by L. B. Davis, and B. O. K. Reeves, pp. 168-189. Unwin Hyman, London.

Reidhead, V. A.
    1979 Linear Programming Models in Archaeology. Annual Review of
    Anthropology 8:543-578.

Renfrew, C.
    1975 Trade as Action at a Distance: Questions of Integration and
    Communication. In Ancient Civilization and Trade, edited by J. A. Sabloff and
    C. C. Lamberg-Karlovsky, pp. 3-60. University of New Mexico Press,
    Albuquerque.

Schott, M. J.
    1986 Technological Organization and Settlement Mobility: An Ethnographic
    Examination. Journal of Anthropological Research 42:15-51.

Singer, C. A.
    1984 The 63-kilometer Fit. In Prehistoric Quarries and Lithic Procurement,
    edited by J. E. Ericson and B. A. Purdy, pp. 35-48. Cambridge University Press,
    Cambridge.

Staatz, M. H.
    1973 Geologic Map of the Goat Mountain Quadrangle Lemhi County, Idaho, and
    Beaverhead County, Montana. Map GQ-1097. United States Geological Survey,
    Washington, D. C.

    1978 Geology and Mineral Resources of the Lemhi Pass Thorium District, Idaho
    and Montana. Geological Survey Professional Paper 1049-A. United States
    Geological Survey, Washington, D. C.

Swanson, E., R. Butler, and R. Bonnichsen
    1964 Birch Creek Papers no. 2 Natural and Cultural Stratigraphy in the Birch
    Creek Valley of Eastern Idaho. Occasional Papers of the Idaho State University
    Museum, no. 14. Idaho.

Thomas, D. H.
    1983 The Archaeology of Monitor Valley 1. Epistomology. In Anthropological
    Papers of the American Museum of Natural History. Volume 58: Part 1. New
    York.

Torrence, R.
    1983 Time Budgeting and Hunter-Gatherer Technology. In Hunter Gatherer
    Economy in Prehistory, edited by G. Bailey, pp. 11-22. Cambridge University
    Press, Cambridge.

    1984 Monopoly or Direct Access? Industrial Organization at the Melos Obsidian
    Quarries. In Prehistoric Quarries and Lithic Procurement, edited by J. E. Ericson
    and B. A. Purdy, pp. 49-64. Cambridge University Press, Cambridge.

1987 Tools as Optimal Solutions. In Time, Energy and Stone Tools, edited by R. Torrence, pp. 1-6. Cambridge University Press, Cambridge.

1989 Retooling: Toward a Behavioral Theory of Lithic Procurement. In Time, Energy, and Stone Tools, edited by R. Torrence, pp. 57-66. Cambridge University Press, Cambridge.

Turner, M. T., J. C. Turner, and R. Bonnichsen
1988 A Long Pleistocene Glacial Sequence in Southwestern Montana. Current Research in the Pleistocene 5:96-98.

White, J. P. and D. H. Thomas
1972 What Mean These Stones? Ethnotaxonomic Models and Archaeological Interpretations in the New Guinea Highland. In Models in Archaeology, edited by D. L. Clarke, pp. 275-309. Methum, London.

Wiant, M. D. and H. Hassen
1985 The Role of Lithic Resource Availability and Accessibility in the Organization of Lithic Technology. In Lithic Resource Procurement: Proceedings from the Second Conference on Prehistoric Chert Exploitation, pp. 101-114. Southern Illinois University Center for Archaeological Investigations Occasional Papers No. 4.

Winterhalter, B. and E. A. Smith (editors)
1981 Hunter-Gatherer Foraging Strategies. University of Chicago Press, Chicago.

Zeller, E. J., G. Dresdoff, M. D. Turner, and J. C. Turner
1987 Southwestern Montana Prehistoric Quarry Aerial Reconnaissance Survey. Current Research in the Pleistocene 4:139-140.