Cost-benefit relationships at South Everson Creek quarries

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Cost-Benefit Relationships at South Everson Creek Quarries

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Presented in partial fulfillment of the requirements for the degree of Master of Arts Anthropology
University of Montana
2000

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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.
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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
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 Tosawih Quarrries by Elston and
Raven (1991-1992), the Bighorn Mountains by Francis (1983), and investigations carried
out at the South Everson Creek Quarrries 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; Torrence 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
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 multifunctionability 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 Sagers (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
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,
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 researchers 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
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).

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 cannot 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, andesites 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
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).
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.
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.
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 resharpened 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 continuous 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 cryptocrystaline 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 toolkit 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 millennia (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 approaches, productivity increases dramatically resulting in an increasing need
for lithic resources so that adequate raw materials will be on hand when food path
variance peaks during autumn. Productivity declines gradually over autumn as plant and
animal resources 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.
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 culture'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 exhausted quickly through extensive
resharpening and will need to be replaced on a regular basis. This leads to the assumption that lithic procurement 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 accessibility 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 possibility 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 variance as illustrated in Figure 5 (Elston 1992:46). According to Elston's model, procurement 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 Elston 1992)

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 procurement strategies. This model suggests that the economics of procurement 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).
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 multiple 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
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 accessibility to those resources.

Francis (1983:25-26) suggests 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 negligible 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 determining 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):
Causal 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 procurement and indirect procurement 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 locales. 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 regularly 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) illustrates 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 scenario, 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)

Edge Prepped Biface

Primarily Thinned Biface

Secondary Trajectories

Secondarily Thinned Biface

Bifacial Tool

(Stage 2)

(Stage 3)

(Stage 4)

(Stage 5)

Life

Resharpening

Discard

Export Form
Kuhn (1994:426) discusses design technology for mobile toolkits. Since they are designed to maximize durability and functional versatility 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).

Interrelations between artifact size, transport cost, and potential utility can be approached as a problem in optimization with beneficial increases in portability having potential 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 strategy, 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 availability and accessibility, 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 occurred (also rank ordered based on abundance and accessibility) (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 accessibility. 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 availability.

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 frequencies of prepared cores.
5. High frequencies of broken and discarded blanks and preforms.

As abundance and accessibility increase, the degree of planned effort decreases and
casual procurement strategies would be practiced. As abundance and accessibility decreases,
the degree of planned effort increases and deliberate procurement 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 procurement and the
degree of curation of tools made from the different raw materials. The more deliberate the
procurement, 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 readily 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
accessibility 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
of blanks or preforms (Francis 1983:116). This leads to the formation of two sets of hypotheses regarding lithic procurement strategies. The first pertains to the procurement strategy used to exploit each individual raw material and the second pertains to the strategies used to exploit the different types of lithic procurement 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 cryptocrystalline 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
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 (Bos taurus), 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 taxus), Richardson’s ground squirrel (Spermophilus richardsonii), deer mouse (Peromyscus maniculatus), cottontail (Sylvilagus nuttallii), jack rabbit (Lepus americanus), coyote (Canis latrans), fox (Vulpes vulpes), wolf (Canis lupus), and black bear (Ursus americanus).

Excavation of Mammoth Meadow 1

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 I 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 BP (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, motting, zoning and motting, 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
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 (Zier 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 Mac Williams (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 Multifunctionality

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, multifunctionability, 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 Finishing (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 \((c-1)(r-1)\), where \(c\) represents column and \(r\) represents row. The tests were conducted at the .05 significance level (\(\alpha\)), 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 \(\alpha\) 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
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.

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

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LATE PREHISTORIC</strong></td>
</tr>
<tr>
<td><strong>Assemblage 1</strong></td>
</tr>
<tr>
<td>Observed</td>
</tr>
<tr>
<td>(O-E)/E</td>
</tr>
<tr>
<td><strong>Assemblage 2</strong></td>
</tr>
<tr>
<td>Observed</td>
</tr>
<tr>
<td>Expected</td>
</tr>
<tr>
<td>(O-E)/E</td>
</tr>
<tr>
<td><strong>ARCHIAC</strong></td>
</tr>
<tr>
<td><strong>Assemblage 5</strong></td>
</tr>
<tr>
<td>Observed</td>
</tr>
<tr>
<td>Expected</td>
</tr>
<tr>
<td>(O-E)/E</td>
</tr>
<tr>
<td><strong>Assemblage 6</strong></td>
</tr>
<tr>
<td>Observed</td>
</tr>
<tr>
<td>Expected</td>
</tr>
<tr>
<td>(O-E)/E</td>
</tr>
<tr>
<td><strong>PALEOINDIAN</strong></td>
</tr>
<tr>
<td><strong>Assemblage 8</strong></td>
</tr>
<tr>
<td>Observed</td>
</tr>
<tr>
<td>Expected</td>
</tr>
<tr>
<td>(O-E)/E</td>
</tr>
<tr>
<td>Totals</td>
</tr>
<tr>
<td>df=12</td>
</tr>
</tbody>
</table>

X2>critical value = reject null hypothesis

Critical Value=21.0261
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
<table>
<thead>
<tr>
<th></th>
<th>Formal Tools</th>
<th>Flake Tools</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LATE PREHISTORIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemblage 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>32(71%)</td>
<td>13(29%)</td>
<td>45</td>
</tr>
<tr>
<td>Expected</td>
<td>31.175</td>
<td>13.825</td>
<td>45</td>
</tr>
<tr>
<td>$(O-E)^2/E$</td>
<td>0.022</td>
<td>0.049</td>
<td>0.071</td>
</tr>
<tr>
<td>Assemblage 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>88(70%)</td>
<td>38(30%)</td>
<td>126</td>
</tr>
<tr>
<td>Expected</td>
<td>87.291</td>
<td>38.709</td>
<td>126</td>
</tr>
<tr>
<td>$(O-E)^2/E$</td>
<td>0.006</td>
<td>0.013</td>
<td>0.019</td>
</tr>
<tr>
<td><strong>ARCHAIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemblage 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>187(77%)</td>
<td>56(23%)</td>
<td>243</td>
</tr>
<tr>
<td>Expected</td>
<td>168.347</td>
<td>74.653</td>
<td>243</td>
</tr>
<tr>
<td>$(O-E)^2/E$</td>
<td>2.067</td>
<td>4.661</td>
<td>6.728</td>
</tr>
<tr>
<td>Assemblage 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>202(68%)</td>
<td>95(32%)</td>
<td>297</td>
</tr>
<tr>
<td>Expected</td>
<td>205.758</td>
<td>91.242</td>
<td>297</td>
</tr>
<tr>
<td>$(O-E)^2/E$</td>
<td>0.069</td>
<td>0.155</td>
<td>0.224</td>
</tr>
<tr>
<td><strong>PALEOINDIAN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemblage 8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>269(65%)</td>
<td>143(35%)</td>
<td>412</td>
</tr>
<tr>
<td>Expected</td>
<td>285.428</td>
<td>126.572</td>
<td>412</td>
</tr>
<tr>
<td>$(O-E)^2/E$</td>
<td>0.946</td>
<td>2.132</td>
<td>3.078</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>778</td>
<td>345</td>
<td>1123</td>
</tr>
<tr>
<td>$df = 4$</td>
<td>$a = .05$</td>
<td>$X^2 = 10.12$</td>
<td>Critical Value = 9.488</td>
</tr>
</tbody>
</table>

Table 2

degrees of freedom were determined using $(c-1)(r-1)$ and the test was conducted at the .05 significance level ($\alpha$). 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 $\alpha$ 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
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 frequencies 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
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](image)

**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 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.
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