THESIS

SCATTERED GLASS: OBSIDIAN ARTIFACT PROVENANCE PATTERNS IN NORTHWESTERN WYOMING

Submitted by

Allison D. Bohn

Department of Anthropology

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WE HERBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY ALLISON DANIKA BOHN ENTITLED, SCATTERED GLASS: OBSIDIAN ARTIFACT PROVENANCE PATTERNS IN NORTHWESTERN WYOMING, BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS.

Committee on Graduate Work

Robert O. Coleman

Dr. Jason M. LaBelle

Dr. Kathleen Galvin

Advisor Dr. Lawrence C. Todd

Department Head Dr. Kathleen Galvin

Abstract of Thesis

SCATTERED GLASS: OBSIDIAN ARTIFACT PROVENANCE PATTERNS IN NORTHWESTERN WYOMING

Home to several high quality sources of the volcanic glass material, obsidian artifacts are found throughout the archaeological record in northwestern Wyoming. Obsidian is a useful lithic raw material for evaluating prehistoric land use patterns because it can be matched with the geochemical signatures of source materials. As part of the Greybull River Sustainable Landscape Ecology (GRSLE) project, this research seeks to evaluate obsidian distribution patterns in the Upper Greybull watershed and the relationship to local and regional land use patterns. The study area is located within the volcanically formed Absaroka Mountain range where there is clear evidence of prehistoric land use from the Late Paleoindian period to recent times. Field and laboratory components were conducted to evaluate several research questions. During the field component, artifacts were recorded following pedestrian surveys and a sample of obsidian artifacts were collected for geochemical characterization. The laboratory component consisted of the geochemical and lithic analysis of the sampled artifacts.

Between 2002 and 2005, the GRSLE project recorded over 40,000 chipped stone artifacts from 166 sites and several isolated finds. Obsidian frequency is not uniform between the tributaries of the Upper Greybull and the material is most commonly found in the lower elevation ranges of the study area. Several varieties of raw material are available locally and regionally. Obsidian is a small portion of the total Greybull assemblage and artifacts are on average smaller than artifacts manufactured from other materials, indicating that obsidian is a highly curated raw material. The Late Prehistoric was the period of the most substantial obsidian use.

A sample of 127 obsidian artifacts was sent for geochemical characterization and revealed an overwhelming propensity toward Obsidian Cliff obsidian. The other obsidian sources responsible for multiple artifacts include Bear Gulch, Teton Pass, and Malad. Teton Pass is approximately the same distance from the GRSLE study area as Obsidian Cliff, but was identified less often. Most projectile points are Late Prehistoric in age and are constructed of Obsidian Cliff obsidian. Late Archaic projectile points in the sample were not constructed of Obsidian Cliff material. Expedient artifacts such as debitage and worked flakes were associated with the more common sources, while rare source artifacts are primarily projectile points or bifaces. There was not a significant difference in artifact size between the source types. Spatial analysis of two sites revealed that parsing out singular obsidian procurement events is highly dependent on site complexity.

Three obsidian interaction zones are identified using several published regional sites and study areas. The GRSLE study area is similar to sites and areas to the north and east, but temporal variability needs to be better understood to evaluate possible shifts in the pattern. Five land use scenarios have been developed to consider possible land use patterns through time. These include seasonal exploitation, montane adaptation, long range adaptation, foothills-basin adaptation, and stochastic acquisition. Seasonal exploitation is the most probable scenario indicated by the available data. The Absaroka Range poses physiographic barriers to importing Obsidian Cliff material into the GRSLE study area. Research along the Boulder Basin Pack Trail will further define the relationship of the GRSLE study area to regional land use patterns.

Allison D. Bohn
Anthropology Department
Colorado State University
Fort Collins, CO 80523
Spring 2007

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CHAPTER 1
Introduction

Archaeological lithic scatters containing obsidian artifacts are ubiquitous throughout the mountains of northwestern Wyoming. These archaeological sites are the result of many behavioral, depositional, and erosional forces. They record dynamic landscape processes, biotic and abiotic, cultural and noncultural. Inferences about prehistoric hunter-gatherer behavior drawn from flaked stone artifacts are crucial because the implements were used by prehistoric people to meet various technological needs, key components of their landscape impacts. Obsidian, a volcanic glass, is easily manipulated to create chipped stone artifacts. The glass is formed under unique geologic conditions and is found in specific locations; much of the archaeological imprint of obsidian procurement and use is the result of the raw material being transported from geologically distinctive source areas. Provenance of the lithic raw material is not simply identifiable by proximity to a known source. Geochemical characterization can be used to evaluate the origin of the material.

Away from source areas, obsidian often constitutes a small percentage of the total raw material assemblage in lithic scatters, arguably the most prominent site type in the Rocky Mountains (Stiger 2001). A lithic scatter refers to an archaeological site that is an accumulation of chipped stone with little discernable vertical structure. Because of the nature of the palimpsest deposit, it is often assumed that lithic scatters lack internal horizontal structure as well (Stiger 2001). Lithic scatters are primarily surface sites composed of discarded flake debitage, possibly a few tools and only rarely a preserved feature (Burnett 2005). When little else is discernable from the palimpsest, every piece of the assemblage is useful to glean information about the prehistoric condition. Therefore, a small percentage of obsidian at a site is significant considering the distance often traveled to reach the final destination. Indeed, the origin of any allochthonous toolstone can shed light on prehistoric travel routes or trade networks employed for acquisition of the material. The research herein investigates provenance of obsidian artifacts found in the Upper Greybull watershed to examine prehistoric land use patterns in northwestern Wyoming.

Winding its way out of the Absaroka mountain range, the Greybull River forms a crescent that provides an interface between the mountains and the Bighorn Basin to the east (Figure 1.1). The area is a fine mesh of culture and ecology woven over thousands of years. Today, the land is managed by the Shoshone National Forest and some of the research area falls into the Washakie Wilderness. Dr. Lawrence Todd began investigations around the upper portions of the Greybull River drainage in the summer of 2002 with a small crew of archaeology students from Colorado State University. The Greybull River Sustainable Landscape Ecology (GRSLE) project continued during the field seasons of 2003 through 2005 and has grown to encompass approximately 1,600 km^2 (40 km north-south by 40 km east-west). The project has focused research along the Greybull River and on several of the small watersheds that feed the river.

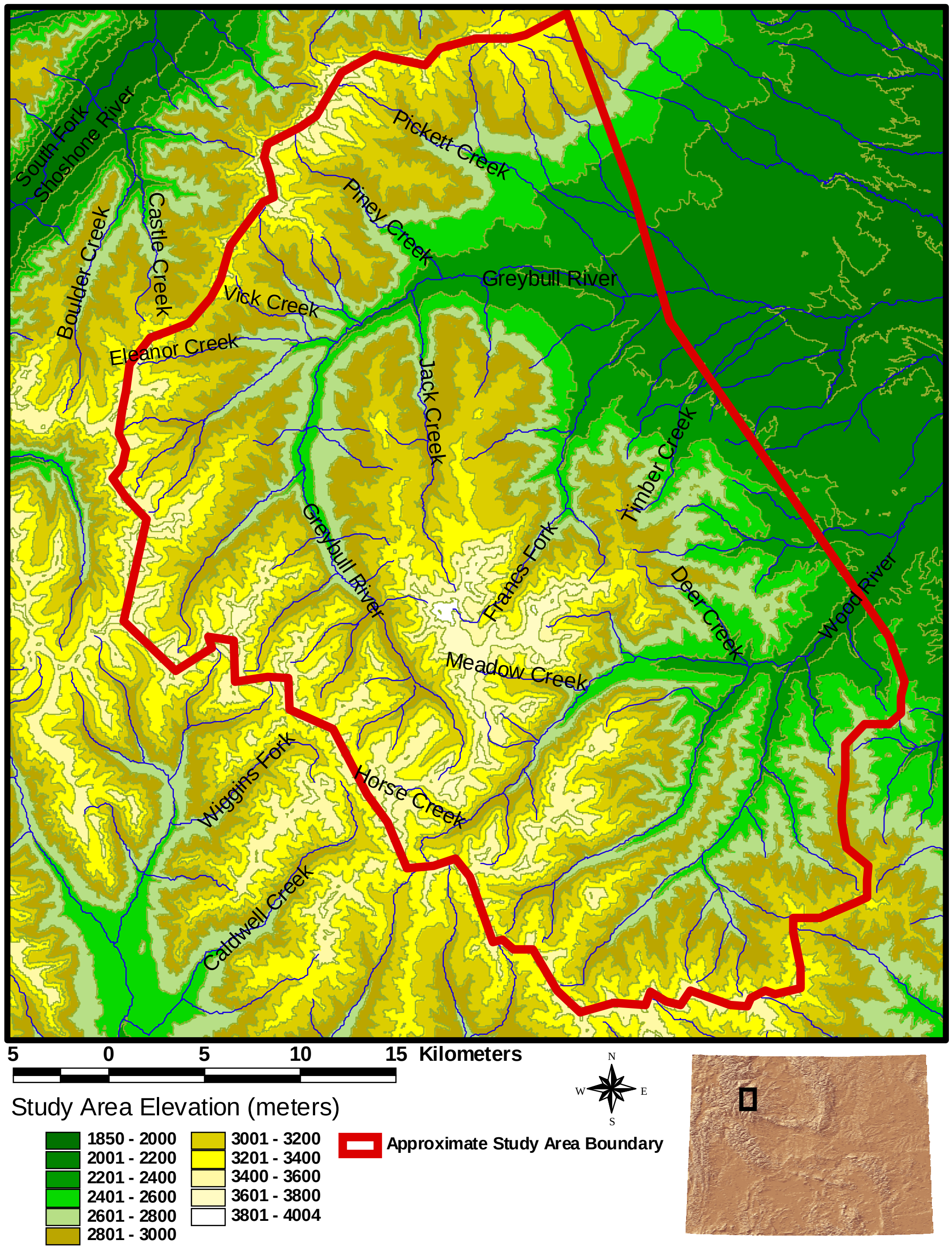

Figure 1.1 Elevation map of study area with state of Wyoming inset. Stream names used in this study are shown.

The GRSLE project investigates human ecological footprints in this portion of the Greater Yellowstone Ecosystem. This portion of the GRSLE project was only conducted near the headwaters or upstream portions of the Greybull River. Subsequently, the project area is frequently referred as the Upper Greybull. The prehistory of the Upper Greybull and the Absarokas was until recently, poorly documented (Burnett 2005). Before the arrival of the GRSLE project, a paucity of research made the area a lacuna in the regional archaeological record. Few sites had been recorded in the tributaries and valleys that drain from the mountains into the Greybull watershed. One goal of the project has been to record the archaeological and ecological context of Greybull River region, while promoting educational, research and conservation oriented relationships with local stakeholders (Todd and Bohn 2005). With the ability to link regional patterns, obsidian provenance studies fit well within the scope of the GRSLE goals and the project provided the resources to make this research possible.

This researcher joined the GRSLE team in 2004 and 2005 as a crew chief, graduate teaching assistant, and data collector. The obsidian project took hold in the last few days before we left for the field in 2004, while working out final negotiations with the land managers at the Shoshone National Forest. The initial idea was to sample obsidian artifacts at a few sites for subsequent geochemical analysis and return the artifacts as soon as possible. At the start, the analysis was considered ancillary to a larger master's thesis project. Through field discussions and general considerations of the scope of research, the author decided that the project would be sufficient for evaluating some basic patterns in prehistoric land use within and around the study area.

As a high quality and relatively rare lithic material in the study area, the incorporation of obsidian in tool kits reflects broad social and ecological interactions distinct from extraction of local materials. Pieces of obsidian are found in some locales as part of the standard subsistence related tool kit. In other archaeological assemblages, obsidian may have functioned in non-subsistence related activities, potentially for ideological or ceremonial purposes (Kunselman and Husted 1996). Raw material selection in general may represent different kinds of uses. While some reasons for use of a material may be related to toolstone functionality (Frison 1991:324), other reasons may be associated with change in style or preference (Kornfeld et al. 2001:318).

Throughout northwestern Wyoming, archaeological sites contain artifacts of different flaked stone varieties, qualities, and derivations. Several sources of high quality toolstone are known, from the Bighorn Mountains to the Hartville Uplift, to have a significant presence in the archaeological record (Francis 1991, 1997; Frison 1991). Among these material types is obsidian, formed as the result of rapid cooling of volcanic flows. Obsidian sources are known throughout the northwestern portion of Wyoming including Yellowstone National Park and the Teton Mountains. Nearby sources in eastern Idaho, such as Malad and Bear Gulch, have spawned some of the material for artifacts in Wyoming sites. Often, archaeologists will seek the source of obsidian artifacts that were deposited at great distances from a known source (Hughes et al. 2002). This has helped to establish the distance obsidian has traveled, but large scale regional studies of the obsidian landscape are rarely undertaken.

This thesis uses the results of geochemical characterization on obsidian artifacts and lithic analysis to evaluate broad patterns of prehistoric land use between the Upper Greybull watershed and the surrounding region (Figure 1.2). The model of the thesis is to develop a local and a regional output. Locally, the research should serve to identify obsidian patterns within the GRSLE assemblage and patterns in prehistoric land use patterns within the GRSLE study area. Inputs considered for the local or project area analysis include the environmental and historical background, and analysis of obsidian provenance and lithic patterns. It is recognized that many inputs to the local system are ignored in the scope of this research, and these inputs are lumped in the generic site formation processes category. The local output is then coupled with regional studies to establish the regional output or synthesis.

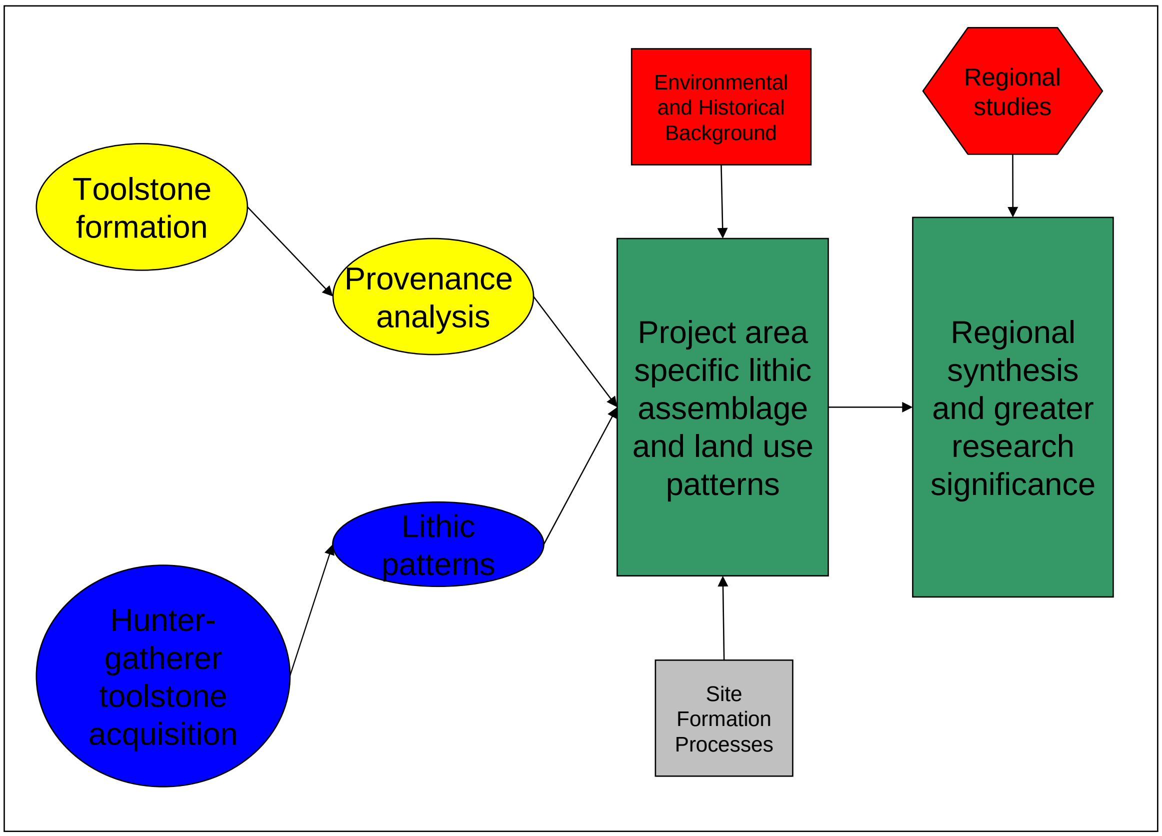

Figure 1.2 Simplified research model. Inputs on the left and top of the diagram are addressed in this document to develop outputs (green). Gray inputs are not addressed.

To support this portion of the research, it is critical to build a referential framework by evaluating some of the inputs affecting the local system. A review of the environmental and historical background of the local study area is necessary to create a foundation (Chapter 1). Hunter-gatherer behaviors in regard to toolstone acquisition and retention must be reviewed (Chapter 2). The GRSLE assemblage must be evaluated as a whole to determine the role obsidian plays in the local lithic record (Chapter 5). Obsidian formation and the process of geochemical characterization must be reviewed to understand the significance of characterization results (Chapter 3). Results of the provenance analysis support the local inquiry (Chapter 5). Beyond the study area patterns, this thesis should demonstrate how GRSLE lithic record informs regional prehistory. Regional studies must be examined to evaluate the significance of the GRSLE results to the region (Chapter 4). Five broad research questions are addressed in this paper.

1) What obsidian sources were used by prehistoric people traveling in the Upper Greybull area and were the sources used equally?

2) Are there any temporal, spatial or technological patterns discernable from the recorded obsidian assemblage?

3) What does the obsidian use along the Greybull tell us about past mobility and land use patterns?

4) How does the Greybull pattern fit in with the regional pattern?

5) How do these patterns of obsidian presence inform us about prehistoric land use in northwestern Wyoming and the immediate region?

The first four of these questions are indirectly addressed in Chapter 5, the results portion of this research. The first four research questions are reviewed and the final question is discussed in the concluding chapter (Chapter 6). In order to answer these questions, a series of supporting information must be examined as discussed above. The research is multiscalar, detailing obsidian patterns on an assemblage, site, and artifact level. The first chapter of this thesis provides an environmental and historical overview of the project area, the goals of this research and the basic data collection methodology. A brief outline of the thesis document concludes this chapter.

The Dynamic Greybull

> "Current ecological understanding has recognized that most ecosystems are dynamic; all are subject to ongoing processes of changing climate and other environmental disturbances, and many landscapes have been shaped by humans for millennia" (Gillson and Willis 2004:990).

A landscape without human impact would be difficult to find on the earth today. Most ecosystems have been prodded by scientific inquiry and shaped in some way by the influence of human action, past or present. The idea of the pristine frontier is becoming a distant memory of our collective conscious (Berkes et al. 2003; Kay and Simmons 2002; Krech 1999; Redman et al. 2004). Humans do not exist in isolation and are part of ecosystems comprising a variety biotic species and abiotic elements. Understanding dynamics of prehistoric landscapes is becoming increasingly important as our scientific community strives to make long term predictions about imminent global change affecting ecosystems and socio-systems. A long term perspective (centuries to millennia) of landscape formation reveals the dynamic nature of many ecosystems (Gillson and Willis 2004).

The Upper Greybull watershed is dynamically situated on the cusp of several environmental and cultural zones. All ecological and social systems are hierarchical entities existing along nonlinear, multi-stabile states (Holling et al. 2002). The mountainous study area contains several ecotones that intertwine downstream with Bighorn basin. The contemporary cultural landscape is influenced by ranching and recreation. The prehistoric cultural landscape was on the cusp of the Great Basin, Plateau, Plains and to a lesser degree the Southwest culture areas. The Upper Greybull River landscape is an integral part of the region and a fundamental part of understanding the land use throughout the Rocky Mountains and specifically northwestern Wyoming.

Environmental Setting

The landscape in the study area is highly discontinuous and patchy. Forested areas are broken up by gentle meadows and ephemeral or intermittent drainages. Steep cliffs and rough terrain also cover many parts of the study area. Elevation and precipitation play a major role in the distribution and density of plant species. Francs Peak, near the center of the study area reaches 4009m and is the highest point in Park County and the Absaroka mountain range (Knight 1994:Table 10.1). The relief of the region surrounding the study area is approximately 2,156m (Knight 1994:Table 10.1). The project sampled obsidian artifacts from a range of landscapes to paint a more complete picture of the distribution patterns (Figure 1.3).

Figure 1.3(a) illustrates the highest site where obsidian was sampled from, and is located above the modern treeline. High altitude sites are difficult to get to today, as they would have been in the past and are infrequently encountered in the process of archaeological survey. The Jack Creek drainage (Figure 1.3b) is a good example of site areas surrounding the mean elevation (2829m) of recorded chipped stone within the study boundaries.

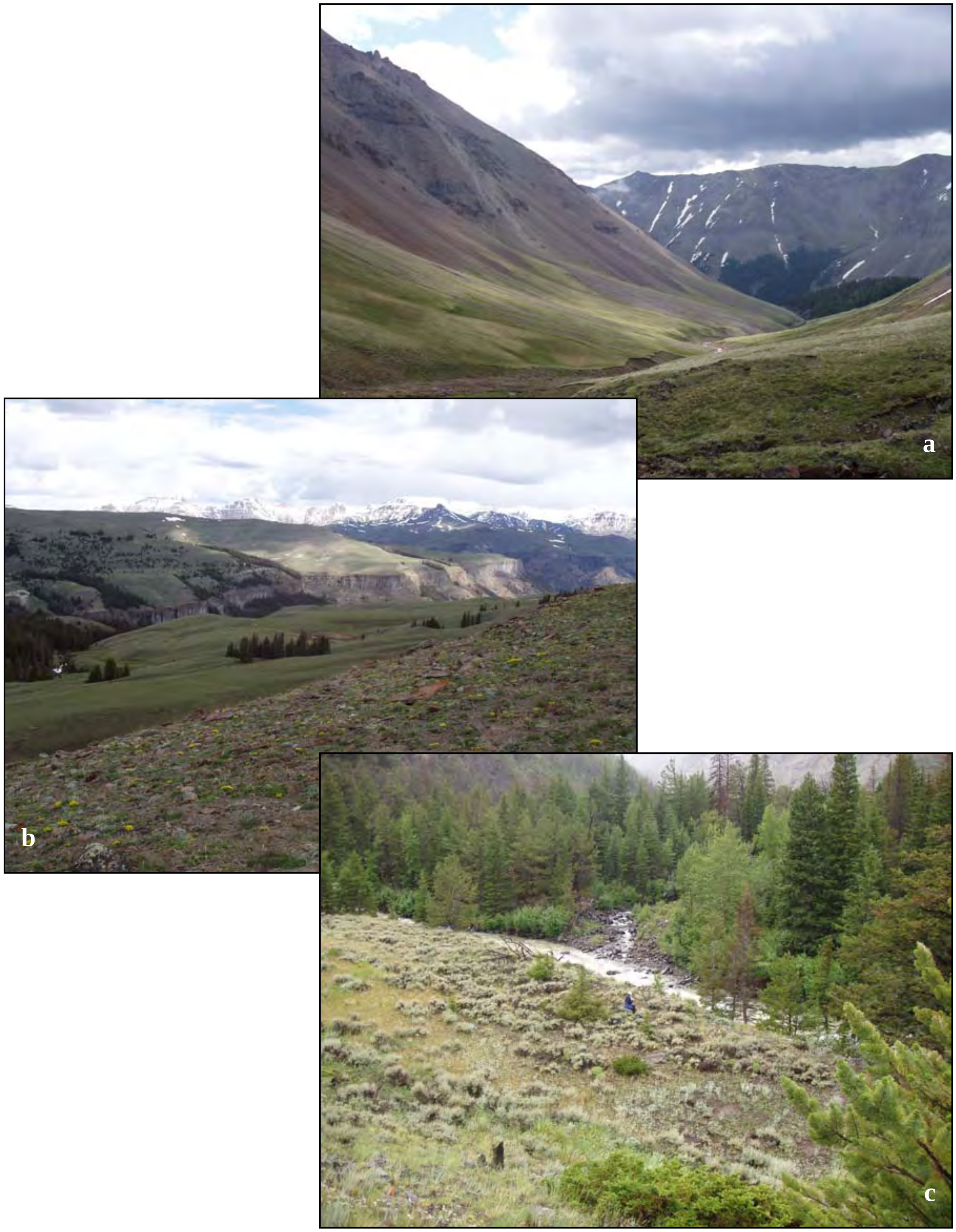

Figure 1.3 Variability of obsidian sampled sites within the watershed. a. High Altitude - Horse Creek; b. Average - Jack Creek; c. Low range Altitude - Greybull River.

Here, rolling lands atop a basaltic rim provide wide open lands with a high surface visibility and is ideal for archaeological survey. The lowest elevations in the study area are often found along major drainages and are frequently forested or heavily vegetated. The vegetation makes site identification difficult; however, sites are frequently encountered where visibility is possible.

The geology of the GRSLE study area is comprised primarily of Eocene volcanics. The Absaroka Mountains formed rapidly between 54 and 43 million years ago; the range has subsequently been exposed to mass wasting and erosion (Burnett 2005; Hiza 1999). Most of the drainages investigated as parts of this research are rimmed by basaltic or breccia cliffs (Breckenridge 1974a, 1974b; Dunrud 1962). A few sedimentary packages outcrop within the area, giving hints of the underlying Paleozoic landscape. These sedimentary structures provided important sources of cryptocrystalline quartz (primarily cherts) for prehistoric peoples in the area (Reitze 2004). The Greybull River is fed by several tributaries flowing in all azmithal directions. Each drainage contains attributes that make them unique in form as the geomorphic process shapes new features. Valleys are formed as the tributaries cut through the bedrock.

Vicissitudes of the landscape have created different patterns through time. The landscape of today is not the same as it was in the past. Fluctuating periods of glacial activity have influenced local changes in geomorphology, soil accumulation, and vegetative communities. While mountains have not moved in the past ten thousand years of human occupation in the region, the face of those mountains is continuously altered by several geomorphologic processes including freeze-thaw cycles and mass wasting, landslides and slumps. Soil accumulation throughout much of the surveyed areas is minimal making the potential for well stratified, buried sites negligible. Treelines and vegetative communities have shifted several times in response to sudden atmospheric changes. Pollen records from other areas indicate an alpine trend of downslope and upslope displacement of treelines nearly synchronous with large-scale climate oscillation changes (Reasoner and Jodry 2000). As the climate has changed, the Greybull area may have looked much different at points in the past influencing the way prehistoric people were able to use the land.

Moisture regimes can also change the way people use landscapes. Increases in winter precipitation in the form of deep snow can make the mountains impassable for most of the year. The meltwater from alpine glaciers and precipitation from summer rains in wet periods have created underfit stream conditions. The result is a landscape surface traced with ephemeral and intermittent creek beds that have carried more water during past conditions. Ecological processes such as tree recruitment that began over the past millennium are still evident in the ecosystems of today. The composition of old-growth forests may reflect recruitment conditions of times past as trees older than 150 years would have germinated in the colder conditions of the Little Ice Age (approx. AD 1590 to 1850; Gillson and Willis 2004:992). Remnant trees can hint to the forest line of the recent past. In the GRSLE study area research has begun to map remnant or "ghost trees" and evaluate the relationship to archaeological sites (Derr 2006; Reiser et al. 2005).

The wildlife community is composed of several large mammals, including mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), moose (*Alces alces*), bighorn sheep (*Ovis candensis*), wolves (*Canis lupus*), coyote (*Canis latrans*), grizzly bear (*Ursus arctos horriblis*), and black bear (*Ursus americanus*). The prehistoric landscape would have included the bison (*Bison bison*), and is debated to have seen different quantities of artiodactyl populations (Kay 1994; Lyman 2004). Small mammals including rabbits (*Lepus sp.*), ground squirrels (*Spermophilus sp.*), and marmot (*Marmota flaviventris*) exist throughout the study area. Several species of migratory birds and water fowl also frequent the area.

Vegetation throughout the study area is dominated by coniferous forests and grass, sedge, forb and shrub meadows. Success of plant species in the mountains is highly dependent on annual precipitation. Flora and fauna species abundances would have shifted through time in response to these climatic factors, in turn affecting resources availability for human populations.

Historical Background

The Absaroka Mountains have seen a variety of cultural uses over the past 13,000 years. Culture change is inevitable over this time scale, but the changes in land use are not often dramatic. Land use is dominated by the prehistoric period, which saw variable patterns of hunting and gathering subsistence for thousands of years. The recent historic period has witnessed more diverse and rapidly changing land uses.

Consideration of the prehistoric cultural chronology is germane to understanding diachronic shifts in mobility and land use. The inhabitants of the northwestern Wyoming region were hunter-gathers at all points in prehistory, but there is variation in degree and pattern through time. While the montane environments may have seen slightly different occupations, chronological markers established for the northwestern plains are generally assumed in northwestern Wyoming regional studies. These periods are considered to be synchronous between the plains and the mountains; however, the mountains typically exhibit sites reflecting greater subsistence diversity across all times (Frison 1991). Much of the chronology for the Upper Greybull and the Absaroka Mountains comes from the well-stratified Mummy Cave site, which spans 9200 years of prehistoric occupation (Hughes 2003; Husted and Edgar 2002). The five major prehistoric periods are the Paleoindian period (11,500 to 8000 RCBP), Early Archaic (8000 to 5000 RCBP), Middle Archaic (5000 to 3200 RCBP), Late Archaic (3200 to 1500 RCBP), and the Late Prehistoric (1500 to 250 RCBP). All of the periods are defined primarily by technological shifts in projectile point manufacture.

The oldest archaeological site in the region is the Colby site, dating to 11,200 RCBP, which exemplifies the Plains Paleoindian period (Frison and Todd 1986). The Paleoindian period in the GRSLE project area is little known, but based on technological attributes, is concomitant with the Foothills-Mountain occupation found in many areas of the Rocky Mountains (Bechberger et al. 2005; Pitblado 2003). Technological attributes of the period indicate conservationist use of high quality lithic materials. While many groups were highly mobile during the Paleoindian period (Kelly and Todd 1988), mobility was dynamic throughout the period in response to local conditions (LaBelle 2005).

The Early Archaic is contemporaneous with the debated climatic shift referred to as the Altithermal, a dryer and warmer period. The lithic materials were still preferentially high quality, but with a wider quality range than during the Paleoindian period. A trend toward decreasing reliance on high quality toolstone generally continues through each prehistoric period (Frison 1991). The Early Archaic period is marked by differing uses of the basin and mountain ranges (Larson 1997). Mobility in the Early Archaic is thought to have been changed slightly from earlier periods as regional inhabitants began to make shorter and more frequent moves (Larson 1997).

The Middle Archaic period in the region is most commonly associated with the McKean technological group (Burnett 2005; Frison 1991) and a broad spectrum subsistence base (Frison and Walker 1984; Husted and Edgar 2002). Both montane and plains environments were used extensively by this technological group, and there was an increased emphasis on plant foods (Frison 1991). The Middle Archaic groups maintained a mobile way of life, but may have occupied sites for longer periods as evidenced in the increase in pit structures (Frison 1991).

A wealth of archaeological materials is associated with the Late Archaic period throughout northwestern Wyoming (Husted and Edgar 2002; Johnson 2001; Kornfeld et al. 2001). The period is marked by discordant site types indicating a diverse population using broad spectrum in some sites and specialized subsistence strategies in others (Burnett 2005; Frison 1991). Because Late Archaic sites have dominated the GRSLE assemblage (Burnett 2005) and are prolific in the region, it may represent a period of increased population density or dramatic shifts in landuse patterns. Mobility during this phase may have been limited if population density was indeed increased.

The Late Prehistoric marks the time when projectile points transition to the smaller bow and arrow point technological form. Transitional arrowhead points can be difficult to distinguish in age between Late Archaic and Late Prehistoric. Technology and lithic material use in this period is generally considered expedient. Mobility during this period is thought to have been fairly low in comparison to earlier periods as an increase in the expedient local lithic materials is evident at most sites (Francis 1991).

An additional period, the Protohistoric, is most often approximated from the time Native populations in a region gained access to horses, metal and other European trade goods, but before the actual establishment of a European population in the area. The name of the mountain range where the research is done gives hint to some of the indigenous groups. By 1804 the Crow, or the Absarokee, were well established in the area (Swanton 1953:391). The area also was frequented by Shoshonian bands during this period (Janetski 2002).

In the historic period, the area was used for sheep herding, cattle ranching, and mining operations (Todd and Mueller 2004; Miller et al. 2005). Most of the area has been under the management of the Shoshone National Forest since it was formed on July 1, 1908 upon the division of the original Yellowstone Forest Reserve (Unknown 1917). Historically, much of the area in the Shoshone National Forest has been considered inaccessible because of the rugged topography (Unknown 1917).

Over the past decade, the Upper Greybull River has seen an increase in recreational use for hunting, fishing, and hiking (Todd et. al 2004). Cattle ranching is a major activity on the contemporary Upper Greybull. Much of the area serves as summer range for ranches headquartered in the Bighorn Basin. All of these modern activities bring interested individuals into the area. The influx has likely resulted in the increase of archaeological damage, specifically artifact collection. We have witnessed a shift from the days where Forest lands were managed for their maximum sustainable economic value to a time when the lands are being conserved for their intrinsic value and value to scientific research. Continued scientific research in the area will shed light on the prehistoric, historic and modern ecological conditions. The obsidian study in this thesis, given the regional perspective, helps to illuminate some of these conditions.

Summary of Chapters

Chapter 2 is a review of the theoretical and conceptual relationship between prehistoric mobility and lithic analysis. Chapter 3 examines the geochemical sourcing process and reviews the background for the obsidian sources important to this study. A review of obsidian studies from regionally important sites is presented in Chapter 4. Chapter 5 provides a multi-scalar examination of the aggregate pattern of obsidian distribution in the GRSLE project assemblage and selected sites, and an individual artifact analysis of artifacts in the source sample. Chapter 6 serves to establish conclusions and possible models for regional mobility; and, provides suggestions for future directions of inquiry in and around the study area.

CHAPTER 2
Developing Analytical Frameworks

Inferring prehistoric hunter-gatherer behavior from the study of flaked stone artifacts is a major component of North American archaeological inquiry (Andrefsky 1994, 1998, 2004; Binford 1979; Bamforth 1986, 1991; Kelly 1988, 1992; Mauldin and Amick 1989; Odell 1996; Shott 1996 and many others). Flaked stone implements were used by prehistoric hunter-gatherers in a variety of daily activities, mainly in subsistence acquisition and production. Lithic raw material types for stone tools are available from a wide range of geologic sources in an array of types and qualities. Often local raw material types may be of low or mediocre quality (Andrefsky 1994). Knowledge of stone quarries consisting of better quality material may have created a reason to incorporate non-local or exotic material types into the lithic tool assemblage.

Transport of exotic raw materials may have taken many forms. Whether through direct procurement of the source or through social exchange systems, the movement of people on the landscape would have made an impact. Obsidian use in northwestern Wyoming was a long-term process as evident archaeologically from Paleoindian to Late Prehistoric times. In fact, people still collect obsidian pieces from prominent sources, mostly as souvenirs. Short-term adaptations resulting in varied behaviors or activities may have created disparate archaeological signatures. In this chapter, a review of hunter-gatherer lithic curation and mobility models is presented to develop an understanding of how mobile communities use raw material landscapes. This chapter evaluates the potential for obsidian source characterization to elucidate prehistoric human-landscape dynamics.

Lithic Curation

Researchers have extensively explored the concept of curation in discussions of tool use efficiency, planning, and tool utility, among other issues (Binford 1979; Bamforth 1986; Odell 1996; Shott 1996). The term was originally coined by Binford (1973) in reference to individual 'curated' artifacts implying a level of care for the artifact that clearly separates it from expedient artifacts (Bamforth 1986). As originally conceived, curated artifacts refer to personal gear and tools that one would prepare and maintain (e.g., an heirloom Swiss army knife) to continue use or preserve its existence. Expedient technologies are considered situational gear. Here, the tools are not significantly altered or maintained, may be made on the spot or only used in rare occasions (e.g., one of the sticks by your door to scrape mud off your boots). This established a dichotomous relationship between curated and expedient tool types. Later, Binford defined curation in terms of curated technologies and assemblages (Binford 1977). Here, a group of tools or an entire site can be classified as curated or expedient. The distribution of lithic raw material within an assemblage or a technological category (i.e., projectile point, core, scraper, etc.) can alter these associations significantly because it can be composed of a variety of materials and qualities.

The ambiguity of the curation concept leaves one questioning what is being curated. The 'curation' concept is further confused by considerations of whether the ‘curated’ artifact was developed in a premeditated subsistence act (Bamforth 1986). In other words, does intention to preserve or prepare the piece determine its curated state? Curation as an archaeological concept is sensitive to how the user defines it.

Such a wide-ranging definition of curation encompasses a variety of strategies and behaviors that mobile hunter-gatherers would have employed under a variety of conditions. Even what is prepared or transported for anticipated future use represents different strategies adapted to varying conditions (Odell 1996). As Nelson (1991) points out, the transport of cores and blanks (potential sources of tools) versus finished tools are distinct endeavors exemplifying diverse strategies. Curation is complex issue involving many technological and behavioral components.

For the purpose of this study, curation is considered the act of transporting allochthonous lithic materials, away from a source to a distant discard location. Curated artifacts can be finished (i.e., projectile point) or unfinished tools (i.e., core). Two important factors in studies of curation are 1.) availability and quality of raw material and 2.) group mobility and land use patterns. Tool production, design, and transport are influenced by the group's mobility and settlement systems, while tool recycling and maintenance are part of tool conservation associated with the scarcity of materials (Odell 1996). Prehistoric hunter-gatherers handled various aspects of the curation process differently depending on distance from source. Below, the behavioral adaptations affiliated with mobility are investigated.

Moving Across Landscapes

Mobility is a property of individuals who may move in many different ways: alone or in groups, frequently or infrequently, over short or long distances, daily, seasonally or annually. The process of moving through landscapes is complex, but may be governed by a predictable series of environment and social factors. Hunter-gatherer bands are romantically idealized as small groups freely roaming the landscape with few material restraints to tether them to any specific locale. While mobility is a key feature in the hunter-gatherer lifeway, it varies temporally, spatially, and organizationally. Some foraging communities move only on rare occasions, some move only short distances and some groups only send satellite factions out. The focus first is on the organization of hunter-gatherer settlement systems. Second, ecological models of foraging dynamics are reviewed. Finally, the special conditions required in high altitude environments are considered.

Organization of Settlement Systems

Binford described the variability he saw in hunter-gatherer settlement-systems with two types, foragers and collectors (1980). The forager-collector continuum described strategic responses to resource distribution within a given environment. The responses create variability in the organization of camp movement relative to food resources. Foragers engage in relatively frequent residential mobility, moving the entire band or local group from one camp to another. Foragers move people to subsistence resources and tend to exhibit generalized, multi-purpose technologies (proverbial duct tape users of the past). Collectors are more often practitioners of logistical mobility.

Smaller parties or individuals split-off to procure resources and bring them back to the residential camp. The use of logistical forays is often coupled with development of specialized technologies to meet the needs of the specific expedition. The home base of collectors is not specifically defined by proximity to food, but may be a response to water or fuel resource propinquity.

Location of residential and logistical forays may be determined by landforms or neighboring settlements as they deter game or plant aggregation. Areas such as the Upper Greybull River that have large landform diversity may require a more variable adaptation, such as a seasonal shift between collector and forager behavioral patterns. Additionally, neighboring settlements may permit logistical use of their territory or range, but prohibit establishment of a base camp. The issue of neighbors coupled with the functional problems of moving large groups of people together, suggests population size and density is a major contributor in the organization of mobile groups (Binford 2001; Kelly 1995).

Not all foragers are perfectly mobile; conversely, not all collectors are purely sedentary. Diverse hunter-gatherer environments led to the continuum disparity. Binford (1980) demonstrated that mobility is related to environmental conditions with the forager-collector model. Environmental factors are systematically related to hunter-gatherer diet and mobility and can reveal patterns about the nature of the lifeway. Foragers and collectors are the extreme ends of a continuum that is generally considered to parallel other scales of seasonal differentiation and resource patchiness. Foragers are generally associated with resources available year round and with more frequent residential mobility. They are more likely located where resource distribution is temporally and spatially homogenous (i.e., hunter-gatherers following groups of migratory game). Ecological heterogeneity lends greater support to the collector pattern. Seasonal environments with more aggregated resources favor the logistical strategy.

Ecological Models

Patch choice models are useful for understanding both residential and logistical mobility patterns. The patch-choice model assumes that resources are heterogeneous and patchy across a landscape. Patches are encountered sequentially and randomly, depending upon their frequency on a given landscape (Kelly 1995:90). A forager will not return to a patch until the resources are rejuvenated. Travel time between patches is not productive. Linked to the patch-choice model is the question of when a forager should move on to another patch. The forager reaches a point of diminishing returns as resources are harvested, and encounter and harvest rates decrease (Kelly 1995:91). Patch abandonment takes time and energy, but the next patch may potentially offer greater forage potential than the depleted patch.

A forager wishing to maximize harvest per unit time spent foraging should leave any given patch when the marginal return rate (the expected rate of harvest over the next small period of time) falls below what can be obtained by traveling on to another less-depleted patch (Smith and Wishnie 2000:512). To maximize their net rate of resource harvest, the marginal value theorem predicts that foragers will move out of a resource patch when the rate of harvest in the patch falls below the average rate for the entire environment (Kelly 1995:90-91). The theorem further predicts that an efficient forager will generally leave a patch well before total exhaustion of resources has occurred.

Ethnographic accounts show that hunter-gatherers do not encounter patches randomly, but instead they will often choose the next forage patch before leaving camp (Binford 1979; Kelly 1995:92). Marginal value theorem assumes that travel time between patches is unproductive. This is, however, rarely the case (Kelly 1995; Winterhalder 1981). While on foray, men and women note the presence of plants, animals or animal signs, and water resources to share or use this information at a later time.

Central place foraging is useful for understanding logistic forays and residential placement. The central place foraging model suggests that foraging communities will locate residential base camps centrally in respect to resource patches (Kelly 1995). That is not to say, however, that residential camps are located in the direct, geographic center of a resource sphere. Rather, hunter-gatherers are assumed to choose a camp location with the potential for highest rates of resource acquisition (Zeanah 2002:241).

Taken together, the patch choice model, marginal value theorem and central place foraging suggest that hunter-gatherers will: 1) choose residential and logistical patches based on resource availability and quality; 2) remain in residential and logistical patches only as long as returns are productive; 3) not return to exploited patches until replenished; and, 4) position residential base camps within a patch to promote gainful logistical endeavors.

Indeed, mobility exerts a strong influence over many elements of the hunting and gathering lifeway. Sahlins (1972) considered mobility as a conditioning factor of cultural attitudes toward material goods. Certainly not all individuals in a group will forage the same. Environment heterogeneity can, as indicated above, have direct implications for mobile strategies. It has been shown that mobility decisions are influenced by resource predictability. In a high alititude setting, such as the Upper Greybull, mobility decisions must be influenced by the dynamic environmental conditions presented to groups navigating the terrain.

High Altitude Occupations

Elevation and relief play a major role in the accessibility of montane environments to human groups (Aldenderfer 1998). High altitude occupations are defined as those occupations above 2500 meters as this elevation marks the hypoxia zone, areas of reduced oxygen at high altitude (Aldenderfer 1998). Sites in the Upper Greybull project area range in elevation from 2200 m to 3100 m, much of which is over 2500 m. Humans have adapted a number of cultural responses to the extremes of montane environments including increased shortwave radiation, low vapor pressure, low atmospheric temperatures, reduced partial pressure of oxygen, and food production stresses (Baker 1984:8-9). The costs to mitigate hazards and minimize risks are high in energy and material expenditure (Aldenderfer 1998; Baker 1984). Most foot-mobile foragers were removed from their aboriginal landscapes by the time anthropologists began to document ethnographic records. Even without direct observation of hunter-gatherer groups, any hiker knows mountains present obstacles requiring significant energy to surmount. Simply walking around in search of resources is more costly than on flatter ground (Aldenderfer 1998). Mobility strategies would be affected by added demands imposed by basic caloric requirements for negotiating rugged mountain topography (Aldenderfer 1998:5).

As if the elevation and relief are not enough to contend with, resources in montane settings are often patchy, discontinuous, and unpredictable. The cost of navigating this sort of terrain is adaptive behaviors that lean towards the conservative, risk averse side. Obviously, this is not to say hunter-gatherer montane groups do not take risks. Montane landscape use is inherently risky and additional risks should be expected to be at a minimum. Conversely, specialized economy groups, such as pastoralist married to the land, tend to be more risk prone in response to attempts to maintain their way of life (Aldenderfer 1998:16; Guillet et al. 1983). Aldenderfer (1998) predicted that mountain hunter-gatherer groups would have embedded lithic procurement in the subsistence round, with few logistical trips made directly for this purpose. Most likely, prehistoric peoples in the GRSLE study area also minimized risk by embedding obsidian procurement in other subsistence endeavors.

Resource acquisition is a factor of mobility, but mobility is also conditioned by the needs of individuals in the group. Lithic raw material is an important component of the subsistence technologies employed by mobile individuals. Replacement of high quality stone would have influenced mobility.

Archaeological Indicators of Mobility

Relationships between lithic technology and mobility regimes may help reveal information about prehistoric land use patterns. The study of mobility is difficult archaeologically (Kelly 1992:55). The concept behind coupling lithic technology and mobility in this thesis is that finding the provenance of a flaked toolstone may reveal where groups were previously on the landscape. The problem, however is that both the resource base and mobility trajectory are difficult to document.

Lithic source documentation can help establish proxies for evaluating prehistoric physical and/or social ranges. For many years, archaeologists have measured the size of prehistoric foraging territories and thus the degree of mobility through the distribution of stone tools relative to the geologic sources of their raw material (Kelly 1992). Distance from a lithic source and artifact curation is not a direct analog for distance an exotic material has traveled (Hofman 1991). Land use is much more complex. Material may have been moved to several areas on a landscape before its final discard. Additionally, heterogeneous landscapes, such as the Upper Greybull and greater region, make straight line travel nearly impossible. Toolstone used in lithic technological systems may either be directly procured from the geologic outcrop or exchanged between the hands of many people. Some archaeologists have argued that the presence of exotic lithic projectile points indicates high residential mobility or a combination of residential, logistical, and territorial mobility during Paleoindian times (Kelly and Todd 1988; Surovell 2000). Such information provides a first approximation of range, rather than mobility, since the raw material could have been acquired through residential or logistical movements, or trade (Kelly 1992).

Archaeologists have tried to reconstruct mobility by examining stone tool technologies production, use, and discard (Bamforth 1986, 1991), but these elements are affected by many factors. Technological patterns may be related to distance traveled to procure raw materials. Bifaces and cores are generally associated with frequent and lengthy travel (Kelly 1988, 1992). These travels may be either residential or logistical mobility strategies. Expedient flake tools and bipolar reduction are associated with infrequent residential moves. Local, low quality lithic raw material is also generally associated with expedient technologies.

Kelly (1992) investigated a statistical relationship between tool assemblage size and diversity. He suggested that collectors produce random assemblages with no correlation, while foragers produce assemblages with a strong positive correlation (Kelly 1992). Additionally, an inverse relationship was proposed between technological diversity and residential mobility. In other words, the more sedentary a group is the larger and more complex the tool kit. This may be the general trend, but the relationship ignores compounding factors such as caching and other embedded cultural practices (Binford 1979). Further, the technological complexity argument obscures the fact that many tools in foraging communities are produced out of organic and degradable materials that are not fully represented archaeologically as a result of landscape taphonomic processes. Indeed, correlations between assemblage size and diversity could be related to many factors (Kelly 1992). Technological diversity may relate directly to the degree of risk involved in prey capture rather than mobility.

Reconstructing prehistoric mobility regimes by technological evaluation is hampered by several difficulties. The relationship between mobility and tool manufacture is likely as complex as mobility patterns themselves. Just reconstructing manufacturing methods of different tool types from flaked stone debitage is wrought with interpretive obstacles (Kelly 1992). While some extant foraging communities still maintain mobile lifeways, stone tools are not routinely used, making model verification difficult (Kelly 1992). Consequently, interpretations of stone tool assemblages as indicators of mobility are largely conjectural.

To further complicate matters, lithic raw material procurement may be embedded in the procurement of other resources (Binford 1979). "The presence of exotic [lithic materials] may simply be a fair measurement of the mobility scale of the adaptation appearing as a consequence of the normal functioning of the system, with no extra effort expended in their procurement" (Binford 1979:275). Procurement of exotic materials is often embedded in other parts of culture systems, as was with the Nunamuit subsistence strategies (Binford 1979). Foraging parties would only seek out lithic sources if it was on the way to or near where they were going. Groups may not be intentionally looking for lithic materials, but a "good" forager would not pass on the opportunity to exploit a new resource. This presents a challenge to direct procurement models.

Palimpsest sites can create yet another challenge to the use of lithic analysis to evaluate mobility or land use patterns. While virtually all archaeological remains are palimpsest deposits (Foley 1981:173), the scale varies in terms of complexity. The lithic scatter sites common to the GRSLE study area are rarely, if ever, representative of single components or occupations (Burnett 2005). Even single occupations will record multiple trajectories of land use (Binford 1982; Yellen 1977). The superimposed nature of the palimpsest deposits captures multiple mobility events. Interpreting mobile regimes from these complex remains requires broad generalizations, and precludes specific tales of the prehistoric condition.

Lithic artifacts can help archaeologists to evaluate prehistoric mobility patterns. Research about the relationship between lithics and mobility requires numerous lines of evidence, however, before distinct assumptions and interpretations are made. Given all of these possible lines of evidence what, if anything, can we learn from the use of obsidian?

Obsidian Considered

Obsidian, through geochemical sourcing, can offer valuable insights into the mobility question by allowing us to reconstruct the procurement range or to approximate distance traveled to obtain resources. Obsidian was obtained prehistorically either by going directly to the source (direct procurement) or through exchange with groups closer to the sources (trade). Distinguishing the prehistoric procurement strategies is difficult (Shackley 1998). One way to distinguish them is to examine the types of obsidian artifacts recovered at sites away from the source. Schoen (1994) has suggested obsidian in northwestern Wyoming was primarily used for production of projectile points, preforms and retouched flakes. If obsidian was directly procured, sites may have more cores and core reduction debitage than if it was traded. Provenance distance affects the amount of reduction that occurs at the source in preparation for transporting material (Roth 2000). Obsidian artifacts from sites close to its origin may be larger in size and have more exterior cortex than obsidian from sites away from the source (Renfrew and Bahn 2000:370-371). If a site is far from the obsidian source, modified cores or bifacial tools may have been produced to reduce transport costs. This implies high mobility and would result in the presence of small non-cortical debitage at the discard or use sites.

Site distance from geologic sources and ethnographic examples of trade systems made it difficult historically for some researchers to entertain the notion that obsidian could have made its way by other means. There is not explicit description, however, of how ‘trade’ should appear archaeologically (Hughes 1998). The most informative attribute of obsidian source studies is the ability to reveal the size of a prehistoric interaction region (Kunselman 1994:1).

Trade versus Transport

While it may seem more prudent to discuss the trade versus transport question in the conclusions, understanding the problem is based more on the nature of hunter-gatherer behaviors than on the results of provenance studies. Technically even traded items have been transported. The term transport here refers to direct acquisition from the source. Exchange and trade are used interchangeably, meaning the exchange of raw material between groups of people. Many authors have addressed this issue (Hofman 1992; Meltzer 1989; Shackley 2005). Unfortunately, it is difficult to test hypotheses purporting to discern trade and transport. The problem can be difficult to decipher for lithic raw materials as exchange and direct acquisition yield the same result, exotic material in an archaeological assemblage (Meltzer 1989).

Reliance merely on trade for acquisition of raw materials is a risky maneuver (Hofman 1992:198). While the bulk of toolstone materials a group uses may not be traded, a few pieces for special use may have made its way into an exchange system. The issue is dependent on several factors including population density, territoriality of the groups on the landscape, and importance of the material. Regardless of the means by which the material is acquired, the resulting action is the interplay of separate ecological and cultural systems. For example, a person moving from the plains to an obsidian source in the mountains would have to pass through different elevational zones, carrying with them food or other resources from different areas. The effect of this zonal transitioning may be negligible, but the presence of a hunter on the landscape could change game movement, introduce seeds from other niches, or bring fire in the area. Further, if other human groups are using the areas that the person is moving through, they may have to deal with a whole suite of cultural roadblocks or relations. If two groups exchange items at a point distant from the source of raw material, the ecotonal and social interaction remains at play.

To truly evaluate a pattern of trade or transport, a regional perspective is necessary within the confines of a single cultural system (Meltzer 1989:23) able to be temporally and spatially defined. Traded exotic stone may be assumed if it is limited in a site to specific tool types (Meltzer 1989:25). This is difficult with obsidian as the nature of the material often precludes the selection of it for processing tools. According to Melzter (1989), the best case scenario for delineating the issue is if a site is composed of all the exotic material it is most likely from direct acquisition or transport; if only a unique stylistic variant is made of the lithic material, it likely arrived at the site via trade. Shackley (2005:120) states that most trades in hunter-gatherer cultures occur between family members or close to the primary source. This suggests that the problem is of minor significance. The question is too specifically tied to temporal, social and environmental factors to establish any broad generalizations. The issue is briefly discussed later in this document as it applies to the results of this research.

Lithic Analysis

A link between mobility and technology has been established, but the nature of the relationship is occasionally debated (Bamforth 1986; Kelly and Todd 1988; Kuhn 1994; Odell 1996). In order to evaluate the mobility models, lithic analyses are employed to extract information from sites. Lithic analysis for this research can be conducted with two general methodologies: aggregate or individual based. Aggregate flaked stone analysis is used to evaluate dynamics of assemblages as a whole. Individual artifact analysis is focused on the sample selected for obsidian sourcing.

Aggregate Analysis

Aggregate analysis is simply the study of the collective in an attempt to segregate an assemblage into meaningful parts. Many types of aggregate analysis have been attempted (Hall and Larson 2004), but all forms use patterning within the overall population to draw inferences about the formation of the assemblage (Andrefsky 2004:201). The goal of this mass analysis is normally to draw generalizations about technology used to create an assemblage or to determine the stage in the reduction sequence. One type frequently employed in raw material origin studies is minimum analytical nodule analysis (MANA) to group debitage into meaningful units (Larson 1990; Larson and Finley 2004). Often, analysis on the aggregate does not differentiate between broken or complete debitage pieces (Andrefsky 2004). The analytical technique forces researchers to ignore taphonomic processes such as frost shattering, thermal stress, and trampling (Rasic 2004) and is not greatly successful at differentiating in technologically mixed assemblages such as those formed by projectile point and core reduction (Andrefsky 2004). The tool is not reasonable for use at all times, but if the assemblage is partitioned into analytical groups such as raw material or technological groups (Andrefsky 2004:207), the tool can highlight assemblage patterning.

This scale of inquiry helps shape our understanding of the broader role of obsidian in the project area dataset. The entire assemblage is evaluated in terms of size grades, tool class and raw material in order to classify parts of the assemblage as curated or not. Aggregate analyses may be used as the first step in establishing the utility of a database for further inquiry. Aggregate studies help to answer questions such as: is obsidian an exotic lithic resource, does it differ from the local material assemblage, and how often do artifacts occur in the record? These types of inquiries can provide the framework to understand the significance of individual artifacts.

Individual Artifact Analysis

The individual artifact analysis is at a finer scale. It can be used to determine technologic mode of production. Are we seeing artifacts that are the result of core reduction or the result of biface reduction? Is there a difference in the technological mode of production used from different sourced materials? Once geologic sources are known, it may help to shed light on why a particular source was of greater interest. Further, data collected from this line of study may help to decipher different technological applications of the materials from separate geologic sources.

Fundamental to any lithic analysis is identification of the artifact type: flake, worked flake, biface, projectile point, core. Artifact type at its base differentiates between formal and informal tool, expedient and curated technologies. Core and biface production are both useful technologies for curated material types. Both can be used directly as tools or as blank slates to create new tools. Some material types may be better suited for certain tool categories. For example, scrapers, gravers, or other formal tools are infrequently found in obsidian collections as obsidian is considered to be poor material for these types of tools (Beck and Jones 1990; Baumler 1997). Obsidian produces an extremely sharp edge when flaked, but also loses the edge quickly during use (Connor and Kunselman 1995:41). Additionally, the brittle nature of the material may cause pieces to shatter into what it is cutting. This makes obsidian a poor choice for butchering tools as one would not want glass fragments in their meat.

Artifacts manufactured from exotic material are generally thought to decrease in size as distance from the source increases. Because of this, size examination is fundamental to lithic analysis. Generally, it is assumed that the more reduced a piece of chipped stone, the further the artifact is from its point of origin. The issue is not simply cut and dry, however, as larger flakes may have been located on a site and selected for further modification prior to discard (Mauldin and Amick 1989:78). Size dimensions alone are not useful for distinguishing differences in the mode of production as both biface and core reductions produce an abundance of small debris (Mauldin and Amick 1989). Raw material weight should also decrease with distance from its point of origin. Flaked stone weight measurements generally correlate with other size dimension measurements specifically length and width (Andrefsky 1998; Mauldin and Amick 1989). Weight is useful as an additional analytical tool supporting other linear dimensions.

Cortex estimates are useful as indicators of early stages of core reduction (Mauldin and Amick 1989:70). Flakes that have cortex completely jacketing the dorsal surface are logically assumed to reflect early reduction, and flakes without cortical cover are assumed to reflect later reduction events (Mauldin and Amick 1989:69-70). Bifaces and projectile points will less frequently exhibit cortex because they have been highly reduced. Bifacial tools containing cortex may represent expedient manufacture.

Presence or absence of lip on the ventral platform is useful to characterize the debitage for mode of production. The presence of ventral platform lipping can be used to distinguish soft versus hard hammer flakes. Soft hammer use is more commonly associated with bifacial reduction, while hard hammer is often related to core modification (Andrefsky 1994). Regardless of the form applied, platforms are prepared to roughen the surface and increase the probability of a successful well-positioned and exact removal. Non-metric platform attributes, such as presence or absence, may be more successful for identifying the mode of flake removal as well as reduction stage (Mauldin and Amick 1989:81). Platform and lip are useful analytical tools for identifying mode of production, but are not greatly informative about mobility conditions and decisions.

Obsidian Lithic Analysis

Obsidian is not found in great numbers in assemblages in northwestern Wyoming and is most often found in conjunction with several other material types. Often, obsidian artifacts are in the minority. Roth (2000) suggested that sites where directly procurement brought in the artifacts will have more cores and core reduction debitage than sites with traded obsidian. However, distance traveled may affect the degree of reduction occurring at the source in preparation for material transport. Obsidian from sites close to a source will often be larger in size and have more cortex than obsidian from sites away from the source. As cores or bifaces may be produced for long distance transport, distant sites will frequently have only small non-cortical flakes (Roth 2000), or broken and fragmented bifaces or cores. Regardless of how or why the obsidian was selected for transport, the end result is the cross over of several ecological and social systems. While humans interact with ecosystems at any scale, the more area covered the more systems are crossed and impacted. A simplistic interaction model is presented in Figure 2.1 to show the relationship between lithic source distance and human impacts to social and ecological systems. The further the source, the greater the impact of interactions because more environments and social spheres are being encountered (Figure 2.1).

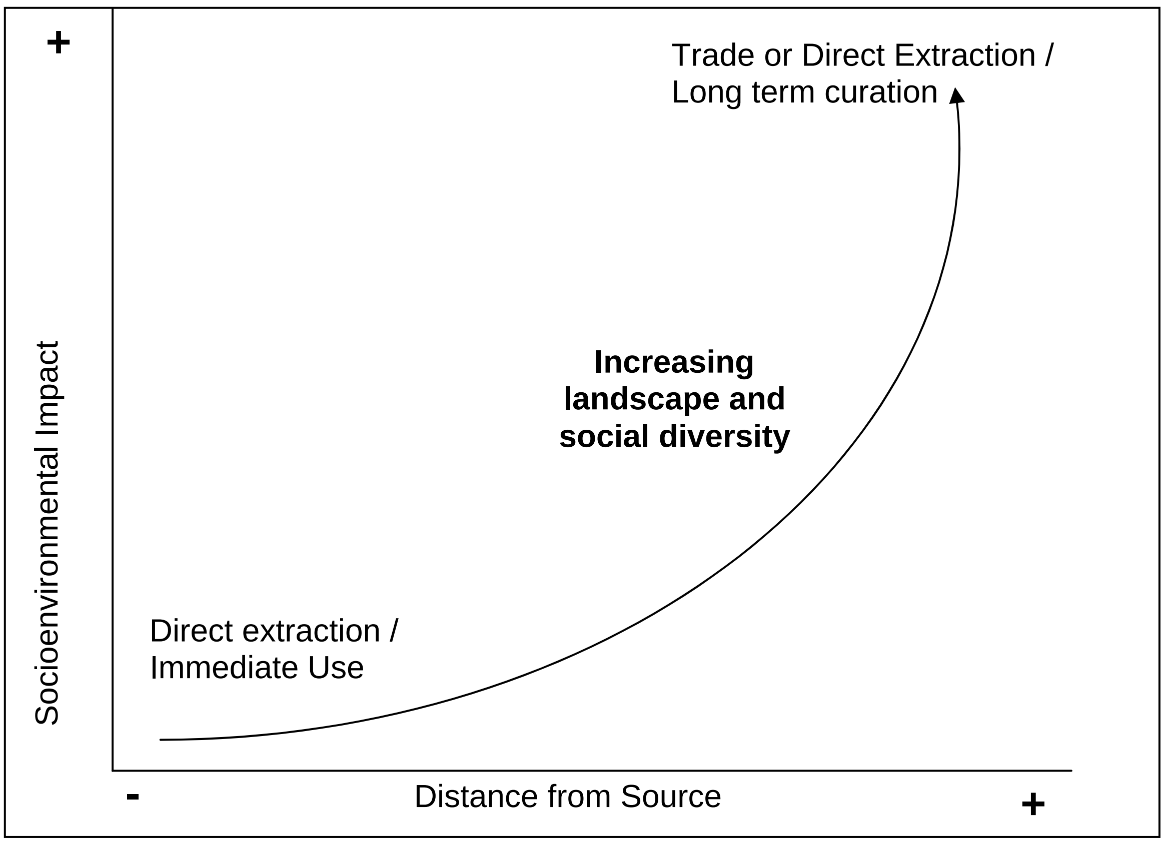

Figure 2.1 Conceptual model of obsidian source distance significance.

The greater the source distance, the greater the likelihood of encountering other social groups. Likewise, the further from a source a piece of material moves, more plants and animals must be engaged as food sources and landscapes as places to inhabitat. Whether trade or direct procurement, obsidian curation in northwestern Wyoming produced an interconnected landscape.

Chapter Summary

A review a hunter-gatherer behavior and how it is reflected archaeologically is germane to the interpretations able to be made from geochemical sourcing results. Foragers will move people to lithic resources and collectors will move curated materials to people. Hunter-gatherers usually fall somewhere between the two extremes, but in general will use patches based on resource productivity. In montane environments, they are more likely to default to risk averse behaviors. As it is difficult to determine whether raw materials have been directly procured or traded, archaeological evidence provides guidelines for evaluating prehistoric mobility ranges, rather than direct analogs for mobility pathways. Aggregate analysis is used to evaluate broad assemblage patterns, while individual artifact analysis is necessary for inquiry that is more specific. The importance to this study is the simple passage of the material across a landscape and what that may imply about how hunter-gatherers were using the land.

CHAPTER 3
Obsidian Source Characterization

Finding the source of obsidian artifacts is a research tool that has been relied upon for nearly four decades. The tool has always been used to reconstruct pathways traversed to obtain the material or to investigate trade routes through which the material traveled. Davis (1972) was the first to combine neutron activation and obsidian hydration to investigate temporal and spatial patterning in obsidian use across several regions on the northwestern plains. Clearly, obsidian source characterization is not a new endeavor, but through the years, the technique has become more accessible and reliable. The information that a source can provide for archaeological investigations is not necessarily straightforward because of the nature of the stone.

Obsidian glass is the result of silicic magma cooling rapidly against air, water, or colder rock after extrusion from a deep source onto the biosphere (Hughes and Smith 1993:80). Obsidian glass is synchronously formed with its sister solid. During the solidification process, some elements are more attracted to the liquid obsidian glass than to the solid (Shackley 2005). "In order to produce aphryric, vitreous obsidian, the melt must have contained a very low H_20 content, or it must have been degassed in some way before eruption" (Shackley 2005:14). The aphryric, vitreous obsidian is the ideal condition for the concoidal fracturing necessary to create chipped stone artifacts. Not all obsidian and volcanic glass is useful for artifact manufacture. Mafic magmas tend to form glasses of poor quality for use as flaked toolstone (Hughes and Smith 1993). Most artifact quality obsidian is rhyolitic in composition and generally free of phenocrysts. The oldest obsidians are typically Cenozoic in age because of the devitrification process (Schmitt 1995:21). Older obsidians are chemically eroded from environmental exposure to a point where the glassy texture is no longer evident.

Obsidian is generally assumed to be homogenous because it is formed as the result of a single igneous event. Each obsidian source has a unique geochemical signature because of the differences in underlying geology in the region the magma was formed (Kunselman 1994:3; Kunselman and Husted 1996:26). Most artifact-grade obsidian is chemically homogeneous within the limits of analytical precision for the elements typically used in provenance studies (Hughes and Smith 1993:80); however, the actual flow may contain several different signatures because of contamination along the margins. The elemental infidelity can create distinct chemical types within one volcanic field or flow (Hughes 1998). This can create problems in interpreting the actual source location where the obsidian was obtained.

First, one must consider what is meant by the term “source”. Throughout this document, the terms “geochemical source” and “geologic source” may be used interchangeable. Technically, the terms describe two separate things. The geologic source is spatially defined by the volcanic field where the stone was derived. The geochemical source refers to portions of the flow that match the same geochemical signature. For the basis of this study, however, the two terms are used interchangeably as the general distance of the source is more important than the exact distance. Additionally, the frequency or pattern of use of the source is more important than the exact distance. The research is designed on a scale to segregate obsidian sources geographically; the pattern of sources used in a region provides information concerning the acquisition and distribution of obsidian (Kunselman and Husted 1996).

Another point requiring attention is the distinction of what the results of the analysis will actually reveal. The data provide a match of the geochemical signature between the artifact and a known geochemical type, not an actual source location. The sources that are discussed in this paper are approximations of chemical signatures. The "source" location may or may not be the exact place from where an artifact raw material was extracted. It is likely that not all potential sources have been identified. During the geochemical analysis, a best fit match is made based on elemental frequencies revealed through the testing. Recognizing this bias and for simplicity sake, this research uses the term "source" as synonymous with "geochemical type" and "geochemical sourcing" with "geochemical characterization", something a geochemist may shudder at.

Identification of obsidian sources is not accurate without the use of geochemical analysis. Color, diaphaneity, inclusions, banding, and similar visible traits can be utilized to group obsidians based on appearance. Several factors affect the appearance of obsidian on the surface of an artifact, making this sort of megascopic classification an unreliable analytical technique (Shackley 2005). Further, different forces have worked to form pieces from the same source. For example, artifact raw material may have been extracted at different points in time resulting in variation in the appearance of the luster. Material from the same flow may have differentially exposed at the source causing different levels of devitrification to the surface of the rock with the same elemental composition. Fire damage to obsidian artifacts has been noted to cause surface oxidation to a silver hue or to cause a dulling of the rock surface (Aaberg 1995:36-37). Heat and dehydration induced exfoliation or spalling may also occur. Potlidding has also been observed on the surface of some obsidian artifacts after exposure to fire (Aaberg 1995).

These are just a few of the reasons why “megascopic” approaches cannot be used to identify sources. Eyeballing obsidian pieces to evaluate provenance is not an easy process and may be impossible with some artifacts. They are useful, however, in forming broad group types. Also, megascopic observations may provide information about site taphonomy after artifact discard, and are therefore useful data to record. Megascopic approaches to classification are usually subjective and difficult to replicate. Shackley (2005:101-105) agrees that it is difficult to assign sources by megascopic analysis with accuracy. Distant sources, those “rare species,” will be missed in this sort of investigation. Geochemical testing is essential for the most accurate determination of the point of origin for obsidian artifacts.

Process of Geochemical Characterization

A detailed review of the processes involved in deriving elemental readings from lithic materials is outside of the scope of this research. The methods are generally reviewed below to provide a cursory explanation of some of the methods used to develop this research. The geochemical sourcing, however, was not directly performed by this researcher and a complete review of the processes involved would require a separate study and title. In other words, this work is not about the process of geochemical sourcing; rather, it uses the process as a tool for evaluating prehistoric land use patterns.

Some of the earliest obsidian sourcing studies in the Great Plains used a technique called neutron activation analysis (NAA) to evaluate the elemental signature of artifacts (Davis 1972; Dixon et al. 1968; Frison et al. 1968). While the process can provide highly accurate results, the technique was not used in this study because it is a destructive technique and it cannot give accurate results for certain elements (Hughes and Smith 1993; Shackley 2005). Several techniques for geochemical analysis, including NAA and x-ray fluorescence (XRF) are used today (Shackley 2005:89). A favored technique for geochemical anaylsis is the non-destructive, energy dispersive x-ray fluorescence spectrometry (edXRF). This process was selected for this research more on the reputation of the practitioner and the non-destructive nature of the test, then on familiarity with the technique.

The edXRF process is not simple. The goal of the process is to evaluate the elemental concentrations in a stone piece. Energy dispersive XRF collects the total range of the energy spectrum at once (Connor and Kunselman 1995:43). Shackley (2005) provides a good general description of the XRF process explaining that:

> *"the atoms in a sample material are irradiated with high-energy primary X-ray photons, electrons are ejected in the form of photoelectrons. This creates electron "holes" in one or more of the orbitals, converting the atoms into ions – which are unstable. To restore the atoms to a more stable state, the holes in inner orbitals are filed by electrons from outer orbitals. Such transitions may be accompanied by an energy emission in the form of a secondary X-ray photon – a phenomenon know as 'fluorescence'" (Shackley 2005:96).*

The fluorescence occurs at energies specific to elements in the sample, appearing at peaks over a given energy spectrum (Davis et al. 1998). It is the intensity of the peak that reveals the elemental concentration. Errors may occur if the obsidian artifact is smaller than the view of the detector. Sample thickness requirements depend on the elements desired for evaluation (Davis et al. 1998). The minimum size requirement of the

Geochemical Research Laboratory is 10mm in diameter and 0.1mm in thickness. It has been considered that the best elemental discrimination among obsidian sources in the northern Rocky Mountains are zirconium versus rubidium, yttrium versus niobium and yttrium versus zirconium (Davis 1995:41). There are many sources in the northern Rockies and not all are relevant to this study; some sources outside of the region are pertinent to this research.

Relevant Sources

Obsidian raw material sources identified using geochemical analysis for artifacts in the study area are reviewed below (Figure 3.1). While the study area is predominately comprised of volcanic substrate, surprisingly no archaeological sources of obsidian have been identified there. Small pebble sized pockets of obsidian have been located in some of the drainages directly to the southwest (Kunselman 1994:8); however, these pockets have not been identified or associated with any archaeological contexts. The closest potential sources to the study area are located the volcanic fields to the northwest and west. The fields along the Snake River Plain through the Yellowstone Plateau are on a track that has shifted over the last 15 million years as the North American plate moved across a hot spot (Pierce and Morgan 1992). The Yellowstone hot spot has been roughly stationary under the plateau for nearly 600 thousand years (Kunselman 1994:3) creating the Cenozoic volcanism and obsidian formation in the modern park.

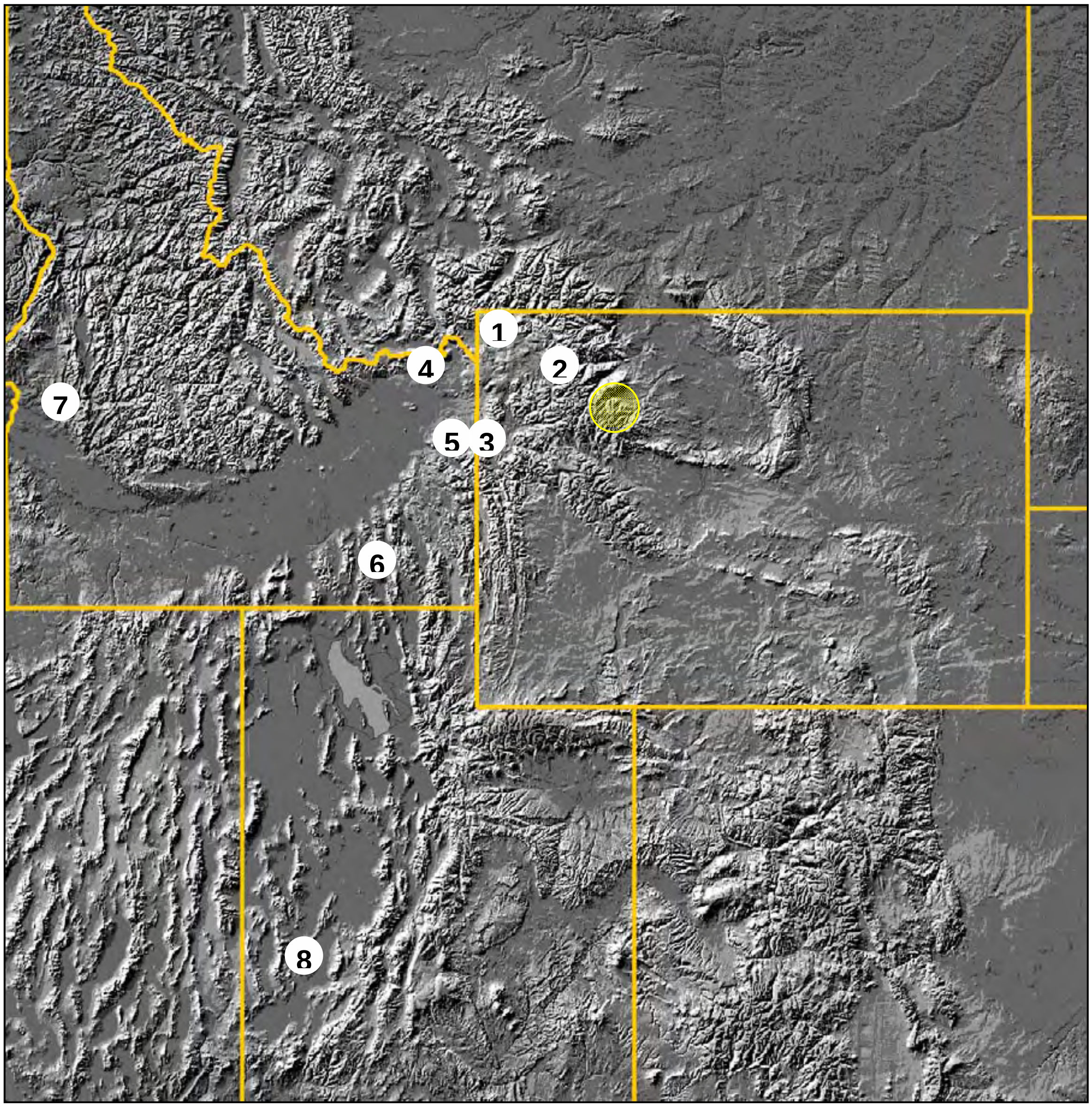

Figure 3.1 Sources of obsidian relevant to this study with project area highlighted. 1. Obsidian Cliff; 2. Park Point; 3. Teton Pass, Crescent H; 4. Bear Gulch; 5. Packsaddle Creek, 6. Malad; 7. Timber Butte; 8. Wild Horse Canyon.

Many of the sources explained in this chapter are the sites of prehistoric lithic quarries, while some represent geochemical type groups that are commonly found scattered around an area. The sources correspond to geochemical signatures, but the location where an artifact actually originated is obscured by several factors. Specifically in many areas, secondary deposits and residuals from ash-tuffs may be underreported because of propinquity to more prominent features. Secondary deposits are often the result of glacial modification to a flow surface. They can, however, be the result of the devitrification process.

A number of obsidian sources are found throughout the region (Figure 3.1). The sources reviewed herein are as follows: Obsidian Cliff, Wyoming; Park Point, Wyoming; Teton Pass, Wyoming; Crescent H, Wyoming; Bear Gulch, Idaho; Packsaddle Creek, Idaho; Malad, Idaho; Timber Butte, Idaho; and Wild Horse Canyon, Utah. The data on the sources are based on research from disparate sources. The sources themselves are often called by several different names (Table 3.1), which can add to the difficulty in obtaining information about the nature of the raw material outcrop. Not all are considered major sources; Park Point and Packsaddle Creek have only minor archaeological evidence supporting their prehistoric use. A few additional sources are discussed briefly.

Table 3.1 Distances to Major Sources Referenced in this Study

Obsidian Source	Distance from GRSLE*	Also referred to as	Location Reference
Bear Gulch	217 km	Big Table Mountain, Camas-Dry Creek, Centennial Mountains, F.M.Y. 90 Group, Spring Creek, Warm Creek Spring, West Camas Creek	Obsidian Lab 2006
Crescent H	137 km	Teton Pass Variety 2, Fish Creek – 2	Schoen 1997
Malad	304 km	Wright Creek, Oneida, Hawkins	Obsidian Lab 2006
Obsidian Cliff	140 km	F.M.Y. 150 Group, Yellowstone Cliff	Obsidian Lab 2006
Packsaddle Creek	162 km	Pack Saddle	Nelson 1984
Park Point	87 km		Obsidian Lab 2006
Teton Pass	142 km	Fish Creek – 1, Fish Creek/McNeely Ranch, Mosquito Creek, Phillips Ridge	Schoen 1997
Timber Butte	560 km	Squaw Butte, Webb Creek	Obsidian Lab 2006
Wild Horse Canyon	685 km	Mineral Mountain Range, Negro Mag Wash, Ranch Canyon, Schoo Mine, Wildhorse Canyon	Obsidian Lab 2006

** Distances calculated from E631447, N4876786 WGS84; the average of all recorded GRSLE chipped stone artifacts.*

The distance between sources and the location individual artifacts were found is difficult to approximate. An exact location where a piece of raw material came from at the source is unknown. Further, the actual distance an artifact traveled to its final resting place is contingent on several indeterminate factors. For the purpose of this study, the relative linear distance (as the crow flies) of a source from the study is figured using a center point for the study area and reported locations of the sources. Distances in Table 3.1 were calculated using the Forward/Inverse© software with the reported locations in

Latitude/Longitude in WGS 84 datum. The Park Point source, located on the eastern side of Yellowstone Lake, is the closest source to the study area. The source, however, is not greatly significant to the region's archaeology. Obsidian Cliff, Teton Pass, and Crescent H are the all approximately the same distance from the study. Timber Butte and Wild Horse Canyon respectively are the most distant from the study area.

Obsidian Cliff

Obsidian Cliff in Yellowstone National Park is one of the most well known obsidian sources in North America. Archaeological research on geochemical patterns of the source have a long history (Wright and Chaya 1985). The Obsidian Cliff flow plateau is located within the Yellowstone rhyolite plateau, an extensive and complex volcanic feature. It is one of the largest Quaternary siliceous volcanic fields on earth (Schmitt 1995). The flow that produced Obsidian Cliff is just over 183,000 years old, covers approximately 14.5 km^2, and is estimated to be 30m thick (Schmitt 1995:20). According to Schmitt (1995), the flow responsible for Obsidian Cliff filled a preexisting valley, rapidly chilling against the old valley wall now exposed as west-facing Obsidian Cliff. Most of the top of the Obsidian Cliff flow is covered by a thin mantle of rubble in loose, fine grained matrix, mostly derived from the frost weathering of local bedrock (Schmitt 1995:20).

The notoriety of the source is largely due to the tourist attention received at the prominent feature of the park. The source has also received attention because of the far reaching influence in the prehistoric world. Obsidian Cliff artifacts have been identified at distant archaeological sites in Iowa (Anderson et al. 1986), Oklahoma (Baugh and

Nelson 1988) and on the eastern side of the Mississippi River including material in Illinois (Hatch et al. 1990; Hughes 1992). The general trajectory of the spread of Obsidian Cliff materials is in all azimuthal directions except south west of the source (Davis 1995:Figure 19). This is most likely because of the rich availability of volcanic glasses throughout the Snake River Plain in modern day Idaho. The Obsidian Cliff locality is the site of several smaller quarries and workshops (Davis et al. 1995: Appendix C).

The quality and the characteristics of the obsidian associated with this geochemical type are wide and varied. Generally, Obsidian Cliff materials are thought to be high quality and consist of mainly black obsidians. The geochemical variety also occurs just to the north of the cliff in the Crystal Springs Flow (Hughes 1998). The geochemical obsidian type is deposited in several areas around the Obsidian Cliff feature. At approximately 140 km from the center of the GRSLE study area, the prominent feature is predicted to play a role in the prehistoric record. Other, distinct Yellowstone Plateau obsidians are germane to the study.

Park Point

Again, not all of the sources in the region are primary deposits. The Park Point source is a small exposure of secondary volcanic glass nodules identified by National Park Service archaeologists on the eastern shore of Yellowstone Lake (Hughes, personal communication 2005). The obsidian is a poor-grade volcanic tuff (Johnson 2001), likely ignimbrite. The distribution of the material from this location is not well known. Material from this location ranges from black to red, is opaque, and may have white crystalline inclusions (Johnson 2001:86). At just under 90 km from the study area, this could have proved a valuable, expedient raw material source for prehistoric people passing by the large lake.

Teton Pass

The Teton Pass source is located in the mountains to the west of Wilson, Wyoming. The obsidian deposits in the Jackson area are highly complex and diversified as many have only been identified in secondary glacial deposits. The Teton Pass type site is a primary source location also known as Love Quarry, after the renowned Wyoming geologist (Hughes and Cannon 1997). This geochemical type has also been referred to as Fish Creek Variety 1, when identified in secondary deposits to the east of the main feature. The main source of the Teton Pass obsidian referred to in geochemical analyses is a volcanic vent (Schoen 1997:218). The high altitude feature, at an elevation of 2743 m, is found immediately south of Teton Pass (Schoen 1997:218). This geochemical group is found at other locations in the Jackson Hole area, most likely as the result of secondary deposits (Schoen 1997).

The main source is easily accessible and well known today. Schoen (1997) indicated that, over the years, the source was looted by recreational users. As a result, the archaeological preservation is not representative of the prehistoric condition. Evidence of pit quarrying is clear at the main source site. The material from the source often has a smoky, translucent appearance. Some pieces are banded, some extremely clear, and some have mahogany inclusions (Schoen 1997:218). The source is located approximately 142 km to the west of the GRSLE project area.

Crescent H

The source known as Crescent H was identified from deposits in a modern day Crescent H subdivision just south of Wilson, Wyoming (Schoen 1997:221). Crescent H is just a few kilometers east of the Teton Pass main source, and is at a lower elevation. Both Crescent H and Teton Pass geochemical types are found at the Fish Creek locality just a few kilometers to the north of this source, leading to much variability in the naming of these sources. Obsidian from this locality is geochemically similar to the Teton Pass Variety 2 or Fish Creek variety 2 (Hughes and Cannon 1997). The Fish Creek Second Variety and the Teton Pass Variety 2 are the same geochemical types. For the purpose of this study, since all these geologic sources are located so close, both are assigned to the Crescent H source designation.

The source has no distinct quarry, rather is marked by distribution of small gravels and pebbles secondarily deposited in a mix of other glacial deposits. "Tested and split cobbles and reduction flakes can be found scattered throughout the area, suggesting extensive procurement from these secondary deposits" (Schoen 1997:221). As with the Teton Pass source, modern land use has confounded the prehistoric state. The GRSLE study area is approximately 137 km to the east of this source. The Crescent H type is megascopically common in smokey, banded appearance and often has mahogany inclusions (Schoen 1997).

Packsaddle Creek

A little reported, but important source is the Packsaddle Creek obsidian. The source is located in Idaho around the Packsaddle Lake and Packsaddle Creek in the

Targhee National Forest (Nelson 1984). Artifacts from the source are found in the Yellowstone National Park assemblage (Sanders 2001). The location also provides obsidian to sites in the Great Basin (Nelson 1984). Packsaddle Creek is not mentioned in a large report about the archaeological significance of eastern Idaho sources (Holmer 1997). At a linear distance of 162 km, the source is not much farther from the study than the Jackson area obsidian types.

Bear Gulch

The source known as Bear Gulch is located in the Centennial Mountains of Idaho, just south of the Montana border. The source is among the most common obsidian type in the region and was originally assumed to be from an unknown location within Yellowstone National Park (Wright et al. 1990). Big Table Mountain is another name attributed to this geologic source. There may be "unknown sources of this geochemical type on the northern as well as southern sides of the Centennial Mountains" (Baumler 1997:155). This possibility requires further study. Additionally, Baumler (1997) indicated the presence of local ash-flow tuff obsidian deposits in the nearby Centennial Valley that currently appear to yield distinct but variable geochemical profiles. Willingham (1995:3) characterized the source as boulder and cobble deposits. Consequently, the material produces more artifacts with remnant cortex (Baumler 1997:148).

Baumler (1997) recognized megascopic variation in a sample of obsidian from different sources. He observed obsidians in his sample that had been geochemically traced to the Bear Gulch source were "always opaque and jet black at any thickness"

(Baumler 1997:153). The source is located approximately 220 km from the center of the GRSLE project area.

Malad

Also referred to as Wright Creek, the source near Malad, Idaho is a secondary deposit in an alluvial setting (Schoen 1994). Obsidian from the Malad source is distributed at sites distant from this location, as far to the east as Arkansas and as far south as southern Texas (Thompson 2004). The Malad source is well referenced in the sourcing literature; however, information on the nature of the geologic deposit is not readily available. The primary context of the obsidian flow is unknown. The material from the source is of high quality, but it has been indicated that there are questions regarding the homogeneity of the chemical composition (Schoen 1994). This is most likely because it is found in secondary deposits. The source is located just over 300 km from the research locale. If distance alone determined proclivity toward obsidian, this source would not be predicted to be found in large numbers in the GRSLE assemblage.

Timber Butte

Timber Butte is located in western Idaho in Boise County along the eastern margin of the Snake River Plain. The source location is listed in the Idaho source literature (Holmer 1997; Northwest Research Obsidian Studies Laboratory 2005), but information regarding the context of the deposit may only be found in difficult to obtain “gray” literature. The nature of the source is not known to this researcher. Most pertinent to this research is the location, which is 560 km from the GRSLE project center.

Distribution of this obsidian type is likely more common in western Idaho and eastern Oregon or Washington states.

Wild Horse Canyon

The Wild Horse Canyon source is located in the Mineral Mountains in southwestern Utah (Lipman et al. 1978). The source yields large areas of artifact grade obsidian in a primary context. The Cenozoic eruption of Wild Horse Canyon flow produced dense black obsidian along the base of the flowline (Lipman et al. 1978). Large blocks up to 0.5 m of the toolstone have been identified. The archaeological significance of this source is greater in the Great Basin and the Southwest than in northwestern Wyoming. The source is the most distant identified in the GRSLE assemblage at 680 km linear distance.

Other Regional Obsidian Sources

The obsidian sources and geochemical varieties listed in this chapter are only a few of the regional types. While Obsidian Cliff is the most well known source within the modern boundaries of Yellowstone National Park, the feature is not the only volcanic flow that produced artifact grade obsidians (Cannon 1996; Hughes and Cannon 1997). All around the Park, remnant flows are exposed in primary and secondary obsidian outcrops (e.g., Cougar Creek, Grassy Lake, etc.). The prehistoric significance of many of these sources is not great. There are many obsidian sources throughout the modern state of Idaho. The Snake River Plain is bordered with secondary and primary obsidian source areas. Sources of obsidian have been found as water worn pebbles in areas of southwestern Wyoming along the Green River (Thompson and Pastor 1997; Kunselman 1998).

While XRF analysis can identify the provenance of most artifacts, it works on known sources whose geochemical constituents have been evaluated. Because of the extensive nature required of the geochemical signature database, “unknowns” occasionally occur in the geochemical analysis field. Sometimes these unknowns may be similar to a source type, but vary enough to warrant doubt about the affinity.

Chapter Summary

Geochemical characterization of obsidian artifacts is a merely a tool used in this study. A complete review of the process and sources herein would be out of the scope of this research. Nonetheless, the process has been employed to establish a series of geologic and geochemical source locations that are important to the archaeology of northwestern Wyoming. The key sources are Obsidian Cliff, Teton Pass, Bear Gulch and Malad. All of the known sources are located to the west (northwest or southwest) of the GRSLE study area. Small sources may exist elsewhere, but do not contribute significantly to the region’s archaeological record.

CHAPTER 4
Regional Obsidian Patterns

Northwestern Wyoming and adjacent lands have a rich prehistoric record. While the presence of obsidian is frequently reported, geochemical analysis is rarely done and even more seldom reported. While many factors including time and finances may impinge on geochemical characterization of artifacts, the result is a fragmented regional database that is difficult to compare for broader prehistoric land use patterns. Evaluating regional patterns in prehistoric obsidian artifact distribution at sites surrounding the study area is a fundamental component of modeling the prehistoric relationships between land use in and around the Upper Greybull drainage. As might be expected, sites closer to obsidian sources will typically have more artifacts manufactured in obsidian than sites further from a source (Schoen 1994).

Following is a description of several sites and study areas surrounding the Upper Greybull project area. The areas vary in land size, assemblage size, and temporal affinity. No two studies were conducted in identical styles. The reports did not all contain the same components of analysis. The information garnered from these regional examples was directed toward information useful to this study. Review may therefore seem to contain disparate units, but an attempt to tie them together follows. Regional comparatives were selected based on significant obsidian patterns, proximity to study area and accessibility of the report.

An attempt was made to select sites and study areas that surround the GRSLE study area (Figure 4.1). The reported obsidian patterns at the following four sites are reviewed: Boulder Ridge Sheep Trap; Mummy Cave; Laddie Creek; Helen Lookingbill. Six large studies were selected as comparisons for the GRSLE obsidian project including Yellowstone National Park, the Jackson Lake Archaeological Project, the Beartooth Alpine Archaeological Project, the Flying D Ranch Archaeological Project, and the Bridger-Teton National Forest (not shown in Figure 4.1). While not all of the sites and regional studies below are used in later analysis, they all inform the regional synopsis and are useful for background development.

Regional Sites

Boulder Ridge (48PA781)

Obsidian artifacts from Boulder Ridge have not been geochemically sourced to date (Eakin personal communication 2005). Initial lithic analysis from the site has revealed a number of obsidian artifacts, including flakes, bifaces and core fragments that are relatively large in size (Finley et al. 2004). Many of the obsidian pieces have reportedly retained portions of the rhyolitic cortex (Finley et al. 2004). It is generally assumed that most of the artifacts from this site are associated with the Obsidian Cliff quarries as this is the closest abundant source of obsidian raw material. The pattern of obsidian artifacts indicates that the artifacts were not curated for long periods of time prior to discard at this location.

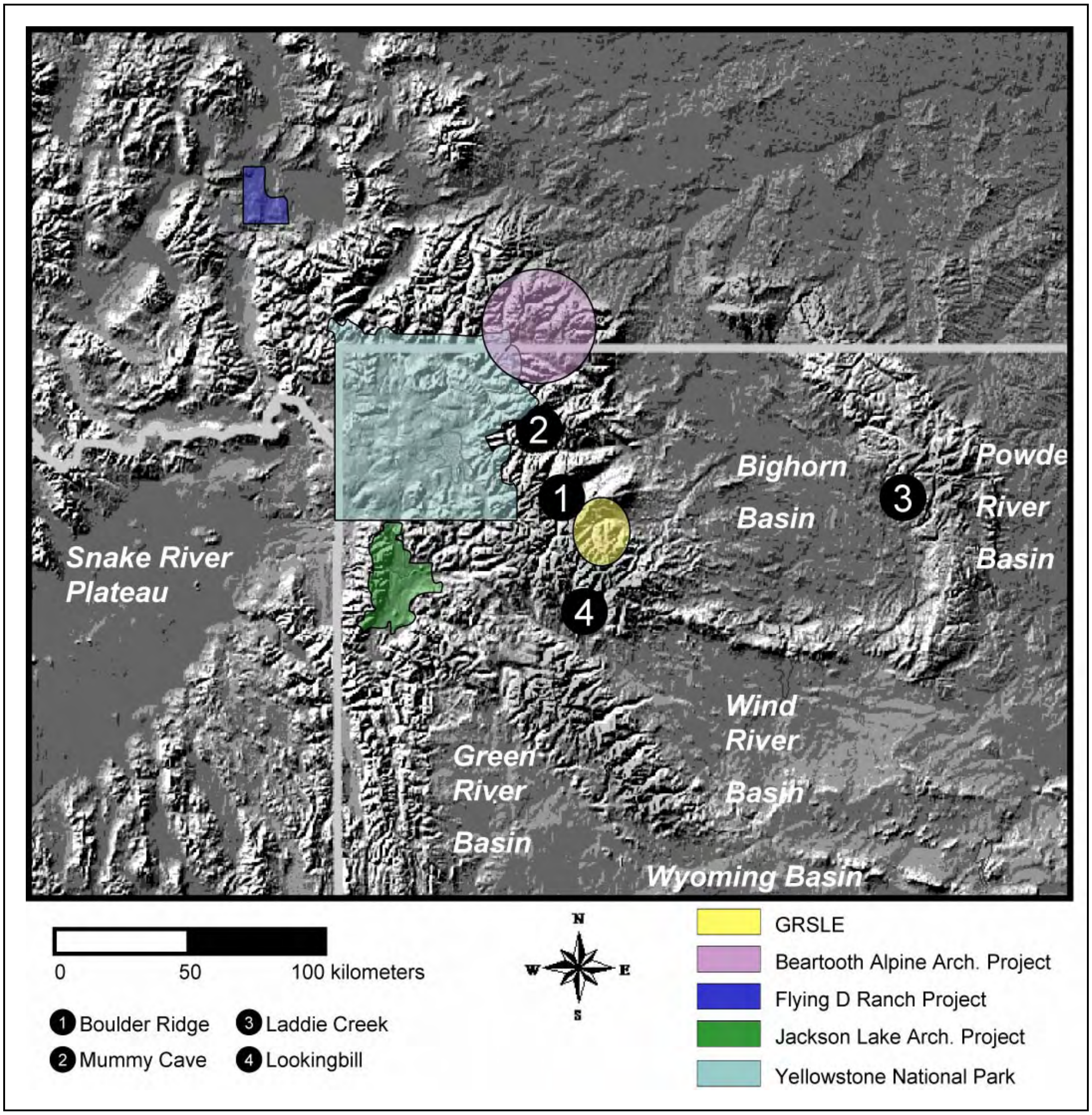

Figure 4.1 Regional sites and study areas discussed in this report. Individual sites.

Laddie Creek (48BH326)

The Laddie Creek site is a multiple level Early Archaic site located in the western foothills of the Bighorn Mountains (Figure 4.1). A small percentage, less than 1%, of the entire chipped stone assemblage was manufactured using obsidian (Larson 1990). Three obsidian artifacts were sourced using XRF. The results indicated two came from

Obsidian Cliff and one from Bear Gulch (Larson 1990:159). It is unclear from the reported data whether the sourced artifacts were proximate or even the same level in their archaeological context.

The small percentage of obsidian matches the pattern seen in many basin sites (Thompson and Pastor 1997). Sites in the basins of Wyoming exhibit less obsidian artifacts than the sites in the mountains. Smith (1999) found that most of the basin sites in southwestern Wyoming were using the Idaho sources more heavily than Obsidian Cliff.

Mummy Cave (48PA201)

The Mummy Cave site is one of the earliest reported geochemical sourcing results in the region. Davis (1972:Table 8, Appendix VII) presented the results of neutron activation source analysis of 52 obsidian artifacts from Mummy Cave. Most of the assemblage was affiliated with the Obsidian Cliff source, but Teton Pass obsidians were also identified. The site has recently been retested as there have been considerable refinements in analytical instrumentation and the inventory of regional obsidian sources has become much better known since the original report (Hughes 2001). Additionally, not all of the obsidian artifacts were included in the early sample. Obsidian was not one of the predominate materials in the Mummy Cave assemblage. Much of the obsidian from throughout the stratigraphic profile comes from Obsidian Cliff source, however, patterns of variability in sourced materials is evident through time (Hughes 2001). According to Hughes (2001), the general trend is a move from a broad obsidian base in the earliest cultural levels to a tighter, more local obsidian base in recent levels. Specific results of the paper are not reviewed here by request of Hughes as refinement of the research is currently underway and pending publication (Hughes personal communication 2005).

Lookingbill (48FR308)

The Lookingbill site is located to the southwest of the GRSLE project area in the southern extent of the Absaroka Mountains. The location is at an elevation of 2621m and is located at a lithic quarry; nonetheless, exotic obsidian materials were found in excavations (Kornfeld et al. 2001). Lookingbill has many similarities to sites in the GRSLE project area with the exception that much of the site assemblage came from stratified excavations. Overall, obsidian artifacts comprise approximately 1% of the total chipped stone assemblage (Larson et al. 1995). Obsidian utilization was concentrated in the Late Archaic components of the site (Kunselman 1994:2). Researchers at the site concluded that dramatic increase of obsidian “in the Late Archaic may reflect greater mobility of the Lookingbill inhabitants” during this time (Kornfeld et al. 2001:318).

Kunselman (1994) evaluated 137 obsidian artifacts from the Lookingbill assemblage. The Bear Gulch source was the most frequently observed (55.5%) and also the farthest source from the site at 215 km straight line distance. The least frequent sources were also the closest linear distance, Teton Pass sources comprising 18.2% of the assemblage. Obsidian Cliff, at 165 km linear distance from Lookingbill was used for 26% of the obsidian artifact source material. It seems that there may have been some preference for the Bear Gulch source by users of this site.

Regional Studies

Yellowstone National Park Sites

The Park itself covers 8,987 km^2 so it is difficult to provide a detailed summary of the patterns here (National Park Service 2004) (Figure 4.1). Yellowstone witnessed the most intensive use during the Late Archaic period with the Pelican Lake projectile point the most recorded type in the park (Johnson 2001:82). The Late Prehistoric period also saw considerable use in the area (Johnson 2001). Obsidian is the dominant lithic type "north and west of the Yellowstone Lake, but frequencies drop-off rapidly to the east and south" (Reeve 1989:58). This is likely related to increasing distance from the dominant Obsidian Cliff source located northwest of Yellowstone Lake.

Artifacts associated with Obsidian Cliff dominate the obsidian artifact provenances (Johnson 2001). Bear Gulch is the second most frequent reported source for obsidian artifacts. Teton Pass, Crescent H, Packsaddle, Timber Butte, and Malad obsidians have also been identified. According to Johnson (2001), raw material analyses indicate that people living on the south shore of Yellowstone Lake had territories to the south into Jackson Hole and southwest into Idaho, while groups occupying the northwest area of the park had greater relationships with the west and north. Further disparity in obsidian distribution was explained by Sanders (2001). He described that the Hayden Valley area (in the northeast of the park) has the highest percentage (86.3%) of Obsidian Cliff obsidians while the north shore and West Thumb of Yellowstone Lake have lower percentages (80.0% and 55.6% respectively) (Sanders 2001:215). The pattern leads Sanders (2001:215) to suggest "the movement of peoples was along the Yellowstone River, through the Hayden Valley, and on toward Yellowstone Lake. The lower percentage of Obsidian Cliff obsidian at the West Thumb sites suggests that the movement of peoples from the Obsidian Cliff source area was more indirect". The pattern does follow a predicted decrease of materials as distance increases and an indirect route between the two points is likely given the tendency of embedded procurement.

The Bear Gulch and Teton Pass sources are nearly equidistant from the West Thumb, but Bear Gulch obsidian is more frequently present (Sanders 2001). As the pattern is similar in the Jackson Hole area, where Bear Gulch is also more prevalent than Obsidian Cliff obsidian (Schoen 1997), Sanders (2001) suggests there was some sort of boundary or obstacle that prevented people from accessing the Jackson Hole sources directly through southern Yellowstone. Alternatively, he suggests that the limited amount of Teton Pass or other Jackson Hole obsidians may reflect a low prehistoric presence in the source areas.

The Osprey Beach site, a Paleoindian site on the shores of Yellowstone Lake, provides insight to eastward movement during that period of time. The site contains several artifacts constructed of a dark green chert (probably comparable to the materials labeled Irish Rock chert in the GRSLE project area), considered to be derived from Absaroka Mountains (Shortt 2001:234). According to Shortt (2001), the site also has several artifacts constructed from Obsidian Cliff obsidian that are poorly made. In comparison, the dark green chert specimens are in better condition. Shortt concludes that the inhabitants of the site were less concerned with curating obsidian knives than with maintaining the integrity of the green chert specimens because of the high availability of the obsidian.

Obsidian Cliff dominates as the major source for obsidian artifacts in the existing park boundaries, yet the material is not distributed uniformly throughout the park. Additionally, obsidian may not have been considered as a highly valuable resource at all times in this area.

Beartooth Mountains

To the north of the Absaroka range lies the Beartooth Mountains of southcentral Montana and northwestern Wyoming. Kunselman and Husted (1996) sampled 377 obsidian artifacts, including 107 projectile points, from private and National Forest collections. The frequency obsidian occurs as a raw material in the Beartooth Mountains was not addressed in the study. Using XRF analysis, the major sources were Obsidian Cliff (79%), Bear Gulch (9%), Malad (3%) and Fish Creek (1%). The percentages changed slightly when evaluating a technological subsample. They were able to determine that 72% of the projectile points were coming from Obsidian Cliff, the closest source (Kunselman and Husted 1996). The second major source was Bear Gulch where 15% of the obsidian was formed; the third was Malad in which 6% of the sample was derived. They also determined that obsidian from Fish Creek variety 2 (geochemically similar to Crescent H) and two central Idaho sources, Owyhee and Browns Bench were each found in 1% of the projectile points.

The study revealed that while the closest source was used most frequently, distance from the source is not the only indicator of source frequency in the assemblage. The Fish Creek source, while closer, was used less frequently than the more distant Bear Gulch and Malad sources. Further, the study revealed that during all periods or cultural affiliations represented, Obsidian Cliff was the most frequently used source for projectile point obsidian (Kunselman and Husted 1996:Table 1). Slight differences occur as Bear Gulch appears to have been used more frequently in the Late Prehistoric period than other periods (Kunselman and Husted 1996:Table 2).

<u>Jackson Lake Archaeological Project</u>

The project reported by Connor and Kunselman (1995) was located directly to the west of the GRSLE project area throughout the Grand Teton National Park (Figure 4.1). Here, they found obsidian was the primary toolstone used for projectile point manufacture likely due to the proximity of reliable sources. Obsidian also dominates the debitage assemblage. A surprisingly small number (44 of 36,836 artifacts) of obsidian cores were identified in the study. The Middle Archaic period saw the greatest use of obsidian for projectile points as 85% of the Jackson Lake projectile points of this affinity were produced of this material. The Late Archaic also reflects a strong affinity (73%) for this material in the manufacture of projectile points.

Connor and Kunselman analyzed 81 obsidian projectile points using XRF analysis. Obsidian Cliff was used most frequently during the Middle Archaic period (Connor and Kunselman 1995:47) and this appears to have been the preferred obsidian source for the period. The closer Teton Pass varieties were favored during all other periods. Use of the Obsidian Cliff did constitute over 20% of the projectile points from the Early Archaic and Late Prehistoric times. Bear Gulch constituted an important source during both the Late Paleoindian and Late Prehistoric Period. As all of the points from the Late Prehistoric period came from either Obsidian Cliff, Teton Pass or Bear Gulch, Connor and Kunselman (1995:47) suggested this may indicate a more circumscribed territory than used by earlier groups.

Flying D Ranch

This project area was located in southwestern Montana to the northwest of Yellowstone National Park and west-southwest of Bozeman (Figure 4.1). Baumler (1997) reported obsidian comprises 2.4% of the lithic assemblage recorded in the area. A sample of 214 obsidian artifacts was evaluated for the geochemical source using XRF technology. The investigation revealed that 63% was from Bear Gulch, 36% from Obsidian Cliff, and less than 1% each from Timber Butte and Malad. Baumler (1997:146) also observed that sites with obsidian did not “exhibit a higher proportion of retouched pieces nor do they seem to have more formal tools when obsidian is excluded from the count”. Obsidian bearing sites in this study were not characteristically different from other assemblages, and likely do not represent a different occupation.

Baumler (1997:147) noted the Bear Gulch source may have been preferred because it is more easily accessible from the Madison River valley. During the Paleoindian period, Obsidian Cliff obsidian is the only geochemical type represented in this sample (Baumler 1997:Table 5). At all other identifiable periods, it appears that the Bear Gulch source was favored. Other studies in Montana have shown a preference for Bear Gulch obsidians throughout the state (Davis et al. 1995:48).

Bridger-Teton National Forest

The Bridger Teton National Forest conducted analysis on 34 projectile points discovered as surface finds throughout the management area (Schoen 1994). The region, not illustrated on Figure 4.1, encompasses approximately 13,800 km^2. The forest extends south from Yellowstone National Park and along the eastern boundary of Grand Teton National Park. The boundary follows the western slope of the Continental Divide to the southern end of the Wind River Range and extends southward encompassing the Salt River and Wyoming mountains near the Idaho border. Surrounding Jackson Hole, it is no surprise that 47% of the projectile points analyzed came from these obsidian sources. Interestingly, only a small percentage of 9% came from Obsidian Cliff and Bear Gulch. Malad was the source for 29% of the artifacts in the study and most frequently represented in the Late Prehistoric sample. The increased use of Malad obsidian "during the Late Prehistoric period would indicate that there was greater movement between western Wyoming and southeast Idaho then during previous time periods" (Schoen 1994). Again, this pattern is observed in the Green River Basin that is straddled by the Bridger-Teton National Forest area (Smith 1999; Thompson and Pastor 1997).

Regional Synopsis

While some diversity is seen between specific prehistoric times, a general pattern of land use can be delineated from the data herein. Directly north of the GRSLE study area, there appears to be a preference for Obsidian Cliff obsidian. Idaho sources play a minimal role in the northern extent of the Absarokas and the Beartooth Mountains. Montana sites generally favored obsidian from the Centennial Mountains. South and west of the project, a strong proclivity for Bear Gulch and Teton Pass obsidians is evident. With this, the project is placed in the middle of two distinct spatial patterns.

The Paleoindian period is not well represented in the regional record and does not exhibit great obsidian use. Little information about obsidian use in the Early Archaic can be inferred from the references. The Middle Archaic was significant in the Teton Mountains, when the connection to Obsidian Cliff was greatest. The Late Archaic period appears to be significant for obsidian use in the southern Absarokas and the Yellowstone National Park area. The Late Prehistoric period saw a more broad use of obsidians in some areas, while in others a preference for southeastern Idaho sources was apparent.

CHAPTER 5
Project Area Results

This chapter is a presentation of the results from analysis of obsidian artifacts discovered in the areas surrounding the Upper Greybull River. First, the data collection methodology is reviewed. Second, aggregate analysis of all obsidian in the 2002-2005 project database is presented to establish the baseline for evaluation. Next, specific results are presented on the analysis of the sample selected for geochemical characterization. The geochemical sample results section includes the provenance results and results of the lithic analysis reported for individual artifacts, site specific and drainage specific patterns. Finally, the data from the GRSLE research area are integrated with the broader regional patterns outlined in Chapter 4.

Data Collection Methodologies

Throughout the Upper Greybull watershed, stone artifacts are scattered creating a record of prehistoric human activities on the landscape. Surveys were conducted as part of the GRSLE project between 2002 and 2005 to record the lithic scatters and associated sites. The goal of the survey was not to create a complete inventory, but rather to sample the archaeological landscape. Sites are often identified and recorded along high traffic corridors such as trails in order to create a baseline for understanding recreational impacts to the landscape. Logically, we must survey, and have, off-trail corridors in order to accurately sample the prehistoric record. Most of the areas sampled, remain those easiest to get to and happen frequently along the gentle slopes of drainages or saddles. High altitude areas and difficult terrain have been surveyed and some sites have been recorded in these areas as well. As the landscape has not changed drastically in the last 13,000 years, it is safe to assume prehistoric people would have used the "easy" travel corridors more intensively than those difficult to traverse.

The GRSLE database is composed of scattered surface observations and mostly palimpsest sites. The initial phases of the GRSLE project have developed inventories to provide data on surface artifact assemblages and an assessment of the potential for buried components. The obsidian research took place over two years and involved both a field and a laboratory component.

Field Methods

The field portion of this research was imbedded in the data collection methodology of the GRSLE project. Artifacts were encountered during archaeological survey, and obsidian pieces were evaluated for collection. Several survey types have been employed in delimiting site boundaries. Survey included 5-meter spacing, 2-meter spacing, random encounter (noodling), and multiple scale imbedded survey plots, depending on the specific site needs. All artifacts proveniences were recorded using uncorrected handheld GPS receivers (Garmin© 12XL® in 2002 and Wide Area Augmentation System (WAAS)-enabled Garmin® Rino 110 and 120 in 2003 through 2005), sub-centimeter GPS (Sokkia© Locus®) or an EDM (electromagnetic distance measurement) total station (Sokkia© Set 4B®).

As the GPS handheld units can have up to a 5-meter error, collection of obsidian artifacts in 2004 included leaving behind a marker to identify the exact location from where the artifact was taken. Notes were also recorded in the author's field book in 2004 to help identify the microenvironment where the piece was taken. During 2005 season, a second provenience was taken on all collected artifacts using the sub-meter GeoXT™ handheld from the Trimble® GeoExplorer®. A goal of the project is to return the artifacts to their locations when all analyses are completed. Several attributes were recorded on every chipped stone artifact in the field including: tool element or type, presence/absence of platform, color, thermal modification, maximum length, width, thickness, and cortex coverage.

Laboratory Methods

The laboratory component of this project was twofold: geochemical analysis and reclassification of lithic analysis. In order to accurately identify source locations, a large database of source geochemical signatures must be consulted. A database and edXRF equipment were not readily available to the researcher, so artifacts were sent to the Geochemical Research Laboratory to perform this portion of the investigation. Geochemical characterization was performed by Richard Hughes at the Geochemical Research Laboratory in the following fashion:

> *"…on a QuanX-ECTM (Thermo Electron Corporation) edxrf spectrometer equipped with a silver (Ag) x-ray tube, a 50 kV x-ray generator, digital pulse processor with automated energy calibration, and a Peltier cooled solid state detector with 145 eV resolution (FWHM) at 5.9 keV. The x-ray tube was operated at differing voltage and current settings to optimize excitation of the elements selected for analysis. In this case analyses were conducted on all specimens for the elements rubidium (Rb Kα), strontium (Sr Kα), yttrium (Y Kα), zirconium (Zr Kα), and niobium (Nb Kα), while certain artifacts required additional analysis of the elements barium (Ba Kα), titanium (Ti Kα), manganese (Mn Kα) and total iron (Fe_20_3). Iron vs. manganese (Fe Kα/Mn Kα) ratios also were computed for some specimens. X-ray spectra are acquired and elemental intensities extracted for each peak region of interest, then matrix correction algorithms are*

applied to specific regions of the x-ray energy spectrum to compensate for inter-element absorption and enhancement effects. After these corrections are made, intensities are converted to concentration estimates by employing a least-squares calibration line established for each element from analysis of up to 30 international rock standards certified by the U.S. Geological Survey, the U.S. National Institute of Standards and Technology, the Geological Survey of Japan, the Centre de Recherches Petrographiques et Geochimiques (France), and the South African Bureau of Standards" (Hughes 2004).

Upon completion of the source testing, a reclassification of the lithic attributes was made in order to ensure continuity in identification. Additionally, traits not recorded during the field component were evaluated at this time. These traits include: weight, platform metrics and attributes, presence or absence of a lip, surface luster, and dorsal ridge appearance.

Aggregate analysis of the GRSLE dataset is based on the primary data collected on site during the field research. Individual artifact analysis was specific to the geochemical source sample. The results of this study are reviewed below for temporal, dimensional, technological, and spatial patterning on both the aggregate and geochemical sample.

The Greybull Obsidian Assemblage

After four summers of research, the GRSLE project has amassed over 40,000 lines of data on chipped stone at 166 sites and several isolated finds. To be clear, obsidian was not the preferred or most commonly used toolstone in the assemblage. Obsidian has been identified as the raw material type in 3.56% of the artifacts recorded to date (Table 5.1). Cherts, some local and some exotic, dominate the Greybull lithic assemblage. The locally available silicified sediments are the second most commonly identified flaked stone material type in the project database. Local sources of toolstone in the Upper Greybull are a combination of igneous and sedimentary materials.

Table 5.1 Raw Material Types Recorded Between 2002 and 2005

MATERIAL TYPE	N	%
EXOTIC		
Obsidian	**1,432**	**3.56%**
Oolytic Chert	1	0.00%
Phosphoria	16	0.04%
Quartzite	2,356	5.85%
Quartzite - Morrison Formation	130	0.32%
TOTAL	**3,935**	**9.78%**
LOCAL		
Basalt	121	0.30%
Chalcedony	2,360	5.86%
Dollar Mountain Chert	2,785	6.92%
Dollar Mountain Quartzite	4	0.01%
Irish Rock Chert	144	0.36%
Madison Formation Chert	86	0.21%
Metamorphosed Shale	6	0.01%
Quartz Crystal	1	0.00%
Silicified Wood	1,015	2.52%
Silicified Sediment	8,141	20.23%
Volcanic	114	0.28%
TOTAL	**14,777**	**36.71%**
UNKNOWN		
Chert	16,979	42.18%
Unspecified	4,560	11.33%
TOTAL	**21,539**	**53.51%**
Grand Total – All Materials	**40,251**	

Non-local material types include obsidian, Morrison Formation quartzites, quartzite, oolytic chert, and phophoria. Obsidian is relatively common of the exotic materials encountered. The obsidian and other exotics exhibit many of the characteristics we have come to identify with a curated lithic assemblage, in various definitions and applications of the term. The closest Morrison formation quartzites are found along the western edge of the Bighorn Mountains. Quartzite is readily obtainable in the Bighorn Basin just to the east. This is probably why it constitutes nearly 6% of the GRSLE database. Oolytic cherts are more commonly found in the archaeological assemblages to the south of the study area and are found along the Green River. Phosphoria is available in the Bighorn Mountains to the east (Francis 1991). Definitive identification of this toolstone type has proved challenging in the GRSLE project as characteristics defining phosphoria closely match the variation seen in some locally available chert materials. The actual number of these artifacts may be larger, but without the possibility of reliable geochemical sourcing, material designation is exigent.

Local materials included a wide range of options for prehistoric peoples. Chalcedony is common throughout much of the study area, frequently occurring as sheet-like deposits from fracture or joint formation. Nodules of chalcedony are also quite copious. Dollar Mountain cherts and quartzites outcrop around Dollar Mountain on the southwestern side of the study area (Reitze 2004). Irish Rock Chert is a local green toolstone that grades from opaque to translucent (Burnett 2005:68). The author and others have observed small (handsized), unmodified nodules of the material throughout the study area. A similar material has been noted elsewhere in the Absaroka Mountains and likely reflects some component of the mineral composition of sedimentary deposits at the point of silicification (Francis 1991; Shortt 2001). Unmodified silicified, or petrified, wood is found in much of the study area as individual nodules making it readily available as a toolstone. Silicified sediments are found throughout the study area. Most of the rock is not of toolstone grade, but high quality material is easily located. Silicified sediment is the second most common toolstone type recorded in the study area.

The general classification of chert describes the bulk of GRSLE artifacts. The material encompasses a wide range of colors, textures and opacities. The broad category likely includes material from several sources both local and exotic. The unspecified material type is largely influenced by data collection. Data entry errors have been changed to the unspecified material designation. Additionally, site encounters requiring expedient recordation have resulted in only noting the provenience of the chipped stone class without recording raw material attributes. The material types defined in the GRSLE database are the analytical frame to distinguish temporal, dimensional, technological and spatial patterns in the obsidian record.

Temporal Patterning

As all of the data in this study were collected from surface archaeology, determining the date of the site and artifacts is challenging. We must rely on relative dating by referencing established chronological sequences. Chronological affiliation of projectile points was identified after Burnett (2005), Frison (1991), and Husted and Edgar (2002). The technological periods are defined in Chapter 1.

Table 5.2 Projectile Point Raw Material by Period

	PL	PL-MA	UA	EA	MA	LA	NLP	LALP	LP	US	Total
Chert	2	1	28	7	10	67	5	4	28	23	175
Local	0	0	8	2	1	17	1	1	18	4	52
Obsidian	0	0	2	0	2	7	0	1	20	5	37
Quartzite	3	1	13	0	1	6	2	0	7	2	35
Quartzite -Morrison	1	0	3	0	1	1	0	0	0	0	6
Unspecified	2	0	1	0	0	1	0	0	0	2	6
Total	8	2	55	9	15	99	8	6	73	36	311

PL=Paleoindian; PL-MA=Paleoindian or Middle Archaic; UA=Unspecified Archaic; EA=Early Archaic
MA=Middle Archaic; LA=Late Archaic; NLP=Not Late Prehistoric, but otherwise not identifiable
LALP=Late Archaic or Late Prehistoric; LP=Late Prehistoric; US=Unspecified/Unidentifiable period

As it appears in table 5.2, obsidian use for projectile points in the Greybull study area was most prominent during the Late Prehistoric, comprising over 27% of the raw materials used in the manufacture. A chi-squared test for homogeneity of the Late

Prehistoric obsidian projectile points was conducted to test the null hypothesis that obsidian and non-obsidian projectile points occur at the same frequency in the Late Prehistoric as other periods.

Table 5.3 Late Prehistoric Obsidian Projectile Point χ^2 Test for Homogeneity

	Other*	LP	Total
Obsidian	11 (22)	20 (9)	31
Non-obsidian**	173 (162)	53 (64)	226
Total	184	73	257
χ^2=22.61 (critical value = 10.82, df=1 p<0.001)			
*excludes NLP, LALP, and US projectile points **excludes unspecified material types			

There is evidence (Table 5.3) to support the claim that the proportions of obsidian and non-obsidian projectile point raw materials are different from the Late Prehistoric and Other periods. It is difficult to say from these data alone whether or not obsidian was used more often across all tool types during the Late Prehistoric or if obsidian use for projectile points was more preferred during this time period. Using a form of cluster analysis, Burnett (2005:89) observed a dramatic increase in obsidian use associated with the Late Prehistoric in the Upper Greybull. It is reasonable to conclude that obsidian was more prevalent during this period.

Most of the projectile points, 57%, are affiliated with the Archaic period (Table 5.2:UA+EA+MA+LA). The Late Archaic specifically appears to be the period of most intense use or projectile point discard. Obsidian is underrepresented during the Late Archaic, constituting only 7% of the projectile point sample for this period, but this is true of obsidian in most time periods. Interestingly, local materials were also used more frequently during this period. Obsidian was not used for manufacture in any of the

Paleoindian period projectile points, a period not commonly observed in the study area (Bechberger et al. 2005). Burnett (2005) found that no artifacts of obsidian were associated with the Early Archaic period. Certainly, no Early Archaic projectile points identified in the database were constructed using obsidian. Many of the projectile points that fall into the unspecified category are complete enough to be identified as projectile points, but too broken to determine the temporal affiliation.

Dimensional Patterning

The size of artifacts, as discussed earlier, is related to the amount of reduction that has taken place on the parent material. Field measurement of all artifacts is done using Mitatuyo digital calipiers to the nearest 0.1 millimeter. When field protocol requires measurements to be taken, the maximum length is recorded for the artifact. Collecting a maximum length using calipers is nearly as fast as collecting a size class data unit. Using a continuous variable (actual length) versus a discontinuous variable (size class) provides more opportunity for analysis. Length can easily be transformed into size class units, but size class units can never be reconstructed to the length variable.

Length of debitage is useful for comparing exotic and local materials (Figure 5.1). Exotic materials should have lower average sizes as distance from the source increases. The relationship between debitage length and material type in the GRSLE dataset has extremely high significance ($F = 365.142$, $p < 0.005$).

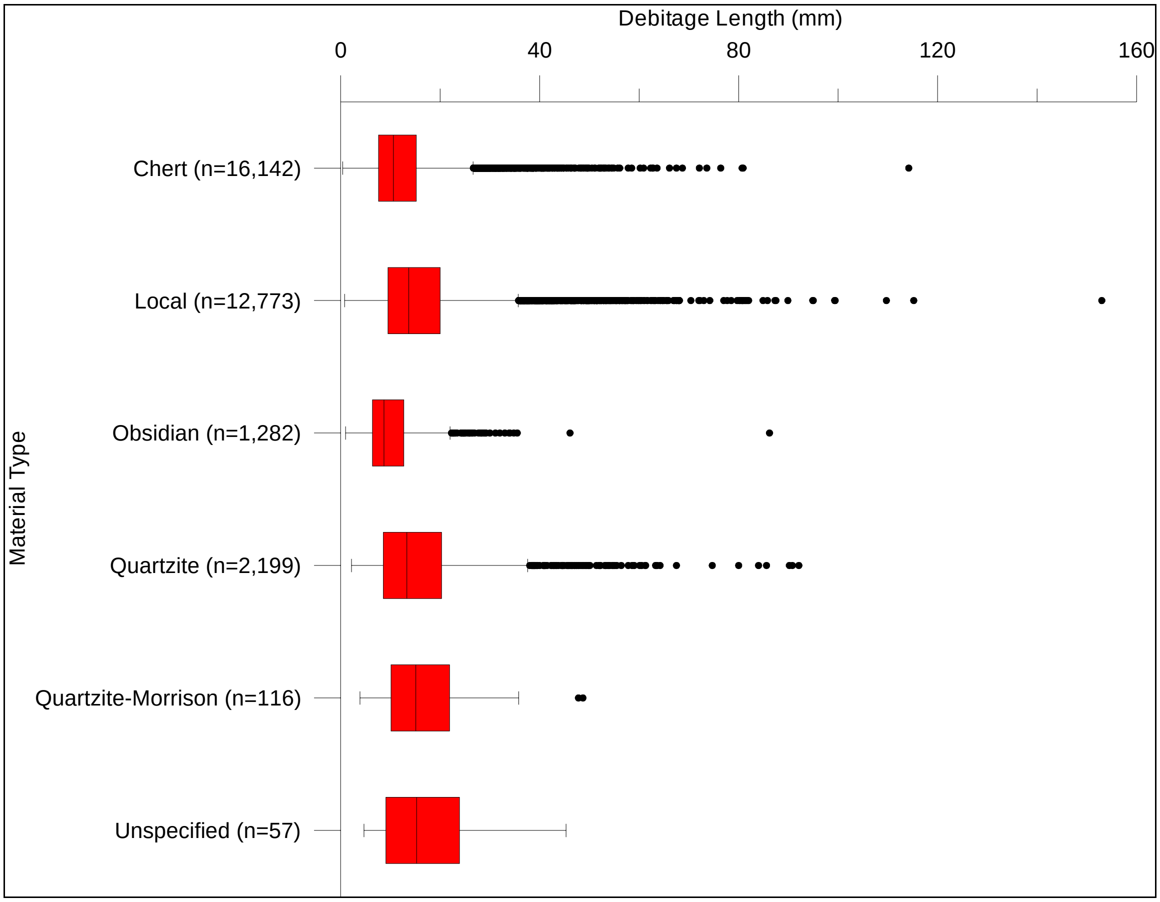

Figure 5.1 Maximum length range of flaked stone debitage by material type (n=32,569).

Obsidian debitage artifacts have the lowest average size at 10.3 mm, further supporting a pattern of curation prior to discard. Most of the recorded obsidian debitage (63%) falls below this mean. The average non-descript chert debitage is 12.4 mm in maximum dimension. Chert dominates the GRSLE debitage assemblage with 16,142 artifacts classified as chert in the field. Local materials have a mean size of 16.3 mm. Those artifacts that fall into the unspecified category have a mean of 16.9 mm indicating some may have local origin. Quartzite is also exotic to the study area and has a mean size of 16.3 mm. The large size range of these artifacts may reflect breakage, quality, and use patterns specific to this material type.

Technological Patterning

Formal tools are far less common than debitage in the GRSLE assemblage. Tools represent just over 3% of all recorded artifacts, but were critical for prehistoric life. Tools in order of frequency are worked flakes, projectile points, bifaces, cores, scrapers and a handful of other tools including gravers, unifaces, awls, and choppers. Raw material quality can determine the type of tool. For example, it may be difficult to predictably form a projectile point from a coarse quartzite. The fine grained Morrison quartzite would be preferred. A few ground stone pieces have been recorded at sites in the Upper Greybull drainage, but are not included with flaked stone analysis.

Local materials are most commonly associated with worked flakes (Figure 5.2). Worked flakes are flakes that appear to have been intentionally modified along the edge for use as an expedient tool. The GRSLE project distinguishes between edge-damaged (minimal edge modification, not distinctly cultural) and worked flakes (implies cultural modification, often >3mm in from flake edge) during field classification. Local material is also used more often to produce cores than other material types. As would be expected, local materials have the highest frequency of cores and worked flakes, the most expedient tool types. Bifaces of all material types are more common than cores in the Upper Greybull, but neither tool is abundant (Burnett 2005).

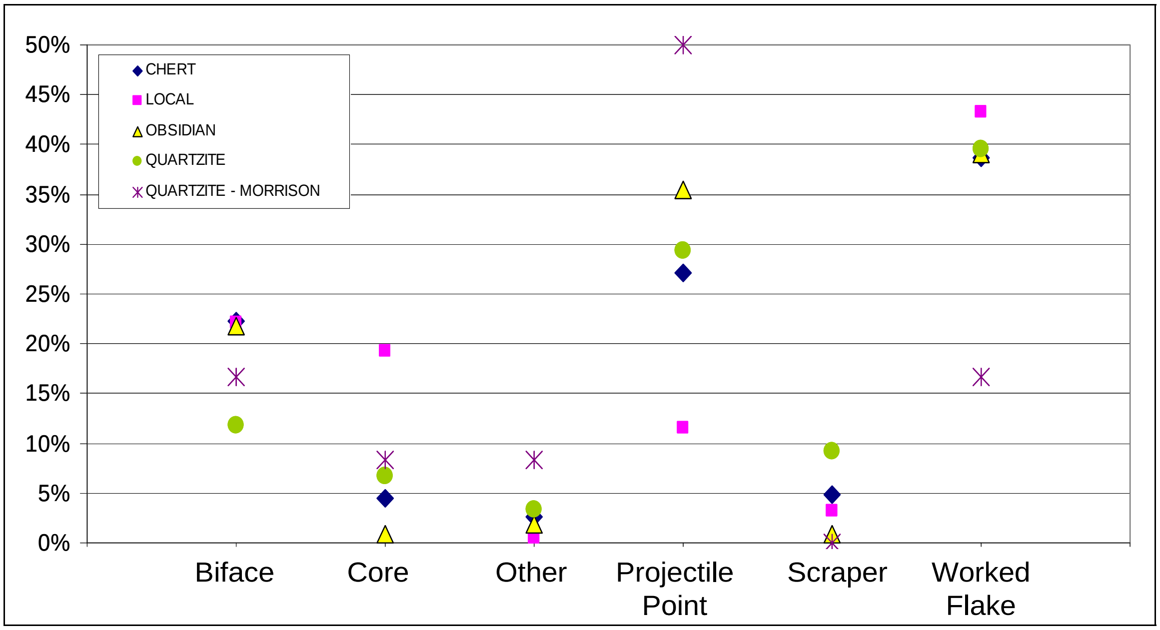

Figure 5.2 Tool richness by material type.

The pattern holds true for obsidian artifacts where debitage dominates the artifact record. Next to Morrison quartzite, obsidian has the second highest frequency of projectile points (Figure 5.2). One obsidian core was recorded in 2002, but the piece was not relocated for geochemical sourcing. Only 59 scrapers have been recorded in the Greybull assemblage; obsidian is the raw material of one of these scrapers. This artifact was recorded in 2002 and not sampled for provenance, but would be interesting to evaluate. While obsidian is rarely used for processing tools, two obsidian gravers have been identified in the study area. As with the single scraper and core, both artifacts were recorded prior to the inception of this obsidian sourcing study. There were more obsidian worked flakes than would be expected for a curated material. The high frequency of worked obsidian flakes may be either the result of it being underrepresented in other tool categories or a taphonomic factor relating to the ease with which obsidian is flaked.

Spatial Patterning

Most of the sites recorded in the study area are multicomponent, open lithic scatters; therefore, determining a specific site function is difficult. While a few rock alignments and features have been recorded, few artifacts, and no obsidian, were directly associated (Kinnear 2005). Of the 88 sites containing obsidian artifacts, obsidian constitutes an average of 9.8% of those assemblages. The obsidian found in the research area does not occur at elevation zones characteristically different than that of other materials (Table 5.4).

Table 5.4 Elevational (meters) Distributions of Chipped Stone

	All Chipped Stone	Obsidian
Maximum	3587	3219
Minimum	2192	2199
Range	1395	1020
Mean	2829	2752

Other Raw Material	Mean Elevation
Chert	2803
Local	2913
Quartzite	2741
Quartzite - Morrison	2900
Unspecified	2707

While the highest point in the study area is 4009 m, no survey has been done above 3800 m and no artifacts recorded above 3587 m. Elevation of local materials is higher on average than any other material type. This likely reflects the focused recording of the Dollar Mountain chert outcrop around the Dollar Cirque with elevations ranging from 2900 m and 3400 m (Reitze 2004). The average elevation of obsidian artifacts is not very different from that of other materials in the Greybull. The fact that there is not a great difference indicates that obsidian raw material users were not using the mountains in a drastically different way from those using other raw materials. It is compelling, however, that the mean elevation of quartzite and obsidian are similar.

The GRSLE study area covers roughly 1,600 km^2, 40 km in the maximum north-south measurement and 40 km maximum east-west measurement. In an area of land this large, it may be expected that the distribution of obsidian would not be equal over the entire area. Parts or drainages of the study area may be expected to hold sites with greater average percentages of obsidian. If for instance, we found a predominance of northern obsidians, we may expect to see a north to south pattern where obsidian percent decreases as you move south. A preference for western obsidian materials may result in an east to west pattern. After mapping the distribution of sites, it does appear that obsidian is more common in the north of the study area (Figure 5.3). The northern portions of the study area appear to have more sites with greater than 10% obsidian than do the sites to the south.

In the majority of obsidian bearing sites, obsidian constitutes 10% or less of the raw material composition at those sites (Figure 5.3). The southern portion of the study area has two areas with exceptionally low obsidian distribution, the Dollar Cirque and the Meadow Creek basin. Meadow Creek is somewhat anomalous as only 11 of the 1,124 chipped stone artifacts recorded in the high mountain (approximately 3,200 m) basin were obsidian. The Dollar Cirque is dominated by local Dollar Mountain materials, but it is intriguing that no obsidian was recorded in these deposits. Slight differences in obsidian distribution are apparent between the tributaries or drainages throughout the watershed (Table 5.5).

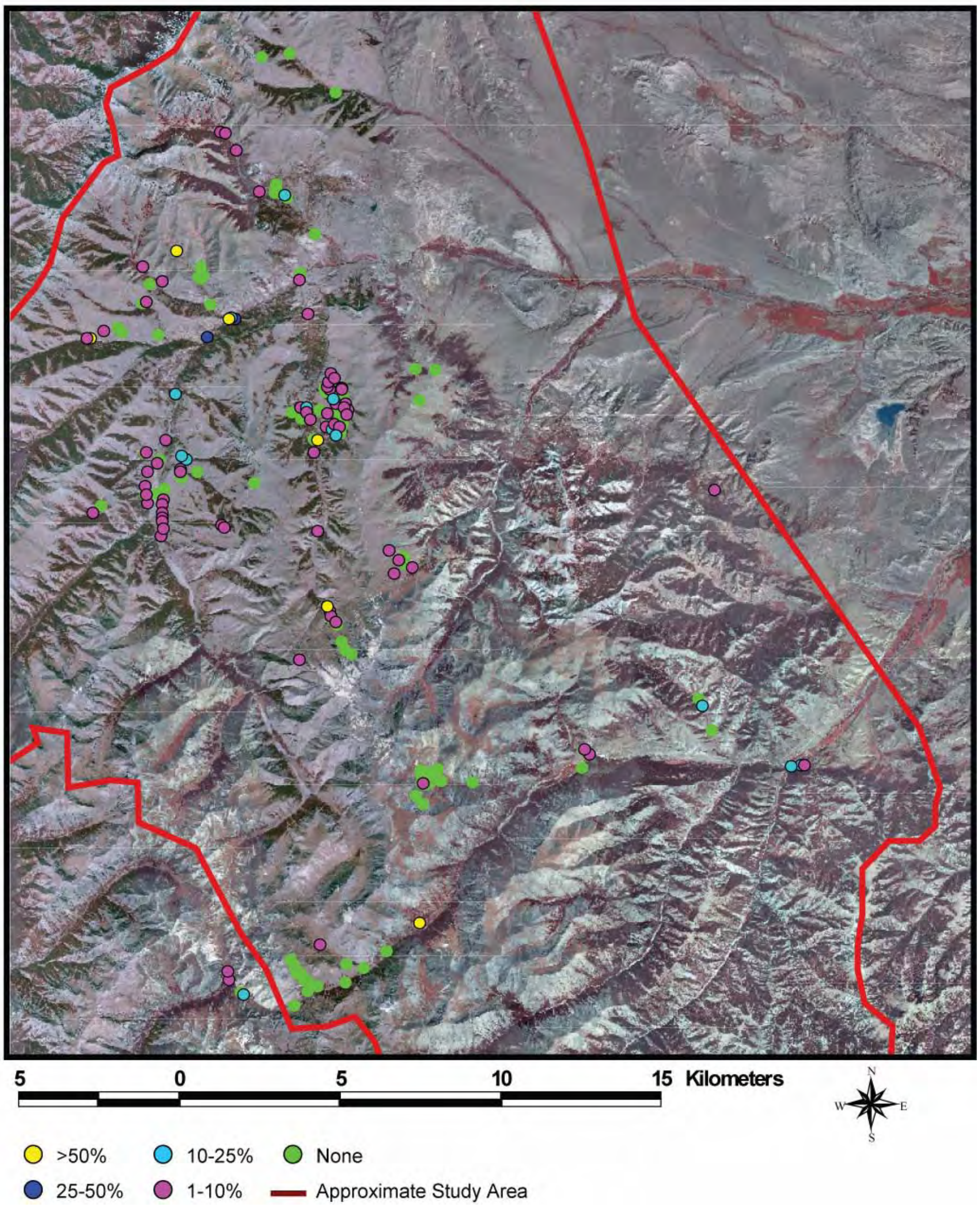

Figure 5.3 GRSLE site distribution by obsidian percent.

Piney Creek and Warhouse Creek have the highest percentages of obsidian. This may be slightly skewed because of sites that were only partially recorded during 2004. Complete recordation of the sites identified in these drainages will help to more accurately define the pattern. The Jack Creek drainage is the most heavily sampled drainage in the study area. This is partly due to its accessibility, a road runs close to much of the surveyed areas, and partly due to the wealth of archaeological sites found along the terraces of this creek. The Jack Creek archaeological record contains an obsidian percentage closer to the overall percentage in the GRSLE assemblage. Twenty-four Jack Creek sites have provided 70 samples for this study. Much of what we define as the Greybull pattern is derived from information obtained researching this major tributary to the Upper Greybull River. The Wood River pattern is high, driven largely by one site, 48PA659 that is dominated by small obsidian artifacts. Horse Creek, Meadow Creek and Caldwell Creek contain the lowest percentage of recorded obsidian artifacts.

Table 5.5 Percent Obsidian by Drainage Basin

Drainage	Percent Obsidian
Caldwell Creek	0.9%
Deer Creek	2.3%
Eleanor Creek	3.5%
Franc's Fork	1.9%
Greybull River	3.1%
Horse Creek	0.7%
Jack Creek	3.5%
Meadow Creek	1.0%
Piney Creek	12.0%
Warhouse Creek	5.9%
Wood River (including Dollar Mountain sites)	4.9%

Overall, obsidian is not a major player in the Greybull, but some interesting patterns have emerged. Most of the obsidian projectile points come from the Late Prehistoric period. Most of the obsidian debitage pieces are very small. Most of the obsidian tools are worked flakes, but a large percentage of the tools are projectile points. Obsidian is somewhat more predominate in the north of the study area.

Geochemical Characterization Results

Sampling for geochemical analysis began in 2004 and continued in 2005. A total of 127 artifacts were collected from 43 sites and one isolated find (Appendix A). The obsidian artifacts were sent to the Geochemical Research Laboratory and processed using edXRF by Richard Hughes as discussed in the methods section. One group was sent in 2004 and a second after completion of the 2005 field season. In 2004, most samples were selected from sites by collecting a "reasonable" amount from sites with more than one obsidian artifact. This arbitrary designation usually meant two or three artifacts in the correct size range. While this sampling methodology is probably sufficient to observe general patterns, it would be easy to miss the "rare species" or materials from distant sources. In 2005, the sampling strategy was expanded to include any artifact that fell within the size requirements for the edXRF process. The sample from the 2005 season did reveal some different rare species, but the major provenance patterns did not change significantly.

After samples were returned from the edXRF analysis, the entire sample group was reanalyzed to define some of the basic attributes and to classify additional attributes.

Following, the results of the geochemical and lithic analysis are presented, after a brief discussion of the sample size.

Sampling Discussion

The geochemical analysis sample must be evaluated to determine if the group is representative of the Greybull obsidian assemblage. Because of the minimum size requirements to run the edXRF procedure, the sample selected for the process does not represent the same size range exhibited in the entire Greybull obsidian population. For instance, the average obsidian artifact (including all tools) in the Greybull database is 10.9 mm. The average size sample was 18.9 mm in maximum length. It is possible to miss the most distant sourced artifacts or “rare species” by only selecting the larger pieces of obsidian. As the reduction sequence indicated and discussed earlier in the document, it is assumed that as an artifact gets further from its raw material source, it will be smaller. The minimum size requirement for the edXRF analysis is 10 mm in length, and 43% of the recorded obsidian artifacts fall into this size range. As the sample represents the size range of 43% of all recorded pieces, it should be considered an appropriate sample size. Additionally, the test itself provided built in sample size testing as samples from 2004 and 2005 were sent separately for geochemical sourcing. The overall results did not vary greatly between the two years (Hughes 2004, 2005).

Provenance Results

Evaluation of the samples for several chemical signatures is necessary to eliminate any chance for overlap of source patterns. Source results are most often shown on bivariate plots rather than normalized ratio plots of relative elemental intensities, such as a ternary diagram that can create errors in the distribution of the trace elements (Hughes 1986, 1998). While fine to use for display purposes, ternary diagrams should not be used for analytical purposes. Plotting the artifacts by strontium (Sr) and zirconium (Zr) signatures reveals distinct groupings for several types and segregation of the six individual artifact sources (Figure 5.4). Four groups exhibit discrete clustering that match signatures of specific sources: Obsidian Cliff, Bear Gulch, Teton Pass and Malad.

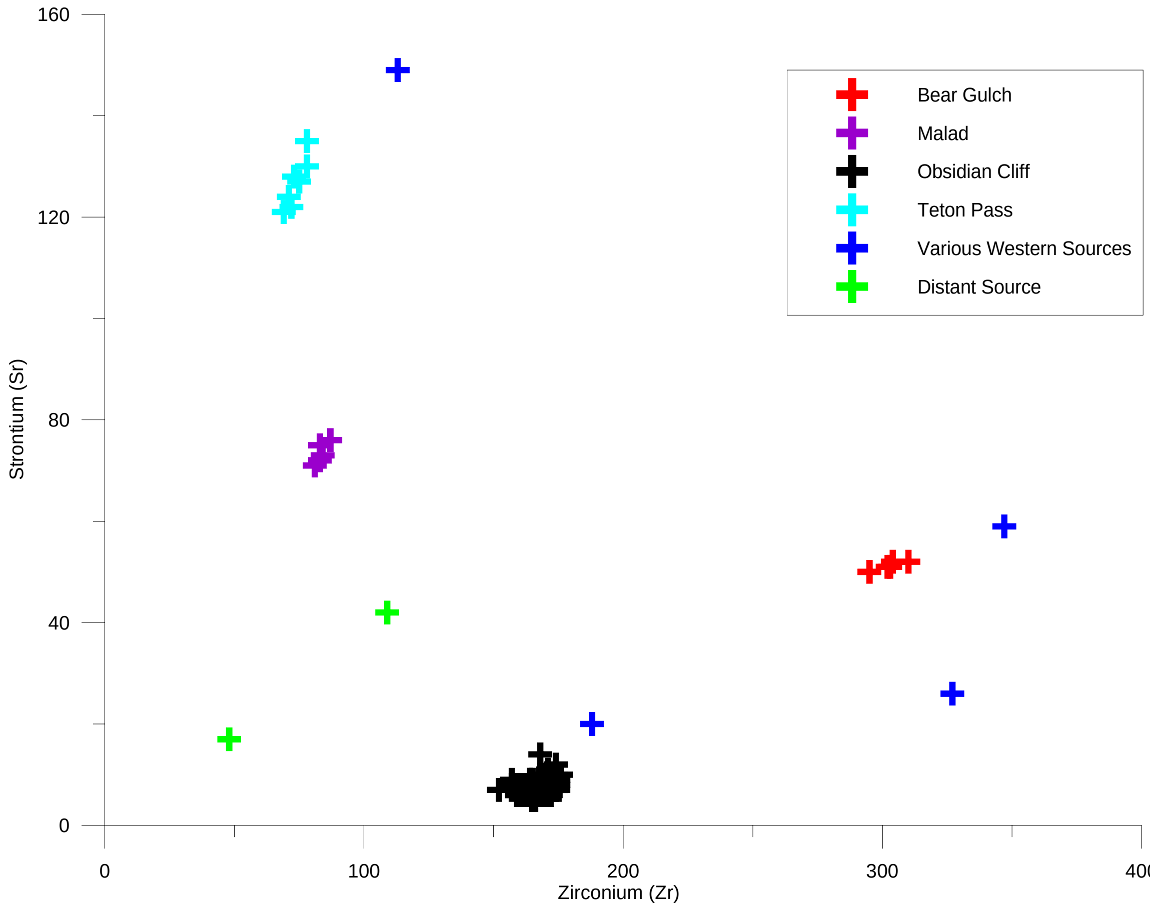

Figure 5.4 Signature traces of strontium and zirconium.
Represented in ppm (parts per million). Single result sources were combined by general distance from GRSLE study area.

While several of the artifacts herein do not seem to fall into any specific pattern, the Geochemical Research Laboratory was able to match the other artifacts with known sources in their database. Only one artifact returned an unmatched source signature, the individual source (Various Western Sources) grouped closest to the Obsidian Cliff cluster.

Plotting samples along several elemental signatures is critical. When the samples are plotted on their yttrium and rubidium results, the Timber Butte artifact, assigned as one of the distant sources, seems to group with the Bear Gulch source (Figure 5.5), showing why it is important to evaluate the intensities of several elements.

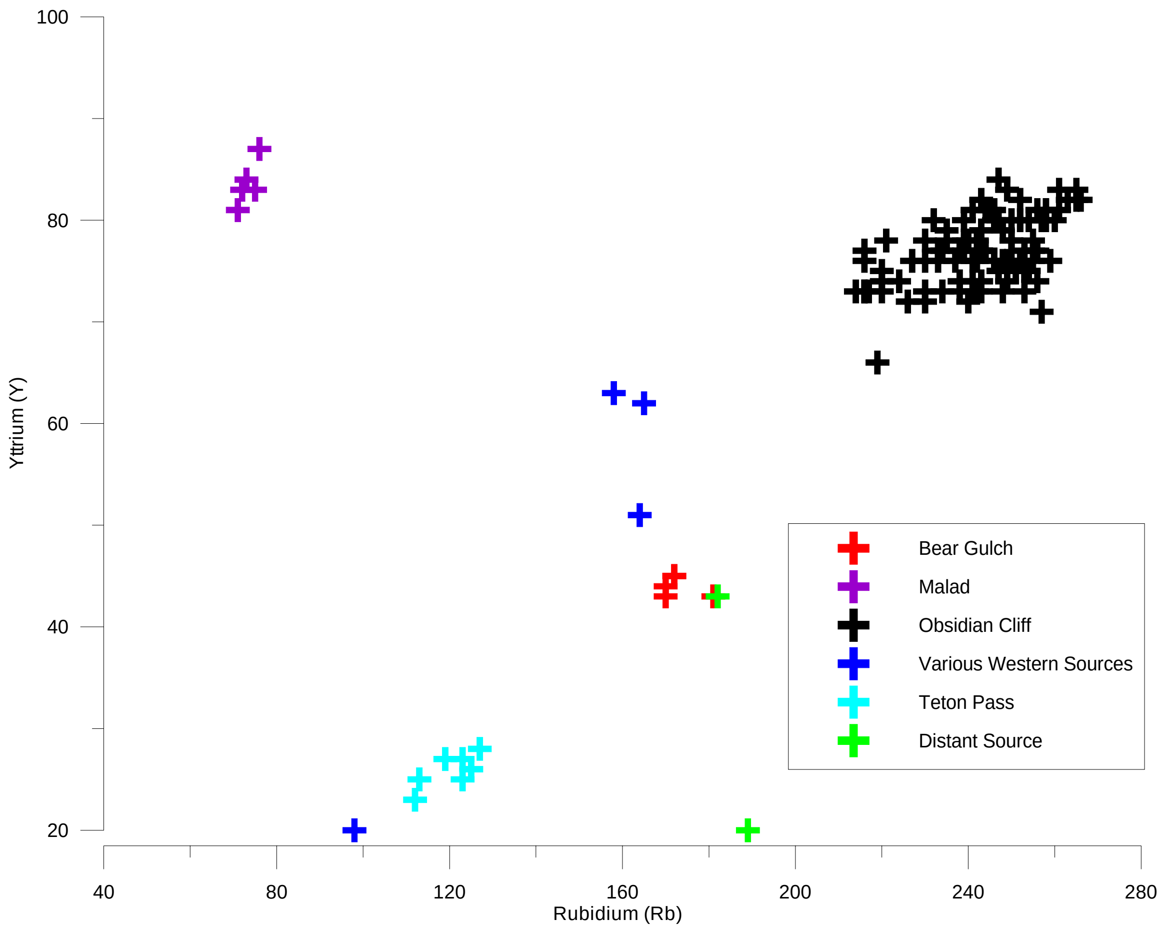

Figure 5.5 Signature traces of yttrium and rubidium.
Represented in ppm (parts per million). Single result sources were combined by general distance from GRSLE study area.

The unknown source seen near the Obsidian Cliff group on Figure 5.4 falls far away from the Obsidian Cliff group in Figure 5.5. The general designation to match artifact geochemical signatures with that of the source elemental range was done at the Geochemical Research Laboratory, but the general patterns are replicated with these simple plots.

Most of the sampled artifacts (78.7%) fit well within the range for Obsidian Cliff Wyoming (Table 5.6). At approximately 140 km linear distance from the GRSLE project area, Obsidian Cliff is one of the closest major sources.

Table 5.6 Geochemical Analysis Results by Source

Source	Number	Percent
Bear Gulch	9	7.1%
Crescent H	1	0.8%
Malad	5	3.9%
Obsidian Cliff	100	78.7%
Packsaddle Creek	1	0.8%
Park Point	1	0.8%
Teton Pass	7	5.5%
Timber Butte	1	0.8%
Wildhorse Canyon	1	0.8%
Unknown	1	0.8%

The other common sources, Bear Gulch, Teton Pass and Malad, fall far behind the frequency of Obsidian Cliff. Teton Pass is approximately the same distance as Obsidian

Cliff, yet represents a much smaller percentage of the GRSLE obsidian assemblage. Park Point, technically the closest site, has only one artifact attributable to it. This is likely due to the source nature as a secondary deposit. Packsaddle Creek, a mere 20 km from the Teton Pass source area is also seldom seen in the project area. Yet, Bear Gulch at over 200 km from the project is the second most frequent obsidian type. The biggest surprises were the distant sources of Wild Horse Canyon in southwestern Utah and Timber Butte in western Idaho. Both of these sources represent a single artifact that traveled 500 km as the crow flies before its final discard. One artifact has a trace element signature unlike any of the geologic standards currently in the Geochemical Research Laboratory comparative reference collection (Hughes 2005). The unknown source is grouped within the various western sources as the signature is similar to secondary sources around Jackson, Wyoming and Yellowstone National Park. The unknown piece is distinct in several elements; however, it appears to be an ash-flow tuff glass and based on the distribution of obsidian-bearing ash-flow sheets it can be speculated to have originated in the Yellowstone plateau, the Teton area or around the upper Snake River Plain (Hughes, personal communication 2005).

While the distance between the source and the study area (Table 3.1) is not the most informative, it is useful for considering why a source may have been favored over another. Further, it is interesting to assess whether the pattern is different when the sample is broken into temporal, size and spatial attributes.

Temporal Patterning

Artifacts identifiable as projectile points should fall within the size limits of the geochemical analysis. Therefore, most projectile points encountered were sampled. While most of the GRSLE obsidian source sample is debitage, projectile points comprise 13% of the sample and provide the potential for obtaining an estimated date. All projectile points in the sample were relatively dated using typological associations. A total of 18 projectile points were sampled including those from the Middle Archaic, Late Archaic and Late Prehistoric periods (Table 5.7).

Table 5.7 Projectile Point Sources by Period

	Archaic	Middle Archaic	Late Archaic	Late Prehistoric	Unspecified	Total
Bear Gulch	--	--	--	1	--	1
Malad	--	--	1	--	--	1
Obsidian Cliff	--	1	--	4	5	11
Teton Pass	--	--	--	3	--	3
Other	1	--	1	--	1	2
Total	1	1	2	8	6	18

No obsidian artifacts can be directly attributed to the Paleoindian period (11,500 to 8000RCBP) or the Early Archaic (8000 to 5000 RCBP). One point is associated with the Archaic, but the specific period within the Archaic is not clear (Figure 5.6a). The one Middle Archaic/McKean (5000 to 3200 RCBP) projectile point is from Obsidian Cliff (Figure 5.6b). It is intriguing that neither of the Late Archaic (3200 to 1500 RCBP) points were sourced to Obsidian Cliff (Figure 5.6c,d). This period is well known regionally as a time of high population density and montane use. Johnson (2001), reported an increased number of Late Archaic projectile points in the Yellowstone

National Park. Burnett (2005) reported that most of the archaeological record in the Upper Greybull is attributed to the Late Archaic. Using a clustering analysis, he found that the obsidian debitage was more frequently proximate to Late Prehistoric projectile points. Most of the source sampled projectile points are from the Late Prehistoric period (1500 to 250 RCBP) (Figure 5.6e-l). This period is well represented by Obsidian Cliff and Teton Pass. Six projectile points are not attributed to a specific period (Figure 5.6m-r).

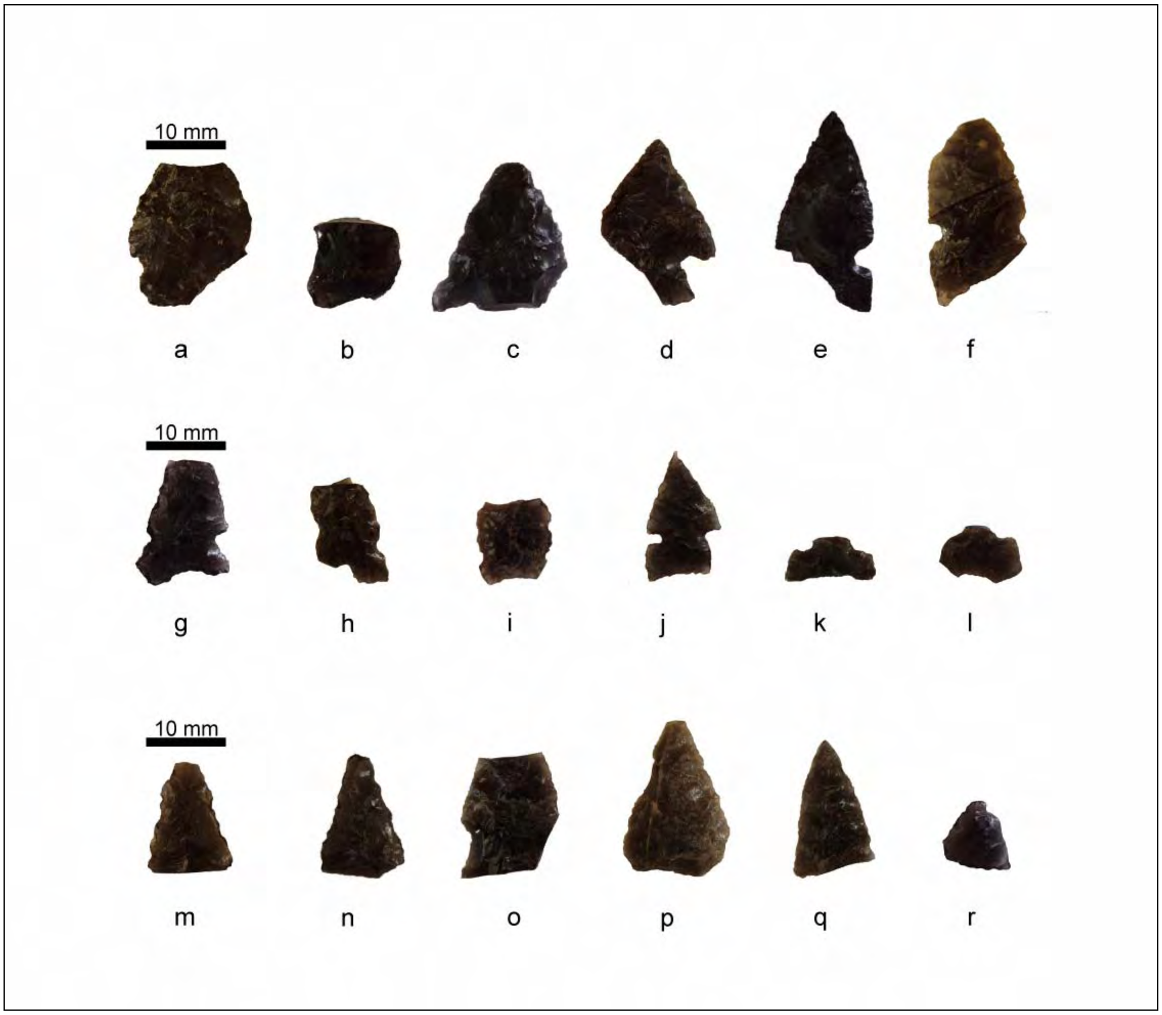

Figure 5.6 Obsidian projectile points sampled for geochemical analysis. a. LCT25 48PA2874 ; b. HTH3 48PA2774; c. SOH15 48PA2884; d. ADB17 48PA2811; e. CRB1 48PA2825; f. ABH1, ABH2 48PA2825; g. ADB6 48PA2832; h. BS93 48PA2881; i. BR2 48PA2792; j. ADB8-KMD026 48PA2772; k. ADB5 48PA2772; l. ADB6-HTH204 48PA2772; m. ADB10 48PA2893; n. LCTB005 48PA303; o. ADB49 48PA2769; p. ADB4 48PA2772; q. BLT34 48PA2736; r. MAT20 48PA2887

Dating sites with obsidian artifacts in direct contact or directly dating the obsidian artifacts would provide a more accurate picture of land use patterns at specific times. Obsidian hydration analysis, a tool for directly dating artifacts, may be difficult for artifacts in this area. Heat damaged lithic materials on GRSLE sites indicates a history of fire exposure and it is possible for fire damage to "reset" the hydration clock. Gryba (2005) found in an experimental study that obsidian artifacts treated with heat to manipulate production ease exhibited a smoothed, rounded edge under microscopic analysis. If heat damage can be identified on GRSLE obsidian artifacts, it may save time and money when selecting a sample for hydration analysis. \

Dimensional Patterning

As discussed earlier, curated artifacts should decrease in size as distance from source decreases. Of the four major sources revealed through souring analysis, Obsidian Cliff or Teton Pass artifacts should yield the largest pieces on average. The results, however, do not reflect this pattern (Figure 5.7). Because of the small samples from Bear Gulch, Malad and Teton Pass, all tool types were included in this analysis. A null hypothesis that sources were the equivalent in artifact size (length, width, and thickness), area, volume, and weight could not be rejected by univariate analysis of variance.

The Bear Gulch artifacts have the highest average length at 21.4, yet the source is much farther than either Obsidian Cliff or Teton Pass (Figure 5.7). The Obsidian Cliff group has the largest range. The range of the Malad sample is the smallest, as only 5 artifacts fall into this assembly. The unanticipated results could be a product of differential tool distribution between the sources (Figure 5.8). If more and larger material

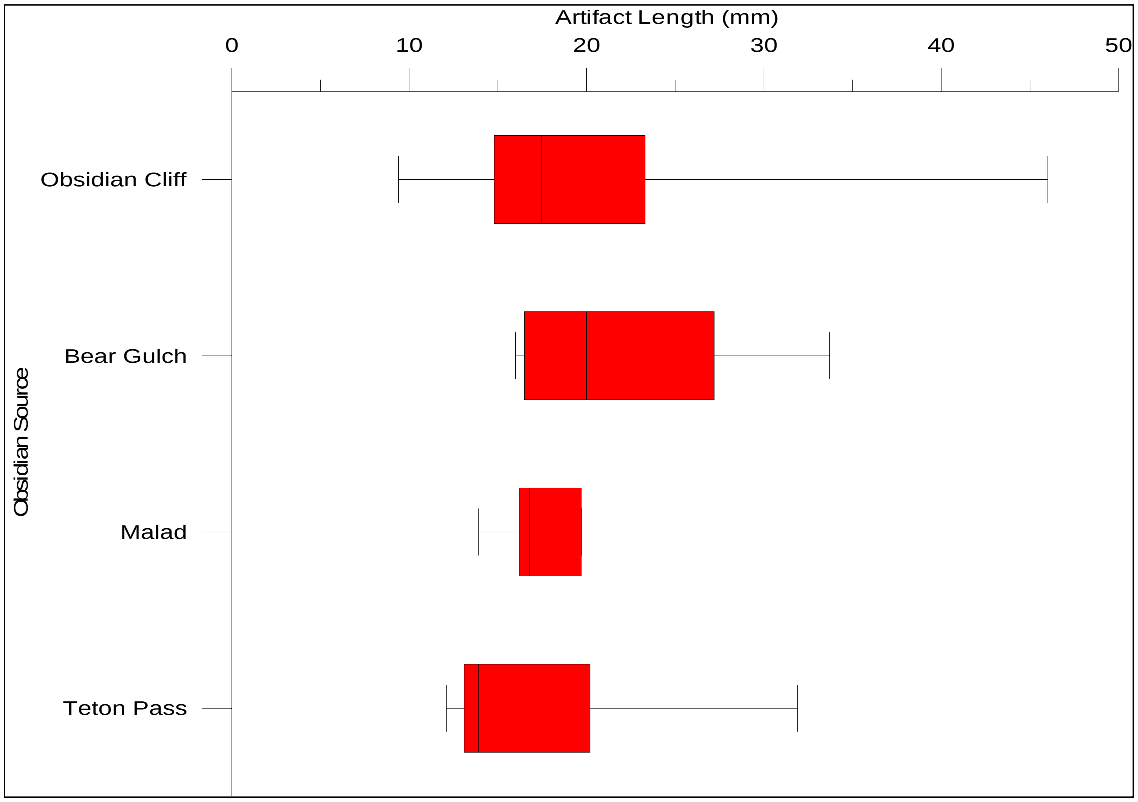

Figure 5.7 Size comparison of all artifacts by source.

is coming from Obsidian Cliff, the potential for more "wasteful" flake removal methods increases. Because of this wasteful behavior, a greater range in the sizes would appear among the most frequented source types. It will be interesting to see if larger samples are obtained from the non-Obsidian Cliff sources, if any statistical significance will be reflected between artifact dimension and obsidian source.

Technological Patterning

As distance from source increases, the amount of waste material from that source should decrease. The distribution of tool types from each source identified in the GRSLE sample is the expected for a curated material (Figure 5.8). Obsidian Cliff artifacts are overwhelming composed of unmodified flaked stone debitage. Teton Pass and Bear

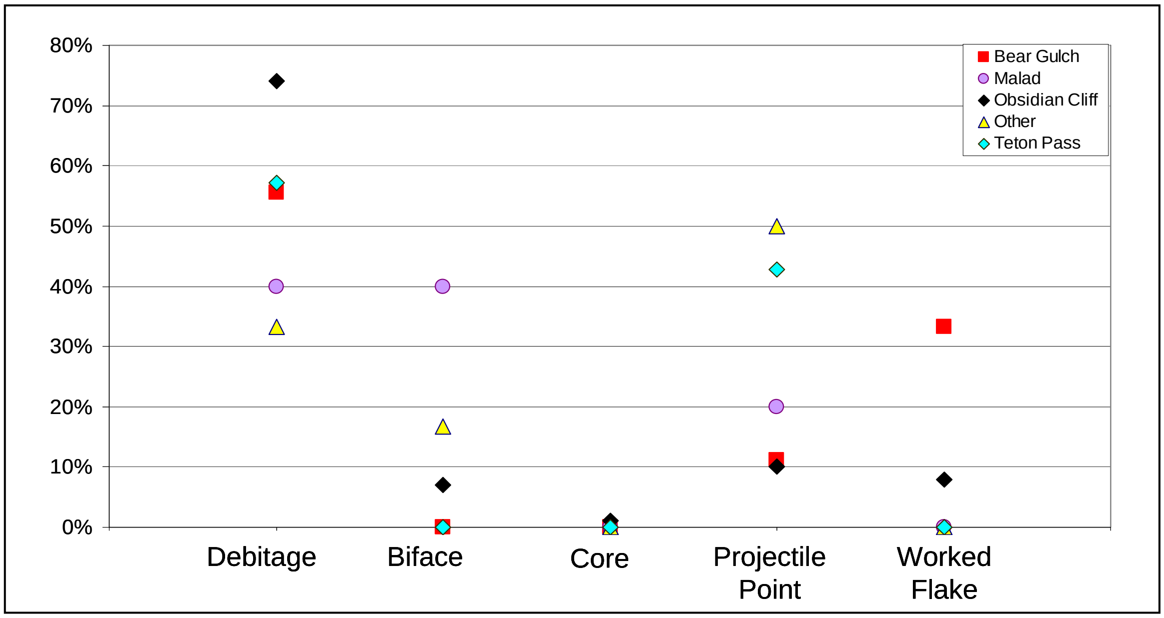

Figure 5.8 Artifact type richness by source. Other category includes all single artifact sources.

Gulch are responsible for a high percentage (>50%) of debitage in the artifact assemblage. Malad, and other minor or distant sources are largely comprised of debitage. Materials other than Bear Gulch and Obsidian Cliff, are most often formed into projectile points or bifaces prior to their discard in the Greybull drainage. The Teton Pass sample is dominated by debitage, but 43% are projectile points. The Bear Gulch artifacts were frequently identified as worked flakes. One of the most distant provenances, Timber Butte, was identified as a projectile point. Rare sources most often are projectile points or bifaces. However, Wild Horse Canyon, the most distant source in the study was identified on a broken, but unmodified, flake.

Curated bifaces from more distant sources would be predicted to be in later stages of production. Bifaces were identified as the tool type of 10 artifacts in the sourcing sample, with only five able to be identified for the stage of production according to Callahan (1979) (Appendix C). Three bifaces were identified as stage 5 (completed) and may be projectile point fragments. The three came from Obsidian Cliff, Malad, and Packsaddle Creek obsidians. Two incomplete bifaces, stage 2 and stage 4, were identified and both originated from Obsidian Cliff. As expected, the most frequent source in the study area is responsible for incomplete bifaces; it would not be expected that the more distant materials would occur as uncompleted bifaces.

Spatial Patterning

The palimpsest nature of sites in the GRSLE assemblage creates many challenges to the interpretive tool kit available in coordination with geochemical sourcing. Again, a total of 43 sites were sampled for the analysis. At most of the sites, more than one sample was collected. Can we separate singular "procurement events" within a site? A parsimonious interpretation of the geochemical sourcing depends on site complexity.

Two sites were selected for spatial analysis based on recognition of relevant components such as several temporally diagnostic projectile points and several obsidian artifacts sampled. The spatial analysis is based on similar work performed for this project by Burnett (2005) in that it evaluates lithic scatter patterns based on proximity of artifacts. Groups of artifacts are created using 2.5 meter buffers on the observed provenience.

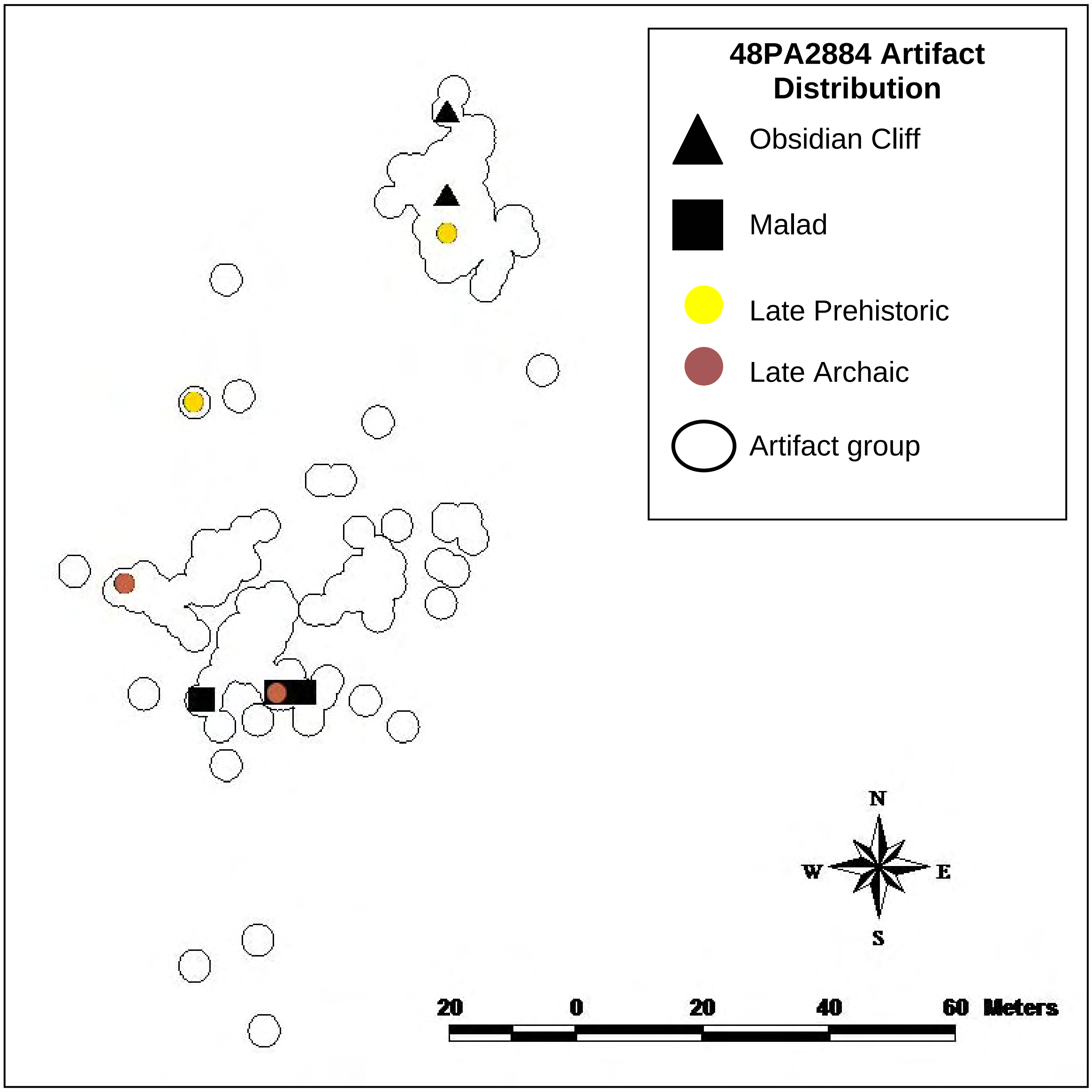

Figure 5.9 Distribution of obsidian types among the artifact clusters at 48PA2884.

In order to protect the integrity of these sites, no specific location map is included herein. It would not be profitable to run through a site by site description for all sites sampled in the project. Requests for site information can be directed to the author or to the Wyoming State Historic Preservation Office.

Site 48PA2884 is of particular interest as the provenances of the projectile points are spatially and temporally distinct (Figure 5.9). The north side of the site seems to represent a Late Prehistoric component, while the southern side a Late Archaic component based on the distribution of diagnostic projectile points. One of the Late Archaic projectile points was traced to the Malad flow. Two additional artifacts in the Late Archaic cluster were also associated with the Malad source. The sourced obsidian pieces that are closer to the Late Prehistoric artifacts match the Obsidian Cliff signatures. Further, the artifacts associated with the Late Prehistoric and Obsidian Cliff source were located on the surface of a small knob. The Late Archaic and Malad source artifacts were located on the side or more eroded surface of the small hill. The proximity of Malad artifacts to the Late Archaic component supports the findings of no Late Archaic projectile points coming from the Obsidian Cliff source.

This creates a picture of two distinct groups using two separate sources, at two different periods of time. Realistically, however, this site is an anomaly in the GRSLE project. Take for example, one of the more complex sites in the study assemblage, 48PA2874.

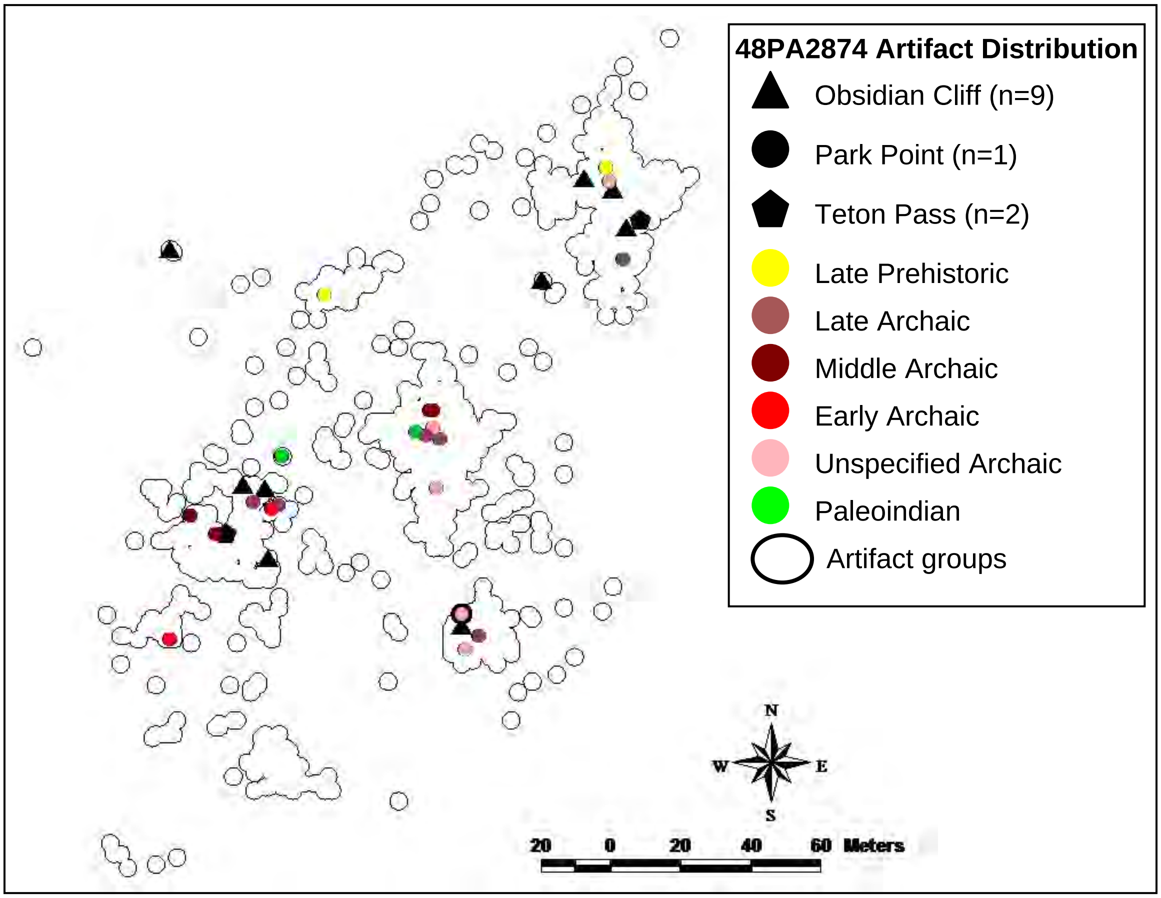

Figure 5.10 Distribution of obsidian types among the artifact clusters at 48PA2874.

At 48PA2874 (Figure 5.10), most of the obsidian artifacts were sampled from multi-component artifact groups. We have six diagnostic clusters, four of which are multicomponent. The single component Early Archaic and Late Prehistoric artifact clusters had no artifacts sourced. The unspecified Archaic and Late Archaic period group had artifacts sourced to Obsidian Cliff and Park Point. No obsidian was sampled from the large cluster in the middle of the site containing a Paleoindian and Archaic (unspecified Archaic, Middle Archaic, and Late Archaic) element. The northern most cluster in the site was determined to be associated with the Late Prehistoric, Late Archaic and unspecified Archaic periods. This group has obsidian from Obsidian Cliff and Teton Pass. The final temporally diagnostic cluster was clearly Archaic, containing components from the Early, Middle and Late phases. As with the northern cluster, this artifact group revealed Obsidian Cliff and Teton Pass obsidians. The artifact clusters on 48PA2874 likely reflect areas of concentrated exposure rather than discrete activity areas.

Clustering analysis may be informative, depending on the site complexity. Some of the major downfalls with this approach to obsidian research include limited site type. In these sorts of scattered surface sites, site type is muddled by taphonomic processes. Site type or even period cannot easily be extracted to elucidate greatly informative patterns about the prehistoric land use range.

It would seem that over such a large project locality, the obsidian source distribution may vary spatially. Watersheds would have been used differently in prehistoric times largely as a response to microenvironment climates (Derr 2006). Because of the design of the reconnaissance survey in the GRSLE project, several watersheds have been incorporated in the study (Appendix A for complete listing of sites by drainage). Analysis of raw material percentages by watershed basin completed prior to the 2005 field season, exposed differential distribution of lithic types (Ollie 2004). All of the sampled drainages connect via the Greybull River, but each are separated to create isolated analytical units (Table 5.8).

Table 5.8 Obsidian Source by Drainage

Drainage	Obsidian Cliff	Bear Gulch	Malad	Teton Pass	Other West	Other Distant
Deer Creek (n=3)	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Eleanor Creek (n=3)	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Franc's Fork (n=16)	81.3%	0.0%	0.0%	12.5%	6.3%	0.0%
Greybull River (n=4) (*incl. Vick Creek sample*)	75.0%	25.0%	0.0%	0.0%	0.0%	0.0%
Jack Creek (n=70)	78.6%	7.1%	5.7%	5.7%	2.9%	0.0%
Piney Creek (n=16)	75.0%	0.0%	6.3%	6.3%	0.0%	12.5%
Warhouse Creek (n=10)	70.0%	20.0%	0.0%	0.0%	10.0%	0.0%
Wood River (n=5) (*incl. Horse Creek sample*)	80.0%	20.0%	0.0%	0.0%	0.0%	0.0%

Obsidian Cliff was the preferred source in each of the drainages. Sites along the major water courses, the Greybull River and Wood River, appear to have yielded the greatest use of Bear Gulch obsidians. The Warhouse Creek sample comes largely from portions of the drainage within a few kilometers of the confluence with the Greybull River, continuing the pattern of higher Bear Gulch distribution along major waterways. One of the most intriguing conclusions drawn from this information is that none of the Piney Creek samples was sourced to Bear Gulch, the second most common source in the study area. This drainage, however, was the discard location of the two rarest obsidian specimens, Wild Horse Canyon and Timber Butte. No Malad pieces were found in the Franc's Fork assemblage, one of the most sampled drainages. The Horse Creek sample, classified here among the Wood River group, was the highest elevation of any sampled piece and was attributed to the Obsidian Cliff source.

Additional Lithic Analysis

The obsidian artifacts collected for sourcing were all recorded in the field according to site specific recordation protocols. In order to eliminate observer variation in coding styles, the artifacts were reanalyzed after the completion of the geochemical analysis. In addition to the attributes (length, tool type, elemental constituents) addressed above, the obsidian artifacts were evaluated for a series of additional traits. The characteristics were width, thickness, weight, platform width, platform thickness, platform description, cortex, presence or absence of a lip, inclusions, surface appearance, ridge appearance, diaphaneity, color, special features, temporal affiliation, and miscellaneous comments (Appendix C). While not all of the attributes are terribly informative for the purpose of this study, it was important to record the information as the artifacts will be returned to the field in the future. Some of the results are reviewed below.

Cortex is difficult to identify on obsidian artifacts for many reasons. It can be exhibited in two main ways: as a rhyolitic or tuffaceous rind or as a shift in luster due to differential hydration rates on the exposed rock surface prior to cultural modification. Only seven of the 127 sampled artifacts had cortex. Two were Teton Pass, one was Bear Gulch and four were Obsidian Cliff. As expected, only the closest major sources, Teton Pass and Obsidian Cliff were the source of artifacts with more than 50% cortex covering the piece (on flakes this is evaluated only on the dorsal surface). Baumler (1997) also noted the presence of cortex on Bear Gulch obsidian specimens. He concluded that rather than pinpointing an early stage manufacture, it was more likely an indicator of the original size and form of the raw material. All of the pieces in the GRSLE sample with cortex also exhibited dulling on some surface.

Surface appearance was examined on all pieces in the geochemical sample. Dulling was recorded on 59% of the artifacts in the sample; however, the researcher was not sure of the exact cause. Not all of the dulling on the sample can be attributed to cortex. The most likely culprit is environmental exposure. More than 1/3 of the dulled artifacts were dull on the ventral surface of the piece flake. Only 41% of the artifacts were described as having a glassy surface. Ten Obsidian Cliff artifacts appeared to be devitrified on the surface. The artifact associated with the Cresent H source also exhibited surface devitrification.

Lithic artifacts often exhibit ridges along scars of previous flake removals. On bifacially worked tools, these ridges will be on both sides. Debitage will only exhibit the ridge lines on the dorsal surface. During the course of the lithic analysis, this researcher began to notice a pattern of differential wear along these features. Wear along these ridges may be the result of long distance transport or landscape taphonomic processes such as trampling. Three ridge types were observed: sharp, smoothed and crushed. Ridge classification was complicated by the fact that several ridge types may be on the same artifact. Only eight artifacts had some combination. Most of the sample (over 51%) exhibited only sharp ridges. Both Obsidian Cliff and Malad sources had more sharp ridged artifacts than any other ridge categorization. Smoothed ridges were observed on 34% of the group. The two artifacts from the most distant sources, Timber Butte and Wild Horse Canyon, exhibited smoothed ridge lines. The majority of Teton Pass and Bear Gulch artifacts also were classified as smoothed ridges. Crushed ridges were the least common designation with just under 8% of the all samples having any crushed edge. All but one of those with crushing were from the Obsidian Cliff source. This likely has less to do with Obsidian Cliff material quality or transportation and more to do with the frequency of the material type on the landscape.

Eight debitage pieces were smoothed along the flaked edge. This is possibly the result of curation duration, but also may have resulted from taphonomic processes occurring after the cultural life of the artifact. If the result of long periods of curation, it may be expected to occur on more distantly sourced pieces. The pieces in the GRSLE assemblage with the smoothing, however, were from Obsidian Cliff (n=6) and Bear Gulch (n=2).

Diaphaneity, color, and special features of the material were recorded as possible indicators to megascopically source material types. Obviously if this were possible, it would lend great value to field research. While it has been established that this is a tricky and erroneous manner of sourcing (Shackley 2005), it can be useful to provide baseline assumptions for some of the material types as a prelude to geochemical analysis. These characteristics were evaluated by placing the artifact up to a 100-watt standard light bulb. Most of the artifacts were simply a translucent black, however, a lot of variation was observed. Many of the artifacts traced to the Teton Pass source appear to vary between opaque and translucent materials, almost giving the appearance of tiger stripes. Other sources produced a similar banded appearance including Obsidian Cliff, Crescent H, Timber Butte and Wild Horse Canyon. The Crescent H artifact was described as gray and smoky fitting with a common megascopic definition from this source (Schoen 1997). One Obsidian Cliff and the Wild Horse Canyon piece were also described as having a smoky appearance. A total of 17 Obsidian Cliff artifacts and one Teton Pass artifact were speckled with either opaque or semi-opaque splotches. A couple of Bear Gulch artifacts were categorized as brown in color, one root beer tinted and the other more mahogany tinted. This is contrary to other studies that reported observations of a consistent black opaque appearance from Bear Gulch artifacts (Baumler 1997:153).

One projectile point and one worked flake were found broken in the field and sent for XRF analysis separately, for a total of two source results for each of the artifacts. The results were consistent with each of the discordant pieces.

Regional Perspectives

As mentioned earlier, a regional perspective is critical to evaluate the significance of the obsidian provenance distribution in the GRSLE research area. Not all sites reviewed for this project have comparable data presented in their reports. Admittedly, comparing sites and study areas of different scales and different formation histories, representing a variety of time periods adds to the difficulty of creating a regional synthesis. An attempt to elucidate valuable regional patterns is made from the available comparative data (Table 5.9).

Table 5.9 Regional Comparison of Obsidian Provenances

	GRSLE	Beartooth Alpine Archaeological Project[a]	Flying D Project[b]	Jackson Lake[c]	Laddie Creek[d]	Lookingbill[c]
Obsidian Cliff	78.7%	79.0%	36.0%	23.5%	66.6%	26.3%
Bear Gulch	7.0%	9.0%	63.1%	12.3%	33.3%	55.5%
Malad	4.0%	3.0%	0.5%	2.5%	0.0%	0.0%
Teton Pass	5.5%	<1%	0.0%	34.6%	0.0%	5.8%
Crescent H	<1%	<1%	0.0%	21.0%	0.0%	12.4%

a. Kunselman 1996
b. Baumler 1997
c. Connor and Kunselman 1995:Table 2
d. Larson 1990
e. Kunselman 1994:Table 2

Obsidian Cliff was the preferred source for the GRSLE and BAAP studies, and the Laddie Creek site. Bear Gulch was favored by users of the Flying D Project area and the Lookingbill site. The source is clearly significant for all areas of the region. While the Malad source plays a role in the obsidian story in many of the areas, it is strongest in the GRSLE. The Wild Horse Canyon and Timber Butte obsidian sources are more distant than any of the obsidian sources from regional sites reviewed herein (Connor and Kunselman 1995; Kunselman 1994; Kunselman and Husted 1996; Sanders 2001). Were GRSLE groups fraternizing more with other groups? Were the people using the GRSLE study area simply more mobile than other regional groups? While the importance of this is unknown, it is interesting.

The regional pattern appears to be that groups in all areas were either interacting or encountering each other using the sources differentially. No area seems to exclusively exploit one lithic resource. A broad regional land use model, based on obsidian source distributions, is presented below (Figure 5.11)

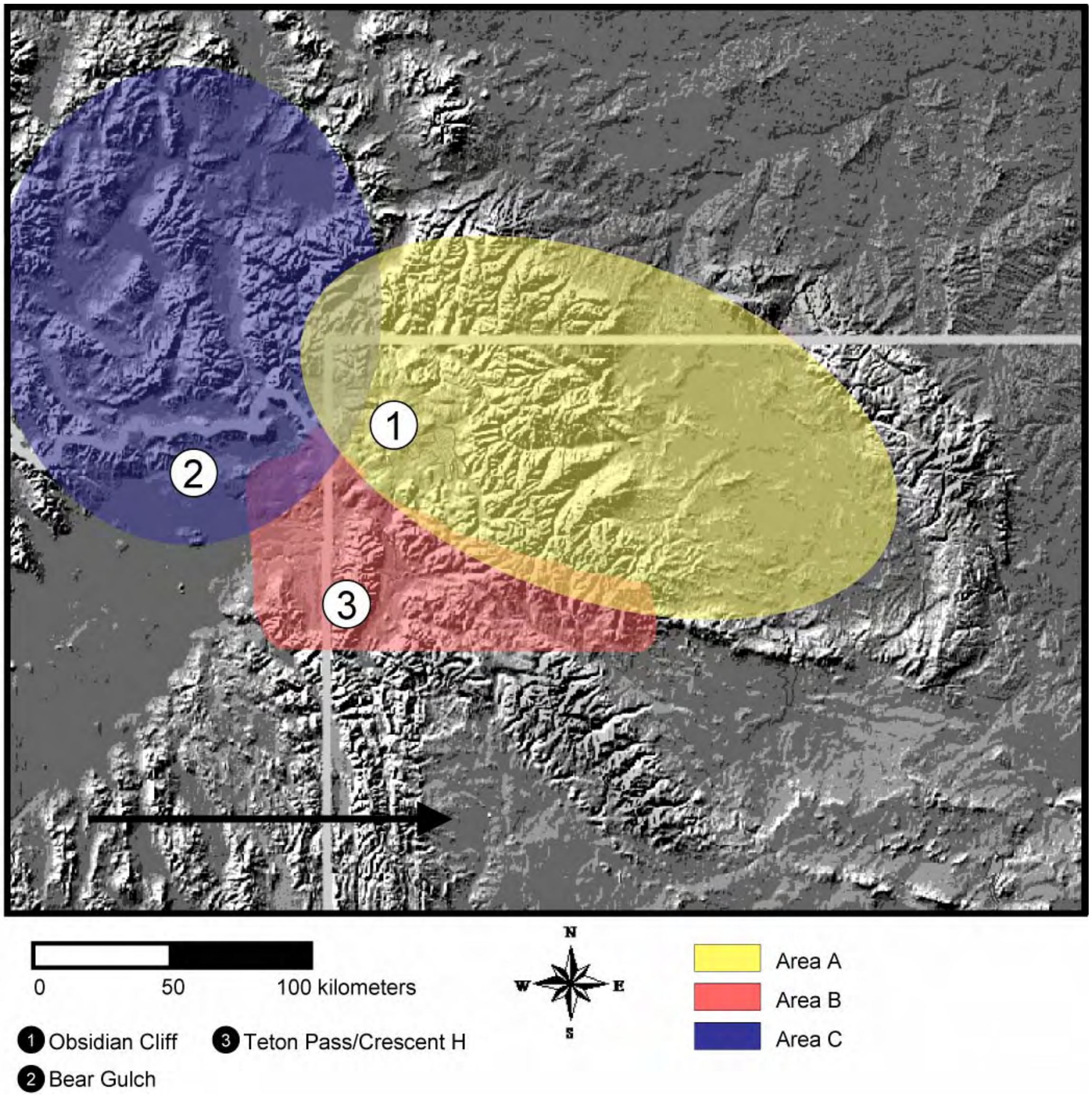

Figure 5.11 Broad schematic of the regional or local obsidian use system including location of major sources in the region.

All of the areas were purposely overlapped to show that none is exclusive. The areas simply represent tendencies. Groups in the northeastern section of the region, area A, were more inclined to the Obsidian Cliff obsidians (Figure 5.11). Southern groups, area B, either stayed local with the Jackson Hole / Teton area obsidians (such as Teton Pass, Crescent H) or worked into the Bear Gulch source. Northwestern groups, area C, preferred Bear Gulch. While this seems obvious, it could be possible that one group was making this regional trek and simply discarding obsidian proximate to the source. If this were the case, no distinctions would be apparent from the temporal information.

Regional Temporal Considerations

One may assume that the dynamism of obsidian distribution in the region would be clarified by parsing out temporal patterns. A preference for quartzite in Late Paleoindian projectile points has been noted at other foothill-mountain assemblages (Kornfeld et al. 2001; Pitblado 2003) and obsidian was not a great influence during this period. Similarly in the Early Archaic, it appears obsidian was an unimportant lithic resource. Obsidian Cliff was likely the major source used in the region during the Middle Archaic. Middle Archaic groups in the Teton Mountain area were favoring Obsidian Cliff (Connor and Kunselman 1995). The one Middle Archaic point in the GRSLE assemblage is from the same source. Additionally, at Mummy Cave, the Middle Archaic component has a strong connection with the Obsidian Cliff source (Hughes 2001).

The time of greatest use (or projectile point discard) in the Greybull is the Late Archaic of which no Obsidian Cliff points have been associated. Interestingly, the Lookingbill collection has an influx of obsidian in the Late Archaic components, most of the obsidians coming from sources other than Obsidian Cliff (Kornfeld et al. 2001). Further, the Yellowstone National Park assemblage is dominated by Late Archaic assemblages from Obsidian Cliff (Johnson 2001). At this same point in time, the use Obsidian Cliff by Beartooth Mountains inhabitants somewhat lessens and increases with respect to the Bear Gulch source. The Late Archaic projectile points from the GRSLE assemblage are from Malad and Timber Butte, both greater than 300km away (Table 3.1).

Is it possible that during the Late Archaic, groups, of the Upper Greybull had limited access to the Obsidian Cliff source and more closely aligned with the modalities towards the far southwest beyond the neighboring Lookingbill inhabitants? This may mean a closer affinity to basin inhabitants than to montane.

The Greybull pattern of obsidian use is greatest during the Late Prehistoric period. Most of the projectile points from this period also come from Obsidian Cliff. The Teton Pass material was also favored during this period of the GRSLE prehistory, as it represents 37.5% of the projectile point provenance for the Late Prehistoric. This seems odd as Bear Gulch was the most common source for Late Prehistoric groups in the Teton Mountains (Connor and Kunselman 1995). Groups in this period were the most liberal obsidian users of all periods.

The results of provenance studies add complexity to the issue of prehistoric land use. Comparing sites and study areas of variable sizes whose boundaries are arbitrary to the prehistoric obsidian may create biases in the interpretation. Simply studying obsidian to interpret prehistoric ranges is problematic as there are no obsidian sources east of Jackson Hole and Yellowstone National Park, and thus movement in that direction is a blank (Connor and Kunselman 1995:46).

CHAPTER 6
Conclusions and Future Directions

Obsidian source utilization adds to the dynamic history painted by the archaeological record. The Absaroka mountain range in northwestern Wyoming has evidence of human use from around 10,000 years before present to current times. Hunter-gatherer subsistence strategies were the primary lifeway in this region until approximately 200 years ago. The mountain range exhibits complex relief patterns, resulting in a heterogeneous landscape, both temporally (with seasons, precipitation-drought cycles, etc.) and spatially (along altitude, slope, aspect, etc.). Additionally, the variance of elevation presents the possibility of higher mobility costs compared to areas of lower elevational variance in the surrounding basins. Prehistoric groups would have been using the mountain ranges extensively in pursuit of lithic resources.

A composite archaeological record including ground stone, game drives, and lithic procurement sites, indicates multiple behavioral adaptations were used across the GRSLE project landscape. The current effective temperature (Bailey 1960; Binford 2001) of the region is approximately 12.42°C (based on weather averages from Meeteetse with January temperatures averaging at -5°C and July temperatures averaging 20°C). This places the area in the most variable arena of mobility behaviors that have been ethnographically recorded (Binford 2001; Kelly 1995). Occupation and subsistence strategies through the range appear to be temporally variable, and mobility regimes are assumed to exhibit the same pattern (Burnett 2005).

Geochemically sourced obsidian samples from the GRSLE project provide a baseline for evaluating prehistoric land use in northwestern Wyoming. It is expected that if we were able to source the entire population of obsidian artifacts (including the debitage smaller than the current minimum required size), the results would change only slightly as indicated by other large regional studies (Kunselman and Husted 1996). In chapter one, five research questions were posed. Considering the information presented in the earlier chapters of this paper each question is addressed below.

<u>What obsidian sources were used by prehistoric people traveling in the Upper Greybull area and were the sources used equally?</u>

Several obsidian sources were used throughout the Upper Greybull prehistoric record. Primarily people passing through the study area were discarding obsidian from Obsidian Cliff. Materials from the Bear Gulch, Malad and Teton Pass sources were also identified in multiple examples. Single pieces of obsidian matched the geochemical signature of obsidian from Timber Butte in western Idaho and Wild Horse Canyon in southwestern Utah. Minor sources in region including Crescent H, Packsaddle Creek, Park Point, and an unknown geochemical type were also linked with single artifacts. The sources were not being used equally. Obsidian Cliff was identified more often than any other source. Prehistoric people were traveling over 140 km to obtain materials from this most frequent source. Only one sample was found from the closest source, Park Point, likely a result of the secondary nature of the source deposits. The sources besides

Obsidian Cliff that saw the greatest use by GRSLE inhabitants all required the material traveled over 140km before the user finally discarded it. Two pieces of obsidian material from sources located over 500km away from the research area were identified.

Are there any temporal, spatial or technological patterns discernable from the recorded obsidian assemblage?

Several interesting patterns have emerged with the obsidian in the GRSLE assemblage. The Late Prehistoric period (1500 to 250 RCBP) saw the greatest use of obsidian based on projectile point raw material frequencies. Obsidian represents the smallest debitage group in the assemblage, indicating high levels of curation by prehistoric groups. Of all the recorded tool types, obsidian is most identified as worked flakes and projectile points. Obsidian artifacts have not been found above elevations of 3200 meters and are most commonly found in the lower ranges of the study area similar to another exotic, Quartzite. The frequency of obsidian artifacts varies by tributary. The material appears to be somewhat more common in the northern section of the study area, but does not exhibit strong azimuthal patterning.

Patterns were also detected within the geochemical characterization sample. While Obsidian Cliff obsidians were used most commonly overall, they may have contributed to a lesser extent as an obsidian source during the Late Archaic (3200 to 1500 RCBP) based on projectile point frequency comparisons. Bear Gulch artifacts are somewhat larger on average than the other sourced materials, but variation in artifact size is not statistically significant between the four most common sources. Obsidian Cliff materials have the greatest range of sizes as expected from the most frequented source.

While Obsidian Cliff artifacts are dominated by debitage, the other frequented sources are identified more commonly as projectile points, bifaces and worked flakes. This is a reflection of the prevalent use of Obsidian Cliff material creating a greater proportion of debitage from tool refinement and manufacture. Spatial patterning of sourced materials within individual sites is greatly dependent on site complexity. Obsidian Cliff obsidian was the favored type in all drainages. Variation in minor source use was observed between drainage tributaries. Drainages may have been favored at different points in time in response to varying resource availability within the drainage, resulting in differential obsidian source distributions.

<u>What does the obsidian use along the Greybull tell us about past land use patterns?</u>

Obsidian use in the Upper Greybull watershed shows that the prehistoric people were holding the obsidian and using it differently than local materials and cherts, bringing it in from locations over 140km from the study area. There is a strong connection between the GRSLE study area and the Obsidian Cliff source area. The people using the Greybull were not accessing obsidian materials in the same way at all points in time, as indicated by the projectile point analysis. Obsidian materials may have served differently in parts of the study area as it is found in greater numbers in the lower elevation ranges and there is variation between the different drainages in the area. The use of specific obsidian source locations resulted in different tool type frequencies. Land use patterns of Greybull inhabitants clearly changed through time and involved interactions beyond the interior of the watershed.

How does the Greybull pattern fit in with the regional pattern?

The overall pattern found in the GRSLE dataset is very similar to patterns observed to the north of this research area in the Beartooth Range. Three generalized spatial affinities in regional obsidian use have been highlighted by this research (Figure 5.11). Throughout the region, technological and temporal variability in obsidian use has been observed. The Late Archaic period is represented by a shift in obsidian source use and general increase in overall number of sites. The Greybull seems to reflect a similar pattern; however, more period specific obsidian sourcing is needed to better define local temporal characteristics in obsidian use. An increase in obsidian artifacts and source variability was apparent during the Late Prehistoric period in the region and the study area.

How do these patterns of obsidian presence inform us about prehistoric land use in northwestern Wyoming and the immediate region?

Because it is impossible to insist on one explanation of the data given the limited nature, five scenarios to explain the GRSLE obsidian patterns are presented below.

Land Use Scenarios

A number of attributes would have affected and influenced prehistoric land use patterns; acquisition of obsidian raw materials is only a minor part of this. Given a regional context, five scenarios are suggested from the evidence presented in this report:

seasonal exploitation, specialized montane adaptation during a specific period, long range adaptation, a foothills-basin adaptation, or stochastic patterning (Table 6.1).

Table 6.1 Land Use Scenario Summary

SCENARIO	DESCRIPTION	CRITICAL EVIDENCE	PERIOD
Seasonal Exploitation	Transhumance	• Seasonality needs to be established • Distinct patterns evident in obsidian amount, size, and tool type by season of occupation	Late Prehistoric
Montane Adaptation	Year-round mountain habitation	• Interaction with basin groups to account for basin materials • Seasonal variation in high and low altitudes • Results in increase of montane raw materials and specialized adaptations	Protohistoric and Historic
Long Range Adaptation	Traveling over large areas in cycles over span of many years	• Few cultural roadblocks, or unlimited territory • Obsidian Cliff last obsidian source visited	Late Paleoindian to Early / Middle Archaic
Foothills-Basin Adaptation	Restricted mobility between Absaroka mountain edge and Bighorn Basin	• Strong links between materials found in GRSLE and Bighorn Basin • High population in region restricting mobility of interior mountain pathways	Late Archaic
Stochastic Acquisition	Chance obsidian acquisition	• Infrequent occurrence of obsidian and no patterning	Earliest use in Paleoindian

Some of the critical evidence has already been supported by the regional archaeological record while some is hypothetical in nature. These scenarios are heuristics for evaluating broad regional land use patterns, and consequently some of the critical evidence may be impossible to prove.

Seasonal Exploitation

Seasonal groups would be using the entire study area, but exploiting different zones as a response to environmental conditions. This pattern is commonly referred to as transhumance, technically the seasonal movement of livestock, but accurately describing a hunter-gatherer pattern of ascending to mountain pastures in summer and descending to relatively warm areas in the valleys, foothills, or basin in winter (Benedict 1992; Burnett 2005; Metcalf and Black 1997). If this were the case, we could expect to see distinct lithic patterns in sites where seasonality can be established. Because of the mountainous terrain, it may be assumed groups would be gathering the obsidian during the warm (passable) seasons. In the fall, sites would have artifacts with larger flakes and possibly the presence of cortex on some artifacts. The early summer sites, those created before the annual restocking, would contain much more reduced pieces of obsidian (if any) and likely, no cortex would remain. Frison (1991:216) suggested that regional groups were making seasonal rounds to the obsidian sources in the mountains at least during the Late Prehistoric period. Obviously, evaluating this model is largely dependent on finding sites with buried components intact enough to reveal seasonality.

Montane Adaptation

A strict mountain adaptation during a specific period may have created some of the obsidian source distributions. The pattern is somewhat similar to the seasonal groups model as human groups would necessarily follow the migratory patterns of food resources. It seems likely that groups exploiting a mountain niche would have detailed knowledge of the obsidian and other local material sources in their foraging range. As the mountains in the region are predominately volcanic in origin, the resulting archaeological record would have a proportionally higher volume of volcanically formed toolstone materials. Additionally, the montane pockets of cryptocrystalline silicates such as Dollar Mountain would have been heavily exploited. This land use was certainly true of the tribes in the area during the protohistoric and historic periods (Janetski 2002). This seems a possible explanation for the increase of obsidian artifacts during the Late Prehistoric period. Integrated use of highly specialized game drives in the GRSLE study area lends credence to a Late Prehistoric montane focus (Frison 1991; Kinneer 2006).

A montane adaptation in Northwestern Wyoming would fit the land use paradigm of the Colorado high country (Benedict 1992; Metcalf and Black 1997). Mountain use is commonly thought to have been the norm for some periods in Rocky Mountain prehistory. Mulloy (1958) suggested a montane retreat during the altithermal climatic event for the northern Rockies (Mulloy 1958). According to Larson (1997:120), "while the altithermal may not have affected high altitude localities to the extent of the eastern plains, ethnographic data shows a changing environment does create stress for groups resulting in a flexibility of settlement-subsistence activities." Basically, even if the mountain environments themselves were not fundamentally altered by the environmental shift, the people likely were affected to some degree. Again, strict montane use may have presented adaptive advantages because of social or environmental factors at points in time. In order to assess this model, we need more data from the interior mountains as the location of the GRSLE study would have been on the fringe of this adaptation due to proximity to the Bighorn Basin.

Long Range Adaptation

Adaptation toward long home ranges is another possibility for the prehistoric land use pattern. In this model, groups would not have been frequenting the study area annually. Long range adaptations have been posited for Plains groups during the

Paleoindian period (Kelly and Todd 1988). The use of an area would cycle over several years and may only see the return to an obsidian source once or twice in an individual's lifetime (Binford 1980). Given the spatial incongruity of the mountainous terrain and the logistic nature of many regional sites, this model seems plausible. In this scenario, groups were likely exploiting the Obsidian Cliff source last in a long chain of obsidian procurement locales, therefore creating the inordinately high percentage of this material in the GRSLE assemblage. To support this scenario, it may be expected that the timing of range events would produce correlates among the distribution of artifacts from spatially distinct non-obsidian lithic source locations and the obsidian sources materials. For instance, one site may have a predominance of lithic (obsidian and other) materials from northern source, while another site would have a predominance of southern lithic resources. Further, this scenario requires lower population densities in the region, allowing for unrestricted (culturally) mobility. A long range adaptation may have been the scenario for the earliest inhabitants of the Upper Greybull, resulting in the sparse record of early sites we have observed.

Foothills-Basin Adaptation

While the largest peak in the Absaroka Range is nestled in the study area, some of it could technically be considered foothills based on proximity of the nearby basin. This adaptation would have been a connected prehistoric land use cycling between the foothills and the basin. This model is similar to seasonal exploitation, but suggests a more limited range and mountain use. The high incidence of Bighorn Basin quartzites and materials from the western foothills of the Bighorn Mountains in the study area supports this model.

Bringing obsidian material into the Upper Greybull would require interaction with other groups at or around the source. Certainly, the development of intergroup exchange relationships would provide a means of risk sharing or buffering (Aldenderfer 1998:19). In montane systems, risk sharing is likely because of the low productivity and high unpredictability (Aldenderfer 1998:20). As discussed in Chapter 2 of this document, exchange or trade is difficult to document archaeologically. It may be expected that traded lithic materials would show up less frequently than procured resources in areas where local material was available. The Foothills-Basin model would require large populations in the region. It is not clear why such an overwhelming trade for Obsidian Cliff material would have occurred, possibly greater affinity with groups to the north than to the southwest and west. The high incidence of Late Archaic sites throughout the region suggests prehistoric users of the Upper Greybull may have been exploiting this type of an adaptation during that period.

Stochastic Acquisition

A model of stochastic acquisition would mean that all obsidian materials were encountered randomly on the landscape. As an embedded part of the subsistence strategy, exotic obsidian materials would be exploited when encountered and not through special logistic trips or trading endeavors. Knowledge of source locations would not be remembered. A preference for any one material would be unlikely in this scenario. It certainly seems as though there is a preference in the Greybull area for obsidian from

Obsidian Cliff, as elsewhere it seems obvious that there is preference for other obsidian sources, therefore chance encounter seems unlikely. Initial movements of human groups into the area would have obviously resulted in a stochastic acquisition of materials. However, knowledge of lithic sources would soon be embedded in the group memory.

Certainly, any of the five scenarios presented above may explain land use patterns at some time in prehistory. Specific scenarios seem more likely for certain periods (Table 6.1). The Seasonal Exploitation land use scenario seems likely for most periods of time after the Early Archaic because high altitude use was limited during prehistoric winter months as it is today. Many factors, both environmental and cultural, would have influenced the land use adaptation occurring during a given period. Mobility and range, and therefore obsidian procurement, are dependent on population density. Throughout the past, forager population density would have waxed and waned with environmental cycles on the local and regional scales through aggregation, dispersion or reproductive fluctuation (Zeanah 2002). The peopling of the North American continent during the Paleoindian period, for example, would at first have allowed for (relatively) unrestricted mobility (Kelly and Todd 1988). As human populations began to establish lives on the landscape and population density increased, mobility regimes would have become more restricted (Surovell 2000). Isolating temporal variability in population densities will help establish regional models of prehistoric land use patterns.

Physiographic Barriers

The landscape of the study area may inform us about how groups were moving around the area. In a mountainous setting, travel corridors are limited. While difficult terrain may be investigated occasionally in search of resources, little leisure time and unpredictability of results would make risky adventures rare. Travel should be limited to areas that would minimize risk, caloric expenditure and travel time (Aldenderfer 2005). Sanders (2001) discusses the potential of the Yellowstone River as a travel corridor for obsidian coming from Obsidian Cliff to the Yellowstone Lake, approximately 15km to the south. The potential of river corridors as means of transporting raw material is compelling for the Upper Greybull. Without the ease of river corridor travel, artifacts may have been moved either directly across the mountains or through lengthy zigzags following game, minor drainages and other environmental conditions. Both of these present costly expeditions in terms of energy and time. The two possibilities for Obsidian Cliff material getting into the GRSLE study area are 1) through the northwest via Boulder Basin/South Fork Shoshone River or 2) through the northeast around Carter Mountain. Either suggestion would see obsidian from Obsidian Cliff leaving the area via the North Fork of the Shoshone River.

The obsidian would travel down the South Fork of the Shoshoni and over the pass to the research area between Eleanor Creek in the study area, Castle Creek in the Boulder Basin, and Hunter Creek to the Shoshone River, the most direct route. This would leave a trail of obsidian changing from large less modified pieces on the Shoshone River side to small more modified pieces on the Greybull River side. The pattern is evident comparing the Boulder Ridge Site assemblage (Finley et al. 2004) with the GRSLE assemblage. Further research along the Boulder Basin Pack Trail will help to define any pattern.

The second possibility cuts around Carter Mountain and drops travelers through the western edge of the Bighorn Basin. This would be more amenable to topographically challenged travelers and appears to be the least costly route. Similar patterning in obsidian artifacts as suggested above would be evident in the record along the southern route towards the Greybull River.

Other travel routes may have existed from the west or southwest. Positing more useful models requires further research. Geochemically sourcing obsidian artifacts in no way presents a clear picture of prehistoric mobility regimes. If prehistoric groups were using the land and distributing the obsidian artifacts in response to environment, it may be expected that the most popular source, Obsidian Cliff, would be found uniformly in all sampled locations. This appears to be the case as all Obsidian Cliff is found in high percentages among all drainages, and in the high and low ranges of elevation. Understanding some of the research problems can help to eliminate error in the future.

Research Problems

Obsidian sampling in this project is largely limited to surface lithic scatters. While the integrity of these sites is jumbled by taphonomic processes, the data are relevant parts of the archaeological record. Rather than being problematic, “the use of XRF technology [on lithic scatters] to determine the source of prehistoric material is a powerful tool. It can take information from surficial sites and palimpsests, and use it generate a series of hypotheses that can be tested at single component, or stratified sites”

(Connor and Kunselman 1995:48). Avoiding sampling from sites traditionally considered to have poor integrity would bias the interpretation of the regional system toward those few prehistoric cases where the behaviors were preserved in stratigraphic sequences (such as Dead Indian Creek or Mummy Cave).

While it is tempting to sample only projectile points that are typological, artifacts cannot be sampled to bias towards tool type. As seen in the GRSLE sample, different patterns are discerned at this level. If the GRSLE project had sampled only projectile points, Obsidian Cliff would still be considered the major source, but to a lesser degree (Table 5.6). Baumler (1997:155) said it best stating that "obsidian can be curated in many packages, with points being but one of them." Further, with the small percentage that obsidian constitutes in the regional record, tool specific sampling protocols would seriously skew the understanding of prehistoric land use patterns. The validity of prehistoric range interpretations hinges on thorough sampling methods.

A problem with inferring prehistoric range comes in the very assumption of a direct link between sources and the end discard location. Exotic material artifacts may have switched hands several times before the discard point, even without direct trade. "There is no reason to suppose prehistoric people, when finding an obsidian piece from an earlier temporal period, did not reuse it" (Connor and Kunselman 1995:41). Extraction of an obsidian material from a source at one point in time, could lead to a projectile point of another period without the creator ever knowing the origin.

Obsidian provenance alone is not an indicator of prehistoric mobility or land use range. Other lithic materials in the Greybull indicate movement to different areas. For instance, steatite (a.k.a. soapstone) artifacts have been recorded in the Greybull research area and identified as material from the Wind River Range to the south (Adams 2003). The boundary of the study area is part of an open system. Prehistorically, people may have been somewhat bounded by the mountain passes, but would have used them nonetheless. The lines we draw around our research areas are generally contrived and may affect the way we interpret the record.

During the literature review for this research, this researcher discovered a bias towards where sites are being recorded. There is a strong indication that site identification is influenced by modern political and state boundaries and transportation corridors. Geochemical sourcing is viewed as a costly project, but helps to flesh out elements of prehistoric land use that are otherwise left to the assumptions of creative archaeologists. A large hole in the regional record exists in the mountains to the east of Jackson Hole and the west of the study area. A push should be made to sample areas that are currently less heavily exploited, before recreation moves here in larger numbers. Additionally, an attempt to geochemically source private collections should be made whenever possible (Kunselman and Husted 1996).

Bias exists on all levels of archaeological inquiry. Further, the nature of geochemical analysis can create debate over the nature of prehistoric procurement. Regardless of the procurement method, direct or indirect, the importance of this study is the direct evidence of the interaction of multiple spheres, ecological, social and technological. How can future research be directed to further evaluate interaction patterns?

Future Directions

This research has created more questions than it has answers. Simply matching geochemical sources with artifacts does little to inform about prehistoric land use; as shown by this research a connection to a more detailed archaeological investigation is required to inform about broader prehistoric land use patterns. Several avenues of research would add to the land use interpretations. Creating a regional GIS model of montane mobility based on least cost analysis would benefit our understanding of potential obsidian travel corridors. Further, it may shed light on some of the regional patterns seen as the result of this research. Understanding the dynamic relationship between watershed characteristics and archaeological assemblages may reveal information about land use. Watershed properties such as flow magnitude, elevation range, and discharge direction should be considered to help further parse out differences in obsidian patterning. Paramount to future research is geochemical sourcing obsidian samples from stratified, buried sites. This will help to date components, but may also highlight site type differences in obsidian source distribution.

Burnett (2005) suggested that obsidian hydration dating unspecified Archaic clusters would benefit the GRSLE project. While problems with inaccuracy make this technique a low priority, this form of testing would help to define diachronic patterns in conjunction with other dating techniques. Hydration analysis is only mildly destructive. The process would clearly mark pieces that have been tested, so that once returned to the landscape they would be readily identifiable. It is advisable to sample for hydration dating from sites that exhibit minimal heat alteration to lithic materials and have additional dating techniques (relative or absolute) available.

Collaboration with ongoing research in the region such as the Boulder Ridge site will help to connect regional patterns. Policies and management that apply fixed rules can lead to systems that increasingly lose resilience (Redman and Kinzig 2003; Gunderson and Holling 2001). The study area should be continually monitored for archaeological conditions as part of an adaptive management policy in the area. This requires cooperation of regional stakeholder including Tribal, Forest Service, Bureau of Land Management and private owners to allow for future testing illuminating regional significance of obsidian source distribution.

The GRSLE project should certainly continue to use geochemical analysis to sample newly discovered obsidian artifacts or previously recorded sites where no samples were collected. It would be useful to combine this with the geochemical analysis of many of the ambiguous chert types. The project should continue sampling as an embedded part of the reconnaissance survey to further define the pattern and reveal rare obsidian types. Additionally, sites targeted for subsurface investigation should have obsidian sourcing as a critical element. Finally, expanding the range of the GRSLE survey to the fringes of the watershed would help to better define the regional pattern. Survey areas should be selected to connect the Upper Greybull watershed with potential travel corridors out of the greater drainage to bring obsidian studies to the next scale.

Appendix A

Site Number	Drainage	Average Elevation	Number of Obsidian XRF Samples						Period(s)
			OC	BG	TP	MD	OW	OD	
48PA2719	Deer Creek	2381	3	0	0	0	0	0	LA
48PA2735	Eleanor Creek	2734	2	0	0	0	0	0	US
48PA2736	Eleanor Creek	2718	1	0	0	0	0	0	US
48PA2769	Greybull River	2354	1	1	0	0	0	0	US
48PA2770	Horse Creek	3217	1	0	0	0	0	0	UA
48PA2772	Jack Creek	2846	4	0	3	0	1	0	UA,EA,LA,LP
48PA2774	Jack Creek	2844	3	0	0	0	0	0	MA,LA,LP
48PA2775	Jack Creek	2846	2	1	0	1	0	0	PLMA,UA,LA
48PA2789	Jack Creek	2840	5	0	0	0	0	0	US
48PA2790	Jack Creek	2899	2	0	0	0	0	0	LA,LP
48PA2792	Jack Creek	2404	1	0	0	0	0	0	PL,MA,LP
48PA2797	Jack Creek	2745	2	0	0	0	0	0	US
48PA2811	Piney Creek	2544	9	0	0	1	0	1	LA
48PA2815	Piney Creek	2590	0	0	1	0	0	1	UA,LP
48PA2816	Piney Creek	2754	1	0	0	0	0	0	US
48PA2817	Piney Creek	2809	2	0	0	0	0	0	US
48PA2821	Vick Creek	2792	1	0	0	0	0	0	LA
48PA2822	Warhouse Creek	2388	1	0	0	0	1	0	LP
48PA2825	Warhouse Creek	2389	4	1	0	0	0	0	LA,LP
48PA2826	Warhouse Creek	2687	0	1	0	0	0	0	LP
48PA2828	Warhouse Creek	2736	1	0	0	0	0	0	US
48PA2832	Warhouse Creek	2871	1	0	0	0	0	0	LP
48PA2835	Wood River	2504	0	1	0	0	0	0	US
48PA2836	Wood River	2200	1	0	0	0	0	0	US
48PA2874	Francs Fork	3099	9	0	2	0	1	0	ALL
48PA2875	Francs Fork	3044	2	0	0	0	0	0	LA
48PA2876	Francs Fork	3121	2	0	0	0	0	0	US
48PA2880	Jack Creek	2763	3	0	0	0	0	0	LA
48PA2881	Jack Creek	2778	1	0	1	0	0	0	LP
48PA2883	Jack Creek	2834	7	0	0	0	0	0	UA,EA,LP
48PA2884	Jack Creek	2843	0	0	0	3	0	0	LA,LP
48PA2885	Jack Creek	2849	0	1	0	0	0	0	PL
48PA2886	Jack Creek	2857	7	0	0	0	0	0	PL,LP
48PA2887	Jack Creek	2894	6	1	0	0	0	0	LA,LP
48PA2889	Jack Creek	2900	1	0	0	0	0	0	US
48PA2891	Jack Creek	2879	0	0	0	0	1	0	UA
48PA2893	Jack Creek	2851	2	0	0	0	0	0	UA,MA,LA,LP
48PA2894	Jack Creek	2892	4	0	0	0	0	0	UA,MA,LA
48PA2895	Jack Creek	2919	0	1	0	0	0	0	LA
48PA2896	Jack Creek	2856	2	1	0	0	0	0	LP
48PA303	Greybull River	2322	1	0	0	0	0	0	LP
48PA48	Wood River	2514	1	0	0	0	0	0	UA,LA
48PA659	Wood River	2803*	1	0	0	0	0	0	US
ISO-JC	Jack Creek	--	1	0	0	0	0	0	US

Appendix B

Table of Geochemical Sourcing Results

ID	SITE	Rb	±	Sr	±	Y	±	Zr	±	Nb	±	Ba	±	Fe/Mn	Obsidian Source
HTH 44	48PA2719	237	4	7	3	76	3	168	4	42	3	nm		nm	Obsidian Cliff, WY
HTH 57	48PA2719	233	4	7	3	76	3	164	4	40	3	nm		nm	Obsidian Cliff, WY
LJM 46	48PA2719	235	4	8	3	78	3	165	4	43	3	nm		nm	Obsidian Cliff, WY
LCT 265	48PA2735	239	4	7	3	78	3	166	4	43	3	nm		nm	Obsidian Cliff, WY
LCT 279	48PA2735	227	4	6	3	76	3	162	4	41	3	nm		nm	Obsidian Cliff, WY
BLT 34	48PA2736	250	4	7	3	80	3	167	4	42	3	nm		nm	Obsidian Cliff, WY
ADB 49	48PA2769	240	4	7	3	78	3	169	4	43	3	nm		nm	Obsidian Cliff, WY
ADB 57	48PA2769	172	4	51	3	45	3	302	4	56	3	774	15	nm	Bear Gulch, ID
HTH 1	48PA2770	258	4	10	3	80	3	168	4	45	3	nm		nm	Obsidian Cliff, WY
ADB 4	48PA2772	98	4	149	3	20	3	113	4	12	3	1202	15	46	Crescent H, WY
ADB 5	48PA2772	123	4	135	3	27	3	78	4	14	3	nm		32	Teton Pass, WY
ADB 6	48PA2772	257	4	9	3	71	3	165	4	51	3	nm		nm	Obsidian Cliff, WY
ADB 7	48PA2772	127	4	130	3	28	3	78	4	17	3	nm		31	Teton Pass, WY
ADB 8	48PA2772	119	4	122	3	27	3	72	4	16	3	nm		31	Teton Pass, WY
JMB 5	48PA2772	241	4	8	3	76	3	168	4	51	3	nm		nm	Obsidian Cliff, WY
ZK 10	48PA2772	253	4	8	3	77	3	172	4	48	3	nm		nm	Obsidian Cliff, WY
ZK 9	48PA2772	244	4	8	3	77	3	173	4	50	3	nm		nm	Obsidian Cliff, WY
HTH 3	48PA2774	254	4	9	3	80	3	170	4	44	3	nm		nm	Obsidian Cliff, WY
HTH 4	48PA2774	252	4	8	3	82	3	169	4	43	3	nm		nm	Obsidian Cliff, WY
HTH 5	48PA2774	230	4	7	3	76	3	166	4	41	3	nm		nm	Obsidian Cliff, WY
ADB 81	48PA2775	118	4	72	3	31	3	83	4	12	3	1609	15	nm	Malad, ID
ADB 82	48PA2775	170	4	52	3	44	3	304	4	57	3	751	15	nm	Bear Gulch, ID
NO 27	48PA2775	230	4	7	3	78	3	152	4	40	3	nm		nm	Obsidian Cliff, WY
NO 28	48PA2775	243	4	8	3	79	3	174	4	42	3	nm		nm	Obsidian Cliff, WY
BS 133	48PA2788	243	4	8	3	77	3	171	4	51	3	nm		nm	Obsidian Cliff, WY
BS 134	48PA2788	180	4	53	3	47	3	307	4	64	3	771	15	nm	Bear Gulch, ID
BS 174	48PA2788	250	4	9	3	76	3	173	4	48	3	nm		nm	Obsidian Cliff, WY
ADB 87	48PA2789	247	4	8	3	80	3	169	4	43	3	nm		nm	Obsidian Cliff, WY
ADB 88	48PA2789	221	4	8	3	78	3	163	4	39	3	nm		nm	Obsidian Cliff, WY
HTH 150	48PA2789	234	4	14	3	77	3	168	4	41	3	nm		nm	Obsidian Cliff, WY
HTH 61	48PA2789	252	4	8	3	80	3	172	4	44	3	nm		nm	Obsidian CLiff, WY
NO 66	48PA2789	258	4	9	3	81	3	171	4	43	3	nm		nm	Obsidian Cliff, WY
JKL 7	48PA2790	253	4	8	3	75	3	172	4	50	3	nm		nm	Obsidian Cliff, WY
LJM 4	48PA2790	243	4	8	3	77	3	168	4	48	3	nm		nm	Obsidian Cliff, WY
BR 2	48PA2792	235	4	10	3	79	3	169	4	43	3	nm		nm	Obsidian Cliff, WY
NO 56	48PA2797	246	4	9	3	80	3	170	4	44	3	nm		nm	Obsidian Cliff, WY
NO 77	48PA2797	263	4	9	3	82	3	168	4	46	3	nm		nm	Obsidian Cliff, WY
ABH 41	48PA2811	257	4	8	3	80	3	166	4	42	3	nm		nm	Obsidian Cliff, WY
ADB 17	48PA2811	182	4	17	3	43	3	48	4	34	3	nm		nm	Timber Butte, ID
ADB 35	48PA2811	247	4	8	3	84	3	168	4	45	3	nm		nm	Obsidian Cliff, WY
ADB 4a	48PA2811	243	4	7	3	73	3	172	4	49	3	nm		nm	Obsidian Cliff, WY
ADB 4b	48PA2811	245	4	70	3	81	3	171	4	49	3	nm		nm	Obsidian Cliff, WY

ID	SITE	Rb	±	Sr	±	Y	±	Zr	±	Nb	±	Ba	±	Fe/Mn	Obsidian Source
ADB 5	48PA2811	239	4	6	3	80	3	170	4	45	3	13	12	nm	Obsidian Cliff, WY
ADB 6	48PA2811	220	4	9	3	75	3	157	4	40	3	nm		nm	Obsidian Cliff, WY
CRB 7	48PA2811	258	4	8	3	81	3	175	4	45	3	nm		nm	Obsidian Cliff, WY
JMJ 21	48PA2811	220	4	6	3	74	3	159	4	39	3	nm		nm	Obsidian Cliff, WY
JMJ 24	48PA2811	124	4	73	3	32	3	84	4	13	3	1608	12	nm	Malad, ID
JMJ 25	48PA2811	239	4	10	3	77	3	172	4	44	3	nm		nm	Obsidian Cliff, WY
ABH 108	48PA2815	113	4	121	3	25	3	69	4	13	3	1246	15	nm	Teton Pass, WY
ABH 118	48PA2815	189	4	42	3	20	3	109	4	25	3	164	10	nm	Wild Horse Canyon, UT
LCT 26	48PA2816	242	4	8	3	78	3	166	4	41	3	nm		nm	Obsidian Cliff, WY
LCT 173	48PA2817	241	4	8	3	81	3	172	4	43	3	nm		nm	Obsidian Cliff, WY
LCT 186	48PA2817	266	4	7	3	82	3	175	4	45	3	nm		nm	Obsidian Cliff, WY
LCT 175	48PA2821	261	4	8	3	83	3	171	4	44	3	nm		nm	Obsidian Cliff, WY
ABH 22	48PA2822	158	4	26	3	63	3	327	4	51	3	1008	15	nm	Packsaddle Creek, ID
ABH 24	48PA2822	249	4	9	3	83	3	164	4	45	3	nm		nm	Obsidian Cliff, WY
ABH 1	48PA2825	224	4	6	3	74	3	159	4	40	3	nm		nm	Obsidian Cliff, WY
ABH 2	48PA2825	243	4	8	3	82	3	174	4	44	3	nm		nm	Obsidian Cliff, WY
ADB 1	48PA2825	250	4	6	3	78	3	168	4	43	3	nm		nm	Obsidian Cliff, WY
CRB 1	48PA2825	172	4	51	3	45	3	303	4	56	3	709	10	nm	Bear Gulch, ID
JMJ 5	48PA2825	257	4	6	3	80	3	172	4	45	3	nm		nm	Obsidian Cliff, WY
ADB 46	48PA2826	170	4	50	3	43	3	295	4	55	3	742	10	nm	Bear Gulch, ID
LCT 29	48PA2828	238	4	7	3	77	3	174	4	44	3	nm		nm	Obsidian Cliff, WY
ADB 6	48PA2832	244	4	7	3	81	3	168	4	43	3	nm		nm	Obsidian Cliff, WY
HTH 170	48PA2835	181	4	52	3	43	3	310	4	57	3	752	10	nm	Bear Gulch, ID
HTH 18	48PA2836	233	4	9	3	77	3	164	4	43	3	nm		nm	Obsidian Cliff, WY
ABH 86	48PA2874	226	4	8	3	72	3	158	4	45	3	nm		nm	Obsidian Cliff, WY
ADB 10	48PA2874	252	4	5	3	80	3	165	4	50	3	nm		nm	Obsidian Cliff, WY
ADB 11	48PA2874	256	4	6	3	77	3	167	4	51	3	nm		nm	Obsidian Cliff, WY
ADB 12	48PA2874	250	4	8	3	78	3	167	4	51	3	nm		nm	Obsidian Cliff, WY
ADB 15	48PA2874	259	4	8	3	76	3	172	4	49	3	nm		nm	Obsidian Cliff, WY
ADB15-2	48PA2874	241	4	6	3	74	3	163	4	47	3	nm		nm	Obsidian Cliff, WY
ADB 16	48PA2874	265	5	10	3	83	3	174	5	51	3	nm		nm	Obsidian Cliff, WY
ADB 65	48PA2874	112	4	127	3	23	3	75	4	12	3	1108	18	31	Teton Pass, WY
LCT 25	48PA2874	164	4	59	3	51	3	347	4	35	3	1367	18	81	Park Point, WY?
LCT 45	48PA2874	217	4	6	3	73	3	161	4	44	3	nm		nm	Obsidian Cliff, WY
NO 131	48PA2874	123	4	128	3	25	3	73	4	13	3	1245	18	29	Teton Pass, WY
NO 154	48PA2874	234	4	5	3	73	3	165	4	47	3	nm		nm	Obsidian Cliff, WY
NO 163	48PA2874	1	4	9	3	2	3	2	4	0	3	nm		nm	Not Obsidian
LCT 149	48PA2875	256	4	7	3	74	3	174	4	47	3	nm		nm	Obsidian Cliff, WY
ZAM 103	48PA2875	265	4	12	3	82	3	174	4	50	3	nm		nm	Obsidian Cliff, WY
LCT 25	48PA2876	253	4	8	3	75	3	166	4	48	3	nm		nm	Obsidian Cliff, WY
MAT 5	48PA2876	260	4	7	3	80	3	167	4	50	3	nm		nm	Obsidian Cliff, WY
LJM 25	48PA2880	220	4	7	3	73	3	157	4	47	3	nm		nm	Obsidian Cliff, WY
LJM 26	48PA2880	255	4	8	3	78	3	173	4	47	3	nm		nm	Obsidian Cliff, WY
LJM 29	48PA2880	261	4	8	3	81	3	175	4	49	3	nm		nm	Obsidian Cliff, WY
BS 21	48PA2881	242	4	9	3	73	3	165	4	47	3	nm		nm	Obsidian Cliff, WY
BS 93	48PA2881	125	4	124	3	26	3	71	4	16	3	1280	21	30	Teton Pass, WY
ADB 27	48PA2883	216	4	8	3	73	3	159	4	45	3	nm		nm	Obsidian Cliff, WY
JKL 20	48PA2883	238	4	8	3	74	3	167	4	49	3	nm		nm	Obsidian Cliff, WY
JMB 103	48PA2883	240	4	7	3	72	3	171	4	47	3	nm		nm	Obsidian Cliff, WY
JMB 44	48PA2883	216	4	8	3	73	3	161	4	48	3	nm		nm	Obsidian Cliff, WY
SLT 6	48PA2883	230	4	7	3	73	3	169	4	47	3	nm		nm	Obsidian Cliff, WY
SOH 74	48PA2883	216	4	7	3	77	3	161	4	44	3	nm		nm	Obsidian Cliff, WY

ID	SITE	Rb	±	Sr	±	Y	±	Zr	±	Nb	±	Ba	±	Fe/Mn	Obsidian Source
ZK 146	48PA2883	255	4	8	3	76	3	174	4	48	3	nm		nm	Obsidian Cliff, WY
SOH 11	48PA2884	121	4	71	3	29	3	81	4	15	3	1657	21	46	Malad, ID
SOH 15	48PA2884	126	4	75	3	21	3	83	4	16	3	1603	18	45	Malad, ID
SOH 51	48PA2884	249	4	7	3	76	3	169	4	47	3	nm		nm	Obsidian Cliff, WY
ZK 101	48PA2884	216	4	8	3	76	3	157	4	44	3	nm		nm	Obsidian Cliff, WY
ZK 115	48PA2884	122	4	76	3	32	3	87	4	14	3	1640	18	44	Malad, ID
CB 91	48PA2885	167	4	50	3	41	3	294	4	62	3	780	18	51	Bear Gulch, ID
EMP 116	48PA2886	256	4	9	3	81	3	173	4	52	3	nm		nm	Obsidian Cliff, WY
MAT 72	48PA2886	248	4	7	3	79	3	171	4	50	3	nm		nm	Obsidian Cliff, WY
MAT 77	48PA2886	254	4	9	3	75	3	172	4	49	3	nm		nm	Obsidian Cliff, WY
MAT 81	48PA2886	246	4	9	3	80	3	175	4	49	3	nm		nm	Obsidian Cliff, WY
MAT 91	48PA2886	253	4	9	3	73	3	170	4	49	3	nm		nm	Obsidian Cliff, WY
MAT 92	48PA2886	242	4	8	3	76	3	169	4	51	3	nm		nm	Obsidian Cliff, WY
MAT 97	48PA2886	248	4	8	3	76	3	174	4	50	3	nm		nm	Obsidian Cliff, WY
EMP 12	48PA2887	164	4	49	3	42	3	296	4	60	3	761	15	nm	Bear Gulch, ID
EMP 5	48PA2887	255	4	9	3	77	3	173	4	48	3	nm		nm	Obsidian Cliff, WY
EMP 6	48PA2887	247	4	9	3	75	3	175	4	50	3	nm		nm	Obsidian Cliff, WY
LJM 38	48PA2887	248	4	8	3	73	3	170	4	49	3	nm		nm	Obsidian Cliff, WY
MAT 20	48PA2887	254	4	10	3	75	3	176	4	49	3	nm		nm	Obsidian Cliff, WY
MLR 1	48PA2887	230	4	8	3	72	3	160	4	48	3	nm		nm	Obsidian Cliff, WY
MLR 2	48PA2887	246	4	7	3	76	3	165	4	47	3	nm		nm	Obsidian Cliff, WY
MAT 4	48PA2889	252	4	11	3	76	3	171	4	50	3	nm		nm	Obsidian Cliff, WY
ZK 18	48PA2891	165	4	20	3	62	3	188	4	27	3	533	15	81	Unknown
ADB 10	48PA2893	251	4	8	3	75	3	173	4	49	3	nm		nm	Obsidian Cliff, WY
CB 72	48PA2893	243	4	7	3	74	3	170	4	49	3	nm		nm	Obsidian Cliff, WY
JMB 33	48PA2894	241	4	5	3	73	3	166	4	48	3	nm		nm	Obsidian Cliff, WY
LJM 37	48PA2894	238	4	8	3	73	3	166	4	51	3	nm		nm	Obsidian Cliff, WY
LJM 47	48PA2894	247	4	7	3	75	3	170	4	49	3	nm		nm	Obsidian Cliff, WY
LJM 48	48PA2894	249	4	7	3	74	3	169	4	49	3	nm		nm	Obsidian Cliff, WY
MLR 137	48PA2895	166	4	49	3	42	3	292	4	62	3	760	15	nm	Bear Gulch, ID
LCT-B 5	48PA303	214	4	7	3	73	3	163	4	40	3	nm		nm	Obsidian Cliff, WY
HTH 64	48PA48	232	4	8	3	80	4	165	4	40	3	nm		nm	Obsidian Cliff, WY
1034	48PA659	246	4	8	3	81	3	173	4	44	3	nm		nm	Obsidian Cliff, WY
LCTT 84	Isolate	219	4	6	3	66	3	161	4	44	3	nm		nm	Obsidian Cliff, WY

Appendix C

Table of Lithic Analysis Results

ID	SITE	EL	POR	SEG	MT	MLEN	MWID	MTHK	WT	PTW	PTT	PTDESC	CTX	LIP	INCLU	SA	DR RIDGE	CHAR	TP	COMMMENTS
LCTT 84		BF	FR	US	C	18.2	15.7	6.4	1.7	999	999		0	NA	0	SF DULL 50%, BR GLS	SH, SM	S		
HTH 44	PA2719	FK	CO	CO	T	18.1	24.9	3.5	1.6	8.9	3.5	PREPARED PLATFORM	0	P	0	GLS	SH	O		
HTH 57	PA2719	FKW	ME	US	T	42	21.2	6.8	7.3	999	999		0	NA	0	DR DULL <25%	SH	S		REFIT WITH LJM046; DULLING POSS CTX
LJM 46	PA2719	FKW	DS	US	T	18.5	16.7	5.2	1.7	999	999		0	NA	0	DR DULL 75%	SH	S		REFIT WITH HTH057; DULLING POSS CTX
LCT 265	PA2735	FKU	DS	CO	T	20.2	13.2	6.4	1.1	999	999	PREPARED, CRUSHED PLATFORM	0	NA	0	DR DULL 100%	SH	S		
LCT 279	PA2735	FKU	CO	CO	T	15.6	12.1	6.5	0.8	999	999		0	NA	ND	DULL	SH	O		
BLT 34	PA2736	PP	DS	CO	T	20.4	12.1	3.1	0.7	999	999		0	NA	0	DULL ONE SIDE	SH	T	US	
ADB 49	PA2769	PP	ME	US	T	18.4	13.9	3.8	1	999	999		0	NA	CRS	SF DULL, BR GLS	SM	T, SP-O	US	
ADB 57	PA2769	FK	DS	US	C	16	10.3	3.7	0.5	999	999		0	NA	0	VN DULL	SH	O		
HTH 1	PA2770	FK	CO	CO	C	35.1	25.9	3.1	2.2	9.2	2.8	PREPARED PLATFORM	0	P	0	GLS	SM	T, SP-O		
ADB 4	PA2772	PP	ME	US	T	21.4	14.7	3.4	1.3	999	999		0	NA	0	DV	SH	GRS, SK, BAND	US	
ADB 5	PA2772	PP	PR	CO	T	5.2	12.1	2.3	0.1	999	999		0	NA	0	DULL 50%	SM	T, BAND=O	LP	
ADB 6	PA2772	PP	PR	CO	T	7.8	11.6	2.3	0.2	999	999		0	NA	0	DULL ONE SIDE	US	T, SP-O	LP	AKA HTH204-062903
ADB 7	PA2772	FKU	DS	US	C	13.1	9.5	1.8	0.2	999	999		3	NA	0	DULL	SM	T, BAND=O		
ADB 8	PA2772	PP	CO	US	T	17.8	11.7	2.2	0.3	999	999		0	NA	0	GLS	SH	T, BAND=S, SP=O	LP	AKA KMD026-2003
JMB 5	PA2772	FKU	DS	CO	C	15.4	10.7	2.6	0.4	999	999	CRUSHED PLATFORM	0	NA	0	DULL	SM	T, SP-O		
ZK 10	PA2772	ANG	US	US	C	17.4	8.1	2.6	0.4	999	999		0	NA	0	DULL <75%	SH	T, SP-O		
ZK 9	PA2772	FKW	DS	US	T	19.8	18.7	3.3	1.4	999	999		0	NA	0	DR DULL 100%	SM	T		
HTH 3	PA2774	PP	PR	US	T	12.7	12.9	5.3	0.9	999	999		0	NA	0	DULL <50%	SM	T	MA	
HTH 4	PA2774	FKU	DS	CO	C	16.9	15.3	1.6	0.5	999	999	PREPARED, CRUSHED PLATFORM	0	NA	0	GLS	CR, SM	T		
HTH 5	PA2774	FKU	CO	CO	T	28.6	19.7	5.6	1.7	10.7	4.1	HIGH PREPARED PLATFORM	0	A	0	DULL 75%	SH	S, SP-O		
ADB 81	PA2775	BF	LT	ME	C	13.9	12.5	4	0.8	999	999		0	NA	0	GLS	SH	S		BROKEN EDGES CONTAIN SEVERAL IRREGULAR BREAKS, ALMOST WORKED ON BROKEN SURFACES; LARGE UNMODIFIED AREA ON ONE SURFACE

ID	SITE	EL	POR	SEG	MT	MLEN	MWID	MTHK	WT	PTW	PTT	PTDESC	CTX	LIP	INCLU	SA	DR RIDGE	CHAR	TP	COMMMENTS
ADB 82	PA2775	FKW	PR	US	T	22.6	13.2	4.3	1.5	7.9	2.8	PREPARED PLATFORM	0	A	0	DR DULL 100	SM	O		
NO 27	PA2775	FKU	PR	US	C	16.2	10.3	4	0.7	9.6	1.7	PREPARED, CRUSHED PLATFORM	0	A	0	DR DULL 100	SM	T		
NO 28	PA2775	FKW	PR	LT	T	24.6	25.7	3.7	2.2	999	999		0	NA	0	DR DULL 100	SM	S		
BS 133	PA2788	FKU	DS	US	C	17.2	13.9	3.3	0.8	999	999		0	NA	0	GLS	SM	T		
BS 134	PA2788	FKU	ME	US	C	16	19.5	2.8	0.9	999	999	CRUSHED PLATFORM	0	NA	0	VN DULL 75	SM	BRS		ROOT BEER OBSIDIAN
BS 174	PA2788	FKU	CO	CO	C	20.2	14.5	3.1	0.7	999	999		0	NA	ND	GLS	SH	T		
ADB 87	PA2789	FKW	PR	US	T	15.4	17.6	3.3	0.7	9.8	2.7	HIGHLY PREPARED, CRUSHED PLATFORM	0	A	CRS	GLS	SM	T		
ADB 88	PA2789	FKU	ME	LT	C	16.5	13.3	3.9	0.7	999	999		0	NA	0	DULL	SM	T		SMOOTHED EDGES ON BROKEN SURFACES
HTH 150	PA2789	FK	PR	US	C	13.8	11.4	3	0.4	999	999	CRUSHED PLATFORM	0	NA	ND	GLS	SH	T, SP-O		BIFACIAL THINNING FLAKE
HTH 61	PA2789	BF5	LT	END	C	9.8	9.8	2.2	0.2	999	999		0	NA	CRS	GLS	SH	T		
NO 66	PA2789	FKU	CO	CO	T	14.3	14.1	4.1	0.6	7.8	2.3		0	A	0	GLS	SH	T		
JKL 7	PA2790	FKU	ME	US	C	18.2	16.1	3.4	1	999	999		0	NA	0	DR DULL <25%	SM	T		
LJM 4	PA2790	FKU	ME	US	C	16.4	15.1	2.9	0.7	999	999	CRUSHED PLATFORM	0	NA	0	DR DULL	SM	T, SP-O		
BR 2	PA2792	PP	PSH	CO	T	11.7	11.3	2.1	0.3	999	999		0	NA	0	GLS	SH	T	LP	
NO 56	PA2797	FKU	DS	US	C	12.4	8.5	3	0.3	999	999		0	NA	0	DULL <25%	SM	T, SP-O		
NO 77	PA2797	FK	CO	CO	T	22.3	13.2	1.6	0.4	5.2	1.1		0	A	0	GLS	SH	T		LARGE BIFACIAL THINNING FLAKE
ABH 41	PA2811	FK	ME	US	C	24.1	16.1	2.9	1	999	999		0	NA	0	DULL 50%	US	T, SP-S		BIPOLAR FLAKE Poss.
ADB 17	PA2811	PP	CO	US	T	22.4	16.1	3.5	1	999	999		0	NA	0	GLS	SM	S, ONE BAND=O	LA	
ADB 35	PA2811	FKU	DS	CO	C	20.4	19.8	4.2	1.4	999	999		0	NA	0	DULL	SH	T		
ADB 4a	PA2811	FK	ME	US	C	19	16.4	2.6	0.9	999	999		0	NA	0	GLS	SH	T		REFIT WITH ADB 4B
ADB 4b	PA2811	FK	ME	LT	C	21.9	13.5	3.1	0.7	999	999		0	NA	0	GLS	SH	T		REFIT WITH ADB 4A
ADB 5	PA2811	FKW	CO	CO	T	26.6	25.3	10.3	5.5	11.5	4.7		0	A	0	GLS	SH	T		
ADB 6	PA2811	FK	CO	CO	T	17.4	21.6	8.2	2.5	13.2	4.4		3	P	0	DR DULL	SM	S		
CRB 7	PA2811	FK	ME	US	C	15.2	11.8	2.5	0.3	999	999	CRUSHED PLATFORM	0	NA	0	DR DULL	SM	T, SP-S		
JMJ 21	PA2811	FK	PR	US	T	22.1	17.1	3.3	1.1	3.8	1.7	PREPARED PLATFORM	0	P		DV	SH	S		
JMJ 24	PA2811	ANGU	US	US	C	18.8	16.3	4.8	1	999	999		0	NA	0	DULL	SM	O		
JMJ 25	PA2811	FKU	CO	CO	T	28.2	28	9.3	6.6	12.5	3		0	P	CRS	DR DULL 100	CR, SH	S		
ABH 108	PA2815	FK	ME	US	C	13.9	12.9	4	0.8	999	999		0	NA	0	GLS	SM	S, BAND=BKO		
ABH 118	PA2815	FK	PR	CO	T	17.8	16.2	6.1	1.8	11.1	4.3		0	A	0	DR DULL 100	SM	GRS, SK, BAND		
LCT 26	PA2816	FK	ME	US	C	13.6	9.4	5.4	0.8	999	999		0	NA	0	GLS	SH	S		
LCT 173	PA2817	FKU	DS	US	C	13.9	13.2	4.5	0.4	999	999		0	NA	0	GLS	SH	T		
LCT 186	PA2817	FK	ME	US	C	15.8	12.9	2	0.5	999	999		0	NA	0	DR DULL 100	SM	T		SMOOTHED EDGES
LCT 175	PA2821	BF	END	US	C	14.3	7.9	2.1	0.2	999	999		0	NA	0	DULL <75%	SH	T		POSSIBLE HAFTING PORTION
ABH 22	PA2822	BF5	LT	END	C	10.4	8.4	3	0.3	999	999		0	NA	0	GLS	SH	O		
ABH 24	PA2822	FKW	ME	CO	T	43.5	24	8.9	7.6	999	999		0	NA	ND	GLS	SM	S		
ABH 1	PA2825	PP	PSH	US	T	15.2	13.7	3.6	0.7	999	999		0	NA	CRS	GLS	SH	T	LP	REFIT WITH ABH 2
ABH 2	PA2825	PP	ME	US	T	13.2	12.9	3.1	0.4	999	999		0	NA	ND	DULL ONE SIDE	SH	T	LP	REFIT WITH ABH 1
ADB 1	PA2825	FK	CO	CO	T	46	17.9	9	4.3	6.8	3.6	PREPARED PLATFORM	0	A	0	VN DULL	CR	T		CORE PREPARATION FLAKE

ID	SITE	EL	POR	SEG	MT	MLEN	MWID	MTHK	WT	PTW	PTT	PTDESC	CTX	LIP	INCLU	SA	DR RIDGE	CHAR	TP	COMMMENTS
CRB 1	PA2825	PP	CO	US	T	27.2	13.4	4.6	1.2	999	999		0	NA	0	DULL ONE SIDE	SM DULL SIDE	O	LP	
JMJ 5	PA2825	FK	ME	US	C	25.4	16.6	10.4	4.4	999	999		0	NA	0	DV, DR DULL 100	SM	GRO		
ADB 46	PA2826	FKU	CO	CO	T	21.1	14.6	5.3	1.2	9.2	4.6	PREPARED PLATFORM	0	A	CRS	DULL	SH	O		SMOOTHED EDGES
LCT 29	PA2828	FK	CO	CO	T	13.7	23.3	6.3	1.6	11.9	5.3	PREPARED PLATFORM	0	A	0	DR DULL <50%	SH	S		
ADB 6	PA2832	PP	PSH	US	T	16.7	13.5	3.1	0.7	999	999		0	NA	0	GLS	SH	T	LP	
HTH 170	PA2835	ANG	US	US	C	33.7	17.8	13.2	7.8	999	999		0	NA	0	DULL	SM	O		
HTH 18	PA2836	FKU	PR	US	T	11.6	7.7	2.6	0.2	4.7	1.9	PREPARED PLATFORM	0	A	0	DULL	SM	T, SP-O		
ABH 86	PA2874	ANGU	US	US	C	20.1	11.2	4.1	0.7	999	999		0	NA	0	VN DULL, DR DULL 75%	SM	T, BAND=S		SMOOTHED EDGES
ADB 10	PA2874	FKU	DS	CO	C	28.6	16.6	5.1	2.3	999	999	CRUSHED PLATFORM	0	NA	0	DR DULL, DV	CR, SH	S		
ADB 11	PA2874	FKU	CO	CO	T	24	14.3	2	0.5	3.7	1.2	PREPARED PLATFORM	0	A	0	GLS	SH	S		BIFACIAL THINNING FLAKE
ADB 12	PA2874	FKU	CO	CO	T	24.8	24	3.5	1.4	4	2	PREPARED PLATFORM	0	P	0	DULL	SM	T		
ADB 15	PA2874	FKW	ME	LT	C	26.7	15.6	8.1	2.7	999	999		0	NA	0	DULL	SM	S		
ADB 15-2	PA2874	FK	DS	US	C	17.3	11.4	2.7	0.4	999	999		0	NA	0	DV	US	T		
ADB 16	PA2874	FK	CO	CO	T	31.2	15.4	2.2	0.9	7	1.5	CRUSHED PLATFORM	0	A	0	DULL	SH	GRT, SK, BAND=BKS		BIFACIAL THINNING FLAKE
ADB 65	PA2874	FKU	CO	CO	T	31.9	17	7	2.6	4.2	1.7	PREPARED PLATFORM	1	A	0	DULL	SH	S, BAND=BKS		
LCT 25	PA2874	PP	PSH	US	T	19.4	17.7	4.4	1.5	999	999		0	NA	RHY	DULL <25%	SM	O	UA	
NO 131	PA2874	FK	PR	US	T	20.2	15.9	2.3	0.9	3.5	1.7	PREPARED PLATFORM	0	P	0	GLS	SM	T, BAND=S		
NO 154	PA2874	FK	DS	CO	C	23.3	16	4.9	2.1	999	999	CRUSHED PLATFORM	0	NA	CRS	DR DULL <25%	SH	T		
ZAM 103	PA2874	FKU	PR	US	C	29.4	10.4	6.7	1.6	999	999		0	NA	RHY	DR DULL 50%	SH	O		
LCT 49	PA2875	FKU	PR	US	C	14.2	11.7	1.7	0.3	4.7	1.5		0	A	0	DR DULL 100	SM	T		
MAT 5	PA2875	FK	ME	US	C	12.5	11.5	1.9	0.3	999	999		0	NA	CRS	GLS	SH	T		
LCT 25	PA2876	ANG	US	US	C	14.5	10.9	5.2	0.7	999	999		0	NA	0	DULL 75%	CR, SH	S		
LCT 45	PA2876	FKU	CO	CO	T	12.2	20.1	6	1.1	999	999		2	NA	0	DR DULL	SM	T		
LJM 25	PA2880	BF4	ME	LT	T	18.7	13.6	3.4	0.7	999	999		0	NA	0	GLS, DV	SH	S		
LJM 26	PA2880	FK	CO	CO	T	10.9	14.8	3.2	0.3	3	1.4	PREPARED PLATFORM	0	A	0	GLS	SH	T		
LJM 29	PA2880	FK	ME	US	C	12	11.7	2.1	0.4	999	999		0	NA	0	GLS	SH	T		POSS. BIFACIAL THINNING FLAKE
BS 21	PA2881	FK	PR	US	C	16.3	11.6	2.6	0.4	3.8	1.8	PREPARED PLATFORM	0	P	0	GLS, DV	SH	T		BIFACIAL THINNING FLAKE
BS 93	PA2881	PP	PSH	US	T	13.8	11	2.5	0.4	999	999		0	NA	0	GLS	SH	S	LP	LARGE UNFLAKED AREA ON ONE SURFACE
ADB 27	PA2883	FKU	DS	CO	C	24.9	13.9	7	2.2	999	999	CRUSHED PLATFORM	0	NA	ND	GLS	SH	T		
JKL 20	PA2883	BF	ME	US	C	23.8	19.2	4.7	2.4	999	999		0	NA	0	GLS, DV	SH	S		
JMB 103	PA2883	BF	ME	FR	C	16.2	12.7	4	0.8	999	999		0	NA	0	SF DULL <25%	SM, SH	S		
JMB 44	PA2883	FKU	PR	US	C	15.6	12.1	4	0.8	12.4	4	PREPARED PLATFORM	0	P	0	DR DULL 100	SM	S		
SLT 6	PA2883	FKW	LT	US	C	26.7	14.6	7.3	3.1	999	999		0	NA	0	DULL, DV	SM	S		SUFACE IS DULLED EXCEPT ON RECENT BREAK, DEVITRIFICATION
SOH 74	PA2883	FKW	DS	CO	C	18.8	11.4	4.9	1.1	999	999		0	NA	RHY	DR DULL	SH	T		

ID	SITE	EL	POR	SEG	MT	MLEN	MWID	MTHK	WT	PTW	PTT	PTDESC	CTX	LIP	INCLU	SA	DR RIDGE	CHAR	TP	COMMMENTS
ZK 146	PA2883	FKU	ME	US	C	14.8	13.5	3.2	0.6	999	999		0	NA	0	GLS	SH	T		
SOH 11	PA2884	ANGU	US	US	C	16.2	12.4	8.9	1.2	999	999		0	NA	0	DULL 50%	SH	S		
SOH 15	PA2884	PP	DS	CO	T	19.7	18.5	5	1.5	999	999		0	NA	0	GLS	SH	S	LA	
SOH 51	PA2884	FKU	DS	LT	C	17	11.3	3.8	0.8	999	999		0	NA	0	DR DULL 75%	CR	S, SP-O		
ZK 101	PA2884	FK	PR	LT	C	14.9	11.7	3.5	0.5	999	999	PLATFORM INCOMPLETE	0	NA	0	DR DULL 100	US	S		POSS BIPOLAR FLAKE
ZK 115	PA2884	BF5	ME	US	C	16.8	13.6	3.8	1.1	999	999		0	NA	0	GLS	SH	O		
CB 91	PA2885	FKW	ME	US	T	13.2	20	6.2	1.2	999	999	CRUSHED PLATFORM	0	NA	0	DR DULL 75%	SM	BRO/BRS/MHS		
EMP 116	PA2886	FKU	ME	LT	C	15.3	11.8	2.1	0.4	999	999		0	NA	0	GLS	US	T, BAND=O		
MAT 72	PA2886	FKU	ME	US	C	23	16	3.9	1.7	999	999		0	NA	0	VN DULL <25%	SH	T, SP-O		
MAT 77	PA2886	FKU	US	US	C	17.5	10.6	4.7	0.6	999	999		0	NA	EX	DR DULL <25%	SH	S		SMOOTHED EDGES
MAT 81	PA2886	FKU	US	US	C	13.1	10.4	2.6	0.4	999	999		0	NA	ND	GLS	SH	T		
MAT 91	PA2886	FKU	ME	US	C	20.8	14.3	2.9	0.8	999	999		0	NA	CRS	DR DULL <25%	SH	S		
MAT 92	PA2886	FKU	ME	US	C	11.8	10.9	2.8	0.4	999	999		0	NA	0	GLS	SH	T		
MAT 97	PA2886	FKU	ME	US	C	17.4	16.4	2.1	0.6	999	999		0	NA	0	GLS	US	T		
EMP 12	PA2887	FKU	CO	CO	T	14.9	16.5	5.2	1	6.1	2.1	PREPARED PLATFORM	0	A	0	DR DULL 100	CR, SM	O		
EMP 5	PA2887	FKU	PR	US	C	15.7	13.3	2.3	0.5	6.1	2.1	PREPARED PLATFORM	0	A	0	GLS	SH	T, BAND=GRS		BIFACIAL THINNING FLAKE
EMP 6	PA2887	FK	ME	US	C	11.2	8.2	3.2	0.2	999	999		0	NA	0	GLS	SH	T		
LJM 38	PA2887	FKU	ME	US	C	13.3	11.7	3.8	0.7	999	999		0	NA	0	GLS	CR	T		
MAT 20	PA2887	PP	DS	US	T	8.7	9.4	2.4	0.1	999	999		0	NA	0	SF DULL, BR GLS	SH	T, BAND=S	US	
MLR 1	PA2887	FKU	CO	CO	T	31.8	17.3	10.7	5.2	7.9	2.2	PREPARED, CRUSHED PLATFORM	1	A	CRS	DR DULL 75%	CR	S		SMOOTHED EDGE
MLR 2	PA2887	FKU	DS	US	C	24.3	16.2	3.9	1.8	999	999		0	NA	0	VN DULL, DR DULL <50%	CR	T, SP-O		SMOOTHED EDGE
MAT 4	PA2889	FKU	CO	CO	T	17.2	16	3.5	0.9	8.7	3.3	PREPARED PLATFORM	1	A	0	DR DULL	SM	S, SP-O		
ZK 18	PA2891	FKU	CO	CO	T	18.6	13.2	6.4	1.6	10.5	4.6	PREPARED PLATFORM	0	A	CRS	GLS	SM	O		
ADB 10	PA2893	PP	ME	US	T	15.4	12	2.8	0.5	999	999		0	NA	0	GLS	SH	T	US/LP	UNFLAKED SECTION ON ONE SURFACE, PROB LATE PRE
CB 72	PA2893	FKU	DS	LT	C	20.8	18.7	4.5	2.1	999	999		0	NA	0	DR DULL 100, DV	SM	S, BAND=BKS		
JMB 33	PA2894	FKU	CO	CO	T	20.6	15.7	7.8	1.8	12.9	8.2		0	A	0	GLS	SM	S		
LJM 37	PA2894	FKU	CO	CO	T	13.1	12.1	3	0.4	5.5	1.6	PREPARED PLATFORM	0	P	0	DULL	SH	T, SP-S		
LJM 47	PA2894	FK	DS	CO	T	15	14.7	6.1	1.2	999	999		0	NA	CRS	DR DULL 50%	SH	S		
LJM 48	PA2894	FKU	DS	LT	C	20.6	21.7	6.3	2.5	999	999		0	NA	0	VN DULL	SH	T		
MLR 137	PA2895	FKU	CO	CO	C	15.9	16.3	3.6	0.8	12.3	3.1		2	A	0	DULL 50%	SM	O		SMOOTHED EDGES
LCT-B 5	PA303	PP	DS	CO	T	15.9	11	3.4	0.4	999	999		0	NA	CRS	GLS	SH	T	US/LP	
HTH 64	PA48	FK	CO	CO	T	14.2	12.4	3.2	0.5	8	3.8	PREPARED PLATFORM	0	A	0	DR DULL<25%	SH	T		
1034	PA659	BF2	US	US	C	26.5	15.9	7.7	2.4	999	999		0	NA	0	DV, GLS	SH	S		

Appendix C – code list

EL=ELEMENT

ANG	ANGULAR DEBRIS
ANGU	EDGE DAMAGED ANG
BF	BIFACE
BF1-5	BIFACE STAGE 1 THROUGH 5
FK	FLAKE
FKU	EDGE DAMAGED FLAKE
FKW	WORKED FLAKE
PP	PROJECTILE POINT

POR - SEG=PORTION AND SEGMENT

CO	COMPLETE
DS	DISTAL
END	END
FR	FRAGMENT
LT	LATERAL MARGIN
ME	MEDIAL
PR	PROXIMAL
PSH	PROXIMAL PLUS >1/2 BLADE
US	UNSPECIFIED

MT=MEASUREMENT STRUCTURE

C	CLAST
T	TECHNOLOGICAL

MLEN=MAXIMUM LENGTH (mm)

MWID=MAXIMUM WIDTH (mm)

MTHK=MAXIMUM THICKNESS (mm)

WT=WEIGHT (g)

PTW=PLATFORM WIDTH

PTT=PLATFORM THICKNESS

PTDESC=PLATFORM DESCRIPTION

CTX=CORTEX

0=0%

1=1-25%

2=25-50%

3=50-75%

4=75-99%

5=100%

LIP

A=ABSENT

P=PRESENT

NA=NOT APPLICABLE, NO PLATFORM

INCL=INCLUSIONS

ND=UNSPECIFIED NODULAR

CRS=CRYSTALINE

RHY=RHYOLITIC

EX=EXLUSION

SA=SURFACE APPEARANCE

BR=BROKEN SURFACE

DR=DORSAL

DV=DEVITRIFIED

GLS=GLASSY

SF=ORIGINAL MANUFACTURED SURFACE OF BF OR PP

VN=VENTRAL

DR RIDGE=DORSAL RIDGE

CR=CRUSHED

SH=SHARP

SM=SMOOTHING

CHAR=CHARACTERISTICS

UNLESS OTHERWISE NOTED, COLOR WAS BLACK

*O=OPAQUE

*S=SEMI-OPAQUE

*T=TRANSPARENT

BAND=BANDED

BR*=BROWN

GR*=GRAY

MH*=MAHOGANY

SK=SMOKEY

SP=SPECKLED

TP=TIME PERIOD

LA=LATE ARCHAIC

LP=LATE PREHISTORIC

MA=MIDDLE ARCHAIC

US/LP=UNSPECIFIED POSS. LATE PRE

US=UNSPECIFIED

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