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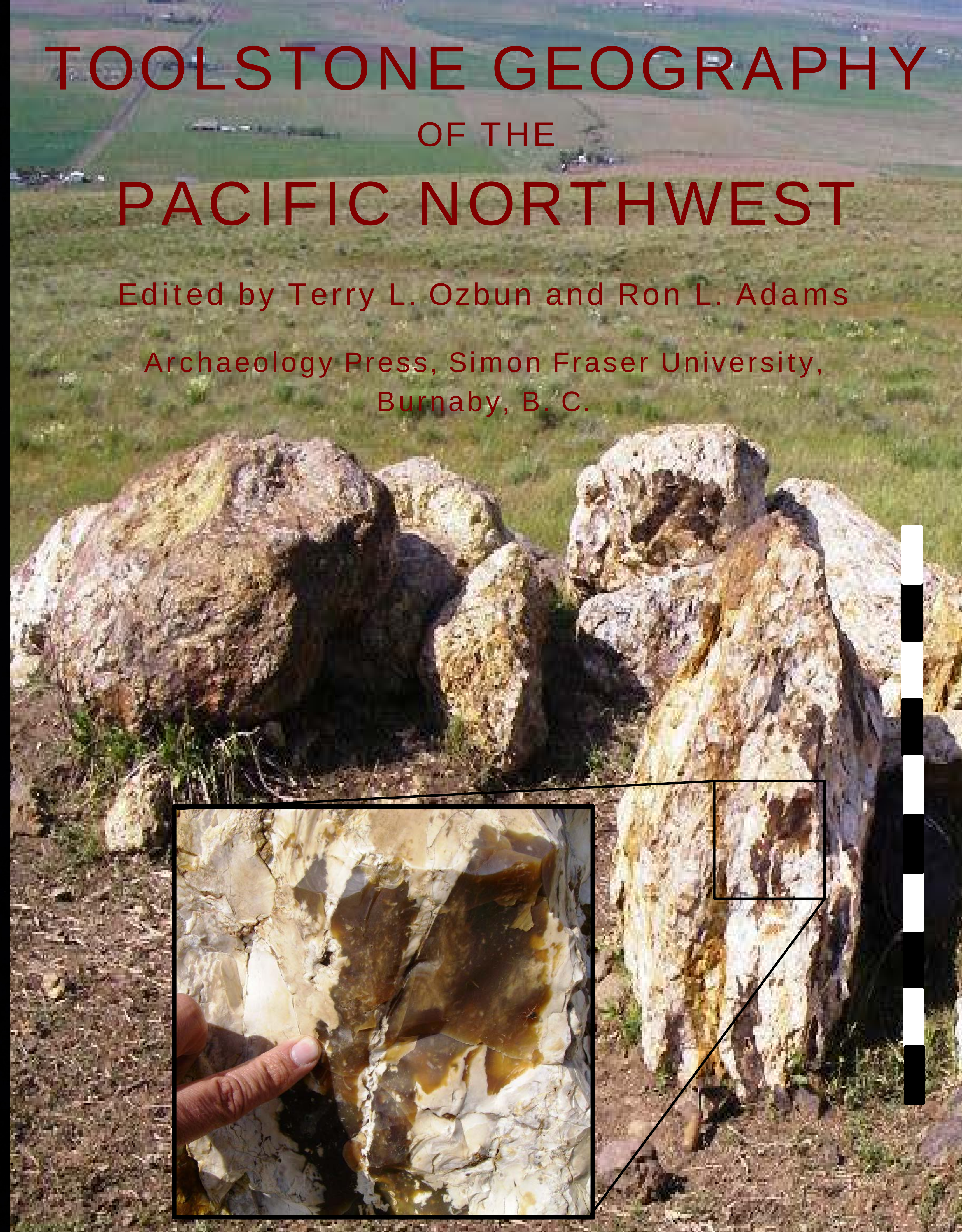
TOOLSTONE GEOGRAPHY OF THE PACIFIC NORTHWEST

OZBUN & ADAMS



TOOLSTONE GEOGRAPHY OF THE PACIFIC NORTHWEST

Edited by Terry L. Ozbun and Ron L. Adams

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Front Cover: Cryptocrystalline silicate boulders at a toolstone quarry site in the Columbia Hills, scale is one meter long (see Chapter 8).

Back Cover: Hozomeen Chert finished biface (approximately 3.6 centimeters wide) from the upper Skagit River valley (see Chapter 6).

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Acknowledgements

Most of chapters in this book originated as presentations delivered in a symposium at the 2011 annual meeting of the Society for American Archaeology (SAA) held in Sacramento, California. A few of the SAA presenters did not submit chapters for the current volume and a few additional authors who were not part of the SAA symposium contributed chapters at our request.

We invited Roy and Maureen Carlson of Simon Fraser University's Archaeology Press to the SAA symposium with the idea that they might be interested in publishing the papers. Gladly they agreed to do so, along with the Archaeology Press editorial board. Roy has been exceptionally supportive and encouraging during the four years it took to bring this work to fruition.

All of the authors represented here graciously submitted to a long and arduous editorial process through which we hope to have preserved the original genius of their contributions while imposing some uniformity of style. We are especially grateful to the authors for their kind indulgence and fortitude. We are proud of the geographical breadth and intellectual depth of the work they provided.

John Fagan and Jo Reese, the owners of the cultural resource management firm Archaeological Investigations Northwest, Inc. (AINW), gainfully employed us and supported our efforts to work on this book. Many of our other colleagues at AINW also helped us in many ways, including some who contributed chapters for this volume.

Apart from the first chapter, which serves as a kind of introduction, the chapters are loosely arranged in a geographical order from north to south. Many of the important toolstone quarries in the region are considered in some depth or more briefly. However, there are many more toolstones not considered at all and many areas of the Pacific Northwest of North America omitted, leaving space for future studies. We hope that some may be inspired to fill these gaps through further research.

Terry Ozbun
Senior Archaeologist and Lithic Technology Specialist
Archaeological Investigations Northwest, Inc.
Portland, Oregon

Ron Adams
Supervising Archaeologist and Ethnologist
Archaeological Investigations Northwest, Inc.
Portland, Oregon

CHAPTER 1

Toolstone Geography and the Larger Lithic Landscape

Terry L. Ozbun
Archaeological Investigations Northwest, Inc. (terry@ainw.com)

What Is Toolstone Geography?

"Toolstone" is a combination of two terms that form a compound word referring to lithic materials used for technological purposes – quite literally, stone for making into tools. Since time immemorial ancient people of the Pacific Northwest made and used stone tools as critical components of technology, economy and culture. These ranged from simple hand-held lithic flake tools (Crabtree 1982) to sophisticated composite tools containing hafted stone elements (Daugherty et al. 1987a; 1987b) to elaborately flaked masterpieces of expert knappers (Meatte 2012; Wilke et al. 1991). Over many thousands of years, myriad lithic technologies in the region have been introduced or invented, developed and proliferated, then been adapted or replaced by newer lithic technologies better suited to changing needs and lifeways. These lithic technologies represented complex systems of knowledge and skills for obtaining suitable raw materials, along with hundreds or thousands of techniques for manufacture, use, maintenance, repair, and recycling of stone tools (Flenniken 1981). The highly-developed ancient systems of lithic technological knowledge and skills are largely lost today. Few modern people maintain the practice of traditional lithic technologies and these are small surviving remnants of a rich heritage in stone working and use in the Pacific Northwest. Also lost is much of the knowledge of the toolstones used in traditional lithic technologies (Andrefsky 1998:40).

Geography is the study of the physical features of the earth's surface and their arrangement and relationships, especially with regard to human interaction with the environment (Bates and Jackson 1984). One aspect of geography that was particularly import for ancient economies was the raw material sources for stone tool industries. The Pacific Northwest contains abundant geological deposits of lithic materials suitable for making stone tools. However, these geological deposits of toolstones are not uniformly distributed across the landscape. Instead, there are distinct variations in the quantities and qualities of toolstones in different places. This geographical variability in toolstone is poorly understood by archaeologists, largely because the characteristics of useful toolstone are not always obvious to people who have not used stone to make a living and are not familiar with the mechanics of stone tool use. Conversely, traditional native people maintained intimate knowledge of the natural landscape, including the toolstones and their geological and geographical contexts – also known as the lithic landscape or toolstone geography (Gould and Saggers 1985:127; Reid 1997:67). Traditional practitioners of lithic technologies knew where to find different types of lithic resources within the territories they traveled. As mobility and trade were key components of culture and economy in the ancient Pacific Northwest, certain cultural groups may have been associated with premium or abundant mineral resources endemic to their respective home ranges.

Why Is Toolstone Geography Important?

Ancient lithic technological traditions have survived in ways similar to native languages. From the eighteenth century to today, European and other non-native invasions of the Pacific Northwest led to

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catastrophic changes devastating native populations and cultures. During this period, very small numbers of native people have maintained the knowledge and practice of both languages and traditional lithic technologies. Now, native languages are resurgent and a small cadre of technicians works to bring back lithic tool traditions as well. For both language and lithic technology, vast bodies of traditional knowledge have been lost. Oral traditions have maintained some languages or remnants thereof. Rare historical transcripts and recordings of native speakers are mined for clues to language traditions, but these go back a few hundreds of years, at best. However, clues to ancient lithic technological traditions are written indelibly in stone going back to the earliest inhabitants of the Pacific Northwest. If we can learn to read these clues encoded into the lithic flakes and stone tools left behind by ancient people, we can begin to reconstruct lost lithic technological traditions.

Knowledge of the raw materials used in these ancient lithic technologies is one aspect of these traditions that we can begin to understand at both local and regional levels. This chapter takes a broad regional look at toolstone geography in the southern Columbia Plateau and adjacent areas. Most other chapters in this book deal with subregions and more local toolstone geography.

Classes of Flakeable Toolstones

Three basic classes of flakeable toolstones are common at archaeological sites in the Pacific Northwest. These are cryptocrystalline silicates or CCS; volcanic glasses, particularly rhyolitic obsidian; and crystalline volcanic rocks such as basalt, andesite, dacite, and rhyolite. In local areas other types of toolstone such as orthoquartzites, silcretes, and mudstones or argillites are important for certain tool types. Voluminous descriptions and sometimes acrimonious debates can be found in the archaeological literature regarding specific geological or mineralogical names for toolstones and whether it is nobler to subdivide them into ever finer categories. Certainly the geological classifications of positivist, reductionist, western science (Mazzocchi 2006:464) has its place and can be useful in archaeological studies. In fact, petrographic and geochemical analyses are the only reliable methods available to most archaeologists for artifact to source attribution. However, the peculiar geological classificatory schemes emanating from the academy were not part of the traditional technologist's nomenclature for toolstones. Ancient knappers likely identified materials according to visual and technical attributes. For the purposes of this paper a simpler division of toolstones is used to bridge the divide between geological and technological classifications.

These basic toolstone types are flakeable, meaning that they exhibit smooth conchoidal (shell-like form) fracture characteristics and, for the most suitable varieties, tend not to break along natural planes in the material. Thus, they can be predictably shaped through specially directed application of percussion and pressure forces to particular configurations of the exterior surfaces of the stone in controlled breakage or fracture processes (Cotterell and Kaminga 1987). Pieces removed in this way are called flakes mirrored by concavities remaining on the parent stone called flake scars. The flakeable toolstones also generally share the characteristic of sharp edges on the flakes and flaked pieces. The sharp edges are usually the key functional attribute of the tools made by flaking stone as these sharp edges are useful for a variety of cutting, piercing, scraping, and shaving activities. Although hardness and durability of the stones and their sharp edges vary considerably within and between the three basic toolstone types described here, stone is generally more durable than the organic materials it is most often intended to work. For example, stone tools are typically tougher than plant fibers they might be used to cut, or hides they might be used to pierce, or wood they might be used to scrape, or bone they might be used to shave. Nonetheless, tool use cuts both ways and wear analysts observe that stone tool edges dull or break-down. Therefore, more durable toolstones were sought for rough-duty tasks and for situations requiring tool longevity.

Cryptocrystalline silicates (CCS)

Cryptocrystalline silicates or CCS is a catch-all category traditionally used in American archaeology to lump together a variety of fine-grained, silica-rich, sedimentary rocks composed primarily of microcrystalline, cryptocrystalline and microfibrous varieties of quartz (in geology often called secondary siliceous sediments). "Crypto," meaning hidden, refers to the small size of quartz crystals, or the stone's fine crystalline texture, which is not visible to the naked eye or even with ordinary light microscopes. Microcrystalline textures are slightly coarser and visible with light microscopy. Since the early use of these terms, electron and other high-powered microscopes have been developed which allow virtually any size of crystal to be seen so that the original meaning of the terms cryptocrystalline and microcrystalline is obscured. Also, the continuous distribution of crystal sizes in these rocks reduces the utility of distinctions between cryptocrystalline and microcrystalline.

Instead of CCS, many archaeologists and geologists prefer the term "chert" as generic for "…all the protean varieties of sedimentary fine-grained siliceous rocks (Luedtke 1992:5)." European archaeologists sometimes use terms such as *silex* (French) or *Feuerstein* (German) as names for this generic class of siliceous sedimentary toolstones. Whatever the name, these are some of the most widespread and abundant flakeable toolstones on earth. Their primary ingredient, silica or silicon dioxide (SiO_2), constitutes over 12 percent of the weight of the earth's crust (Götze 2010:164) although CCS materials comprise less than 1 percent of the earth's volume of rock (Luedtke 1992:17). CCS materials occur in a wide variety of geological contexts including marine and lacustrine deposits and in hydrothermal veins, vugs, and interbeds associated with igneous rocks.

The most common varieties of CCS are often distinguished as chert, flint, jasper, chalcedony, and petrified wood. CCS materials referred to as cherts and flints typically form in marine or lacustrine sediments and are generally opaque and contain microfossils derived from aquatic silica-secreting microorganisms essential to their silica mineral formation. Cherts and flints are commonly colored in dull brown and gray hues and may be distinguished from one another by color value with the lighter colors typically characterized as cherts and darker colors called flints. Others differentiate cherts as CCS materials formed in limestones and flints as formed in chalks (Brandl 2010:183). Jaspers typically form in hydrothermal environments and are generally opaque, and red, brown, yellow, or green reflecting traces of iron or other oxidizing mineral content. Kostov (2010:209) provides several definitions of jasper and describes "true jasper" as a term widely used "…for SiO_2 bearing rocks of predominantly metasomatic or metamorphic origin." The term metasomatic refers to the process by which the chemical composition of a rock is changed through the introduction or extraction of chemicals dissolved in fluids that migrate through rock pores. Chalcedony can form in a variety of contexts, often as a precipitate during emplacement of silicic to intermediate volcanic rocks. Chalcedonies have a microfibrous structure, meaning that the crystals "…grow as radiating fibers in bundles" and are typically translucent and pale colored (Luedtke 1992:24). Petrified or silicified wood forms by silica replacement of organic structures in trees and often other organic materials entrained or entombed in the same sedimentary deposits. The degree of mineralization in petrified wood can vary such that the outer layers of a tree trunk appear to be a homogeneous chalcedony that no longer exhibits its woody character while the inner layers of the same petrified tree truck retain rings and cellular structures along with remnant organic compounds (Luedtke 1992:35).

All of these CCS materials are classified in a variety of ways depending on the orientation of the writer. Typically, classifications are based on either genetic criteria determined by how the rocks or minerals form or practical criteria based on technical properties that make them useful for specific industries. Because these sedimentary rocks can form over millions of years and under changing geological conditions (diagenesis), the same piece of rock, or hand specimen, can include layers, lenses, or conglomerated clasts of different varieties of CCS. Silica mineral diagenesis is a dissolution-precipitation process "…characterised by increasing crystallinity, crystal size, and structural order. Total water content decreases as the microstructures becomes (*sic*) more ordered and compacted. This is reflected in the mineral densities which increase as they become more crystalline (Lee 2007: 16)." This diagenetic view of silica minerals explains why heterogeneous individual hand specimens can be difficult to categorize according to traditional classification systems based on macroscopic visual traits. That is, a single piece of CCS material may exhibit a variety of colors, may be translucent in one area and opaque in another, and may exhibit fossilized organic structures in some parts and not in others.

CCS materials occur throughout the Pacific Northwest. Cherts occur in the Coast Ranges and jaspers in the Cascades. The Columbia Plateau contains unusually abundant high-quality CCS materials in large clast sizes. One area, known as the Yakima Folds, is a geological region characterized by compression folds or wrinkles in the Columbia River Basalts. CCS materials occur in beds sandwiched between massive basalt flows and these layers are exposed by the folding of the basalts and subsequent erosion. These interbeded deposits contain petrified wood and other silicified organic materials often composed of cherts, chalcedony and opal (the latter a non-crystalline silicate). Some of the most productive bedrock or primary geological CCS toolstone quarries or quarry areas in the Yakima Folds region are: Saddle Mountains (Flenniken and Ozbun 1993; McCutcheon et al. 2008); Yakima Firing Center (Chatters and Zweiffel 1987); Canoe Ridge (Ozbun et al. 2002); and Columbia Hills (Adams, this volume).

These CCS toolstone sources and many others in the Yakima Folds region provided high-quality and large-size raw materials for rich lithic industries of the southern Columbia Plateau (Figure 1). Clovis knappers were among the first to take advantage of this resource as evidenced by the spectacular large bifaces of the East Wenatchee Clovis Cache (Meatte 2012).

Volcanic Glass or Obsidian

Volcanic glass or natural glass is a non-crystalline igneous rock (George 1924). Obsidian is the glassy textural class of volcanic rock formed when extruded magma cools too rapidly for mineral crystallization or is prevented from crystallizing due to high viscosity (James et al. 1996:95; Shackley 2005:11; Skinner 1983:27). A glassy texture completely lacking in granularity is called a holohyaline texture and volcanic glasses are typically described as <u>nearly</u> holohyaline meaning a glassy texture with a few tiny crystals or microlites. Sometimes the term aphanitic is also used, but this term applies better to crystalline volcanic rocks with small crystals less than 1 mm in diameter (see below). Since obsidian is simply a textural classification applicable to glassy igneous rocks of varying chemical compositions, obsidian can be basaltic, andesitic, dacitic, or rhyolitic, depending on silica content.

The most common and abundant type of obsidian is rhyolitic obsidian, formed by silica-rich (68 to 77 percent SiO_2) viscous lava flows or domes (Skinner 1983:28; Shackley 2005:Figure 2.3). The high percentage of silicon dioxides defines, in part, its classification as rhyolite and also causes (along with bonding to alumina) the lava to be highly viscous thereby inhibiting the movement of ions and crystal formation. A very small percentage of microscopic iron oxide crystals, commonly magnetite, finely dispersed in the non-crystalline glass give obsidian a dark or black color. Red, brown, or green hues sometimes result from variation in the oxidation state of the iron minerals. Color banding is caused by oxidation of flow surfaces subsequently folded into the lava as it moves. Tiny gas bubbles stretched by the flow of the viscous lava can produce a reflective sheen or chatoyancy, also called cat's eye effect in some obsidians (USGS 2012).

Basaltic glass could also be called obsidian in some instances because of its texture, but is more often called tachylyte or tachylite to distinguish its relatively low silica content and geochemistry. Because its low viscosity melt does not inhibit crystallization during cooling, tachylyte generally forms as thin rinds at the margins of basalt flow sills and dikes where it cools more quickly than crystals can form (James et al. 1996:95). These rinds are often too thin for use as toolstone but occasionally exceed 5 mm in thickness and are suitable for technological purposes (e.g. Weisler 1990).

Volcanic glasses also form or occur in pyroclastic ash flows. Ash flow tuffs or ignimbrites are produced from explosive volcanism and consist of ash, pumice, welded tuff, and other lithic materials (Wilson and Hildreth 2003). Hot gases exsolving from the magma expand and propel the ash flow to form voluminous and wide-spread ignimbrite deposits consisting mainly of ash and frothy pumice but also sometimes volcanic glass. These deposits are generally associated with evolved magma compositions, as are rhyolitic obsidian flows or domes, sometimes from the same volcano. Portions of the magma that contain little or no water may not froth from degassing and instead form glass nodules. The heat of the ash flow or glowing avalanche may round these clasts or cast

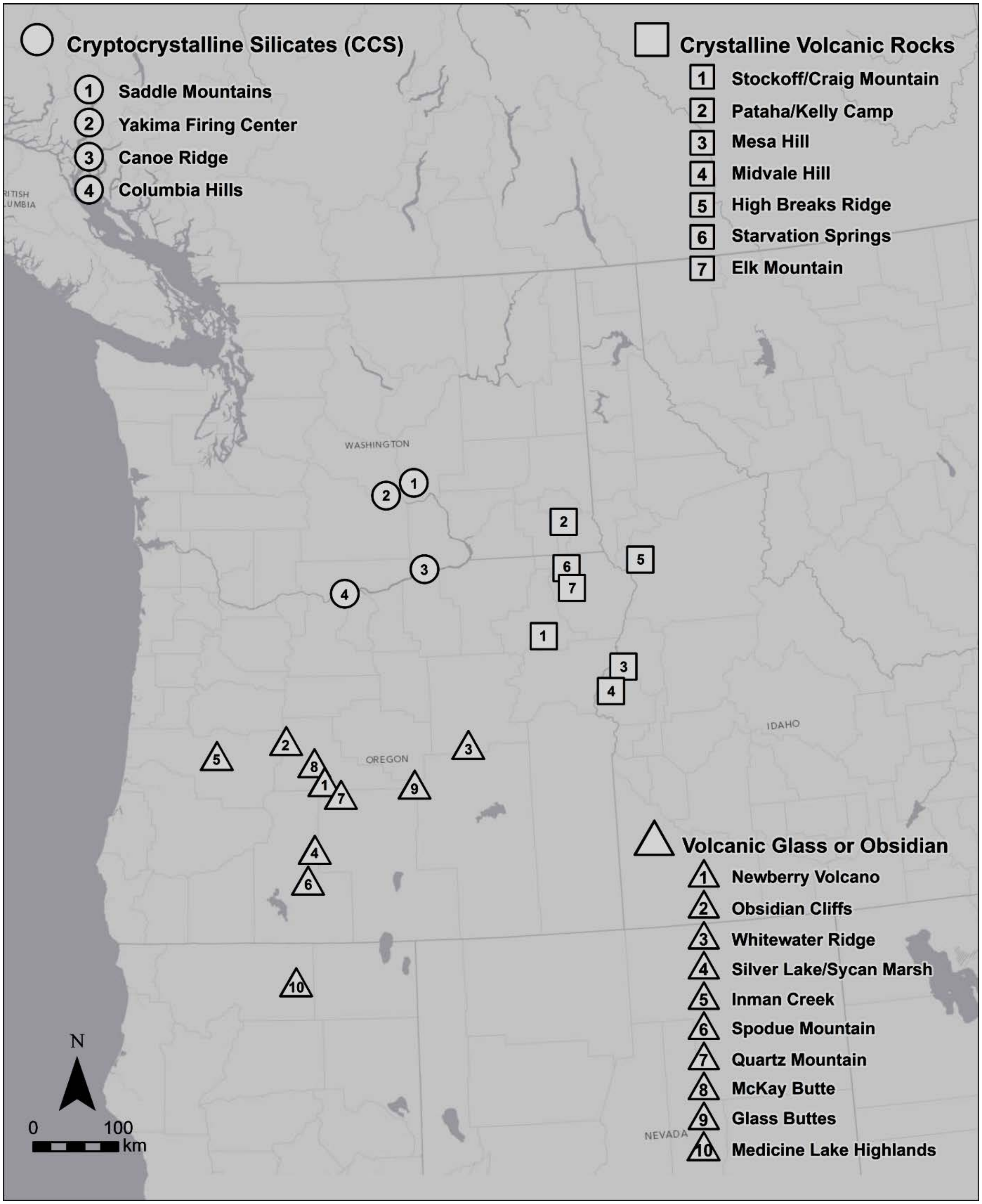

Figure 1. Geographic distribution of toolstone sources mentioned in the text.

impressions of pumice grains on their surfaces. Clast shrinkage during cooling can wrinkle the cortical surfaces of obsidian nodules resulting in development of a distinctive wrinkled (raisin-like) pyroclastic cortex. Also, previously formed obsidian from within or near a volcanic vent can be violently shattered and obsidian clasts entrained in the ash flows become incorporated into the ignimbrite deposits. Aerially ejected obsidian bombs typically have vesiculated centers unsuitable for use as toolstone.

Beds or layers of glassy welded tuffs called vitrophyre (porphyritic volcanic rock with phenocrysts in a glassy groundmass) can also form within the ignimbrite deposits as a result of heat and pressure associated with the volcanic events that produce them. Vitrophyre is typically opaque and welded glass shards representing the parent ash are visible in microscopic thin section (Skinner 1983:33-35, 55-56). Welded tuffs are sometimes called ignimbrites in the older geological literature.

Obsidian is relatively soft – 5 to 5.5 on Moh's hardness scale, so it requires application of less force in flaking to shape into stone tools and is less durable that most other toolstones. The brittleness of obsidian may have been turned to an advantage for some purposes, such as use for projectile point tips, since it can shatter in a wound and cause rapid hemorrhaging, leading to faster death in prey animals. Nonetheless, the more durable obsidians tended to be favored in some ancient technologies. The key attribute of obsidian is its fracture edges which are sharper than the ground edges of surgical steel scalpels. Sharp but durable edges on obsidian tools can be formed by specialized burin and radial break techniques that produce square or nearly square margins.

Oregon is the epicenter of obsidian toolstone in the Pacific Northwest. Craig Skinner's Northwest Obsidian Studies Laboratory lists the top ten obsidian sources in Oregon, meaning those to which artifacts found in Oregon archaeological sites have been most frequently sourced. These top ten are: Newberry Volcano; Obsidian Cliffs; Whitewater Ridge; Silver Lake/Sycan Marsh; Inman Creek; Spodue Mountain; Quartz Mountain; McKay Butte; Glass Buttes; and Medicine Lake Highlands.

These major obsidian sources cluster in central and southcentral Oregon, although the last is in an adjacent area of northern California (Figure 1). These sources are some of the more than 60 rhyolitic domes and dome complexes of the High Lava Plains and adjacent volcanic regions. Intensive extraction and initial reduction of obsidian materials throughout prehistory characterizes all ten of these sources (See Stueber, this volume for a discussion of Glass Buttes). These materials were also exported broadly to surrounding areas. Some have argued that, in addition to its utilitarian value, obsidian signaled prestige on the Northwest Coast and elsewhere outside of obsidian source areas (Dillian et al. 2007; Sobel 2006).

Crystalline Volcanic Rocks

Dark gray extrusive (erupted onto the surface of the earth) volcanic rocks are abundant and occur in widespread voluminous deposits through much of the Pacific Northwest. These crystalline volcanic rocks vary in mineral composition (particularly alkalis) and in silica content on a continuum (Bakewell 1993; Bakewell and Irving 1994). By weight percent SiO_2, they range from basalt (less than 52 percent silica) to andesite (52 to 63 percent silica) to dacite (63 to 68 percent silica) to rhyolite (greater than 68 percent silica). They also vary in texture from glassy or aphyric (lacking in phenocrysts, see volcanic glass or obsidian above) to aphanitic (fine-grained crystals too small to be seen by the naked eye or smaller than about 1 mm) to phaneritic (crystals visible to the naked eye or larger than about 1 mm) to porphyritic (containing larger phenocrysts in a glassy or fine-grained ground mass) (Bates and Jackson 1984). Typically, the longer a lava takes to cool the larger the crystals can grow. Most extrusive lavas cool too quickly to form rocks with crystals larger than about 2 mm in diameter and therefore are generally aphanitic (fine-grained) or nearly aphanitic. The fine-grained and more silicic volcanic rocks generally exhibit better conchoidal fracture (are easier to knap) and form sharper edges on stone tools. Crystalline volcanic rocks are generally harder or tougher than obsidians and therefore hold their edges better when used for rough-duty tasks (See Reid et al. this volume).

Traditionally in archaeology, fine-grained gray toolstones have been classified as basalt. However, most of the artifacts that have been casually characterized as basalt in the archaeological literature are actually andesites, dacites, or other similar varieties of fine-grained and highly silicic rocks (Bakewell 1993; 1996; Reid 1997). The low silica content of basalt, in fact, makes it unlikely that basalt would be selected for flakeable toolstone, although it is well-suited for use in ground stone tools such as pestles which are reduced using a pecking technology rather than by flaking. The higher silica content of these andesites, dacites, and rhyolites typically makes them easier to flake. From a geological and geographical perspective higher silica content produces more viscous magma or lava that tends to mound-up and form more localized domes than the fluid lavas that form expansive flows of basalt. Therefore, primary geological deposits of the glassier volcanic toolstones like dacite (and obsidian) are likely to be confined to relatively smaller hills or mountains than are the less glassy widespread basalts spread over vast horizontal plains.

While the Columbia River Basalt Group is best known for its expansive basalt flows, its various member formations also included more localized and silica rich andesites and dacites, particularly in their eruptive centers. The more siliceous rocks of the Grand Ronde Basalt Formation and the Powder River Volcanic Field were widely used for toolstone in the "tri-state uplands" area where the boundaries of Washington, Oregon, and Idaho come together (see Reid et al. and Smits and Davis, this volume). This is the area where a concentration of eruptive vents known as the Chief Joseph dike swarm produced main phase basaltic eruptions as well as subsequent silicic eruptions (Wagner et al. 2012:2; Camp and Hanan 2008:480-481).

Among the crystalline volcanic rock prehistoric quarries identified in this area, the Stockhoff quarry complex on Craig Mountain, may have produced the most stone tools through the Holocene (see Smits and Davis, this volume). The Stockhoff quarry complex and the other quarries listed below have been described in the archaeological literature as productive toolstone quarries for volcanic crystalline rocks: Stockhoff/Craig Mountain (Smits and Davis, this volume); Pataha Canyon/Kelly Camp (Reid et al., this volume; Flenniken et al. 1991); Mesa Hill; Midvale Hill (Bucy 1974); High Breaks Ridge (Dickerson 1998); Starvation Spring (Jaehnig 1992); and Elk Mountain (Nisbet and Drake 1982).

These major crystalline volcanic toolstone sources form a distinct cluster in the tri-state uplands area of the Chief Joseph dike swarm (Figure 1). Intensive extraction and initial reduction of andesites and dacites, especially during the early and middle Holocene characterizes these sources. However, the degree to which they have been exported to surrounding areas is unknown. This may be a reflection of the broad availability of similar materials elsewhere, or perhaps, a measure of our inability to identify patterns of trade and exchange in these materials.

The Larger Lithic Landscape

The geographical clustering of highly productive toolstone quarries for CCS, obsidian, and volcanic crystalline rock shows a distinct regional pattern. Geologically, the CCS cluster is associated with the Yakima Folds region of south central Washington. The obsidian cluster is in the High Lava Plains of south central Oregon and adjacent areas to the south and east. The volcanic crystalline or fine-grained volcanic toolstone cluster is associated with Chief Joseph dike swarm or the Grand Ronde formation. This pattern is, of course, a reflection of simple geological availability – people went to the stone. However, it also shows that ancient knappers selectively favored certain lithic raw material sources and returned to those sources repeatedly over many millennia. These quarries and source areas show evidence of extensive use over the whole period of human residency in the region.

These toolstone sources share certain traits that made them highly attractive for ancient toolstone users. All of these toolstones are aphanitic or fine-grained – a trait that allows creation of sharp edges. They are also isotropic and homogeneous providing excellent flakability or control of conchoidal fracture. They are abundant and not easily depleted within the source locations, so they are a dependable resource over time. However, perhaps the characteristic that sets them apart from many other sources is availability of large pieces or clasts of raw material, typically much greater than 256 mm in diameter (boulder-sized on the Wentworth scale).

Lithic technologies are strictly reductive. Materials can only get smaller as they are shaped, used, and maintained. Although many ingenious strategies were used in prehistory to extend lithic tool lives through resharpening, reworking, and recycling, eventually lithic tools become too small for effective use. Large geological clast sizes allow for production of cores, flakes, blanks, and finished tools of large sizes. Large initial size serves to sustain long tool lives, an important factor in ancient tool design (Ozbun 1991; Meatte 2012).

Bedrock or primary geological deposits typically have larger clast sizes than secondary deposits. By their very nature, secondary deposits are weathered and broken fragments of the bedrock or primary geological materials and occur as gravels. Sometimes these gravels are as large as boulders or cobbles, but the farther they are transported by colluvial, alluvial, or glacial processes, the smaller they become. The major toolstone centers described above are all primary geological deposits of relatively recent age and available clasts are as large as is practicable for designing and manufacturing long-lasting tools.

Of course, identifying the most desirable toolstone sources is only part of understanding toolstone geography. Many less desirable sources were also used because they were conveniently located closer to the places where flaked stone tools were needed. Some lithic technologies were specifically developed to make use of smaller, duller, checked, faulted, or otherwise imperfect toolstones. For example, small pebbles of grainy vein quartz were reduced using a bipolar technology to create tiny microliths for hafting into efficient composite fish knives at Hoko River on the Olympic Peninsula (Flenniken 1981). This area, like most of western Washington, is notoriously impoverished with regard to high-quality flakeable toolstones.

Where high-quality toolstones are not present, marginal toolstone materials are often pressed into service. These may be from primary or secondary geological sources. At the Bear Creek archaeological site in Redmond, Washington, coarse-grained volcanic and metamorphic rocks obtained from on-site or nearby glacial tills were used to manufacture a variety of flaked-stone implements (Kopperl et al. 2010). Ill-formed tools and flakes with indistinct attributes were produced from these poor-quality raw materials. Nonetheless, they were expedient and adequately served local needs along with some imported higher-quality materials.

People adapted to toolstone deprivation by developing ways to use what was available, sometimes through the substitution of organic materials, for example to arm weaponry. Bone was commonly used for projectile point tips on the lower Columbia River (Fuld 2012) and elsewhere in the northwest, particularly west of the Cascade Range (Ogle 2004). Bone, antler, or wooden materials were sometimes used in the place of stone projectile points, although stone seems to have been preferred for most types of hunting weaponry. Interestingly, when glass bottles were introduced to the lower Columbia River area during the fur-trade era, the bottle glass was used much like obsidian to make projectile points, scrapers, and burin tools for bone and wood working (Ozbun 2008).

There are many other geological, technological, and cultural factors to consider in studies of toolstone geography for the Pacific Northwest. The papers in this volume detail some of these considerations, but there is much more to know. Noteworthy topics of future study might include the abundance and distribution of hydrothermal jaspers in the Cascade Range, pyroclastic obsidian in southern Oregon and southern Idaho, and bedded cherts in adjacent areas of the Great Basin. Another worthy area of further study is the redistribution of toolstones by secondary geological processes which can be partially addressed through the often neglected identification on artifacts of cortex types – cortex types that reflect primary or secondary geological origins of toolstones, such as the distinctive incipient cone cortex type characteristic of the alluvial transport of gravels in the traction loads of streams. However, understanding the application of diverse technological strategies to particular geological conditions offers the most promise for insight into toolstone geography of the ancient past in the Pacific Northwest.

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CHAPTER 2

Nephrite/Jade: The Preeminent Celt Stone of the Pacific Northwest

Jesse Morin
Tsleil-Waututh Nation (thejdmorin@gmail.com)

Nephrite/jade is rather different from all the other toolstones discussed in this volume, as it was exclusively used for making ground, rather than flaked stone artifacts in the Pacific Northwest. While most toolstone was selected for its property of being able to fracture it in a controlled manner, nephrite was selected for the exact opposite reason – namely it is exceedingly difficult to fracture at all. Because of its extreme toughness, nephrite was a very desirable material for the production of stone celts (adzes, chisels, and axes). Nephrite from the Pacific Northwest is dominated by shades of green, but can occur in a myriad of colors. Being a semi-precious gemstone, polished nephrite also has remarkable aesthetic qualities – namely translucency and luster. The combination of incredible toughness, durability and unique aesthetic properties make nephrite a remarkably singular toolstone. Besides celts, there are very few other artifact types aside from production debris (e.g., knives, pendants, scrapers, points) made of nephrite in the Pacific Northwest. Despite its general rarity in the environment, nephrite was the most commonly used toolstone, or more specifically 'celt stone', for the production of stone celts in the Pacific Northwest. This paper first briefly describes the cultural context of indigenous nephrite use, second describes the petrology and petrogenesis of nephrite, and third reviews the distribution and occurrence of *in situ* and secondary nephrite deposits.

These sections are not intended to either: provide a definitive description of the geology of nephrite in the region (for interested readers see Adams et al. 2007; Fraser 1972; Harlow and Sorensen 2005; Iizuka and Hung 2005; Leaming 1978; Simandl et al. 2000; Wen and Jing 1992), a summary of the prehistoric use of nephrite technology in the Pacific Northwest (see Emmons 1923; Darwent 1998; Mackie 1995; Morin 2012), nor an introduction to a nephrite sourcing study (see Morin 2012). Rather, my intention is to provide the geophysical contexts for assessing the accessibility of nephrite as a celt stone by indigenous peoples in the Pacific Northwest. I suggest that indigenous utilization of alluvial nephrite from the Fraser and Bridge Rivers, rather than from discrete quarry sites, has significant implications for understanding the social relations of nephrite procurement and ownership. Namely, I suggest that the contexts of nephrite procurement – primarily targeted chance encounters of nephrite cobbles/boulders in river gravels – limited the potential for either individual or corporate ownership or domination of nephrite source areas, and did not require any form of hierarchical organization of labor to meet local and distant demands for nephrite celt stone. Instead, I suggest that local nephrite procurement was largely individualized and open to all local inhabitants. Procurement likely occurred primarily by individuals or small groups regularly scouring Fraser and Bridge River gravel beds during winter months proximate to their winter villages.

The Salish Nephrite Industry

Based on my extensive inventory of all major museum repositories and archives holding pre-contact material culture from the Pacific Northwest (Morin 2012), I can confidently state that the traditional territories of Interior and Coast Salish peoples of the Fraser River drainage and Salish Sea regions were the centers of nephrite celt production and use in the Pacific Northwest (PNW). There are literally thousands of celts reported from this

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region, and based on my mineralogical analysis of a sample of over 1000 celts and celt fragments from here (Morin 2012), nephrite was definitely the most commonly used raw material. I refer to this distinctive technological tradition as the ‘Salish Nephrite Industry’. Nephrite celts do indeed occur outside of these regions at very low rates, and other rocks, such as chlorite, were used for producing celts in some areas. The earliest evidence for nephrite celt use dates to about 3500 B.P., but such evidence is sparse until 2500 B.P. when there is a veritable explosion of nephrite celt use associated with the Marpole Phase (2500-1000 B.P.).

As nephrite cannot be flaked in a controlled manner, celt blanks were instead laboriously sawn from alluvial pebbles, cobbles and boulders. Estimates for producing a single sawn nephrite celt range from about 40-100 hours, exclusive of times spent in raw material acquisition (Darwent 1998; Morin 2012), thus making these tools very valuable. Sawn cores are distinctive, very rare artifacts, with fewer than 140 examples reported for the entire PNW, of which only 65 of 131 analyzed examples have been confirmed to be nephrite (Morin 2012). Remarkably, nearly all of these sawn cores are from two relatively restricted locales along the Fraser River: the Hope vicinity at the entrance to the Fraser Canyon, and the Lytton-Lillooet locality in the Mid-Fraser region. I refer to these locales as the primary nephrite celt production zones. The Lytton-Lillooet locality in particular has both the most numerous and largest sawn nephrite cores in all of Cascadia. Communities in these two locales clearly specialized in the production of nephrite celts beyond their own requirements, as the greatest number of celts are found on the Lower Fraser River and the Salish Sea – regions containing absolutely no evidence of nephrite working. I refer to these later regions as the primary nephrite celt consumption region. Importantly, there are very few nephrite sawn cores from outside these two locales, indicating that unworked nephrite celt stone was neither commonly exchanged, nor regularly obtained by long-distance quarrying forays from other regions. Nephrite celt stone was fashioned into finished or largely finished celts in the locations along the Fraser River where alluvial nephrite was most abundant and exchanged to the adjacent Coast and Canadian Plateau regions.

Late Prehistoric Period (3500 B.P. to contact) sites on the Lower Fraser River and Salish Sea typically contain nephrite celts, and in some cases they are very numerous. Over 300 celts are reported from various excavations and surface collections of the Marpole site (on the Fraser River in modern Vancouver) alone, for example. In coastal assemblages celt size varies markedly from 10-300 mm in length, but typically are small (median length ~50 mm), heavily worn, and have been extensively reworked through continual resharpening and occasionally have been bisected into two smaller celts (Mackie 1995; Morin 2012). It is probable that the larger celts were hafted as adzes and the smaller ones as chisels and were used in a variety of heavy and fine woodworking tasks. The extreme toughness of nephrite (Bradt et al. 1977; Leaming 1978; Harlow 1993) would probably make nephrite celts more durable, that is, requiring less frequent resharpening, being less liable to fracture, and thus with longer use-lives, than celts made of other materials (e.g., semi-nephrite, quartzite, serpentine, bone, antler, mussel shell). These celts were probably highly curated and valued tools because: they were non-local, they were time consuming to produce, and they were very functional in woodworking. In Coastal sites, assemblages containing celts are mainly found in shell middens, especially large shell middens associated with major winter village sites (e.g., Beach Grove, Katz, Port Hammond, False Narrows, Marpole, Musqueam), and rarely found in association with burials (for rare exceptions see Burley 1989 and Curtin 2002). I think it is near certain that large increase in the use of these artifacts is associated with the origins of an indigenous material culture reliant on heavy woodworking (e.g., canoes, plank houses, boxes) and may be related to the origins of carving specialists such as canoe makers and carvers.

Nephrite celts were also used throughout the adjacent Canadian Plateau, approximately concurrently with the Coast. On the Plateau, celts are nearly all made of nephrite, are typically larger (median length ~133 mm) than those on the Coast, and consist of two types: small functional celts, and large non-functional celts ranging up to 500 mm in length. While nephrite celts larger than about 150 mm long are quite rare on the coast (N=11), they are rather more common on the Canadian Plateau (N=48), especially around the town of Lytton (N=15). Similar examples are reported from as distant as northern Idaho on the Columbia Plateau (Morin 2012; Smith 1910). Indeed, there is direct historic evidence that these large celts were non-functional valuable 'property', not tools as such, but rather used in high value transactions (James Teit quoted in Emmons 1923). Nearly all of these large celts are made of very high-quality and often beautiful nephrite, as only pure and homogeneous bodies of nephrite can be used as cores from which to saw out such large objects. Based on traditional production times of nephrite *mere* clubs in New Zealand (Beck 1912), these large nephrite 'property celts' would have taken upwards of one thousand hours to saw from a large boulder core, and procurement of suitable nephrite boulders would have also been no trivial task. Because of the rarity, beauty and especially the enormous labor costs, large property celts would have been exceedingly valuable. 'Property celts' are exclusively recovered from invariably poorly reported mortuary contexts on the Plateau, and are probably all more recent than 1200 B.P. (Morin 2012; Sanger 1969). I suggest that they were amongst the most valuable property and most emphatic symbols of wealth among elites on the Canadian Plateau (see Hayden 1998).

The sections above provide a brief synopsis of the Salish Nephrite Industry, a widespread and long-lasting technological tradition. I highlighted key aspects of nephrite celt production, and the Plateau-Coast dichotomy in celt form to emphasize the diversity of this technological tradition, and to hint at the complexity of the economies that functioned to circulate such objects. Having provided this cultural context for nephrite celt stone use, I now shift the discussion to a detailed geological description of nephrite and its occurrence in Cascadia.

Petrology of Nephrite in the Pacific Northwest

Nephrite is one of two unrelated rocks (the other being jadeite) commonly referred to as 'jade'. Although locations in British Columbia have the appropriate geological conditions for occurrence of jadeite (Leaming 1978:6), it has not been identified north of California (Harlow and Sorensen 2005). Nephrite, however, has been identified at over 50 *in situ* bedrock locations and as placer or gravel deposits over broad areas in Western North America, and especially, in British Columbia (see

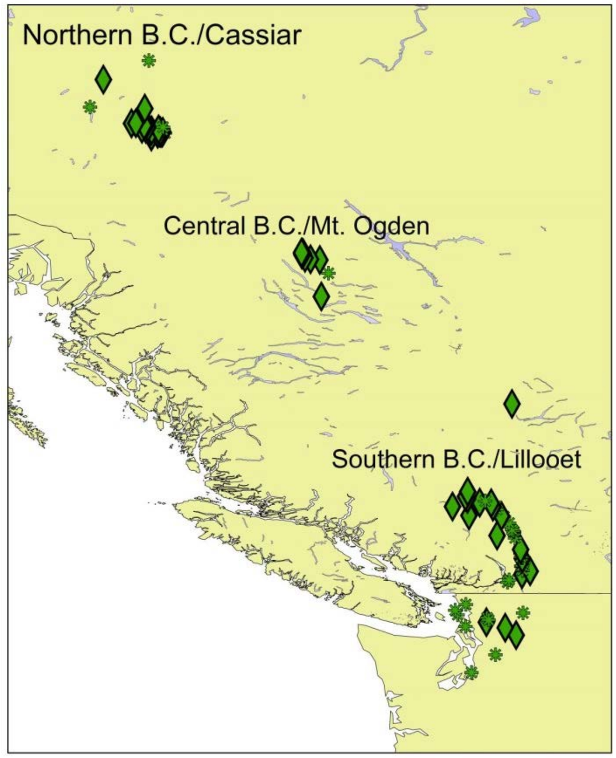

Figure 2-1. Nephrite sources in the Pacific Northwest. Diamonds are *in situ* nephrite sources, and asterisks are 'float' (colluvial or alluvial) nephrite sources.

Figure 2-1). Nephrite in Western North America is a metasomatic hydrous monomineralic rock that is noted for both its visual properties and extreme toughness; nephrites from other parts of the world, such as China, are derived from different processes and parent rocks. Briefly, nephrite is a rock composed of tremolite/actinolite with a distinctive 'nephritic' or felted texture (Leaming 1978:8) and often contains other trace minerals such as serpentine, talc, chrome garnet, chlorite, vesuvinite and diopside (Harlow and Sorensen 2005; Leaming 1978:11). Tremolite-actinolite is an amphibole mineral series that makes up over 90 percent of nephrite rocks. Amphiboles are long double chains of silica tetrahedrons and attached cations (e.g., iron and magnesium) (Blatt et al. 2006: 27). Tremolite and actinolite differ from each other only in the proportion of iron to magnesium, with tremolite ($Ca_2Mg_5Si_8O_{22}(OH)_2$) containing only magnesium and no iron (theoretically it contains no iron, in the real world, some iron is always present), and actinolite ($Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$) containing magnesium and iron (Leaming 1978:8).

The minerals that make up nephrite are described by Leaming (1978:11) as "characterized by a peculiar texture in which microfibrous tremolite occurs as twisted and felted bundles, tufts, and sheaf-like aggregates in interlocking random orientation." Tremolite crystals lacking completely felted or nephritic textures but having acicular crystals or large sheaves are described as semi-nephrite (Beck 1984:7). Thus, while there are no chemical differences between tremolite/actinolite, semi-nephrite, and nephrite, there are significant differences in the textures of these rocks, and these differences in texture have profound implications for the physical properties of these materials. The felted or nephritic texture of nephrite makes it extremely tough (Bradt et al. 1973:727: Rowcliffe and Fruhauf 1977). Toughness can be described as resistance to breakage. While nephrite is not a particularly hard rock (Moh = 6.5-7), it is the toughest naturally occurring material in the world (Brandt et al. 1973; Harlow 1993). The extreme toughness and relative hardness of nephrite causes it to be particularly resistant to physical weathering. Because of these properties, it is therefore able to be transported notable distances from its bedrock sources by natural forces. The toughness of nephrite is also its most desirable property as a celt stone.

While no single element determines the color of nephrite (Wilkens et al. 2003), the proportion of iron to magnesium and the inclusion of other minerals in nephrite have a marked effect on its visual properties. Primarily, greater concentrations of iron in nephrite tend toward green (Wen and Jing 1992). Nephrite made of pure tremolite (i.e., with very low iron content and) tends to be white; nephrite containing more actinolite-ferroactinolite (i.e., contain more iron) tends towards green – often vibrant green; and nephrite extremely rich in ferroactinolite tends towards black (Harlow and Sorensen 2005; Wen and Jing 1992). Green nephrite is most common in British Columbia, while white nephrite is rarest (Fraser 1972:82). Nevertheless, there is a remarkably wide range of 'greens' within B.C. nephrites. Leaming (1978:7), for example, required 16 different Munsell color designations to adequately describe 47 bedrock specimens of B.C. nephrite. Some of this variability probably relates to the formation of nephrite deposits, iron/magnesium ratios described above, and perhaps post-formation oxidation processes (see Beck and Mason 2010).

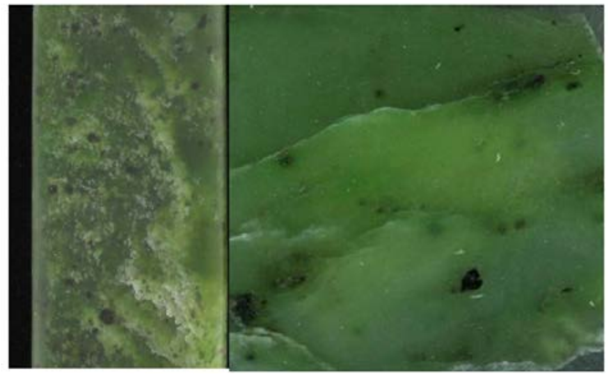

Figure 2-2. Black chromium spinel (pictotite) inclusions in nephrite.

Nephrites from British Columbia often contain inclusions. To the naked eye, inclusions within nephrite tend to be irregularly shaped small spots, flecks (~0.5 to 2 mm in diameter), or short streaks. These inclusions are often spinels or chrome garnets (Iizuka and Hung 2005; Leaming 1978). There are two distinctive types of inclusions common to B.C. nephrite. The larger of the two types of inclusions are chromium spinels, are black, and can occur as semi-spheres or as thin flat tiny sheets (Iizuka and Hung 2005), and are often immediately recognizable with the naked eye (see Figure 2-2). The second common type of inclusion in B.C. nephrite is bright green, spherical, and typically much smaller than the black inclusions. These green inclusions are chromium-calcium garnets called uvarovite (Iizuka and Hung 2005: 50), and are also visible to the naked eye if the artifact or hand sample is examined closely (see Figure 2-3). Experts with 2-4 decades experience mining, working, and handling nephrites can recognize material from Cassiar, for example, by the size, shape and arrangement of these green inclusions that are very common to nephrite from the famous Cassiar source.

Nephrite in British Columbia is thought to develop in a metasomatic reaction – that is, a chemical reaction between rocks of very different chemistries with the presence of water (Harlow and Sorensen 2005; Harlow et al. 2007; Leaming 1978). In British Columbia, nephrite was formed hundreds of millions of years ago in the Triassic and Jurassic periods (Gabrielse 1990; 1998a, 1998b; Monger 1989; Simandl et al. 2000), at the zone of contact between ultramafic serpentine rocks and siliceous

Figure 2-3. Green chromium garnet (uvarovite) inclusions in nephrite.

sedimentary rocks (or their metamorphosed equivalent) (Leaming 1978:14). In this 'reaction zone' serpentine bodies and sedimentary bodies exchange material, that is, a chemical reaction, in a liquid matrix and recrystalize dependent on the local pressures and temperatures. Under such conditions actinolite/tremolite is formed. For this actinolite/tremolite to develop into nephrite, that is crystallize with a nephritic texture, requires "a stress free environment and rapid crystal growth from innumerable centers. Further, the growth of the fibers must be entirely random" (Leaming and Hudson 2005:173). This random structure may be inherited from the parent serpentine rock (Leaming and Hudson 2005:173). If this material is particularly pure, then it is nephrite.

Nephrite tends to form in small deposits called lodes that range from tens of centimeters in diameter (see Simandl et al. 2000: 344), to lenticular bodies up to 10 m high, by 100 m long by 50 m wide (Leaming 1978:17). The bodies of nephrite are typically surrounded by 'seminephrite' and serpentine (Figure 2-4). Seminephrite is actinolite/tremolite with a partially developed nephritic or felted texture, and usually contains notable amounts of serpentine and talc (Beck and Mason 2010; Simandl et al. 2000). The major factors that cause nephrite to form in Cascadia are then: 1) tectonic uplift along an orogenic belt – represented by the Cordilleran Mountains, and 2) contact between serpentine and siliceous sedimentary rock bodies or their metamorphic equivalents.

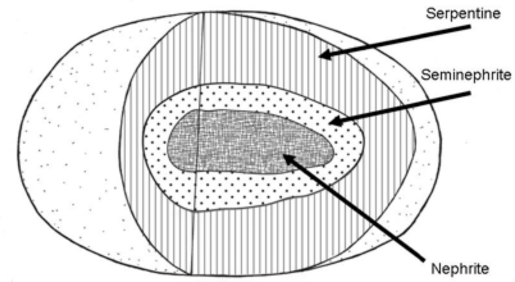

Figure 2-4. Hypothetical nephrite lode.

Nephrite Occurrences in Cascadia

The richest nephrite deposits in North America, and indeed some of the richest deposits in the world, occur in British Columbia, but can also be found in California, Wyoming, Alaska, Washington State, Oregon, and the Yukon. The following discussion reviews nephrite sources in three major regions of British Columbia, Northern Central and South, and Washington State. Each of these four major 'source regions' actually contains numerous geologically distinct bedrock occurrences of nephrite, and many secondary sources. As Southwestern British Columbia was clearly the primary region of indigenous use of nephrite, greater detail will be devoted to describing deposits there.

British Columbia

There are three major regions in British Columbia where *in situ* or bedrock nephrite is found. These all fall along a roughly north-northwest running nephrite-bearing belt (Leaming 1978:19) (see Figure 2-5). The most northerly source is in the Cassiar Segment around Dease Lake and Cassiar. Second, there is a major nephrite bearing region in Omineca Segment northwest of Prince George near Mt. Ogden (alternatively Ogden Mountain). Finally, in the Lillooet Segment there are a number of nephrite source locations west and south of Lillooet, west of Lytton, and east of Hope. I devote particular attention to them because they were definitely the most intensively utilized by indigenous peoples in the past.

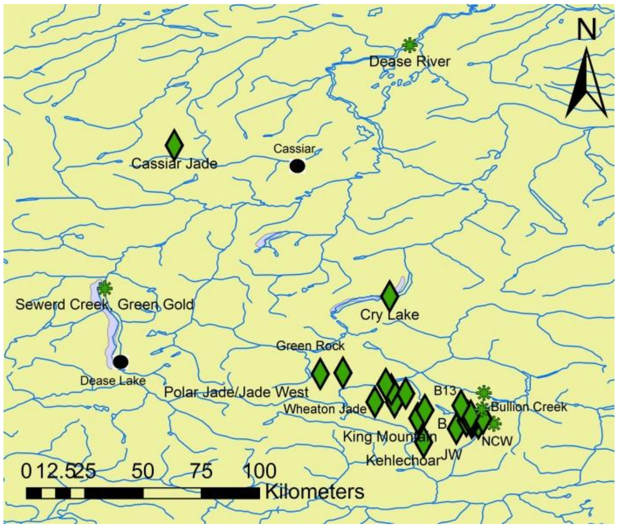

Figure 2-5. Nephrite sources in Northern B.C. Diamonds are *in situ* nephrite sources, and asterisks are 'float' (colluvial or alluvial) nephrite sources.

Northern B.C.: The Cassiar/Dease Lake Region

Nephrite was first identified by Euro-Canadians in Northern B.C. in 1938, but it was not until about the 1980's, that the Northern B.C. Group around Cassiar began to be intensively quarried, and subsequently has been the centre of the B.C. nephrite industry (Leaming and Hudson 2005: 39). Indeed, Dease Lake claims to be the 'jade capital of the world' (Leaming and Hudson 2005: 38) (see Figure 2-5). There are large bodies of *in situ* bedrock nephrite here and innumerable 'float' or colluvial/alluvial/glaciofluvial deposits (see Figure 2-5). Within this region there are three main loci of nephrite occurrences.

The first, and perhaps most well known, deposit is at Cassiar (see Figure 2-5). When this nephrite deposit was encountered, it was blasted through, and discarded in enormous quantities during the course of an asbestos mining operation (Leaming 1978:35-36). It is reported that upwards of a thousand tons of nephrite was dumped in tailings of this mining operation before anyone had realized that the nephrite was in fact far more valuable than the asbestos (Leaming and Hudson 2005:54). According to provincial records, 1,700 metric tons of nephrite have been extracted from this source (MINFILE 104P 005). Leaming (1978:9, 36) notes that this material is chemically distinguishable from other varieties given this high chromium content (within the chrome garnets). However, from the data presented, it appears that Cassiar nephrite is only marginally more chromium rich than Seyward/Dease Lake or Noel Creek nephrite (Leaming 1978:9). Specimens I have obtained from this source likely represent several of the many lodes of nephrite encountered accidentally in the course of asbestos mining. Here the nephrite deposit was below ground, and was not likely available for indigenous exploitation.

A second major *in situ* deposit of nephrite in this region occurs near Seyward Creek immediately northeast of Dease Lake (Gabrielse 1990; Leaming 1978:36) (see Figure 2-5). This source is associated with the Kedahda Formation and is part of the Cache Creek Terrane, and was formed between late Mississippian and Triassic periods about 325 – 200 million years ago (m.y.a.) (Gabrielse 1998a:49, 54). Alluvial nephrite presumably from this source can be recovered from Thibert and Delure creeks, and from Dease River (Leaming 1978:35). While only 5 metric tons of nephrite has been extracted from the Seward Creek source (MINFILE 104J057), the fact that it occurs in comparatively widespread alluvial contexts suggests that it would have been readily accessible for tool production in the past by indigenous peoples (K. Makepeace, Personal Communication, 2009). My samples from Dease River are from alluvial contexts and are visually distinctive from the Seyward Creek material. I submit that some of this material is from an entirely different source than Seyward Creek/Dease Lake.

The third and most widespread group of nephrite sources in the Northern B.C. or Cassiar group occurs east of Dease Lake and south of Cry Lake (see Figure 2-5). The potential nephrite deposits associated with this area are amongst the largest in the world at about 50,000 metric tons (Leaming 1978:38). Bedrock or *in situ* deposits here include the famous Polar deposit, Kutcho, Wheaton Creek, King Mountain, Provencher Lake, Letain Creek, Two Mile Creek, Greenrock Creek, King Kong, Baggins, and the Kehlechoa River (B.C. Ministry of Energy, Mines, and Petroleum Resources; Gabrielse 1998; Leaming 1978:33; Leaming and Hudson 2005). Similar to Cassiar, some of these deposits have produced very large quantities of nephrite, such as the approximately 2,500 metric tons removed from Kutcho (MINFILE 104I 78). As with the Seward Creek deposits, these deposits are also associated with the Cache Creek

Terrane and date from about 325 – 200 mya (Gabrielse 1998: 54). There are extensive quantities of ‘float’ nephrite in alluvial and colluvial contexts surrounding several of these sources (Leaming 1978:30-35). Representative sampling of all of these sources and ‘float’ deposits would be a major undertaking. This area would have had significant quantities of nephrite boulders and cobbles that could have been exploited in the past by indigenous peoples.

Overall, the Northern B.C. nephrite sources in the Cassiar district are extremely rich by global standards. The plentiful ‘float’ nephrite in particular would have been accessible during summer to indigenous peoples living in the region throughout the Holocene. The absolute dearth of reported nephrite artifacts from archaeological sites in this region, however, suggests that this material was not utilized here, but it may have been traded to the Coast. My samples of nephrite in this region can only be considered representative of four of the many *in situ* sources here. Of the three major source regions in B.C., the Northern or Cassiar region has the lowest likelihood of indigenous exploitation.

Central B.C. Group – Omenica

This region is approximately located in the centre of British Columbia, northwest of the city of Prince George. There are two major *in situ* nephrite bedrock outcrops in this region, and both have extensive associated boulder fields or ‘float’ deposits (see Figure 2-6). Nephrite has been extracted on an industrial scale near the upper reaches of the Omenica River around Mount Ogden at both Lee and Ogden creeks, and other nearby claims (Fraser 1972; Leaming 1978:26-28; Simandl et al. 2000). The claim at Ogden Creek near Mount Ogden has been a major global producer with records of over 1,400 metric tons extracted (MINFILE 093N 165). Individual talus boulders identified in this vicinity weigh 70 - 150 metric tons (Leaming 1978:32; Leaming and Hudson 2005: 50). Such individual boulders dwarf entire *in situ* nephrite deposits in some areas (Oregon and Washington). Nephrite has also been recovered in small quantities from Vital, Silver, Quartz, Kelly, Teegee and Kwanika creeks (Fraser 1972:12). All of these sources occur at the margin of the Cache Creek Terrane where it abuts a local serpentinite body (Leaming 1978:31). As with the Northern Region deposits, the Mount Ogden sources date between about 325 – 200 m.y.a. (Pennsylvanian to Jurassic, Simandl et al. 2000: 341). This source has undergone much more extensive geological research than any other nephrite deposit in B.C. and is the best described and understood (Fraser 1972; Simandl et al. 2000).

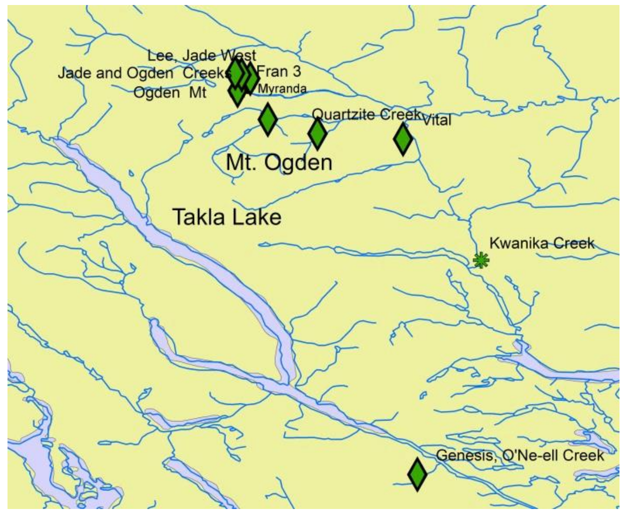

Figure 2-6. Nephrite sources in Central B.C. Diamonds are *in situ* nephrite sources, and asterisks are ‘float’ (colluvial or alluvial) nephrite sources.

The other major *in situ* nephrite source in the Central Region is near Mount Sidney Williams at O’ne-ell Creek (see Figure 2-6) (Fraser 1972; Leaming 1978). This deposit is again occurs at the margin of the Cache Creek Terrane and dates to about 325 – 200 m.y.a. (Leaming 1978). Although the production records are incomplete for this source, extraction appears to have been a small fraction of that removed from Mount Ogden.

In summary, ‘float’ nephrite cobbles and boulders in Central British Columbia in the vicinity of Mount Ogden occur in quantities that would have been available for indigenous use. However, the general paucity, but not absolute absence, of nephrite artifacts in this region, suggests that it was not locally utilized. Instead of nephrite, indigenous peoples in this region utilized flaked and ground basaltic materials, or less commonly, a pale green chlorite slate for ground celts (Morin 2012). Further, given that this region is a part of the Fraser River watershed, and that glacial processes appear to have moved large (multi-ton) boulders some distance from their original location, some nephrite from this region may have been carried by the Fraser River to locations far to the south. An intensive geoprospection and provenancing study of origin of nephrite boulders and cobbles in the Fraser River would be the only way to investigate this issue.

Southern B.C. – Lillooet Group

The nephrite deposits in Southern British Columbia along the Lillooet Segment should be of primary interest to archaeologists because: 1) there are many relatively abundant *in situ* and alluvial nephrite sources, 2) there is substantial archaeological evidence for manufacturing of nephrite implements, and 3) there are thousands of nephrite artifacts recovered from archaeological sites in and around this region. For these reasons, I devote particular attention to the distribution of nephrite in Southern B.C. below. In the following sections, I first describe the distribution of known *in situ* nephrite sources, then discuss the important sources of alluvial nephrite boulders and cobbles along the Fraser River.

The first *in situ* nephrite deposits in Canada were discovered in the Shulaps range (Leaming and Hudson 2005: 19; G. Vanderwolf, Personal Communication, 2008). *In situ* nephrite deposits occur in a number of known sources in the Shulaps Mountain range immediately northwest of the town of Lillooet (see Figure 2-7). These source locations include Hell, Hog, Brett, Jim, Blue and Marshall Creeks and Lac La Mar (Leaming 1978:21-27, see Figure 2-7). Most of these sources occur at the headwaters of such creeks in the range of 2000 m elevation. Alluvial nephrite can be found along the streambeds of these sources and is common in the Yalakom and Bridge Rivers that drain the region. Within these river systems, boulders weighing up to 20 tons are reported (Leaming and Hudson 2005:16), and smaller boulders and cobbles are of course much more common.

All of these sources occur at the contact margin between the Shulaps Ultramafic Body (or Mission Ridge Pluton) and the Bridge River Terrane (Journeay and Monger 1994; Leaming 1978:21). Many of these sources appear to have been rather productive and were quarried on an industrial scale, but production records are rare to non-existent. For a brief period in the 1960's, the Lillooet area was the world's largest nephrite producing region (Leaming 1978). Some 100 metric tons were removed from the Hell Creek source in 1973 alone (MINFILE 092 JNE 063). The 6-ton nephrite boulder in the Simon Fraser University Academic Quadrangle pond is also from the Hell Creek source (Leaming and Hudson 2005:24). The Brett Creek source appears to have been entirely mined out well before 2006 (Joseph Morin, Personal Communication, 2006). Much of the alluvial nephrite within the Bridge River is likely derived from these sources, and it is quite probable that the Bridge River conveys considerable quantities of nephrite into the Fraser River (Morin 2012). Indigenous collection of materials derived from these sources along streambeds, or the Bridge, Yalakom, or Fraser Rivers is near certain.

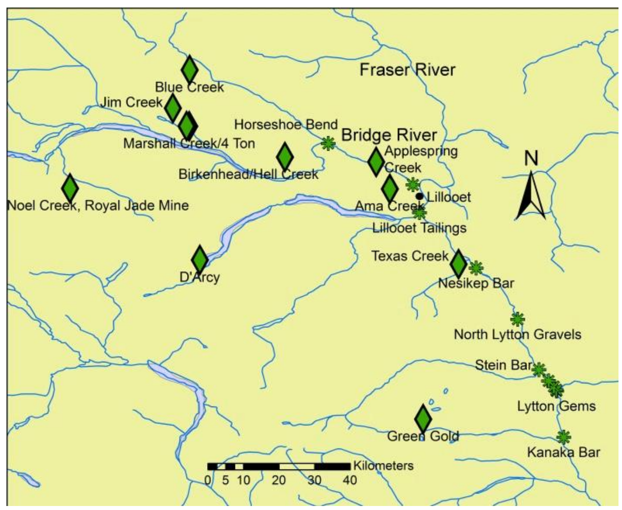

Figure 2-7. Nephrite sources in Southern B.C. Diamonds are *in situ* nephrite sources, and asterisks are 'float' (colluvial or alluvial) nephrite sources.

There are three other *in situ* nephrite sources along the Bridge River, but not associated with the Shulaps Range formation: 1) the Ama Creek or Moon Creek (both names are applied to this single creek) source about 3 km north west of the junction of the Bridge and Fraser Rivers, 2) the Applespring Creek source located adjacent to the Bridge River road approximately 5 km west of the bridge over Bridge River, and 3) at the Horseshoe Bend 400 m downstream from the confluence of the Bridge and Yalakom Rivers (Leaming 1978:21-22) (see Figure 2-7). The nephrite from all of these sources appears to be of low quality and none have seen any industrial quarrying. Some of the alluvial nephrite that is and certainly was commonly collected from the Bridge River is likely derived from these sources, and the Bridge River almost certainly transports this material into the Fraser River. Again, indigenous collection of materials derived from these sources along streambeds, or the Bridge, Yalakom, or Fraser Rivers is highly probable.

South of the Shulaps Range in the Cadwallader Range, there are two further important *in situ* nephrite bedrock sources at D'Arcy at the west end of Anderson Lake, and at Noel Creek south of Gold Bridge at the west end of Carpenter Lake (Figure 2-7). The D'Arcy nephrite source has not been recently exploited to any degree (Leaming and Hudson 2005:18; Leaming 1978:28). This source appears to lie on the contact margin of a small ultramafic body and the Cayoosh Assemblage (Journeay and Monger 1994; Leaming 1978:21). The Noel Creek source was at one point a major producer, with records of over 500 metric tons extracted (MINFILE 092 JNE 118). The Noel Creek source appears to lie at the contact between the Bridge River Terrane and the Caldwallader Terrane (Journeay and Monger 1994). There are no reports of alluvial or 'float' nephrite in the vicinity of these locations, but some 'float' nephrite would be expected. As float nephrite appears to be comparatively rare around these two sources, I would expect a moderate to low probability of indigenous exploitation of these sources.

There are two well documented and two poorly documented *in situ* nephrite sources in the mountains on the west bank of the Mid-Fraser (see Figure 2-7). One is near the headwaters of Texas Creek/Molybdenite Creek (Leaming 1978:21). This source has not seen industrial scale quarrying. Another small *in situ* nephrite source is reported about 40 km further downstream the Fraser near the headwaters of Kwoiek Creek west of Lytton (Leaming 1978:21). While nephrite not has been quarried here on an industrial scale, vesuvianite, which according to Darwent (1998) is commonly misidentified as nephrite, occurs in large quantities here (Leaming 1978:21). Slightly further downstream, between Boston Bar and Spuzzum there are two further poorly documented *in situ* sources of nephrite also associated with the Kwoiek fault. Although the geology is discontinuous, both the Kwoiek Creek/Skihist, and the Texas Creek sources are found at the contact margins of the Bridge River Terrane (sedimentary) and the Scuzzy Pluton (ultramafic) (Journeay and Monger 1994). Nephrite from these four sources would almost certainly be carried downhill by alluvial or colluvial processes and enter the Fraser River system. If this material was transported via alluvial action in any quantities, it would probably have been collected and utilized in the past.

There is one final known source of *in situ* nephrite on the Coquihalla River about 20 km east of Hope, just 100 m south of the Coquihalla Highway (see Figure 2-7) (Leaming 1978:19; Monger 1989). This nephrite deposit occurs at the contact margin of the Bridge River Terrane (sedimentary) and the Methow Terrane (serpentinized ultramafics) (Journeay and Monger 1994). This source is located near Sowaqua Creek and was encountered during highway construction in the early 1980's. In the following seasons following its discovery, this source was completely mined out. Previous to the complete quarrying of this source, float nephrite on the Coquihalla River was perhaps more plentiful, while now it is found only very rarely. This material would have been carried down the Coquihalla River and entered the Fraser River near Hope. Given the proximity of this source to the Lower Fraser Valley with archaeological sites containing large numbers of nephrite tools, it is possible that this source was heavily utilized in the past.

Finally, there are unconfirmed reports of a nephrite source on the east side of Harrison Lake near Cogburn Creek (Leaming 1978: 20). Here, the Bridge River Terrane (sedimentary) contacts the Spuzzum Pluton (ultramafic), thus providing the appropriate conditions for nephrite formation (Journeay and Monger 1994). If nephrite does occur at this location, it would be the most proximate location within British Columbia to the major centers of prehistoric nephrite tool use near the mouth of the Fraser River.

Fraser River Gravels. With regards to the context of aboriginal procurement of nephrite toolstone, the exact *in situ* location of sources is probably not particularly relevant. I suggest that the primary contexts of indigenous nephrite collection were the gravel bars of the Fraser River rather than bedrock or colluvial sources. I state this with some confidence as all of the 131 sawn boulders/cobbles/pebbles I have analyzed have some portion of cortex that is consistent with alluvial transport (i.e., rounding and smoothing). And, as described above, most nephrite from Southern B.C. sources ends up being carried downstream in the Fraser River. Mackie (1995:46) provides an excellent account of the distribution of nephrite in the gravels of the Fraser River and much of this discussion overlaps considerably and inevitably with his.

First, most of the *in situ* sources of nephrite in this region are located at elevations approaching 2000 m in very rough terrain. Hell Creek is apparently named so in reference to its particularly rugged terrain (G. Vanderwolf, Personal Communication, 2008). At such high elevations, bedrock is usually only exposed for a month or two every year around August, and occasionally remains snow covered throughout the year (*ibid*). George Vanderwolf describes himself as nearly dying of hypothermia while staking the Hell Creek claim (~2200 m) during a blizzard in the late summer (Tenove 2005). Once the nephrite deposit has been located, it needs to be cut out of the bedrock using a diamond saw. Due to its extreme toughness, modern diamond saws can only cut nephrite at a rate of about a half meter per hour. I suspect that prehistoric indigenous technology would have been practically useless for extracting bedrock nephrite. If prehistoric peoples could extract nephrite from the bedrock, or collect colluvial or float material in the immediate vicinity, there remains the daunting problem of transporting it back home. Some of these sources are so remote even today that helicopter and horseback are the only options for carrying out nephrite (Leaming and Hudson 2005; G. Vanderwolf, Personal Communication, 2008). If prehistoric people did carry nephrite out of the alpine zone on their backs, it was probably only in limited quantities.

Second, the Fraser is a very powerful river and has the ability to transport very large boulders and cobbles considerable distances. The terminus of most gravel in the Fraser River is in the vicinity of Chillwack (Leaming 1978). Beyond this point, the Fraser River only has enough force to transport sand and silt (see Smith and Ferguson 1995). The annual Fraser River flood cycles seasonally deposit nephrite boulders and cobbles along the gravel bars of the Mid-Fraser, the Fraser Canyon, terminating in the Chilliwack gravels (see Church and Jones 1982). However, the distribution of alluvial nephrite from Lillooet to Chilliwack is by no means uniform in terms of the quantity or size of nephrite boulders, cobbles and pebbles.

Alluvial nephrite is most common and occurs in the largest clast sizes most proximate to *in situ* or bedrock outcrops. Near the major *in situ* nephrite sources along the Bridge and Yalakom rivers, where nephrite miners extracted hundreds of tons of nephrite per year at the peak of their operations (Leaming 1978; Leaming and Hudson 2005), alluvial boulders individually weighing from 10-20 tons were occasionally located. An example of such massive alluvial boulders can be seen in the Academic Quadrangle pond at Simon Fraser University – a 6 ton nephrite boulder from Hell Creek (Leaming and Hudson 2003:24). Smaller, and more manageable, nephrite boulders (~2-10 kg) and cobbles were also relatively plentiful along the Bridge, Yalakom and Fraser Rivers in the vicinity of Lillooet and Lytton. All reports agree that while alluvial nephrite can occasionally be found from Lytton to Hope, it is much less frequently encountered than from Lillooet to Lytton (Emmons 1923; Leaming 1978). There is, or was, an *in situ* nephrite source on the Coquilhalla River about 20 km upstream from Hope, and alluvial nephrite from this source likely could also have been procured along the banks and gravel bars of the Coquilhalla and around Hope. Nephrite is much more rarely found around Chilliwack than it is farther upstream, and the size of the cobbles or pebbles is much smaller than further up the Fraser River (Leaming 1978). Leaming (1978:19) describes such deposits of alluvial nephrite as typically being neither abundant nor very large, and "(g)enerally, the largest boulders are found farthest from Lillooet" (21).

At periods of low water levels, especially between October and April, the gravel bars along the Fraser River would be exposed to the greatest extent, and freshly deposited nephrite could be procured (Environment Canada 2009; Morrison et al. 2008). Note that contrary to opinions held amongst many archaeologists, this is not coincidental with the late summer sockeye salmon fishery. Rather this is coincident with the period of winter sedentism in large villages practiced by all groups along the Mid-Fraser and Fraser Canyon during the Late Prehistoric Period (3500 B.P. to contact). Such winter villages are invariably located with 3 km, and usually much closer, to the Fraser River, and short mid-winter excursions from these villages down to the Fraser gravel bars would have been by far the most cost-effective way to procure nephrite toolstone.

Another important reason to believe that nephrite toolstone was procured from the Fraser gravels rather than *in situ* sources is the Fraser's ability to naturally 'test' the quality of the material. When quarrying bedrock nephrite, a rather high percentage of the material is discarded because of flaws, fissures and other impurities (Leaming 1978). Such imperfections would have also made such nephrite useless for making celts. Nephrite or any stone washed down the Fraser River is continually sandblasted, bumped and battered many thousands of times during its journey. Because nephrite is far tougher than nearly every other rock in the world, rocks of pure flawless nephrite are gently rounded and polished by this process and can be transported hundreds of kilometers (see also Beck 1984 for New Zealand). Flawed and imperfect nephrite transported by the Fraser River will break apart much more rapidly. This is the reason that so many of the alluvial boulders collected along the Fraser River are of such exceptionally high quality material (Leaming 1978). The sandblasting of nephrite boulders by the sands suspended in the Fraser River remove any oxidized cortex from nephrite, making it readily identifiable (Leaming 1978:19). Of the prehistorically sawn nephrite boulders I have examined, all that display cortex are consistent with such alluvial transport. Thus, I think the gravel beds of the Fraser River would have been by far the most attractive locations for past peoples to collect nephrite celt stone.

The Fraser River from the Bridge River in the north to the Chilliwack River in the south has hundreds or thousands of gravel bars of various sizes. The larger of these gravel bars are named, such as Boston Bar, Sailor's Bar, and American Bar (see Forsythe and Dickson 2007: 37; Hudson 2006: 162-3). In the Mid-Fraser and Fraser Canyon sections, these bars are relatively permanent due to the highly entrenched nature of the Fraser River there. Further downstream, approximately from Hope to Chilliwack, the large gravel bars are probably more dynamic and occasionally form moderate sized islands within the river. All of these gravel bars would be seasonally modified by floodwaters and would have new boulders and cobbles deposited on them. With regards to nephrite occurrences, alluvial cobbles and boulders are more common and larger upstream towards the Bridge River, and smaller and less common downstream towards Chilliwack (Leaming 1978). The areas richest in alluvial nephrite – from Lillooet to Hope – have been set aside as a 'jade preserve' by the provincial government and alluvial nephrite can be quarried by anyone. No stakes or claims can be made on gravel bars within this preserve (Hudson 2006:162). I propose these alluvial sources of nephrite would have been the primary contexts for indigenous quarrying of nephrite toolstone in the Pacific Northwest.

A single local rock hound (Arn Homelin, Personal Communication, 2011) with several decades experience looking for nephrite on the Fraser River has provided me with the most detailed description of how to locate alluvial nephrite in Fraser River gravel bars. As this is the most precise and detailed description of procuring alluvial nephrite that I have encountered, I report his comments here in some detail. Homelin, (Personal Communication, .2011) has collected nephrite on many Fraser River gravel bars, but has spent most of his effort on bars around Hope and Yale, and has found the bars around Hope to have generally been the most productive. While he could not comment on the general abundance or average size of nephrite in general areas of the Fraser (beyond his favorite bar at Hope), he did note that his largest find was at Kanaka Bar (downstream from Lytton), where he recovered a nephrite boulder weighing about 100 kg. When specifically questioned regarding gravel bars between Lytton and Lillooet, Homelin (Personal Communication, 2011) indicated that there were few bars in this region (likely due to the steepness of the topography), but that those regions were generally viewed as 'rich' in alluvial nephrite. The following two paragraphs briefly describe some of Homelin's (pers. comm. 2011) strategies and tricks for successfully identifying alluvial nephrite in the Fraser River.

First, nephrite occurs on both the 'high bars' (those commonly above the water level) and the 'low bars' (those that are usually inundated), but is more plentiful and larger on the 'low bars'. This is the case for two reasons: 1) nephrite is dense and is not transported by the Fraser as readily as other rocks of comparable size, and 2) the 'high bars' are scoured more often by rock collectors than the 'low bars'. Additionally, knowledge of the anatomy of individual gravel bars is important for identifying the most likely place to find nephrite. Alluvial nephrite is most often found at the upstream side (or top end) of such bars, at the transition zone between alluvial deposits of larger and smaller clasts (rocks). Nephrite and other dense rocks are preferentially deposited on the 'river side' of these transition zones, while less dense rocks are deposited on the 'outside' margin of these transition lines. The best strategy to locate nephrite is then to literally crawl on ones knees along these transition zones on the 'top end' of these grave bars.

The Fraser River carries a considerable quantity of suspended sand, clay and silt, as evinced by its brown 'chocolate milk' color. As the Fraser River water levels recede towards winter, the rocks in the gravel bars are covered by perhaps millimeter-thick fine coating of brown clay-silt. This greatly impairs visual identification of any rocks. As the fall-winter rains become more incessant, this layer of clay-silt begins to wash off of these rocks. Because of the smooth and finely polished cortex on alluvial nephrite (from natural sandblasting in the Fraser) compared to other rocks, the clay-silt layer washes off it somewhat earlier than off of the other rocks. Therefore if one times one's search for alluvial nephrite with the onset of the rainy season correctly, you can increase your probability of locating nephrite by closely inspecting all rocks that are washed clean by the rain. Homelin (Personal Communication, 2011) suggests that it takes approximately three years of experience to be able to 'read' the gravel bars and identify alluvial nephrite with any level of success.

The terraces immediately adjacent to the banks of the Fraser River are also composed of materials washed down the Fraser system. These terraces were specifically targeted by early placer miners looking for gold from about A.D.1858 to about 1900. Using techniques perfected in the California gold fields, American and Chinese miners systematically washed and sorted millions of tons of such sediments along the Fraser (Forsythe and Dickson 2007:27-69; Kennedy 2008). Green rocks were ignored by the Californian miners, but were recognized as jade by acute Chinese miners and were apparently smuggled back to China in coffins with deceased countrymen (Hudson 2006: 92). While nephrite can be recovered from these large gravel terraces, it is unlikely that these deposits were utilized to any significant degree before contact. Overall, I have seen more visual diversity in the nephrites from the Lillooet locality alone than in any other nephrite bearing region in the Pacific Northwest.

Glaciers

The present distribution of quaternary materials (sediments such as gravels, silts, and glacial tills) near the surface and the rocks found within such deposits in British Columbia is largely not the result of slow steady processes. Rather the dominant factor behind the distribution of such materials is punctuated by past glacial activity. During the Pleistocene, most of British Columbia, and all of the nephrite bearing regions therein were heavily glaciated by the Cordilleran Ice Sheet (Clague 1989; Clague and James 2002; Clague et al. 1980). Such ice sheets and melt waters derived from them transported and deposited enormous quantities of gravels, silts, sands throughout B.C. and Washington (Clague 1989a; Clague and James 2002). The movement of such ice sheets is complex and was occasionally marked by reversals in direction (Clague 1989), but generally the direction of such flows was away from the high elevation mountains of the Canadian Cordillera. The nephrite deposits near the peaks of the Shulaps and Caldwader Ranges west of Lillooet for example would have experienced intense glacial scouring and nephrite bearing rocks would have become dislodged and embedded in massive glaciers slowly flowing downhill. From this location, the glaciers and embedded nephrite may have flowed west towards the coast, east towards the interior, or southwards through the Fraser Canyon, depending on the height of adjacent glaciers (Clague 1989). Because of the extreme toughness of nephrite compared to almost all other rocks, it would be more likely to survive complete disintegration before being deposited by glacial action. For these reasons, glacially transported nephrite from the alpine sources in Southern British Columbia could potentially occur as small 'erratics' many hundreds of kilometers from the *in situ* source. In particular, 'float' nephrite found on Orcas, Vashon and Whidbey Islands in Puget Sound is probably derived from *in situ* sources in B.C. that was transported to Puget Sound with the 'Puget Lobe' extension of the Cordilleran Ice Sheet around 17, 000 B.P. (Porter and Swanson 1998). It is presently unclear how much nephrite throughout British Columbia and Washington was redistributed through glacial activity, and how often such secondarily deposited material was utilized in the past.

Washington State

Washington State contains has both *in situ* bedrock and Quaternary (fluvial, colluvial or glacially derived) or 'float' deposits of nephrite. Leaming and Hudson (2005:79) report four *in situ* deposits: Mount Higgins and Helena Ridge near Darrington, Cultus Mountain near Mt. Vernon, and at Mount Stuart about 100 km east of Seattle (see Figure 2-8). Some of these sources have been quarried on an industrial scale, removing up to five tons of nephrite (Leaming and Hudson 2005:79). Float nephrite is reported from Orcas, Vashon and Whidbey Islands, along the Nooksack, Skagit, and Stillaguamish Rivers, around Deer Creek near Oso, and around Darrington (Ames and Maschner 1999:171; J. Aylor, Personal Communication, 2009; Leaming and Hudson 2005: 79; B. Meirendorf, Personal Communication, 2009) (see Figure 2-8). Harlan Smith (1907:368) reported finding nephrite cobbles and boulders on the beach at Mareitta, and indicated that this material looked similar to the nephrite he was familiar with from Lytton.

Briefly, this float nephrite is probably derived from glacial transport during the Pleistocene (Porter and Swanson 1998). George Mustoe indicated to me (Personal Communication, 2009) that this float nephrite appears to be eroding from Late Pleistocene deposits. Leaming suggests that it was deposited there by the Fraser River (Leaming and Hudson 2005:79). Both the Nooksack and Skagit Rivers may have *in situ* bedrock nephrite sources within their drainages that are carried downstream by fluvial transport (J. Aylor, Personal Communication, 2009). All of the sources above were potentially available for indigenous quarrying or collection for tool production. George Mustoe indicated to me (Personal Communication, 2009) that Washington nephrite is greenish black, uniform in texture, and visually very different from the nephrites that are found in the Fraser River gravel bars around Hope.

While I have much less data for Washington State than for British Columbia, it appears that the indigenous use of nephrite is very similar or identical to much of Southern B.C. and is essentially a part of the same Salishan nephrite working tradition or industry. Briefly, small nephrite celts are recovered from shell midden contexts from the San Juan Islands, the Southern Salish Sea, and Puget Sound – albeit at a much lower recovery rate than in the Gulf Islands, Southeastern Vancouver Island, and the Lower Fraser River. Larger nephrite celts rare, but occasionally recovered from mortuary contexts along the Mid- and Upper reaches of the Columbia River in eastern Washington (M. Collins, Personal Communication, 2009; Darwent 1998). Again, these large celts appear are much more rare here than on the Canadian Plateau. Nephrite production debris (sawn cores, debitage and saws) is very rare but occurs in at least two sites in Washington. By way of comparison, there are numerous individual sites in British Columbia with more evidence of nephrite celt production than is evident in all of Washington State.

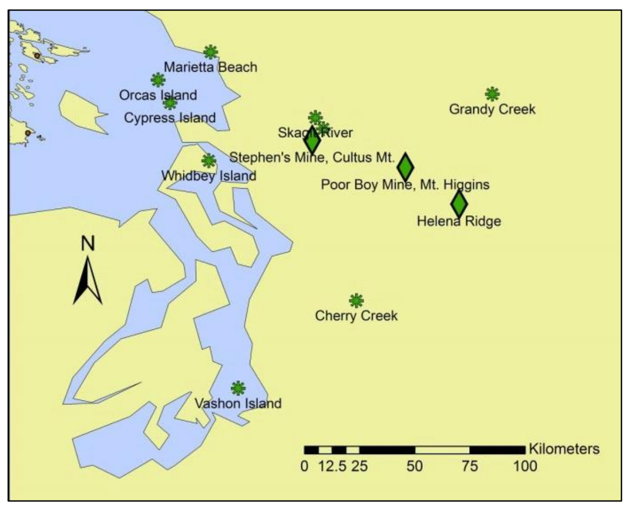

Figure 2-8. Nephrite sources in Washington State. Diamonds are *in situ* nephrite sources, and asterisks are 'float' (colluvial or alluvial) nephrite sources.

Conclusion

This chapter presents a brief review of non-nephrite celt stones, and a detailed overview of the petrology and petrogenesis of nephrite in British Columbia and Washington State. It highlights the geological contexts of nephrite, and the processes that have transported nephrite since its formation. Particular attention is drawn to the potential and apparent precontact utilization of nephrite from various sources. Three major source areas are identified (Northern, Central, and Southern B.C.), each of which contain many discrete outcrops and secondary deposits of nephrite. Additional potential sources are also identified in Washington State, but the majority of the nephrite that occurs there may originate from B.C.

Most importantly, I argue that the gravel bars of the Fraser River from Lillooet to Chilliwack provided the most plentiful and reliable context for nephrite quarrying during the prehistoric period. Alluvial nephrite is both naturally 'tested' for flaws and is more readily accessible from winter village locations near the Fraser River. The fact that alluvial, rather than bedrock nephrite was utilized by indigenous peoples has both important cultural implications, and implications for carrying out a traditional 'sourcing' study of matching artifacts to bedrock sources. First, as indigenous utilization of individual quarries or outcrops was very unlikely, and the fact that alluvial nephrite is rather diffusely distributed, it is improbable that a group or person could readily 'own' or control access to this material. Further, it is probable that nephrite procurement would be carried out by individuals or small groups; as such procurement would require virtually no organization of labor. Second, as the cultural context for nephrite procurement was at secondary deposition locations (river gravels), geochemical matching of artifacts to bedrock sources would at best <u>describe the natural distribution of nephrite in the Fraser River</u>. Instead, such a sourcing study should emphasize the cultural context of acquisition and production, and thus attempt to correlate nephrite artifacts with alluvial nephrite, and especially alluvial nephrite with evidence of cultural use (e.g., saw marks) (see Morin 2012). This provides the foundation for understanding the prehistoric utilization of nephrite in the Pacific Northwest.

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CHAPTER 3

Primary Toolstone Sources and Pre-Contact Period Quarrying Behaviour in the Thompson River Drainage of South Central British Columbia

Mike K. Rousseau
Antiquus Archaeological Consultants Ltd. (antiquus@shaw.ca)

Introduction and Background

Much remains to be learned about the character and natural distribution of flakable silicates and dacites on the Canadian Plateau, but some detailed published information is available (Bakewell 1991a,b; Bakewell and Irving 1994; Ball *et al.* 1998; Commisso 1999; Greenough *et al.* 2004; Kowal and Ball 1999; Leaming 1971; Mallory-Greenough and Greenough 2004; Mallory-Greenough *et al.* 2002; Richards 1988; Rousseau 2000). This chapter presents a general description and discussion of six large and abundant "primary" toolstone sources located in the Thompson River drainage of south-central British Columbia (B.C.) (Figures 3-1 and 3-2). Information presented herein is intended to serve as a basic descriptive guide to assist researchers attempting to ascertain natural toolstone quarry sources for lithic material types commonly represented in archaeological lithic assemblages at sites in south-central B.C. Also presented are reasons why some lithic material types are better suited for specific functional purposes, and thus help explain why they were selectively preferred by pre-contact period technicians.

Identification, recording and detailed archaeological investigation of natural silicate toolstone sources in southern B.C. are still in a nascent stage. I have spent considerable time examining road-cut exposures, gravel bars in streams and rivers, gravel pits, and bulldozed fields over the last 30 years, and have gradually identified at least 25 other "secondary" toolstone sources currently known within the study area, but most of these are either highly localized or of limited areal extent, and often contain low incidences of accessible stone suitable for flaking. While these secondary sources certainly have local, regional, and inter-regional archaeological significance and importance, they are not included herein because the descriptive information alone would fill a volume.

Figure 3-1. Location of study area in South Central British Columbia.

Visual comparison and memory recognition of distinctive types of toolstone removed from known source quarries remains the easiest, simplest, and cheapest method for identifying source localities. X-ray fluorescence, petrographic analysis, and other geochemical methods (Bakewell 1991a, b;

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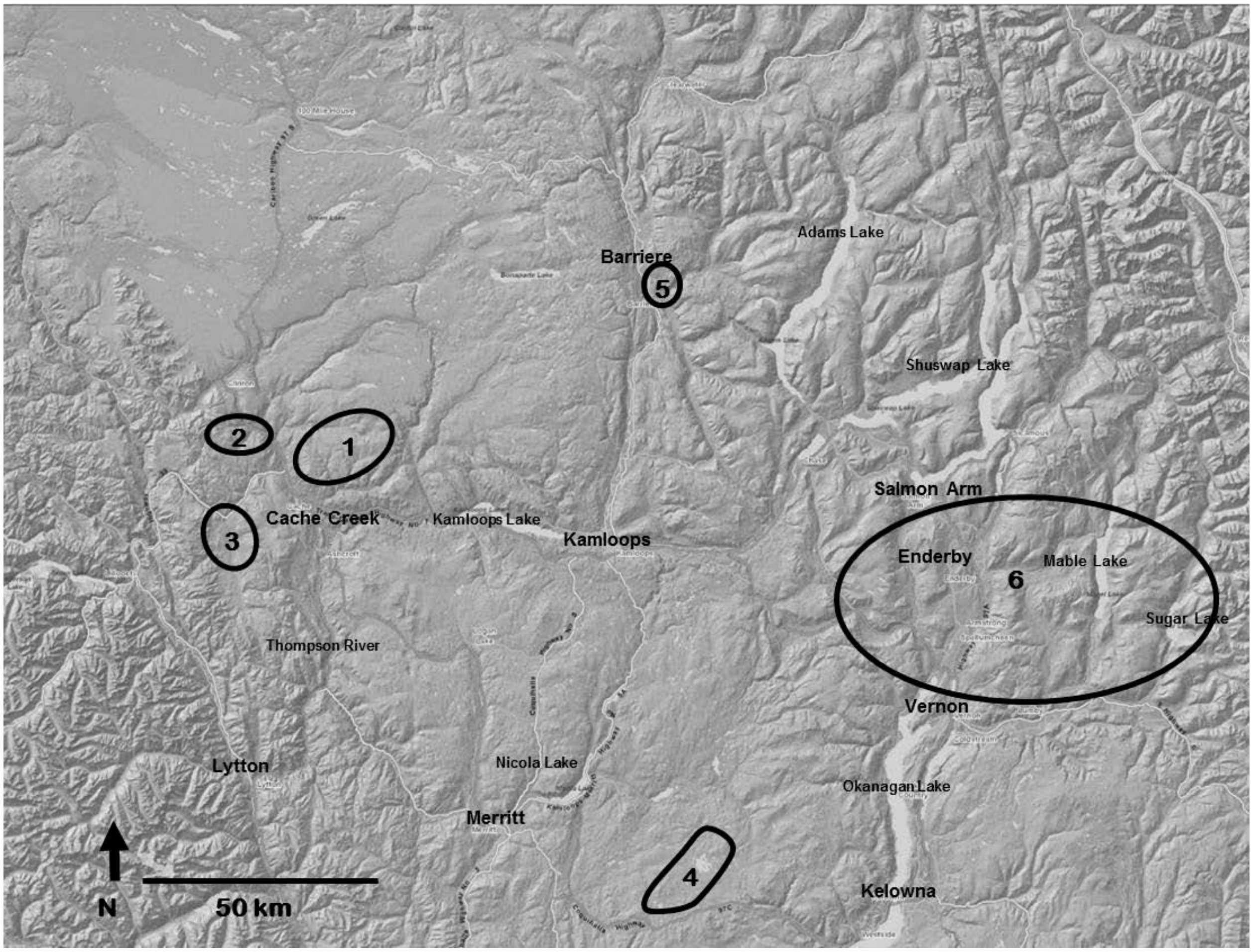

Figure 3-2. Map showing approximate locations of six primary tool stone sources in the Thompson River drainage: Source (1) Cache Creek/Arrowstone Hills dacite and silicates; (2) Maiden Creek dacite and silicates; (3) Upper Hat Creek silicates and dacite; (4) Pennask Lake/Okanagan Highland dacite; (5) Barriere chert; and (6) Shuswap banded chert. Adapted from IMAP BC map image.

Bakewell and Irving 1994; Ball *et al.* 1998; Bertin 1978; Commisso 1999; Greenough *et al.* 2004; Kowal and Ball 1999; Mallory-Greenough and Greenough 2004; Mallory-Greenough *et al.* 2002) are surely more accurate and reliable methods commonly used for identification of some stone sources, but they require specialized equipment and some expenditures of money and time that may not be practical for most lithic analyses.

The six toolstone sources presented below have a wide variety of microcrystalline and cryptocrystalline silicates with very unique sets of physical properties that allow them to be easily and accurately visually matched with their quarry source. Visual physical traits with excellent diagnostic value include considerations of weathering and patina on cortical surfaces, groundmass color(s), relative hardness, texture, lustre, internal molecular structure, inclusions, groundmass bedding or banding, perverse flawing, hinging, and general response to direct percussion and pressure flaking techniques.

Surficial and bedrock geology in the study area includes the “Cache Creek Group” and “Kamloops Group” (Campbell and Tripper 1971; Church 1982; Dawson 1896; Drysdale 1913; Duffel and McTaggart 1951; and Ewing 1981a,b; Leaming 1971). Most of the six toolstone sources presented below are known high-quality silicate sources associated with Tertiary period/age geologic deposits dating between 65 and 2 mya during the initial part of the Cenozoic Era. It was characterized by world-wide moderate to tropical climates, and in south-central B.C., Tertiary age volcanic and marine sediments are obvious by their conspicuous bright colors that commonly include true, pastel, and mixed shades of yellow, orange, red, purple, brown, green, grey and sometimes light blue. Small isolated pockets are visible along valley sides in locations where bedrock protected them from being impacted and removed by glacial and fluvial processes. These volcanic and marine floor deposits often contrast sharply with immediately adjacent glacial deposits and bedrock, and some contain chalcedonies and cherts that have formed in cavities, bubbles, seams, and buried organics (e.g., petrified wood). Plant, insect and fish fossils in fine clays and silts, and seams of coal are also sometimes directly associated with Tertiary age sediments and flakable silicates, but not always.

"Primary" toolstone sources are defined as locations where fair to excellent quality silicate rocks with good flaking properties can be easily found exposed on the ground surface and exposures in medium to high densities over fairly large geographic areas. Six known primary toolstone source localities are described and discussed. They include: **(1)** Arrowstone Hills and Cache Creek locality; **(2)** Maiden Creek drainage northwest of Cache Creek; **(3)** Hat Creek Valley west of Cache Creek; **(4)** Pennask Lake locality in the Okanagan Highlands; **(5)** Barriere locality on the North Thompson River; and **(6)** the southern Shuswap Lakes locality (Figure 3-2).

Arrowstone Hills/Cache Creek Locality Dacite and Silicate Source

The best-known and most abundant toolstone quarry in south-central B.C. is the Arrowstone Hills/Cache Creek dacite source located northeast of the town of Cache Creek (Figures 3-2 and 3-3). It is associated with heavily eroded Tertiary age volcanic lava flows, ash-rain sediments and marine deposits, and terraces and pockets of associated colluvial, glacial and glacio-fluvial deposits. During the early post-contact period it was a widely known local fact that First Nations people gathered toolstone there in pre-contact period times, hence this upland was dubbed "Arrowstone Hills". Arrowstone Creek, a major confluence of Cache Creek, has dissected through a large heavily eroded extinct volcanic crater containing widespread medium to high densities of buried dacite pebbles,

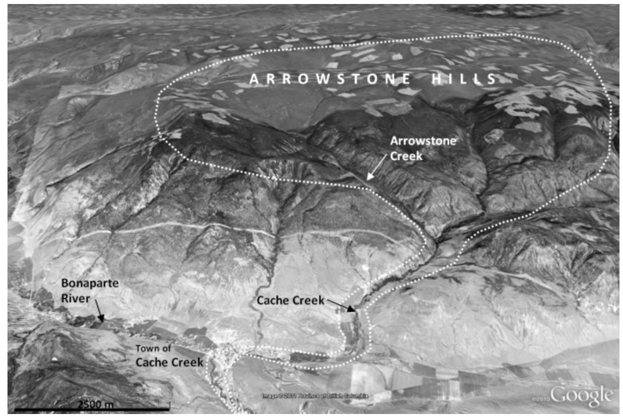

Figure 3-3. Oblique aerial view of Arrowstone Hills showing currently estimated natural surfacial distribution of Cache Creek Dacite, looking northeast. It is the most abundant and easily accessed sources of high quality dacite in south-central BC.

cobbles, and small boulders (Figure 3-3).

Prior to the early 1990s, most archaeologists referred to this toolstone as "Cache Creek basalt", and this moniker is still occasionally used today by some. Detailed petrographic studies conducted by Bakewell (1991a,b) revealed that it is actually a very high quality dacite, and this more accurate term is now acknowledged and used by most researchers. Currently, known dacite exposures at the Arrowstone/Cache Creek source encompass an area measuring approximately 100 square km (Figure 3-3). This is an estimate based on my personal familiarity with the source area, and on data secured during forestry-related impact assessment fieldwork (Ball *et al.* 1998; Kowal and Ball 1999). This conjecture of areal extent may be a bit conservative; future fieldwork may prove the source area to be somewhat larger in an eastern direction.

Extensive valley bottom fluvial gravel bar deposits and along Arrowstone and Cache Creeks, and colluviums along valley sides, are very productive for glacio-fluvial and fluvially rounded and smoothed dacite clasts of all size. Many clasts have been transported down into the town of Cache Creek where they can be found in moderate densities, and in lower densities along gravel bars and exposed banks of the Bonaparte River further downstream to the south. Despite past intensive procurement during most of the 11,000 year-long pre-contact period, in the right locations it is still easy to find up to a hundred flakable cobbles over the course of a few hours. A handful of archaeologists and hobbyist flintknappers continue to exploit parts of this source area with low regularity and impact. There can be little doubt that there are still millions of dacite clasts that remain buried throughout the Arrowstone Hills upland, and along bottoms and sides of Arrowstone and Cache Creeks.

Clasts vary greatly in form, with elongate lozenge, elliptical, discoidal, tabular, spherical, ovoid, egg-shaped, and football-shaped forms being most common (Figures 3-4 and 3-5). They typically range in size from 1 to 15 cm in maximum dimension, but small boulders ranging from 15 to 30 cm are sometimes found in localities where densities are moderate to high. Externally, many have multiple flat polygonal and elongate "fluted" facets, and are moderately to fairly angular with low to moderate degrees of surface feature rounding. Surface weathering and cortex/patina development on most clasts is commonly very thin semi-transparent, "frosty" "smoky" or "milky" white, light grey, or occasionally pale white-blue (Figure 3-4). A low proportion of clasts (usually larger cobbles and boulders) have moderate to thick "chalky" patina on one or more surface facets or sides that is precipitated calcium carbonate formed on the bottom of clasts while incorporated in alkaline glacial till deposits.

Most clasts have internal groundmasses that are jet black, black, and dark grey-black, with textures ranging from medium and fine-grained microcrystalline, to smooth cryptocrystalline. Lustres range between dull, waxy, greasy and glassy. While most groundmasses are fairly homogenous, they are not truly isotropic. Typically, internal structure of most clasts is characterized by visible lamellar or "bedded" flow planes whose orientations are accentuated and easily observed on many weathered cortical surfaces (Figure 3-4). These flow planes/lamellae are sometimes observable on fresh-struck internal surfaces as thin alternating grey-black and black parallel bands. Overall clast form is also dictated to some degree by these flow planes, with longer axes of cobbles and pebbles being oriented parallel to them. Small randomly spaced low density silicate phenocrysts and crystalline seam inclusions are sometimes present, but are more common in jet black glassy/vitreous groundmasses. Some of the grey-black medium and fine-grained groundmasses lack such inclusions, and are typically less flawed.

Figure 3-4. Selected examples of typical Cache Creek dacite pebbles and cobbles from Arrowstone Creek showing range in clast forms and cortical surface variation.

Figure 3-5. Fresh-struck flakes and chunks of Cache Creek dacite showing range of variation in groundmass textures and traits.

From a technological perspective, Arrowstone/ Cache Creek dacite is almost a perfect toolstone. Small pebbles ranging from 2 to 5 cm in maximum dimension are very abundant, and during the pre-contact period these smaller ones were commonly reduced by bipolar technique. If bipolar force is applied in parallel compliance with the lamellar structure of the groundmass, numerous usable thin, flat and sharp "shear" flakes can often be easily produced from a single pebble. Microblade cores are also easily produced from small elliptical pebbles by splitting them transversely and using resulting fracture facets as initiation platforms to very effectively remove blades oriented parallel to the internal lamellar bedding structure.

Cobbles and small boulders of this stone are also ideal for direct freehand techniques, and very large and remarkably thin flakes can be reliably produced from fine-grained dacite cobbles using both hard and soft-hammer percussion methods. The most effective means of striking medium-size and large flakes involves directing impact force loads along and parallel to, or slightly oblique to, the lamellar groundmass structure. Medium and fine-grained (i.e., non-glassy) dacites are clearly the best for successfully producing large flake blanks, as they have fairly homogenous and semi-isotropic groundmasses that are usually flaw free, allowing good flaking control and better chance of success during production of tools involving significant investments of time (e.g., formed unifaces and bifaces). They also lend themselves very well to pressure flaking, allowing production of large, thin, well-made bifaces and other complex tool forms. Medium-grained and fine-grained dacites are also more resilient and functionally durable than glassy/vitreous dacites which tend to have a greater incidence of crystalline inclusions, flaws, cracks, and cortical bruising which render them more prone to shattering, hinging, and unpredictable and erratic flaking results. While all dacite cobbles can be easily and successfully reduced into a variety of useful tool forms, after spending some time reducing the suite of groundmass types, it becomes readily apparent that medium and fine-grained dacites are technically superior to glassy/vitric clasts. This selective preference is also reflected in many lithic assemblages from archaeological sites throughout the study area.

High quality flakable dacite clasts found in the Arrowstone/Cache Creek locality provided local pre-contact period inhabitants of the region with an inexhaustible supply of excellent quality toolstone that was used for many thousands of years. The lower southern aspect of the source area would have been visited year-round, but upland areas to the north could have only been accessed from late Spring to late Fall. Archaeological sites directly associated with natural Cache Creek dacite exposures can be very large, often extending many hundreds of metres along flat and gently sloping terrace edges and stream channels. Cultural deposits at these sites are often thick (0.5 to 1.0 m below ground surface), with continuous cultural deposits at larger sites at or near clast-rich areas extending to depths of 2.0 m below surface. Cultural deposits at most sites are moderate to very high density, and comprised mostly of initial reduction stage de-cortication waste, block shatter; core preparation flakes, complete and broken/snapped tool flake blanks, a moderate to high incidence of ovate, leaf-shaped and triangular bifacial performs, and millions of hard and soft-hammer flakes resulting from their production. Some upland areas with high natural clast densities contain obvious evidence for hand-excavated pre-contact period quarry pits (adits) measuring several metres across (Bruce Ball pers. comm. 2011).

While it is not widely known or acknowledged, the Arrowstone/Cache Creek area source also contains isolated patches of low to medium density cryptocrystalline silicates. Small to medium size (4 to 10 cm) nodules and blocky clasts of translucent chalcedony, multi-coloured (mostly red, brown and yellow) cherts, and sometimes opal, can be found with dacite clasts in low density associated with Tertiary Age volcanic basalt flows and related isolated pockets of marine sediments, and also incorporated in glacial till and steam deposits. Petrified/silicified wood is also present in some areas, notably in the northwest aspect of the source area. Archaeological sites lying within and near this source indicate that these less abundant silicates were also being sought and reduced, but they typically only represent less than 2 percent of most quarry-related assemblages.

Maiden Creek Dacite and Silicate Sources

The Maiden Creek dacite quarry and its nearby companion silicate source are located northwest of the town of Cache Creek between the Bonaparte River and Mid-Fraser River region (Figures 3-2 and 3-6). These medium to high density sources have been previously presented in Rousseau (2000:177-181), and their more salient traits are presented and summarized below. This very abundant dacite source area occupies about 20 square kilometres in upper Maiden Creek drainage basin. Pebbles, cobbles and small boulders of good to excellent quality dacite can be very easily found in moderate

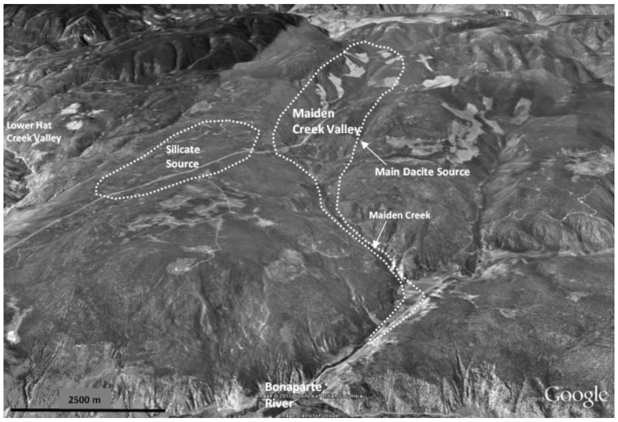

Figure 3-6. Oblique aerial image of the Maiden Creek dacite and silicate sources, looking west.

Figure 3-7. Cobbles and pebbles of Maiden Creek dacite showing range of clast forms and typical cortical surfaces.

Figure 3-8. Examples of fresh-struck surfaces of Maiden Creek dacite showing range in groundmass textures.

to high densities within exposed glacial till deposits, stream banks and channels in the upper drainage area, and in lesser concentrations to the east along Maiden Creek valley bottom down to the Bonaparte River. Dacites from this source are generally similar in structure and appearance to those found at the Arrowstone/Cache Creek source to the east, but there are some significant visually evident physical differences that allow them to be differentiated from each other with a fair degree of certainty.

Dacite clasts from Maiden Creek vary in size from small pebbles up to small boulders, and many are discoidal, elliptical, trapezoidal, elongated, tabular and blocky (Figure 3-7). On average they tend to be thicker than those from the Arrowstone/Cache Creek source, and outer surfaces of many have several intersecting flat polyhedral and elongate “channel-like” facets. Cortex/patina development is usually moderate to pronounced, and while some are thin and semi-translucent, most are opaque medium to light grey or white. Grey clast surfaces commonly have a faint graphite-like metallic sheen. On some larger blocky clasts, cortex development is very thick, especially on those with distinctive flat “rippled” and “corrugated” facets that are always oriented parallel to internal groundmass flow planes (Figure 3-8; lower right). This “corrugation” trait is very rarely present on Arrowstone/Cache Creek clasts. In some extreme cases the cortex development resembles chalky patinas similar to those found on English or Texas flint nodules. There is an abundance of bedrock limestone (Marble Canyon) surrounding the western edge of this dacite source, and thick calcium carbonate precipitates on some specimens may be attributed to direct contact with this geologic unit and/or groundwater with high concentrations of dissolved limestone.

Relatively homogenous groundmasses range in colours from jet black, dark to medium grey-black, medium grey, and occasionally even light grey (Figure 3-8). The lighter grey hues have semi-translucent and diaphanous properties that have caused some researchers to mistakenly identify them as grey chert. In contrast, dacite clasts from the nearby Arrowstone/Cache Creek source to the east are most always jet black to dark grey-black. Groundmass textures are generally rough medium-grained to smooth fine-grained microcrystalline, with fewer numbers of clasts being smooth and slightly vitric. Lustres commonly vary between dull, waxy, and greasy, but shiny glassy dacite clasts are far less common here than in the Arrowstone Hills Cache Creek source to the east. A high incidence of Maiden Creek dacite groundmasses also have faintly visible to obvious lamellar flow plane banding characterized by thin, ribbon-like bands of alternating black and dark grey-black lamellae that displays an interesting "candy cane" or "zebra stripe" appearance when flaked obliquely through the flow plane bedding axes. Fresh-struck internal textures mostly range from medium to fine-grained microcrystalline. Internal phenocrysts and other inclusions are also present, but are less common than those in dacite clasts from the Arrowstone/Cache Creek source.

Maiden Creek Dacite is also an excellent toolstone, and is easy to flake using hard and soft-hammer techniques. Removal of very large and exceptionally thin hard-hammer flakes is most easily accomplished when percussive force is initiated slightly obliquely or parallel to the internal flow planes. Such large flakes are ideal for successfully producing flake blanks to make a variety of formed bifacial knives and projectile points, formed unifaces, and other simple tool forms. Internal flawing and perverse fracturing are not as common in the Maiden Creek dacites as they are with clasts from the Arrowstone/Cache Creek source. Attempts to successfully remove flakes at angles set acutely or perpendicular to the bedding planes is rewarded with some success, but is sometimes seriously hindered by random internal fractures, perverse fracturing and shattering, and abrupt stepped and hinged flake terminations.

Numerous archaeological sites have been identified within the upland aspect of the Maiden Creek dacite source area during routine forestry-related projects over the last two decades. Most of them are directly related to quarrying activity and contain moderate to extremely high densities of primary and secondary reduction waste extending to depths of 1.0 m below surface, attesting to long term continuous exploitation of this stone spanning several millennia. Many assemblages from archaeological sites between the Bonaparte River and the Fraser River to the west contain high proportions (60 to 90 percent) of Maiden Creek dacite. However, the main high density dacite concentration lies in the upland western aspect of the source area, requiring considerable expenditures of energy to access, find, reduce, and transport the toolstone to be used at valley bottom sites. Because it is not as readily accessible as the Arrowstone Hills/Cache Creek source, Maiden Creek dacites may be less common in regional site assemblages, and not as widespread. There is good evidence indicating this dacite was sought and used for the last 5000 years. The greatest intensity of exploitation of dacite from the Maiden Creek source area probably occurred during the Plateau horizon (ca. 2400 to 1200 BP) of the Late Prehistoric Period.

A short distance south of the main Maiden Creek dacite source area there is a widespread surficial scatter of low to medium density clasts of multi-coloured microcrystalline and crypto-crystalline silicates. The most common are small pebbles and cobbles of semi-translucent and opaque yellow, yellow-orange, orange, orange-brown and brown chalcedonies and cherts visually similar to those commonly found throughout much of Upper Hat Creek valley about 20 km to the south (see below). Cobble sizes range between 5 to 10 cm in diameter, and some contain both semi-translucent chalcedony and multi-coloured opaque cherts on the same piece of stone. Cortical surfaces commonly have a dull or frosted appearance, and fresh-struck groundmass surfaces have smooth textures and pearly or waxy lusters. Overall flakability of most of these hard cherts and chalcedonies is considered poor to fair, as they commonly have groundmasses with high incidences of cracks and flaws, and crystalline inclusions and seams that significantly hinder successful production of usable flake blanks larger than 3 cm.

The Maiden Creek silicate source also has at least one locality where angular chunks of "opal" can be found on the ground surface in association with eroding basalt bedrock. Most colours range from pale yellow, light yellow, light green, light green-blue, light green brown, bright orange, blood red, and occasionally iridescent white and pinkish-white. Opal groundmasses typically have very smooth to glassy textures, a semi-opaque to diaphanous translucency, and fresh surfaces have waxy to greasy lustres. It is a relatively soft and very brittle stone, and most specimens are fraught with extensive cracking that result in a high incidence of block shatter and large amounts of waste when being flaked. This opal was not commonly sought for producing stone tools because its flaking qualities are poor, and because it is soft and brittle, most tools produced from it would have short use-lives. While there was some direct evidence for pre-contact period reduction of small amounts of this opal in the immediate source area, it is rarely found at archaeological sites surrounding this source area.

Small to large chunks of petrified (opalized) wood from the trunks and branches of large trees are also found scattered throughout the Maiden Creek silicate source area. The internal structure of the wood can be easily seen on most specimens, which vary in colours that include opaque white, light grey, light brown, medium brown, and dark brown. Some pieces with high silica content are fairly translucent and slightly iridescent. Patination is usually well developed on weathered surfaces. As a general rule, this material does not respond well to flaking, as it has a tendency to shatter and fracture into elongate chunks and blocky flakes that conform to the internal wood-grain structure. It flakes more predictably and easily when force is applied parallel to the internal elongate structural axis of the wood. Flaked petrified wood is sometimes represented in very low frequency (less than 1 percent of lithic assemblages) at Late Period archaeological sites throughout the study area, where it is found as small waste flakes, and occasionally projectile points, scrapers, or simple flake tools were made from it.

Upper Hat Creek Silicate and Dacite Sources

Upper Hat Creek Valley is located southwest of the town of Cache Creek between the Fraser River to the west, and Thompson and Bonaparte Rivers to the east (Figures 3-2 and 3-9). It has long been a destination for rock and gemstone collectors, and geologists and archaeologists conducted detailed investigations there during the 1970s (Leaming 1971; Pokotylo *et al.* 1982; Rousseau 2000:171-174). Various chalcedony and cherts are available as randomly distributed low density float on the ground surface, in the hummocky glacial ablation terrain that occupies most of the valley bottom, and in stream embankments, channels, and gravel bars throughout the source area. Most of the scattered silicate materials are found in randomly localized

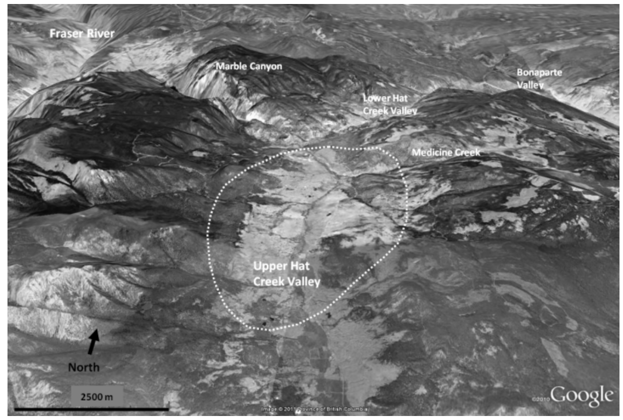

Figure 3-9. Oblique aerial view of Upper Hat Creek Valley showing estimated extent of chert and dacite source area, looking north.

low to medium density concentrations in the northern aspect of this source.

The most common silicates are polychrome chalcedonies and cherts with colours ranging from pale yellow, light and medium yellow-brown, medium brown, and occasionally dark green, dark brown, red-brown and red (Figure 3-10). This general suite of silicates has long been called “Hat Creek chert” by archaeologists, but it also includes translucent and semi-translucent chalcedonies with the same basic colours. Clast size varies considerably, from small pebbles to boulders up to 1 metre in diameter. Those contained in the glacial till and glacio-fluvial deposits are often amorphous, angular and blocky with irregular surfaces; those from creek channel contexts more rounded and smooth. Polychrome mottling, convolutions, and “mosaic” patterns are very common, and many clasts exhibit variable silica content and admixtures of several colours and textures.

Typical Hat Creek chert clast groundmasses are irregular in internal consistency, and are rife with numerous cracks and flaws that cause a moderate to high incidence of perverse fracturing when being hard-hammer flaked. Nevertheless, some larger pieces have portions that are relatively homogenous and isotropic, and large thick flake blanks can be successfully removed. It is a very hard and durable stone, and in pre-contact period times it was actively sought and employed to make curated and specialized tools requiring long use lives (e.g., simple flake knives, unifacial scrapers, shavers, planers, gravers, perforators, etc.). Its hardness makes soft-hammer and pressure flaking difficult; high force loads are required to successfully detach

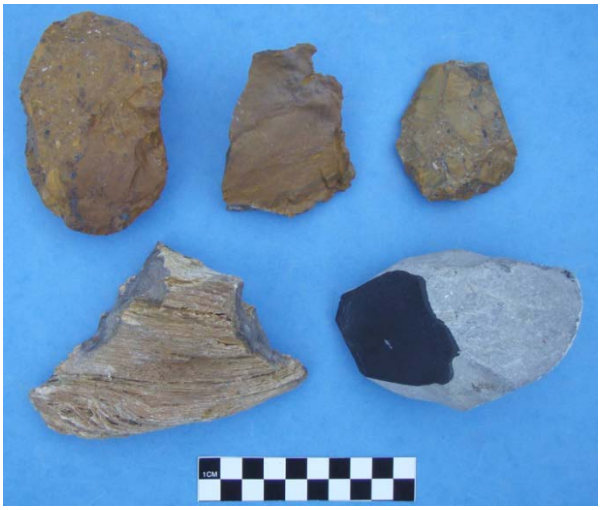

Figure 3-10. Examples of Hat Creek yellow-brown chert, a piece of flakable petrified wood, and a dacite cobble with fresh flake scar from Upper Hat Creek.

flakes. Consequently, well-formed bifaces made from this suite of cherts and chalcedonies are rarely found at archaeological sites, whereas simpler formed and unformed unifaces sometimes are.

There are many recorded and investigated sites within the immediate source area that contain significantly high proportions of Hat Creek chert, lending ample testament for extensive pre-contact period use. Large quantities of highly localized lithic reduction waste suggest that flake blanks were commonly produced from these silicates with intent to transport them to other locations. This toolstone is found in low frequencies at archaeological sites within a 50 km radius, and is best represented at sites to the west on the east side of the Mid-Fraser, and in the east within the Bonaparte and lower Thompson River valleys.

Other flakable toolstone found scattered throughout the Upper Hat Creek source in low clast numbers include pebbles and cobbles of transparent, pale grey and pale yellow chalcedony (agate). Chunks and bits of petrified wood (Figure 3-10) are also found incorporated in glacial till in several locations, but it is generally of poor quality and unsuited for successful lithic reduction. Low densities of pebbles and small cobbles of good-quality dacite can also be found randomly distributed in the local glacial till deposits and creek beds. Some of these dacite clasts may have originated from the Maiden Creek source area a few kilometres north, having been carried southward by glaciers. However, typical Hat Creek dacite cobbles are a bit different in appearance from those of the Maiden Creek and Cache Creek sources. Most are elongate, discoidal, and elliptical, moderate to well-rounded, and have a heavily smoothed and weathered appearance. Cortical surfaces are usually opaque and moderately to relatively thick, with light and medium grey patina colours being most common. A slight dull graphite-like metallic sheen is common on most clasts. Groundmasses are jet black and relatively homogenous with very few tiny random inclusions, and most often medium and fine grained with moderately dull to waxy lustres. Highly vitreous clasts are rare. Like dacites from other sources in the study area, it has a lamellar flow-plane structure that allows easy and effective removal of large thin flakes when hard-hammer force is applied parallel or slightly offset to the flow planes. It pressure flakes very well, and is ideal for making large thin bifaces, unifaces, and simple flake tools.

There is a documented highly localized source of multi-coloured cherts on lower Medicine Creek (Leaming 1971; Rousseau 2000:173-174) where it intersects through a glacial debris lobe at the valley floor/wall juncture (Figures 3-9 and 3-11). Local rock collectors visit this location on a regular basis to seek high quality silicates that range in color from orange-yellow, orange-red, red, purple-red, dark purple, and sometimes black. These pebbles and cobbles are found predominantly in the stream bed during low water, and also eroding out of a high vertical glacial till exposure on the north side of the creek. Specimens I have seen from this source have groundmasses similar to those described above for the yellow-brown Hat Creek cherts and chalcedonies, being typically fraught with flaws and irregularities. However, some clasts have relatively homogenous and flaw-free portions that are well-suited for making small and medium-size flakes and tools. There is archaeological evidence for reduction of stone from this source along the creek, but rock collectors have removed most archaeological cores and waste flakes from the ground surface. I suspect that this specific location still contains a low to moderate incidence of chert and chalcedony clasts buried in the glacial deposits on the north side of Medicine Creek, and medium density buried lithic reduction scatters in the overlying aeolian silts.

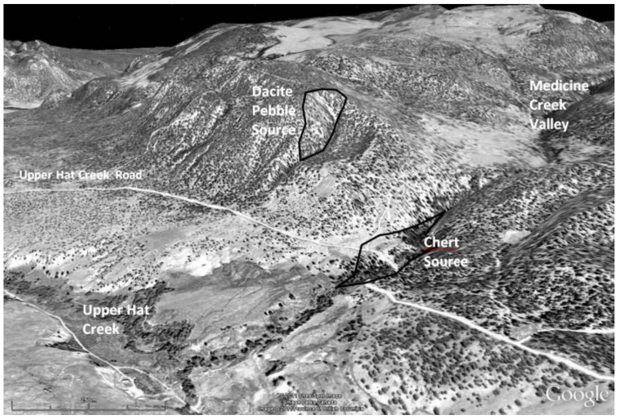

Figure 3-11. Oblique aerial view showing locations of highly localized Medicine Creek chert and nearby high density dacite pebble sources in Upper Hat Creek Valley, looking northwest.

There is an abundant and highly concentrated exposure of very small dacite pebbles located about 1 km northeast of the intersection of Upper Hat Creek road and Medicine Creek (Figure 3-11). Thousands of dacite pebbles are eroding out of a steep prominent talus slope at the southwestern side of a ridge, which is a steeply uplifted section of a soft Tertiary-age marine sediment deposit. All clast outer surfaces have a smooth rounded and weathered appearance. Clast forms range from elliptical, discoidal, lozenge-shaped, egg-shaped, football-shaped, and occasionally spherical. Dacite at this highly localized source is unique from that found at other large dacite sources (i.e., Arrowstone Hills, Maiden Creek, Pennask Lake) in that the vast majority of pebbles range only between 2 and 5 cm in maximum dimension, and they have a very distinctive well-developed light grey to medium grey metallic matte patina that makes them appear as if they were coated with a semi-translucent or opaque layer of graphite or lead. Groundmasses exhibit textures that range from fine-grained to vitreous, and have dull, waxy, and sometimes glossy lustres. These pebbles also have a lamellar flow-plane internal structure that allows them to be very easily reduced by bipolar technique to produce small thin flakes when force is applied compliant to the flow plane lamella axes. There is an abundance of archaeological evidence for pre-contact period exploitation of these small dacite clasts at the base of the talus slope, where it is obvious that intensive bipolar reduction occurred for a very long time. Clasts from this source may have also been used to produce microblades, since their size and form are ideal for making reliable microblade cores, but this remains to be conclusively shown. Because most clasts from this dacite source are so small, it is unlikely that they were actively sought for involvement in any intentional exchange or transport outside of this immediate source locality.

Pennask Lake/Okanagan Highlands Dacite

This large source is situated between the towns of Merritt and Peachland on a high altitude undulating plateau known as the Okanagan Highlands (Figures 3-2 and 3-12). Dacite pebbles, cobbles, and small boulders of varying shapes are found in low to moderate densities in glacial till exposures surrounding Pennask Lake and in stream and creek channels leading in and out of it. These clasts have properties that are visually quite similar to those of the Maiden Creek source, although they appear to have experienced a greater degree of surface fluvial processes. Many clasts have a moderate to well-developed dull grey patina much like the larger dacite cobbles found in Upper Hat Creek. Typical groundmasses are mostly always dark grey-black, and textures range from medium to very fine-grained, with most fresh-struck flakes having dull to slightly waxy surface lustres. Glassy/vitreous groundmasses are very rare. Internal flaws and cracks are few, but small randomly distributed crystalline silica phenocryst inclusions are sometimes present. Groundmasses are relatively homogenous, and like the Arrowstone/Cache Creek, Maiden Creek and Upper Hat Creek dacites, they too have obvious lamellar flow-plane internal structure. Of all the dacites, I consider those from Pennask Lake to be the most granular and "platy". Dacite from the Pennask Lake source has several excellent toolstone properties. Relatively homogenous and flaw-free groundmasses permit easy production of large and medium-sized flake blanks using hard and soft-hammer techniques. Clasts flake best when force is applied parallel or just slightly oblique to the internal flow-plane lamina, and extraordinarily large and thin flakes can be produced that are ideal for successful production of large, thin, well-made bifaces, formed and unformed unifaces, and simple flake-tools. However, attempts to remove flakes by applying

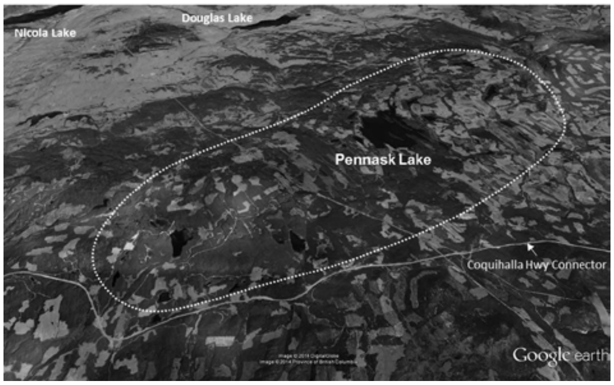

Figure 3-12. Oblique aerial image of the Pennask Lake locality showing estimated extent of natural dacite source, looking north.

force perpendicular to the internal flow planes are often less successful, resulting in high incidences of shattering, stepping and perverse fracturing. Pressure flaking that is more-or-less compliant with the lamellar structure of the groundmass consistently allows very long thin flakes to be detached across flake and tool surfaces.

Since this dacite source is located in a fairly high altitude context that is generally snow-locked during winter and late spring, it could only have been visited during late spring to early fall during pre-contact period times. Numerous high density dacite scatters containing mostly primary lithic reduction waste flakes are located on Pennask Lake shorelines and islands (Figure 3-12). Test excavations at some of these sites have revealed continuous high density primary reduction lithic waste extending to 1 metre below surface, making it clear that dacite was regularly and intensively quarried and reduced in this locality for a very long time.

Because this dacite source lies midway between the Nicola Valley to the west, and Okanagan Valley to the east, inhabitants of both regions made regular use of this abundant source of high quality stone during the pre-contact period. My many years of experience in the Okanagan Valley leads me to conclude that most of the dacite represented at sites there probably originates from the Pennask Lake source. Many Middle and Late period site assemblages in the Nicola Valley contain dacite that likely originates from the Arrowstone Hills /Cache Creek source to the northwest, but it is highly likely they made greater use of the Pennask Lake source. The excellent flaking properties of this stone would have been particularly beneficial to Early Period big-game hunter-gatherers, since large bifaces made from it could be reliably produced and easily maintained. Middle Period inhabitants of the adjacent valleys visited the Pennask Lake source during seasonal upland hunting and trout fishing forays, returning to valley bottom base camps where it was used regularly by resident groups and casually distributed. During the Late Prehistoric Period this stone continued to be collected and transported during seasonal subsistence forays. It may have also been quarried and distributed via organized formal inter-regional exchange systems, but this seems unlikely given the high altitude context, low surface visibility due to thick vegetation cover, and significant expenditures of energy required to move any significant quantities of this stone for valley bottom site consumption.

Barriere River Chert

The Barriere River chert source encompasses most of the small town of Barriere located north of Kamloops in the middle of the North Thompson River Valley (Figures 3-2 and 3-13). It is documented as a frequent rock collector destination in Leaming (1971). Blocky, tabular, angular, and slightly to moderately rounded pebbles, cobbles, and small boulders of this very distinctive lithic material are found in low to moderate frequencies within fluvial sand and gravel deposits comprising the large valley-bottom delta at the confluence of the Barriere and North Thompson Rivers. During the pre-contact period these clasts were collected from exposed banks and gravel bars along the river during low water levels, and they can still be found in low to moderate abundance in these same contexts today. My inspections suggests clasts are most common in the eastern aspect of the source area, and are likely being derived from a more concentrated source contained in the slightly higher glacial outwash terraces and colluvial deposits flanking the eastern valley floor-wall juncture.

These highly distinctive metamorphosed "limestone" cherts are represented in a suite of colours including pastel shades of white, cream, beige, light brown, light to medium grey, grey-green, light green, pink, pink-purple, red-purple, and red-brown (Figures 3-14 and 3-15), with the most common colours being greys and greens.

Figure 3-13. An oblique aerial view of the town of Barriere showing estimated extent of the Barriere chert source in the North Thompson River Valley, looking northeast.

Figure 3-14. Selected cobbles and small boulders of Barriere chert showing clast formal variation and common external and internal colours.

Polychrome clasts with several separate and intermixed colours are quite common. Cortex formation on most specimens is very thin and transparent, allowing internal groundmass colours and structural features to be easily seen (Figure 3-14). Most cortical surfaces are just a bit lighter in colour compared to their groundmass. Small lunate and crescentic conchoidal impact fracture pock-marks are occasionally evident on the surface of better-quality clasts that have been transported down the Barriere River. Typical groundmass textures vary from dull to "frosted" microcrystalline to smooth cryptocrystalline, and fresh-struck surface lustres vary between dull, pearly and waxy. Good quality clasts often exhibit multicoloured and multidirectional striations, veins, and ribbon-like bands that are wavy, contorted and sometimes disjointed, giving the stone an interesting and aesthetic appearance. High incidences of internal flaws and cracks have resulted from metamorphic distortion, and from clasts being transported downstream in high-energy glacio-fluvial and fluvial contexts.

While most Barriere chert groundmasses are very dense, brittle, and often fraught with numerous random intersecting cracks, flaws, and distortion irregularities, a fair number of the larger and more siliceous clasts have fairly homogenous portions that are well-suited for successful production of simple chipped stone tools. Collectively considered, the overall flakability of these cherts ranges from poor to fair. Internal flaws and unpredictable reduction results contribute to production of large quantities of shatter and blocky waste. It is also a very hard and resilient stone, requiring large force loads to detach medium and large flakes using direct hard-hammer technique. It is also often difficult to effectively execute simple secondary retouch and pressure flaking control. Many formed tools found at archaeological sites indicate sparing use of unifacial or bifacial retouch, probably for this latter reason. Despite the technical and physical shortcomings of Barriere chert, its superior hardness and durability are well-suited for creating very sharp and long-lasting tool edges, thus simple unmodified and unifacially retouched flake tools were commonly produced from it.

Occupants of the North Thompson River valley regularly made extensive use of dacites obtained from the Arrowstone Hills/Cache creek source to the west, but there are numerous sites in Barriere and surrounding localities that also contain medium to high proportions of Barriere chert. It has also been found in low frequencies at sites throughout the North Thompson River valley and its lesser tributaries and adjacent uplands between Kamloops and Blue River. There does not appear to have been any intentional organized formal effort to export it beyond the North Thompson River valley for use in other adjacent regions. This is not surprising, since this stone is clearly technically inferior to the abundant dacites and other high quality silicates available in the southern aspect of the study area. Regular local exploitation of Barriere chert probably began during the Middle Prehistoric Period, but this remains to be supported by excava-

Figure 3-15. Fresh-struck flakes of Barriere chert showing typical groundmass traits.

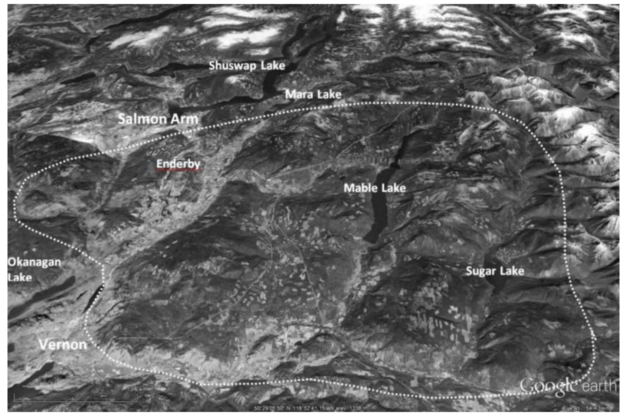

Figure 3-16. Oblique aerial view of the southern Shuswap area showing the currently known extent of widely scattered low-density Shuswap banded chert cobbles that are occasionally found in exposed glacial till deposits on the sides of valleys, and in valley bottom creeks and rivers, looking north. A suspected "mother lode" of this material remains to be identified.

tion data. Its local and regional popularity was greatest during most of the Late Period, particularly over the last 2,400 years.

Shuswap Banded Chert

"Shuswap banded chert" is a very distinctive medium to high quality silicate toolstone long known to archaeologists but rarely acknowledged or discussed. It is sometimes found in low to moderate frequencies (20 to 40 percent) in lithic assemblages secured from investigated and observed archaeological sites surrounding Shuswap Lake, Mara Lake, Mable Lake, and Sugar Lake; at many sites along the South Thompson River to Kamloops; along the shores of Kamloops Lake and west along the Thompson River to Ashcroft; in the Enderby and Falkland localities; and occasionally at sites in the North Okanagan as far south as Kelowna (Figures 3-2 and 3-16). This general area is well known to rock collectors, and contains many heavily eroded Tertiary-age volcanoes, lava flows, and marine sediments that are known to yield a variety of chalcedony and chert silicates.

Despite its common and sometimes relatively abundant appearance at many archaeological sites in the southern Shuswap region, a localized moderate to high density concentration or "mother lode" of this toolstone remains to be found and recorded by archaeologists. Over the last three decades I have made several intentional efforts to find a concentrated source, but have only succeeded in recovering a few isolated pebbles and cobbles in very low densities incorporated in colluviums, glacial tills and glacio-fluvial gravel exposures in road-cuts, stream and river channels, and gravel quarries between Vernon and Sugar Lake, and in the Enderby and Falkland localities (Figure 3-16). It currently appears to have a fairly widespread and low-density natural distribution, probably resulting from the original formation source of this stone being heavily impacted, diluted, and subsequently spread randomly over the landscape by late Pleistocene glacial processes. However, I remain convinced that there is a localized medium to high density source of this stone somewhere south and/or southeast of Shuswap Lake, as it appears in moderate frequencies with a high incidence of waste in some site assemblages in that general locality. My diligent search for a dense concentration will continue.

Shuswap Banded chert is a hard, dense and resilient toolstone with medium to high colloidal silicate content. It can be readily visually identified by a unique constellation of physical traits, and is most commonly found as small tabular and blocky rounded pebbles and cobbles varying between 5 and 15 cm in maximum dimension. Cortical surfaces are generally tan or light grey coloured, moderately to heavily weathered, and flaked surfaces oxidize fairly rapidly to form patinas that are much lighter than their groundmasses (Figure 3-17). Groundmass textures vary from fine-grained microcrystalline to smooth and vitreous crypto-crystalline. Lusters vary between dull, pearly, waxy, greasy and glossy. Most clast groundmasses are opaque, but better quality and lighter coloured examples of this stone are slightly diaphanous along thin flake margins when held against a strong light source. It varies in a range of colours, with pastel and natural shades of tan, beige, light grey, light brown, light pink-brown, light grey-brown, medium grey-brown, medium grey-purple, medium brown, medium brown-purple, dark brown and black-brown being the most common. It is not unusual to have several colours evident on one piece of stone. Fresh-struck internal surfaces are darker in colour compared to their cortex.

The most obvious and diagnostic visual trait is the presence of numerous very thin, closely spaced, parallel micro-stratigraphic lamina that alternate in colour throughout the groundmasses. These ribbon-like lamina are often straight, wavy, randomly distorted, contorted, discontinuous, disjointed and/or “re-healed”, and appear to be the result of very thin alternate (possibly seasonal) sediment bedding that underwent some distortions prior to being impregnated and solidified with colloidal silica. As a result, flaws, cracks, microcrystalline inclusions and seams, and other inconsistencies are common in many clast groundmasses, causing them to often respond unpredictably when percussed. However, some pieces can be quite homogenous and relatively flaw-free, and lend themselves well to being easily and successfully formed using soft and hard-hammer reduction and pressure flaking. Collectively considered, I regard this toolstone to have fair to good overall flakability.

Shuswap banded chert was clearly given frequent attention and selective preference during pre-contact period times. While it was used to produce a wide variety of tool types, it appears to have been employed for making reliable unformed and formed unifacial flake tools primarily intended for moderate to heavy load cutting and scraping activities, and for hafted tools intended to have long use-lives. This is likely because it is hard and durable, and thus a good choice for these concerns. Medium-size and large bifacial knives, well-formed scrapers, and gravers were produced from this stone in moderate numbers, as were low numbers of

Figure 3-17. Selected examples of Shuswap banded chert showing typical range of cortex and groundmass variation.

projectile points, and microblades. The relatively high incidence of this lithic material at sites in the eastern half of the Thompson River drainage area indicates that it was regularly exploited and widely distributed in this area on a fairly consistent basis. Excavation data from many sites firmly indicate it was known and used with low regularity starting around 6000 years BP. Its use persists through time, appearing in low frequencies (5 to 10 percent) of lithic assemblages at some Middle Prehistoric Period sites, with larger proportions (10 to 30 percent) in Late Prehistoric Period sites.

Pre-Contact Period Quarrying and Toolstone Distribution

The culture-historical framework used to discuss quarrying and stone tool production behaviour through time follows that outlined for the Canadian Plateau by Richards and Rousseau (1987), Rousseau (2004, 2008), and Stryd and Rousseau (1996). For the sake of descriptive simplicity, the information and interpretations are presented and discussed using the three basic temporal periods: the *Early Period* (ca. 11,500 to 7000 years BP), the *Middle Period* (ca. 7000 to 3500 years BP), and the *Late Period* (3500 to 200 years BP). Specific cultural manifestations within these periods are also mentioned and discussed where deemed pertinent.

Early Period (ca. 11,500 to 7000 years BP)

Not much is known about toolstone quarrying due to the paucity of excavation data for the Early

Period. Early pioneers surely had first choice of a wide variety of flakable microcrystalline and cryptocrystalline silicates exposed and strewn across barren landscapes by glacial and glacio-fluvial processes. Large dacite, chalcedony and chert clasts would have been available in variable densities throughout much of the study area, notably in upland plateau contexts. Since these early people were highly mobile in pursuit of big game, good quality silicates were incidentally collected as fortuitously encountered while travelling or during the course of daily subsistence tasks. Silicates used by these Early Period people were often carried great distances before eventually being deposited at archaeological sites. Therefore, some of the earliest sites in the study may contain silicates derived from sources many hundreds of kilometres away (notably from the Columbia Plateau to the south), and conversely, sites in distant regions may have silicates that were originally obtained from within the Thompson drainage system.

Putatively early bifaces and projectile points found in the study area (Rousseau 1993; Rousseau 2008:221-225; Stryd and Rousseau 1996: 179-185) are made from medium-grain and fine-grained dacites, and high quality chalcedonies that were well-suited for their big-game hunting needs (Rousseau 1993, 2008). Currently, the earliest solid evidence for use of dacite and Hat Creek chert is from the basal component of the Landels site (EdRi 11) south of Cache Creek where a radiocarbon date on associated bone found below Mazama tephra dated to around 8400 years BP (Rousseau 1991, 1993; Rousseau *et al.* 1991). This indicates knowledge of the Hat Creek and probably Arrowstone/Cache Creek sources by this time. Although there is currently no direct evidence for it, initial exploitation of the Arrowstone Hills/Cache Creek dacite source likely began during the beginning of the Early Period. Exposed dacite clasts would have been abundant, obvious, and very easily obtained in both the upland and lower aspects of this source area.

Middle Period (ca. 7000 to 3500 years BP)

Middle Period archaeological sites are quite common in the study area, and numerous excavated components have yielded excellent lithic assemblages containing readily identifiable toolstone from sources mentioned here. There is ample supportive evidence for regular exploitation of most primary toolstone sources, and several less-important secondary sources. People exploiting these quarries during non-winter months had relatively easy access to an abundance of dacites and other flakable silicates, allowing them to be somewhat more selective with respect to stone quality. Direct acquisition from natural toolstone sources was the main mode of toolstone procurement, and involved physically fit individuals belonging to mobile residential groups and participating in upland subsistence forays. There is no direct archaeological evidence for any organized lithic exchange; most of the raw materials represented in Middle Period lithic assemblages can be assigned to known local or regional sources.

Regional human populations during the Middle Period were relatively low compared to the Late Period, thus there was much less exploitation pressure on primary quarries. However, investigated and observed sites within or in close proximity to the Cache Creek/Arrowstone Hills, Maiden Creek, and Pennask Lake dacite sources suggests that a major proportion (about 20 to 30 percent) of the primary stage reduction assemblages were deposited in these localities during the Nesikep Tradition (Rousseau 2004:3-12). Archaeological sites within and surrounding Arrowstone Hills and Maiden Creek dacite sources are numerous, extensive, and extremely high density, often containing many tons of lithic reduction waste associated with diagnostic biface forms that can be related to the *Early Nesikep Period* (ca. 7000 to 6000 years BP), and *Lehman Phase* (ca. 6000 to 4500 years BP) (Rousseau 2004, 2008; Stryd and Rousseau 1996:185-197). The primary objective at these quarry sites was production of large flake blanks using hard-hammer technique, and soft and hard-hammer flaking of medium-size to large triangular, oval, elipitical and tear-shaped bifaces that were later intended for flake cores, bifacial and unifacial knives, and other more complex tools. Moderately mobile local and regional inhabitants commonly made frequent intentional and/or “embedded” visits to this source area to replenish toolstone as needed. Dacite from this source was also transported and casually exchanged inter-regionally by these fairly mobile groups, and it is well represented in assemblages at major Middle Period sites within and adjacent to the Mid-Fraser, Thompson, North Thompson, South Thompson, and Shuswap River valleys.

Middle Period lithic technicians actively sought and used dacite on a regular basis, and while they had easy access to all grades of it, they seemed to prefer medium and fine-grained microcrystalline groundmasses over those that were crypto-crystalline and glassy. This is probably because many glassy clasts are more brittle, and rife with internal flaws, cracks, and random phenocryst inclusions that reduce its technological value and reliability. Many Middle Period formed bifaces typically range from medium-size to quite large (up to 15 cm long) and most are remarkably thin and very well-made. This is especially true of the ***Early Nesikep Period*** (ca. 7000 to 6000 years BP) and ***Lehman Phase*** (ca. 6000 to 4500 years BP) when technicians were actively taking advantage of lamellar dacite groundmasses to produce large thin flake blanks by applying force loads parallel or slightly obliquely to, their internal bedding planes. This "directional compliancy" afforded by the internal lamellar structure of medium and fine-grained dacites is key to understanding how pre-contact period lithic technicians most successfully and effectively reduced cores and produced large flake blanks from them. Pressure flaking was executed with the same conscious consideration of this lamellar structure, allowing removal of very long and thin flakes extending up to and sometimes beyond the longitudinal mid-line on many bifaces.

During the ***Lochnore Phase*** (ca. 5000 to 3500 years BP), dacite still dominates most lithic assemblages (70 to 80 percent), however, many components contain stone from a wide variety of nearby secondary sources (20 to 30 percent), and from gravel bars and exposures (10 percent) in close proximity to base camps and established villages. This reflects the fact that people participating in this cultural manifestation were less preoccupied with exploiting upland resources, and more focussed on riverine and valley bottom environments for most of their food, stone and textile needs. Very small quantities of obsidian, usually in the form of small secondary retouch or pressure flakes, occasionally appear in *Lochnore Phase* assemblages. A small number of X-ray fluorescence analyses show that some originate from Anahim Peak in northwestern B.C., and from the Whitewater Ridge and Glass Buttes source localities in eastern Oregon. The paucity of obsidian should be viewed as being the result of occasional obsidian tools or small clasts making their way into the study area via low-level, informal, familial or inter-regional exchange systems.

Late Period (ca. 3500 to 250 years BP)

Current excavation data for the ***Shuswap Horizon*** (ca. 3500 to 2400 years BP) indicates that people participating in this cultural pattern most commonly exploited toolstone that was gathered incidentally within a few kilometres of valley bottom villages and most base and field camps during the course of daily subsistence activities. As a result, extensive use was made of a wide variety of locally available, poor to good quality siltstones, quartzites, rhyolite, chalcedonies and cherts. Dacite typically comprises about 50 to 75 percent of lithic assemblages, and most of it is medium to fine-grained, suggesting that the abundant Arrowstone Hills/Cache Creek, Maiden Creek, and Pennask Lake sources were being regularly visited and used with low to moderate intensity. Well-organized formal inter-regional commodity exchange networks involving toolstone did not exist during the *Shuswap Horizon*, but small quantities of dacite may have been intentionally moved from west to east by way of casual inter-group or inter-family exchange. Good to high quality extra-local cryptocrystalline silicate stones typically constitutes only a small part of most lithic assemblages (less than 5 percent), with colourful cherts and translucent chalcedonies being the most prevalent "exotics".

The beginning of the ***Plateau Horizon*** (ca. 2400 to 1200 years BP) is coeval with the emergence of a highly organized formal exchange system and interaction sphere that involved many large villages and networked extensively throughout major valleys of the Canadian Plateau. There is ample evidence to suggest that fair to excellent quality flakable silicate lithics were being regularly exploited and moved over fairly large distances on a regular long-term basis. By far, the most common lithic raw material quarried, exported and used throughout the study area during the *Plateau Horizon* are dacites from the Arrowstone Hills/Cache Creek and Maiden Creek source areas. The Pennask Lake dacite source was of lesser inter-regional importance, and was frequented during the non-winter months primarily by groups occupying the Nicola and Okanagan Valley regions to the west and east respectively.

There is an obvious high selective preference for dacites during the *Plateau Horizon*, and they usually comprise about 70 to 90 percent of most lithic assemblages deposited in valley bottom sites. The collective abundance of this lithic material at sites of this age throughout the study area is staggering, and can only be explained by continuous large-scale importation from the primary dacite sources. It is realistic to envision small groups and entrepreneurs targeting and transporting large quantities of raw dacite pebbles, cobbles and small boulders, as well as processed flake blanks and bifacial tool preforms. A person or dog can easily carry 10 to 15 kilos of stone over fairly long distances, and it is likely that most of this dacite (and small quantities of other good quality silicates) were gathered and carried down to the valley bottoms by small groups, and then transported by canoes along major waterways to villages and camps along the lower Thompson River, Kamloops Lake, North Thompson and South Thompson River, and Shuswap Lake regions.

By about 2000 years BP, the *Plateau Horizon* reached a cultural climax, and human populations reached their maximum throughout most southern B.C. (Richards and Rousseau 1987; Rousseau 2004). At this time, most primary and secondary toolstone source areas were well-known to occupants of the Thompson River drainage, and were regularly visited and exploited by lithic technicians to gather good quality stone for personal, inter-familial, inter-village and intra-village socio-economic purposes. High demand for toolstone during this population maximum saw serious depletion of some of the more readily accessible low-altitude dacite exposures, forcing technicians to venture into mid- and upland areas to target smaller and lower density secondary toolstone sources that were repeatedly visited and exploited during the course of organized subsistence forays for other nearby upland resources. Greater familiarity with small secondary silicate sources in adjacent highlands resulted in a regular infusion of fair to good quality silicates (i.e., chalcedonies and cherts) into the lithic consumption at valley bottom sites, and late *Plateau Horizon* lithic assemblages commonly contain 10 to 30 percent “exotic” silicates. Many of these silicates are hard and resilient, and they were commonly used to produce tools with intended long-term use-lives, and/or for use on medium to hard contact materials. Small amounts of obsidian from sources in the distant north (Anahim Peak) and south (Oregon/Glass Buttes) are sometimes found at large village sites, but constitute less than 0.5 percent of assemblages.

During the ***Kamloops Horizon*** (ca. 1200 to 250 years BP), there was a greater reliance on stone secured by direct personal acquisition, and/or casual, semi-formal, or familial exchange systems. Although regular movement of good quality stone via organized intra-regional exchange networks persisted during this time, it was less organized and less extensive than during the previous *Plateau Horizon,* and less stone was quarried and transported. Dacite continued to be the most sought-after toolstone (80 to 95 percent of assemblages), and was commonly used to produce the majority of chipped stone tool types. Some sites contain assemblages with low to medium densities of poor to fair local flakable lithic materials gathered from within catchment areas, presumably to offset periods when better quality dacites were scarce. Also, *Kamloops Horizon* pithouse village sites often contain a high incidence of lithic raw material recycling, and it is not unusual to find artifacts and waste from earlier cultural manifestations that have been brought back into service, reworked into other tool forms, or reduced by bipolar technique to create usable flakes. This suggests periodic shortages or restricted access to better quality stone during the winter months. Various kinds of “exotic” silicates were still in common use during the *Kamloops Horizon*, but they are less commonly employed compared to the *Plateau Horizon*, often comprising only about 5 to 10 percent of typical excavated lithic assemblages. This may be the result of heavy exploitation and eventual depletion of some of the more obvious and readily accessible silicate sources during the preceding *Plateau Horizon*. A less intensive inter-regional formal exchange network during the *Kamloops Horizon* may also be partly to blame.

Directions for Future Toolstone Source Investigations

Although one cannot argue against the certainty provided by more precise “scientific” analysis methods, simple visual identification of toolstone sources from artifacts and lithic waste in archaeological assemblages is still the easiest, quickest, most practical and cheapest means. Experienced lithic analysts familiar with character traits of various types of stone from primary and secondary sources in their study area and peripheral regions could probably attain a fairly high degree of accuracy and confidence in correct source identification (e.g., from 75 to 90 percent), thereby allowing greater certainty and support for any post-analysis behavioural inferences drawn from them. While accurate toolstone type differentiation and correct respective natural source assignations are easiest where high levels of visual/physical trait variability exists between stone from known sources (e.g., localized and isolated exposures of polychrome cherts and chalcedonies), this task is made much more difficult and less certain in areas with numerous widespread and easily accessible sources yielding stone with identical or very similar visual and physical properties (e.g., ubiquitous common exposures of obsidians, basalts and dacites).

Archaeologists should familiarize themselves with the nature, context, and distribution of local geologic formations and exposures that are already known to contain toolstone, and be vigilant for them while in the field. Geologists and petrologists should be consulted whenever possible, as they can more accurately identify and classify toolstone types, provide insights into their physical and technical traits, and help identify geologic contexts where they can be found. Surficial geology maps sometimes provide information leading to source identification, as do local and regional prospecting and rock collecting publications. Rock-hound and lapidary groups are ubiquitous, and their members can sometimes provide a wealth of oral information.

Be aware that many other smaller “secondary” flakable toolstone sources have been identified in the Thompson River drainage and surrounding regions, and most have one or more types of stone with unique visual diagnostic physical and technical traits that permit fairly easy and certain source identification in archaeological lithic assemblages. I submit that all secondary sources should be recorded and documented, no matter how small or seemingly insignificant. Many source locations are directly associated with archaeological lithic deposits relating to initial reduction stage activities, and they should be recorded on site forms and registered. Efforts should be made to determine approximate horizontal extents of all toolstone source areas, and to provide a general account of relative clast size and abundance; tasks that may be fairly simple and quick for secondary sources, but more difficult and time-consuming for extensive primary sources where clast size and relative abundance can vary greatly across the landscape. For each source, representative clast reference collections should be gathered, catalogued, described and stored at an institution or facility accessible to lithic researchers. Eventually, this accumulated data will provide a comprehensive descriptive accounting of visually and chemically distinct toolstones types and their known natural source distributions, creating a solid basis for advancing insights and inferences about past quarrying behaviours, lithic technological systems, annual and seasonal subsistence and settlement patterns, group mobility and catchment territory, and the nature and extent of casual, informal, and formal intra- and inter-regional exchange systems and networks.

Use of X-ray fluorescence and/or other geochemical means to fingerprint toolstone samples from sources should continue to be a major research focus. Much like obsidian, dacites lend themselves well to being fingerprinted, and samples analyzed from different source areas often have individual compositional signatures that allow them to be differentiated from each other with high levels of certainty. This may be true for other toolstone types as well, and these possibilities should be explored using this method. Academic institutions should be encouraged to purchase X-ray fluorescence guns, and allow researchers access to them for lithic source cataloguing and archaeological assemblage analyses.

Lastly, we need to continue studying and refining our understanding of the complex and myriad inter-relationships existing between toolstone physical traits, patterns of preferential lithic material type selection, technical traits and flakability, reduction methods and strategies, suitable task/functional applications, microwear/ use-wear patterns, and artifact recycling/reworking behaviour. Stone tool replication and controlled experimental use involving different lithic types applied to various contact materials are very useful research endeavours that result in considerable technical and functional intimacy with specific toolstone types, and consequently help elucidate why and how they were selectively collected, transported, reduced, modified and employed by pre-contact period people. Results of these studies, and any behavioural inferences that can be derived from them, should be conveyed to other researchers orally and via publications.

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CHAPTER 4

Chert Artifact-Material Correlation at Keatley Creek Using Geochemical Techniques

Heather Kendall
Simon Fraser University (hkendall@me.com)

Brandi Lee MacDonald
McMaster University (macdonbl@mcmaster.ca)

Indigenous use of toolstone deposits has long intrigued archaeologists. Questions about lithic material type, procurement strategies, and toolstone deposit locations can be addressed through geoarchaeological and archaeometric applications such as macroscopic, microscopic, and geochemical material analyses. Our research uses instrumental neutron activation analysis (INAA) and X-ray fluorescence (XRF) to assess variation between chert toolstone deposits in the mid-Fraser region of British Columbia. With these data, we then explore the relationship between toolstone deposits and chert debitage excavated from Structure 109 (ST 109), a semi-subterranean dwelling (also referred to as housepit in an archaeological context) located at the Keatley Creek site (EeRl-7), in the mid-Fraser region of British Columbia (Figure 4-1).

The relative abundance of chert in archaeological contexts and its prevalence in Quaternary deposits indicates its importance as a toolstone material for ancient populations and, as such, it can provide information on hunter-gatherer toolstone exploitation in prehistory. For example, the location of these toolstone deposits and their proximity to settlements provides information about exchange between communities. Thus, the goal of our research is to investigate the geographic relationship between chert toolstone deposits and chert materials in archaeological contexts, and how archaeologists can use this information to expand the current understanding of the procurement and movement of siliceous toolstone materials in the mid-Fraser region (for additional details see Kendall 2014).

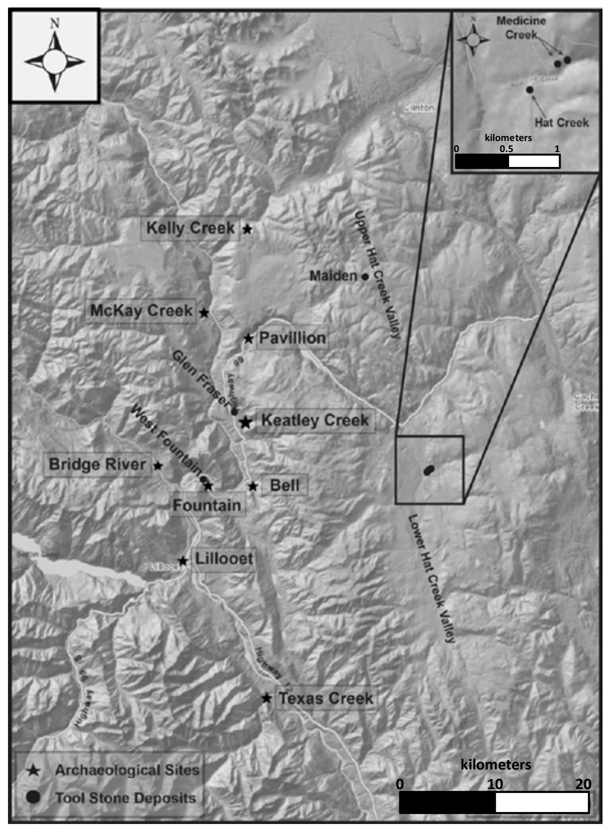

Figure 4-1. Siliceous toolstone deposits of the mid-Fraser Region (Kendall 2014:18).

Background

To effectively link chert artifacts to toolstone

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deposits, we collected samples from both the lithic assemblage of ST 109 and chert toolstone deposits. Deposits were identified using Geologic Survey of Canada maps (British Columbia Geological Survey 2008; Duffel and McTaggart 1951), geologic literature, and a previous study by Rousseau (2000). The majority of the toolstone deposits are within reasonable travelling distance (20 km), or a few days travel from the Keatley Creek site. Reasonable travelling distance was determined by the deposits' accessibility. For example, the deposit being located on or near major water corridors, or along frequently used hunting/gathering trails for expedient collection.

The Keatley Creek Archaeological Site (EeRl-7) and Structure 109

Keatley Creek is one of the largest documented archaeological sites in the Interior Plateau, covering 19 hectares with over 120 semi-subterranean structures (Hayden and Adams 2004). Human occupation of the site began ca. 7,000 B.P. and persisted into the Kamloops Horizon (1200–250 B.P.). It is generally agreed that there was a population climax at the site during the Plateau Horizon (3500–1200 B.P.), within the Plateau Pithouse Tradition (Richards and Rousseau 1987:22-23). However, see Harris (2012) and Prentiss et al. (2003) for conflicting opinions.

The study area is situated within the Interior Plateau of British Columbia, an archaeologically significant region with numerous large pithouse village sites in close proximity to one another. In terms of geology, the Interior Plateau is an elevated expanse of metamorphic bedrock overlain by a significant sedimentary environment that contains numerous Quaternary and Neogene age siliceous deposits (Ewing 1981). The materials from these types of deposits are likely to have been used for prehistoric stone tool production and were probably obtained for this purpose by the hunter-gatherer populations that inhabited the many villages in the area. The locations of some of these material deposits are known, but none have been correlated to artifacts from housepit sites using geochemical techniques as part of a provenance study; however, characterization studies have been conducted in this area on basaltic materials (e.g., Bakewell 2000; Greenough et al. 2002, 2004)

Structure 109 is located on the periphery of the Keatley Creek site on the first terrace east of the site's core. Archaeological excavations of ST 109 were first conducted in 1988, 1989, and 1998 as part of the Fraser River Investigations into Corporate Group Archaeology Project (Hayden 2000; 2004). Two occupations were recorded: 1) the earlier Plateau (Stratum VII); and 2) the more recent Kamloops (Stratum III) Horizon floors. Excavations revealed unprecedented amounts of chert and chalcedony debitage associated with the Kamloops deposits relative to other excavations at the site. During the 2006 Simon Fraser University Archaeology Field School, directed by Robert Muir (Muir et al. 2008), the earlier excavations of ST 109 were reopened and expanded.

The 2006 excavations of ST 109 recovered 101 tools and 2,662 pieces of debitage (Muir et al. 2008), of which 1,606 pieces were chert and chalcedony material; all of the formed tools were made from basalt. Considering all excavations at Keatley Creek, chert and chalcedony comprise less than 7 percent of the total lithic debitage (Hayden et al. 1996; Morin 2006:107), making the abundance of silicates recovered from ST 109 atypical. Based on the uncharacteristic lithic material choice, other researchers have hypothesized that these siliceous materials might be from a non-local source, brought in by trade with other contemporaneous communities outside the mid-Fraser region (Hayden and Adams 2004:96).

Geological Background

The main geologic features of the British Columbia Plateau region are the deeply incised Thompson and Fraser rivers valleys. These valleys contain dense accumulations of Quaternary and Neogene deposits left by glacial outwash. Over 12,000 years ago, the entire surface of this region was covered in a large ice sheet exceeding depths of 2000 meters (Hayden and Ryder 1991). When the Ice Age ended 11,500 years ago and the glaciers receded, they deposited boulders, cobbles, pebbles, gravel, sands, and silts on the landscape (Hayden 2005:2-3; Hayden and Ryder 1991). Using geologic classification, the bedrock of this area of the Plateau is known as the Kamloops Group, with the Cache Creek group in close proximity (Ewing 1981:1464; Rousseau 2000:166). The Kamloops group is defined as an assemblage of Lower to

Middle Eocene volcanic and sedimentary rocks found in south central British Columbia. Of particular interest is the area west of Kamloops, which runs into Lillooet and the vicinity of Keatley Creek. This area contains the basal Tranquille Formation, which consists of 500 meters of lacustrine and deltaic sediments (Ewing 1981:1464-65); common areas for silicate rocks to occur either through formation, diagenesis, or deposition.

The Cache Creek group is situated in the vicinity of Marble Canyon, which is southeast of the Keatley Creek site. According to Duffel and Taggart (1951), the bedrock is composed of chert, argillites, minor agglomerates and tuffs that are exposed along the Thompson River and Cariboo Highway from Martel to Cache Creek and north to Clinton (Rousseau 2000:166). A large component of this formation is the recrystallized limestone exposed in Marble Canyon and the Pavilion Mountains. The limestone contains inclusions of chert, argillite, and greenstone.

Methods

Our research used basic visual and advanced geochemical techniques to characterize and source the chert debitage excavated from ST 109. Due to the high propensity of inter- and intra-site variation within chert outcrops and deposits, this provenance study required a method that could test for rare earth, trace elements, and elemental density with high precision. Each chert deposit may contain the same elements, but the composition percentage of each element varies (i.e., each chert deposit has different amounts of trace elements and based on the variation detected by INAA, it is possible to identify where a specific piece was quarried). In the interests of a clear and focused research question, chalcedony materials were not included in the elemental statistical analysis.

Collection of Material: Toolstone Deposits

Toolstone deposits were selected after reviewing the extensive work done by the Geological Survey of Canada (Duffel and McTaggart 1951; Monger 1985; Monger and Price 2002), consulting with archaeologists (Austin 2007; Crossland and McKetta 2007; Rousseau 2000; Rousseau, personal communication 2009) and rockhounds (Hudson 2006), and conducting pedestrian surveys of the mid-Fraser region. Samples were collected from each area in 10-m intervals running north to south, across the extent of the deposit. Each sample was placed in a labelled paper bag within a larger plastic Ziploc freezer bag. At each deposit, two to three GPS points were recorded at the deposit boundaries and one in the centre. Five to ten digital photographs were taken of each deposit.

Chert samples were collected from six deposits in the mid-Fraser region: 1) Ashcroft Blue; 2) Glen Fraser; 3) Hat Creek chert; 4) Maiden Creek; 5) Rusty Creek Red and; 6) West Fountain deposits. These deposits are within 20 km of the Keatley Creek site and are situated on or near major rivers, or close to traditional hunting routes (Tyhurst 1992). In addition to geochemical analysis, samples taken from these deposits were analysed for their basic mechanical properties including strength, hardness, elasticity, and homogeneity (see Table 4-1).

Strength (brittle, strong) was gauged based on grain size as observed using a petrographic microscope at 30X magnification. Hardness was determined using the Mohs scale of mineral hardness. Elasticity (elastic, non-elastic) scores were based primarily on grain size and the presence/absence of pores, cracks, and fissures within the sample. Finally, homogeneity was determined by the presence/absence of inclusions, veins, and other irregularities observed using a petrographic microscope at 30X magnification.

Artifacts from ST 109

One thousand six hundred and six pieces of silicate debitage from the 2006 excavations of ST 109 were analysed for material type, weight, crystalline structure, texture, and strength. Material type was defined according to the Keatley Creek typology established by Hayden (2004), which is based in part on physical properties and on the material characterizations done by Bakewell (1995) for his graduate thesis on chert material characterization. The Keatley Creek typology categorizes lithic toolstone materials and includes various types of cherts, chalcedonies, and basalts. Included in this typology are 20 chalcedony types, nine chert types, and five forms of quartz. The Chert 2 and Chalcedony 6 types comprise the majority of the materials excavated from ST 109.

Table 4-1. Mechanical Properties of the Mid-Fraser Toolstone Deposits.

Deposit		Strength/ Tenacity	Mohs	Elasticity	Homogeneity	Colour/ Texture	Translucency/ Lustre
Glen Fraser		Brittle	5-7	Medium	Inclusions of quartz veins	Mottled; red, orange, and white/ Coarse	Opaque/ Varies – matte, some shiny
Rusty Creek Red Chert		Brittle	7	High	Homogenous; no visible inclusions, has a vitric appearance	Red / Fine	Opaque/ Matte
Blue Ridge/Moran Chalcedony		Not Brittle	7	High	Homogenous	Grey/ Fine	Translucent/ Shiny
		Not Brittle	7	High	Homogenous	White/ Fine	Translucent/ Shiny
Hat Creek Deposits	**Maiden Creek**	Brittle	7	High	Homogenous	Yellow/Fine	Opaque/ Matte
	Medicine Creek	Brittle	5-6	Medium	Inclusions; pockets of quartz	Red, yellow/ Coarse	Opaque/ Shiny
	Hat Creek	Brittle	7	Medium	Homogenous	Red/ Fine	Opaque/ Waxy Lustre/ Matte
Ashcroft Blue		Brittle	7	Medium	Homogenous; vitric appearance	Bluish green/ Fine	Opaque/ Matte

We selected debitage samples from the Kamloops floor and associated construction fill to represent this entire occupation. Samples were not taken from the earlier Plateau horizon, as all of the artifacts recovered from this occupation were produced from fine-grained basalt. Weight was measured in grams, and recorded to determine which samples exceeded 1 g, making them viable for INAA testing. Samples that did not exceed 2 mm in thickness were not considered viable for pXRF analysis.

INAA

Instrumental neutron activation analysis is capable of detecting and measuring elements with high precision, accuracy, and sensitivity and is therefore highly suited to bulk elemental characterization (Pollard et al. 2007). Basically, samples are bombarded with neutrons from a nuclear source. A number of the atoms present in the sample are then converted into radioactive isotopes that decay at known rates. These radioisotopes emit gamma energies characteristic of each element. The gamma energies were measured using a high-purity germanium (HPGe) detector and their electrical signal is diverted through an amplifier, and then sorted into channels along an electromagnetic spectrum measured in kiloelectron volts (keV). The peaks that form as a result are the spectrometric end products of elements that produce radioisotopes.

Samples were cleaned in an ultrasonic cleaner and left to dry overnight. They were then weighed to approximately 1 g and sealed in high-purity polyethylene vials. Two irradiations were performed on samples to acquire data on elements that produce short, medium, and long-lived isotopes. In total, data on 34 different elements were acquired for each sample. For this experiment, we tested for major, minor, and trace elements that are characteristic of, and routinely measured in, the analysis of chert geochemistry. Six standard reference materials (SRMs) and control samples were run with each bundle of samples. Standard reference materials used for this analysis include SRM 1632c Coal, SRM 1633b Fly Ash, SRM 688 Basalt and SRM 278 Obsidian Rock; all issued by the National Institute of Standards and Technology (NIST).

Samples were run through a pneumatic tube system and subjected to a ten second thermal irradiation at a neutron flux of 5×10^{13} n cm^{-2} s^{-1}. Each sample was left to decay for 10 minutes, and gamma emissions were measured by a hyper-pure germanium (HPGe) detector for 5 minutes. The elements measured for the short-lived procedure include Al, Ba, Br, Ca, Co, Cl, Dy, Mg, Na, Ti, U and V. Samples were left to decay for approximately 24 hours after which a second 5 minute count was performed to acquire data on Eu, K, La, Mn, Na, Sm and Sr. The samples were bundled and subjected to an in-core irradiation for another two hours at a neutron flux of 5×10^{13} n cm^{-2} s^{-1}. These samples were left to decay for 7 to 10 days, after which they were counted for 30 minutes each to measure concentrations of Au, As, Ba, Br, Fe, La, Na, Nd, Sb and Sm. Approximately 14 to 16 days after the long irradiation, samples were counted for another 30 minutes to measure concentrations of Ce, Co, Cr, Cs, Eu, Hf, Lu, Rb, Sc, Ta, Tb, Yb and Zn. The raw data in counts per second were weight corrected and calculated using PEAK software.

pXRF

Portable X-ray fluorescence (pXRF) technology was chosen as a technique in this study for its non-destructive qualities, availability, accuracy, and efficiency. Samples were tested on each side to determine the amount of intra sample variation. Using a Bruker Tracer III-V+ pXRF, we tested 48 geologic samples and 19 artifact samples for the following 18 elements: Si, S, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Rb, Sr, Y, Zr, and La. Ten samples were tested from each deposit with the exception of Ashcroft Blue, Hat Creek, and West Fountain, for which six samples were tested from each. All samples were subjected to X-rays for three minutes at 40 KV, with a vacuum and no filter. The data generated by pXRF were transferred into JMP for statistical analysis.

Results

As discussed, compositional data for artifacts and toolstone deposits were collected using INAA and pXRF. Based on previous geochemical studies by Bakewell (1995:5) and Sieveking et al. (1972), we used elements indicative of the clastic component (this component consists of silicate minerals in clay, silt, and sand) within cherts. The minerals are stoichiometrically constructed from major and minor elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, and P). The geochemical data derived from INAA and pXRF analysis included the majority of these elements, and the counts were used to calculate the mean and standard deviation of the toolstone deposits (Tables 4-2 and 4-3). These summary statistics reveal which elements are responsible for the variation between the deposits.

INAA Statistical Analysis

We used boxplots to discern patterns and identify outliers within the toolstone deposit samples. Using these plots, we identified Cr, Fe, and Zn as elements that have the potential to characterize some of the deposits. We then plotted these elements using bivariate plots for the toolstone deposits. Although the sample size was limited to one, for the Ashcroft and West Fountain deposits, we were able to separate these deposits from the rest using bivariate plots of Cr, Fe, and Zn. This pattern was replicated in the pXRF results, in which more samples were analysed. Bivariate plots and principal component analysis (PCA) results were inconclusive and could not characterize the remaining Glen Fraser, Hat Creek, Maiden Creek, and Rusty Creek Red deposits individually (See Kendall 2014 for detailed characterization of the toolstone deposits).

Table 4-2. INAA Summary Statistics for Toolstone Deposits.

Element	Glen Fraser *n= 6*	Maiden Creek *n= 6*	Hat Creek *n= 8*	Ashcroft Blue *n= 1*	Rusty Red *n= 2*	West Fountain *n= 1*
Al	4581 ± 2519	7676 ± 10937	3814 ± 3778	1558	1319 ± 208	1794
As	1 ± 2	10 ± 17	143 ± 169	44	11 ± 3	4
Au	0	0	0	2	0	0
Ba	130 ± 159	144 ± 272	299 ± 483	237	28 ± 6	34
Br	1 ± 0	17 ± 40	0	159	1	1
Ca	698 ± 682	1996 ± 2339	1503 ± 1338	2253	464 ± 27	636
Ce	6 ± 8	7 ± 12	3 ± 2	22	0	1
Cl	11 ± 8	14 ± 10	38 ± 46	4	9	1
Co	1	2 ± 1	1 ± 1	6	1	0
Cr	2 ± 2	3 ± 4	4 ± 4	6	1	11
Cs	0	0	2 ± 3	2	0	0
Dy	1±1	0	0	1	0	0
Eu	0	0	0	1	0	0
Fe	9071 ± 16670	14242 ± 18750	75216 ± 114291	24248	30294 ± 9372	25845
Hf	0	1 ± 2	0	4	0	0
K	949 ± 629	913 ± 1522	311 ± 273	1339	52 ± 10	161
La	5±4	4 ± 8	1±1	16	1	1
Lu	0	0	0	1	0	0
Mg	248 ± 145	287 ± 352	366 ± 373	848	53 ± 4	380
Mn	86 ± 129	66 ± 75	196 ± 254	191	38 ± 5	100
Na	106 ± 93	1231 ± 2997	165 ± 124	923	108 ± 2	47
Nd	3±1	4 ± 8	2 ± 1	17	1	1
Rb	0	0	0	0	0	0
Sb	0	2±1	2 ± 2	1	44±3	0
Sc	1±1	1±2	0	16	0	2
Sm	1±1	0	0	0.00	0	0
Sr	1551 ± 774	1963 ± 611	4030 ± 2740	4294	623 ± 597	1600
Ta	0	0	0	0	0	0
Tb	0	0	0	1	0	0
Ti	197 ± 117	353 ± 404	188 ± 229	767	37 ± 8	106
U	0	1 ± 1	3 ± 3	1	0	0
V	26 ± 46	21 ± 30	36 ± 37	12	58 ± 20	24
Yb	0	1 ± 2	0	3	0	0
Zn	14 ± 26	8 ± 11	9 ± 7	55	0	23

Table 4-3. pXRF Summary Statistics.

	Glen Fraser	Maiden Creek	Hat Creek	Ashcroft Blue	Rusty Red	West Fountain
Element	*n= 10*	*n= 10*	*n= 6*	*n= 6*	*n= 10*	*n= 6*
Si	56568 ± 16182	51358 ± 24204	54720 ± 20975	41230 ± 11793	31804 ± 20144	45780 ± 21816
S	1221 ± 247	1147 ± 179	1220 ± 146	565 ± 79	1244 ± 172	1110 ± 298
K	4801 ± 1475	3927 ± 1051	3958 ± 1702	1066 ± 22	3708 ± 821	3485 ± 742
Ca	16372 ± 42387	2169 ± 1543	1947 ± 1277	12495 ± 2461	2351 ± 1182	1859 ± 1948
Ti	1586.67 ± 1330	1261 ± 1060	2296 ± 3980	7267 ± 1076	722 ± 1182	455 ± 1208
V	210 ± 176	193 ± 159	180 ± 143	292 ± 153	722 ± 408	138 ± 131
Cr	184 ± 129	200 ± 256	287 ± 579	46 ± 71	361 ± 985	2480 ± 1374
Mn	3298 ± 8683	703 ± 1234	1983 ± 3724	3042 ± 673	2100 ± 3209	364 ± 532
Fe	63508 ± 66720	120673 ± 101749	209255 ± 349046	180621 ± 26164	346914 ± 26707	187391 ± 43575
Ni	2235 ± 448	1941 ± 415	1926 ± 839	1338 ± 125	1535 ± 1395	5987 ± 1464
Cu	1022 ± 395	1092 ± 379	1346 ± 588	1338 ± 236	1107 ± 357	1067 ± 379
Zn	186 ± 112	243 ±153	248 ± 140	634 ± 98	165 ± 106	206 ± 110
As	1300 ± 397	997 ± 438	1938 ± 1950	847 ± 192	819 ± 414	816 ± 331
Rb	802 ± 203	912 ± 264	2558 ± 4534	1045 ± 231	2338 ± 3171	940 ± 177
Sr	888 ± 313	792 ± 525	841 ± 709	5442 ± 802	625 ± 167	516 ± 858
Y	434 ± 209	357 ± 185	297 ± 196	1075 ± 212	237 ± 161	285 ± 177
Zr	892 ± 1039	611 ± 375	763 ± 1284	4361 ± 671	263 ± 155	298 ± 736
La	272 ± 95	245 ± 76	228 ± 100	233 ± 113	241 ± 83	233 ± 103

Table 4-4. Principal Components Analysis of the Mid-Fraser Silicate Deposits and Artifacts Characterized by Neutron Activation at the McMaster University Reactor. Values in Bold Indicate Strong Elemental Loading.

	Prin1	Prin2	Prin3	Prin4	Prin5
%Variance	34.477	21.424	20.733	13.543	9.823
Cumulative % Variance	34.477	55.901	76.634	90.177	100
Eigenvalues	1.7238	1.0712	1.0367	0.6772	0.491
K	**0.47023**	**0.66266**	**-0.30473**	**0.48300**	-0.11669
Cr	**0.38412**	**0.53146**	**0.66600**	**-0.24869**	0.25417
Fe	**0.78985**	-0.23980	0.21137	-0.17169	**-0.49444**
As	**0.64675**	**-0.53904**	0.13919	**0.32900**	**0.34368**
Rb	**0.55947**	0.03982	**-0.66045**	**-0.44597**	0.22433

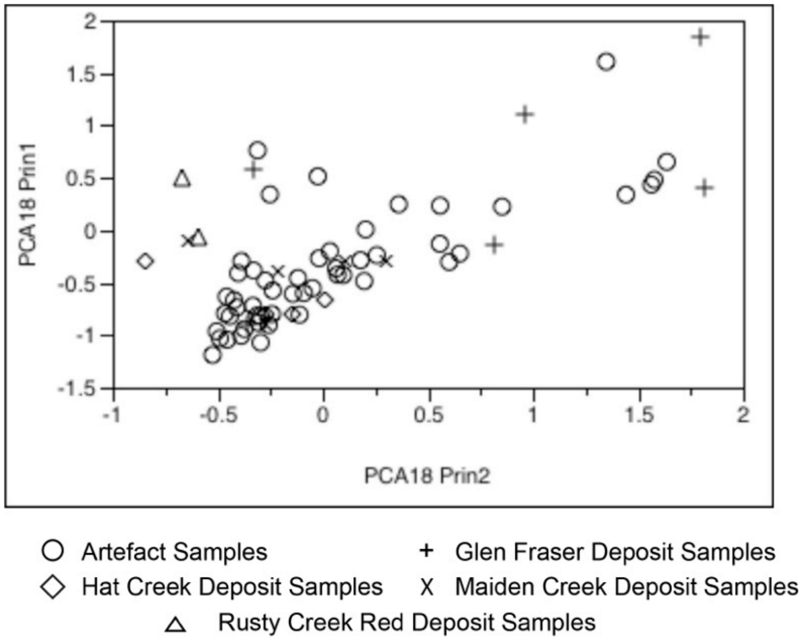

Figure 4-2. Bivariate Plot of Principal Components Analysis of the mid-Fraser Silicate Deposits and Artifacts Characterized Using INAA.

To explore the relationship between the artifacts from ST 109 and the toolstone deposits, we conducted PCA. Principal components analysis of the INAA data revealed that greater than 76 percent of the cumulative variance for the data set of the analysis is explained within the first three principal components (Figure 4-2, Table 4-4). Iron, potassium, and arsenic are responsible for most of the variation within the dataset. Scores for the first and second principal components suggest that the mid-Fraser toolstone deposits and artifacts are indistinguishable. Therefore, using the available data it is not possible to correlate the artifacts to any of the four toolstone deposits. In addition, no relationship was identified between the artifacts and the West Fountain and Ashcroft Blue deposits.

pXRF Statistical Analysis

Characterization of the toolstone deposits is detailed in Kendall (2014). We used bivariate plots of the Ashcroft Blue (Ti by Zn) and West Fountain (Cr by Ti) deposits to investigate the potential for a relationship. These plots revealed that no relationship exists between these deposits and the artifacts, based on the current dataset. Principal component analysis of the pXRF data (Figure 4-3) for the remaining four toolstone deposits and artifacts were inconclusive. This PCA represents 82.1 percent of the dataset explained within the first three principal components (Table 4-5). The majority of the variation in the dataset is caused by all of the elements within the analysis, suggesting that there is not enough variation within the group to distinguish groups of artifacts and deposits. These results suggest that the artifacts are related to the Glen Fraser, Hat Creek, Maiden Creek, and Rusty Creek Red group of deposits.

Since the pXRF dataset is more comprehensive (with a greater number of samples for each deposit than was possible for the INAA analysis), we chose to conduct additional statistical analyses. We used canonical discriminant analysis (CDA) to further explore the relationship that exists between the Glen Fraser, Hat Creek, Maiden Creek, and Rusty Creek Red group of deposits. Figure 4-4 clearly shows similar results to the PCA plots—the group of four deposits is related to the artifacts excavated from ST 109. According to Table 4-6, this CDA accounts for 99 percent of the cumulative variance of the dataset within the first three analyses. Figure 4-4 offers further insight into the toolstone deposits, and their relationship to the artifacts, in that the artifacts overlap with and are plotted closer to the Glen Fraser and Hat Creek deposits. The bivariate plot of Canonical 1 and Canonical 2 reveals that the

Table 4-5. Principal Components Analysis of mid-Fraser Silicate Deposits and Artifacts Characterized by pXRF. Values in Bold Indicate Strong Elemental Loading.

	Prin1	Prin2	Prin3	Prin4	Prin5
%Variance	43.309	21.807	16,994	16.217	1.673
Cumulative % Variance	43.309	65.115	82.109	98.327	100.00
Eigenvalues	2.1654	1.0903	0.8497	0.8109	0.0837
K	**-0.55007**	0.26156	0.08528	0.78719	0.04552
Cr	**-0.31705**	**0.65241**	**-0.30496**	**-0.30496**	-0.00537
Fe	**0.93502**	0.28086	0.05782	0.05782	0.20852
As	**-0.31817**	**0.63976**	-0.16867	-0.16867	-0.04420
Rb	**0.88704**	**0.32881**	0.25770	0.25770	-0.19508

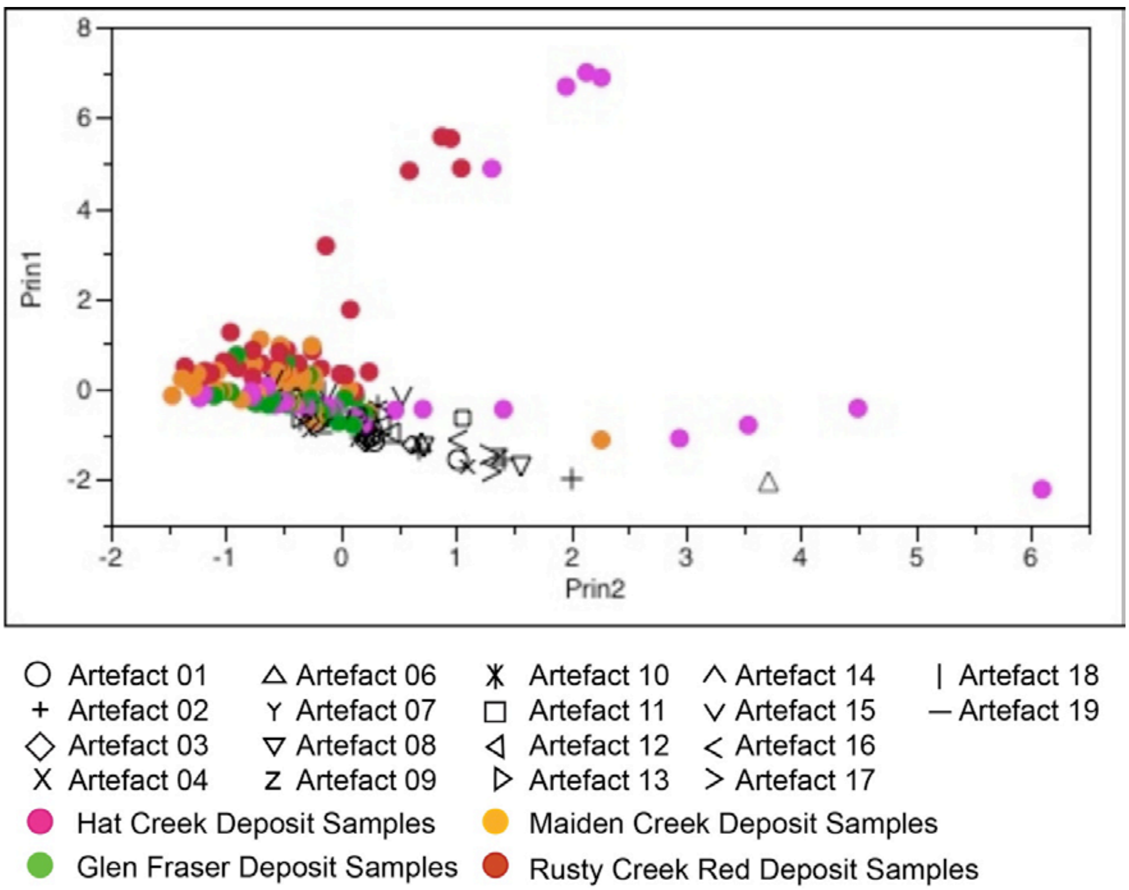

Figure 4-3. Bivariate Plot of Principal Components of the mid-Fraser Silicate Deposits and Artifacts Characterized Using pXRF.

Table 4-6. Canonical Discriminant Analysis of pXRF Data for the mid-Fraser Toolstone Deposits and Artifacts (*wilks F= 20.7357, prob<.0001*).'

	CD1	CD2	CD3	CD4
%Variance	76.29	18.99	4.58	0.12
Cumulative % Variance	76.29	95.29	99.88	100
K	**0.7464**	-0.7217	0.0001	**-0.0304**
Cr	**0.0559**	**0.0740**	**0.0986**	**1.0349**
Fe	**-1.4641**	-2.3161	0.5011	0.1897
As	**0.4197**	**0.3019**	0.5861	-0.3321
Rb	**1.4721**	**2.0840**	0.3740	-0.2209

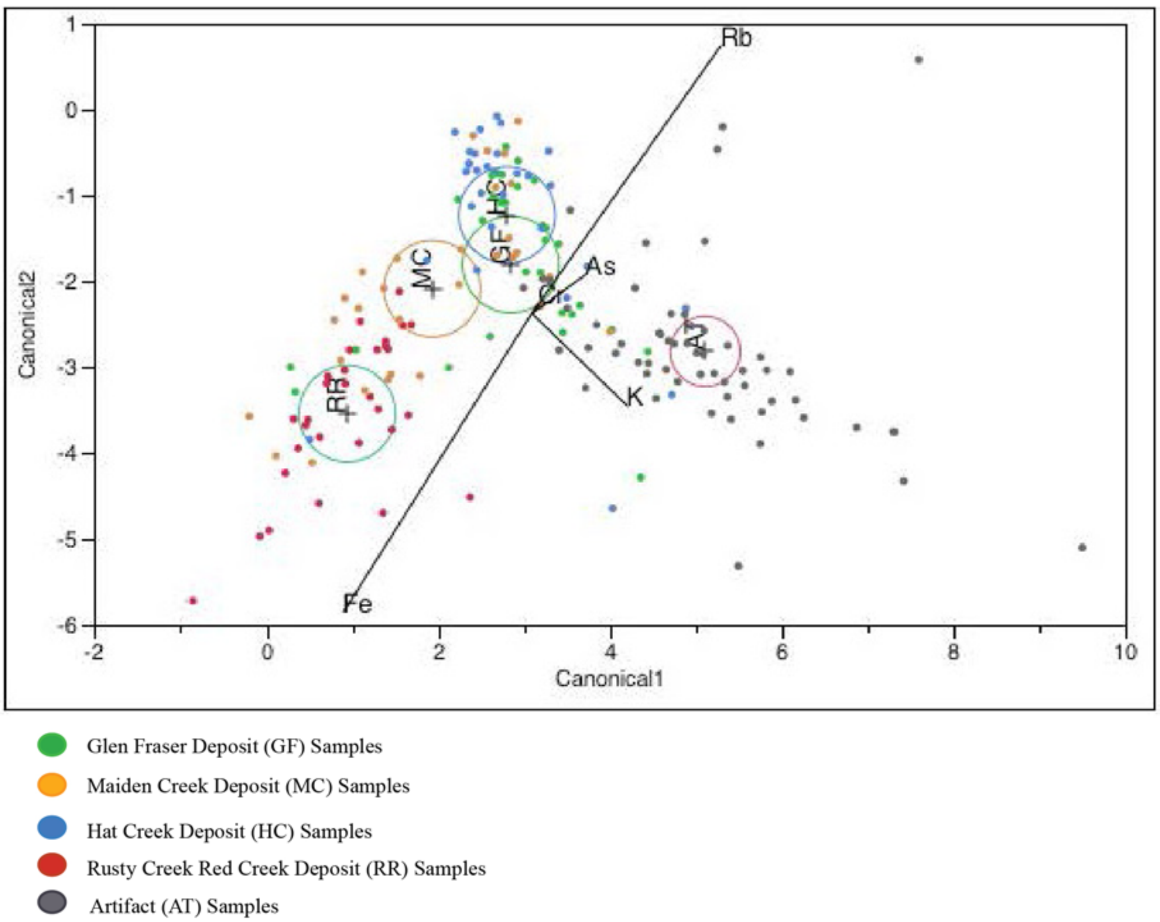

Figure 4-4. Scatterplot of canonical discriminant functions one and two showing all of the toolstone deposits in the mid-Fraser region. Ellipses represent 90 percent confidence interval of group membership. This plot explains 62 percent of the cumulative variation in the dataset.

elements Cr, K, and As are showing that association, and the elements Fe and Rb are loading Canonical 1 and Canonical 2. The CDA also reveals that the Rusty Creek Red deposit is somewhat removed from the group of deposits considering Canonical 1, but remains elementally similar to both the Hat Creek and Glen Fraser deposits (Figure 4-4; Table 4-6).

Discussion

Chert is one of the most common material types recovered from archaeological contexts. This prevalence in the archaeological record makes chert a valuable material for investigations into the use of toolstone deposits in the past. To trace toolstone deposit use, archaeologists can use geochemical techniques to establish the geochemical "fingerprint" of a particular deposit, or group of deposits. Once this unique fingerprint has been determined, archaeologists can then correlate artifacts to toolstone deposits to ascertain if the inhabitants of a site visited different deposits in an area.

Archaeologists have long considered the mid-Fraser region to be an area rich in many resources; including toolstone deposits (see Alexander 1992; Rousseau 2000; Tyhurst 1992). Generally, most of the toolstone silicate materials occur as small irregular nodules (under 30 cm) of opaque chert of varying colour and quality. The material typically appears on steep benched slopes, or at the base of hillsides. There is no evidence of tool manufacture at the deposit areas.

Our research demonstrates that the artifacts from ST 109 do not show a relationship to the West Fountain and the Ashcroft Blue deposits. Principal component analysis of pXRF and INAA data reveal that the Glen Fraser, Hat Creek, Maiden Creek, and Rusty Creek Red deposits are very similar, or closely related to the artifacts from ST 109. Both of these deposits are within 20 km from the Keatley Creek site. Additional CDA of the pXRF data showed similar results, but emphasize the similarity between the Glen Fraser and Hat Creek deposit, based on elemental composition. Interestingly, the CDA indicates that the artifacts are more closely associated with the Glen Fraser and Hat Creek deposits, while the Maiden Creek and Rusty Creek Red appear to be more closely related to each other than with the artifacts.

Conclusion

This study highlights the value of geochemical techniques for the characterization and discrimination of toolstone materials, and the applicability of such studies to queries of past resource use and movement.

Our small-scale study on toolstone deposits in the mid-Fraser region has proven that geochemical characterization is possible. Furthermore, our research suggests that the inhabitants of ST 109 were using locally derived chert toolstone materials during the Kamloops Horizon. Expanding this work to include a greater sample size from all of the deposits will improve our ability to distinguish these deposits from one another. Although our study could not pinpoint a particular deposit as the origin for the chert material present at ST 109, we have determined that the inhabitants of ST 109 were exploiting local resources within 20 km of the Keatley Creek site.

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CHAPTER 5

Implications Between Technological Organization and Portable X-Ray Fluorescence Analysis on Lithic Material Use at Two Rockshelter Sites on the Southern Northwest Coast

Rudy Reimer and Tyrone Hamilton
Simon Fraser University (rudyr@sfu.ca; th3524@mun.ca)

Introduction

Igneous toolstone dominates artifact assemblages along the Northwest Coast (Bakewell 1998; Kwarsick 2010; Reimer 2012). Until recently, the analysis of lithic assemblages on the Northwest Coast contributed little to our broader understanding of the ancient life ways of a dynamic range of cultures of this region. However, recent analyses by Hall (1998, 2003), Rahemtulla (1995, 2006) and Reimer (2004, 2006, 2012) show for this region a wide range of variation between lithic workshops, habitation and seasonal camps sites in different areas, time periods and associated cultures. However, many Northwest Coast archaeologists commonly assume that cores, tools and debitage at the sites they are investigating originate from local sources (typically beaches, creek and river beds), without full consideration of the variability of source materials that can exist from one assemblage to another. Another broad assumption in regional literature (Ames and Maschner 1999; Matson and Coupland 1995; Moss 2011) is that the characterizing and sourcing of dark grey to black igneous toolstone is not possible as it is with obsidian. In this paper we take these assumptions regarding the access and use of toolstone on the southern Northwest Coast to the test, and echo the sentiment of Andrefsky (2009), who considers raw materials as an organized choice when he points out that lithic raw material sources and use play an important role in technological organization. Furthermore, he points out that we must go beyond basic visual characterization of lithic materials to better understand ancient land use patterns.

In this paper we ask, can x-ray fluorescence determine the differences between igneous source materials? Moreover, can we apply these results to artifact assemblages? Likewise, what is the role of these materials at two archaeological sites in the southern Northwest Coast region of British Columbia? Characterizing and eventual sourcing of lithic materials through elemental analysis provides a robust contribution to our developing understanding of how these materials moved and circulated in and amongst cultural groups.

Geological Background

Geologically, the lithic landscape is built because of plate tectonics and the numerous volcanoes of the Pacific Ring of Fire that dominate the region (Monger 1994). Specifically, the Juan de Fuca Plate is sandwiched between the much larger Pacific Plate and North American Plate. Convergent plate subduction leads to the melting of crust material, producing abundant magma and pressure (Monger 1994). This feeds volcanoes, causing the numerous eruptions that eventually formed the lava flows that ancient peoples of the region utilized for stone tools (Reimer 2012). Physiographically, the southern Northwest Coast, near Vancouver, British Columbia, stretches from sea level to glaciated mountains over 2,000 m above sea level. Numerous rivers and lakes drain the heavy annual rainfall and snow pack down through sub-alpine meadows and parkland, past mid- and low-elevation old-growth

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Archaeology Press, Simon Fraser University, 2015

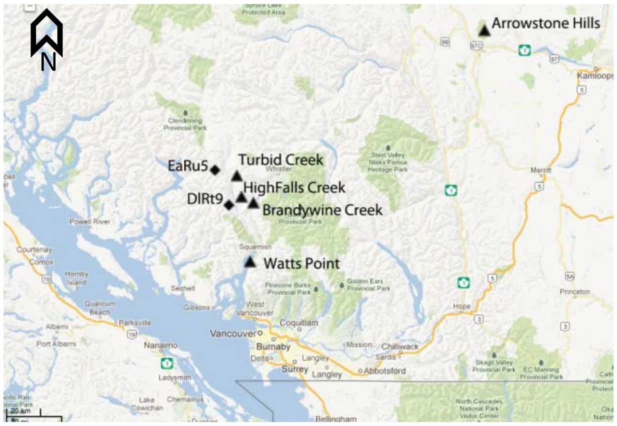

Figure 5-1. Southwestern British Columbia, lithic sources (triangles) and archaeological sites (diamonds) considered in this study.

cedar, fir, and hemlock forests, into the Salish Sea and eventually the Pacific Ocean. By comparison, the interior Plateau is dryer, with less vertical relief and a varied array of patchy environments.

Before we describe the sources included in this study, we must first define, archaeologically, what a lithic source actually is (R. Green 1998: 226-228). We use a combination of definitions provided by Glascock et al. (1998:16) and Shackley (2011) who consider both the physical and elemental nature of lithic sources. Physically, an igneous lithic source can occur as primary and secondary deposits. A primary deposit is a lava flow/outcrop or major pyroclastic field (consisting of bomblets) surrounding a volcanic cone(s). Secondary sources and deposits result from erosion activity from glaciers, streams, gravity, or other geological processes that transport material away from a primary zone. Up until now, standardized visual and elemental analysis of igneous lithic sources has been hampered by the fact that these materials are more widespread, in varying sized outcrops, and typically worked into secondary deposits by numerous geomorphological mechanisms (Reimer 2012).

Within the Squamish region, the Garibaldi volcanic belt is responsible for widely available lithic raw material (Kelman et al. 2003; Kelman 2005; Evans and Brooks 1991; Green 1991; Green et al. 1988; Mathews 1957, 1958). Eruptions in this area extend back to the Miocene and as recently as the early Holocene (Kelman 2002:197). Numerous lava flows, exposed as large outcrops at high elevation, are exposed to continual weathering, resulting in a wide range of materials being easily available in local streams and creeks, draining into Squamish River system (Reimer 2012). Notable outcrops and source areas include, Turbid Creek, High Falls Creek, Brandywine Creek and the Watts Point lava dome (Figure 5-1). On the interior Plateau, the Arrowstone Hills source is the result of 50 million year-old shield volcano eruptions (Ewing 1981a and b). Culturally, this source also has a long history of use (Baker et al. 2001, Commisso 1997, 2000; Ewing 1981b; Greenough et al. 2004) (Figure 5-1).

Archaeological Background

The archaeological record of both the Northwest Coast and Plateau spans the past 12,000-10,000 years B.P. (Carlson 1996; Pokotylo and Mitchell 1998; Reimer 2012). Regional researchers (Ames and Maschner 1999; Matson and Coupland 1995; Moss 2011) roughly define the temporal periods of each region into Early (12,000-7,000 BP), Middle (7,000-3,500 BP) and Late (3,500-European contact). Many researchers focused on the topic of complex hunting and gathering, the development of social elites, and household archaeology. A general pattern of this research shows an increase of social complexity, resource intensification, and trade and interaction on a local to regional scale (Ames and Maschner 1999; Hayden 1992, 2000a and b1999; Matson and Coupland 1995). Major regional studies have focused on the role of the range and the amount of marine and land resources utilized by local Coast Salish Indigenous peoples (Matson and Coupland 1995; Ames and Maschner 1999; Moss 2012).

The sites considered here are within Squamish Nation territory, southwestern British Columbia (Figure 5-1). Squamish Nation territory situates along the shores of the Burrard Inlet, Howe Sound and the Squamish River valley. The Squamish Nation represents one faction of the larger Coast Salish cultural-linguistic group inhabiting the region referred to as the Salish Sea. Broadly, archaeological settlement patterns on the southern Northwest Coast start at large sites that tend to be villages or primary resource locations that stretch along coastlines and the river valleys. Away from villages in less exposed locations at specific resource locales are seasonal camps that range along coastlines, river valleys extending up to mid elevation and forested areas. Finally, temporary

Table 5-1. Stratigraphic Layers and 14C Dates for DlRt9.

Layer	Description	14C Date B.P.	Lab Number
A	0-5cm partially disturbed, silt to coarse sand and rook spall, abundant charcoal	30±40	Beta 227278
B	5-10cm yellow to brown silt and sand, some roof spall, abundant charcoal	190±40	Beta 227278
C	25-40cm coarse grey sand, little charcoal	1360±40	Beta 227279
D	40-50cm coarse grey to yellow sand with cemented roof spall cobbles, sparse charcoal	1390±40	Beta 227280

hunting and gathering camps located in high elevation sub-alpine and alpine areas indicate the entire landscape was used for a wide range of uses (Reimer 2000, 2003, 2012). The two sites considered here, are mid elevation rockshelters, in forested contexts, above the confluences of major rivers (Reimer 2012; Squamish Nation 1992). They represent key locations, away and above ethnographically known villages, ranging 300-400 m above sea level and valley bottoms.

DlRt9 situates near the confluence of the Squamish and Ashlu Rivers, 22 km north of the modern town of Squamish (Figure 5-1). It is approximately 300 m above sea level on the southeastern slopes of Buck Mountain. It is a mid-sized rock-shelter, measuring 20 m east to west and 10 m north to south. A dozen pictographs mark its interior walls; depicting deer hunting, spirit animal relations (e.g. bear paws, thunderbird lightening). The surface of the site contains historical materials associated with a traditional trap line registered under the name of George Moody, who traversed the area for plant and animal resources up until the 1960's. A rusted double bladed axe head, remains of a pair of work boots and remnants of newspapers dating to the late 1930's and 1940's illustrate recent use of the shelter. Additionally, a hearth feature visible through a semi-circular ring of rocks is also visible at the site. Excavations of 2 1x1-m units, from the shelters back wall, outwards to the edge of the hearth revealed an intact stratigraphic sequence to a depth of 50 cm below surface. Within this sequence, four distinct layers associated with activities around the hearth feature. Table 5-1 summarizes these layers and ^{14}C dates. Faunal remains at the site were sparse, with deer being the likely ungulate acquired along the nearby mountain slopes, while mountain blueberry was an abundant plant gathered and brought back to the site from higher elevations, likely prepared for fall-winter storage. Two thousand eight hundred eleven artifacts were recovered from the two excavation units at this site. The majority of these were visually assessed as dacite, while the remainder included 52 obsidian, 9 quartz crystal, 8 pieces of quartzite, and a single piece of mica and slate. Technological organization focused on core-flake tool production, and a small degree of tool maintenance occurred on site (Reimer 2004).

EaRu5 situates at the top of the Elaho River canyon (Figure 5-1), 42 km north of the modern town of Squamish (ARCAS 1999). It is a strategic location as it guards access, north into the main Elaho valley, south to the Squamish-Elaho River confluence and west up and over the Coast Range into neighboring Sechelt Nation territory (Reimer 2004). The site consists of two small rockshetler boulders, one measuring 10 m in size, the other 20 m. A single excavation unit was placed in the larger shelter and revealed a stratigraphic sequence extending to 40 cm below surface (Reimer 2004). The excavation unit was placed in-between the shelters back wall and an ethnohistorical hearth feature on the site's surface. As with the DlRt9 shelter, the strata at EaRu5 are intact and illustrated seasonal (spring to fall) use over several hundreds of years (Table 5-2). Faunal remains at the site show a focus on ungulate hunting (deer and mountain goat) while botanical remains show a wide range of environments utilized for sentience (Reimer 2004). Lithic debitage analysis concluded that the people using EaRu5 likely acquired toolstone from a nearby creek or the beds of the Elaho and/or Squamish Rivers. Technology focused on an expedient cobble-core reduction strategy for basic tasks, such as cutting, scraping and sawing, while tool maintenance was minimal. Four hundred thirty two artifacts were recovered in the single excavation unit, with 418 visually assessed as dacite, 13 obsidian, and a single piece of slate. Of the 432 artifacts, only 20 are formed tools (projectile points, bifaces, knives, scrapers) and the remaining cores, flakes and debitage (Reimer 2004). Only 12 artifacts are formed tools (projectile point, bifaces, scrapers). Similar to DlRt9, the technological organization focused on core-flake tool production and a small degree of tool maintenance occurred on site (Reimer 2006).

Table 5-2. Stratigraphic Layers and 14C Dates for EaRu5.

Layer	Description	14C Date BP	Lab Number
A	0-12cm yellow to brown silt and sand, little charcoal	75±35	CAMS 111663
B	13-33cm dark brown to black hearth feature	225±25	CAMS 111664
C	34-39cm dark brown to black hearth feature grading with depth into grey sand	655±35	CAMS 111665
D	40cm coarse grey sand and cobbles	1210±35	CAMS 111666

Analytic Methods

The instrument used in this analysis is a Bruker AXS Tracer III-V+ portable EDXRF. In the lab, the instrument was mounted in a stable stand, allowing for easy maintenance of a fixed position. It is equipped with a rhodium tube that emits x-rays, a peltier cooled silicon PIN diode detector, operating at 40 kV and 13uA from an external power source. Samples ran for 180 live seconds with a filter comprised of 6 mm Cu (copper), 1 mm Ti (titanium), and 12mm Al (Aluminum). The Tracer produces an x-ray beam at a 45-degree angle from the centre of the analyzer window that measures 4 mm across. Placing it in front of the instrument with clean, flat surfaces that covered the entire instrument window ensured that each sample was exposed to x-rays. This ensured that each sample achieved an optimal count rate and minimized x-ray scatter.

X-ray counts, processed through the S1PXRF Canada program, developed by Bruker, allow the user to examine spectra live time during analysis or review afterwards. Results, converted to parts per million through another Bruker program, S1CalProcess, uses the rhodium Compton backscatter and a database of nearly 40 previously known and established values for obsidian sources around the world, as determined by the University of Missouri Nuclear Reactor. This database empirically calibrates the instrument by comparing expected values with those produced by the instrument for the following elements manganese (Mn), iron (Fe), zinc (Zn), gallium (Ga), thorium (Th), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr) and niobium (Nb).

In total, 306 samples were examined, 53 from primary geological source deposits (Table 5-3), 166 artifacts from DlRt9 (Table 5-4), and 87 artifacts from EaRu5 (Table 5-5). Selection of samples from archaeological sites came from each site's layer/level bags. Visual analysis of site assemblages concluded that a single type of raw material- dacite -dominates them. As such, only these materials were subject to analysis. From each bag, we visually examined its contents for the widest range of visual lithic raw material variation. This helped us determine if the ancient users of each site used a single or multiple sources of toolstone (e.g. coarse to fine grained material, different colour, hardness, luster, amount and density of phenocrysts).

Results

Sources

Figure 5-2 provides graphic geochemical data on the geological sources considered in this study. Separation of all the source materials is possible using pXRF and a range of mid to high range Z trace elements (Rb, Sr, Y, Zr, and Nb). The clearest separation of these source materials uses Sr and Zr, both elements abundant in each source, while the other elements illustrate less separation. Confidence

Table 5-3. Source Data for Materials Included in This Study. All Values in ppm.

Source	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
Turbid	1045	37577	123	1	10	33	3946	15	224	5
Turbid	1151	40767	116	8	10	36	4307	18	225	4
Turbid	1246	40461	142	8	11	34	4234	16	245	5
Turbid	1014	42451	139	10	11	35	5362	19	244	4
Turbid	979	40664	119	4	8	40	4873	14	220	5
Turbid	1177	42222	109	6	8	35	5181	18	238	6
Turbid	1193	39224	144	13	8	36	4043	15	237	5
Turbid	1195	39680	124	-1	10	32	4036	16	216	4
Turbid	1097	42613	121	5	12	38	3327	17	203	5
Watts	717	26094	70	14	0	26	1032	15	154	3

Table 5-3 (continued). Source Data for Materials Included in This Study. All Values in ppm.

Source	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
Watts	671	27709	77	14	1	27	1014	14	145	5
Watts	595	28496	71	13	1	32	1017	13	147	5
Watts	689	26074	63	14	0	28	1052	14	148	6
Watts	713	26393	68	13	2	31	1050	13	153	6
Watts	548	25721	66	14	2	26	941	15	144	1
Watts	696	28447	69	13	3	27	1056	13	156	6
Watts	408	23697	61	14	1	24	942	12	138	5
Watts	759	27519	81	13	2	32	1089	12	166	4
Watts	680	30130	96	14	4	33	1106	12	157	5
Watts	709	29693	102	15	0	34	1067	14	151	4
Watts	635	32018	88	13	0	31	1036	13	153	4
Watts	614	25505	68	14	0	29	972	13	142	3
Watts	653	28663	81	14	2	28	1023	12	154	3
Watts	502	27239	70	14	2	29	1054	13	148	2
Watts	643	27153	74	14	1	28	1054	10	153	6
Brandywine Creek	1107	32313	95	9	3	33	1717	12	167	4
Brandywine Creek	1003	37452	116	11	5	38	1747	15	167	3
Brandywine Creek	1039	34859	93	10	7	34	1648	11	156	5
High Falls	1203	57942	143	1	2	26	3294	17	188	5
High Falls	1177	60790	148	1	10	22	3323	16	214	5
High Falls	1079	60998	150	0	9	25	3327	17	186	6
High Falls	1221	56934	133	8	6	24	2900	14	189	4
High Falls	1221	56874	140	0	8	22	3034	17	199	7
High Falls	1144	60603	144	0	10	22	3174	16	219	5
High Falls	1195	52193	144	9	10	33	2336	14	208	9
High Falls	1324	54709	131	4	11	30	2227	15	209	7
High Falls	1137	47236	122	9	8	29	2784	14	204	6
Arrowstone	470	18058	63	15	11	140	563	13	213	9
Arrowstone	609	16148	74	16	10	138	528	13	213	7
Arrowstone	317	15740	80	17	13	137	535	11	218	8
Arrowstone	537	18073	60	15	12	129	525	12	214	7
Arrowstone	320	14811	70	17	9	123	536	11	199	7
Arrowstone	324	18067	62	16	10	121	497	10	195	7
Arrowstone	481	17550	56	15	10	127	530	15	202	9
Arrowstone	483	17481	68	16	10	118	533	11	199	7
Arrowstone	463	19667	59	15	9	129	535	11	198	7
Arrowstone	412	18747	58	15	9	122	515	10	208	9
Arrowstone	441	14749	63	14	7	111	477	10	186	7
Arrowstone	355	16012	68	16	11	120	512	13	205	6
Arrowstone	436	17106	73	16	11	126	494	11	188	9
Arrowstone	382	17180	47	14	12	118	576	11	199	8
Arrowstone	526	18107	65	15	11	126	538	11	204	9
Arrowstone	529	20582	94	17	13	133	542	11	214	6

Table 5-4. XRF Data for Artifacts from DlRt 9. All Values in ppm.

Context	Source	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
DlRt9 Unit1 LayerA-0 Tool	High Falls	685	31009	97	14	3	29	3044	14	176	5
DlRt9 Unit1 LayerA-0.10	Watts	749	27711	84	14	1	23	1310	10	132	3
DlRt9 Unit1 LayerA-0.11	Brandywine Creek	817	28951	86	14	2	24	1657	12	129	5
DlRt9 Unit1 LayerA-0.2	High Falls	720	29729	147	18	5	28	2722	13	169	3
DlRt9 Unit1 LayerA-0.6	High Falls	677	29065	96	15	3	25	2861	12	172	3
DlRt9 Unit1 LayerA-0.7	High Falls	775	29508	95	14	6	25	2912	13	171	6

Table 5-4 (continued). XRF Data for Artifacts from DlRt 9. All Values in ppm.

Context	Source	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
DlRt9 Unit1 LayerA-0.8	High Falls	725	29598	115	16	4	23	2739	13	173	5
DlRt9 Unit1 LayerA-0.9	High Falls	684	29984	130	16	6	25	2854	12	179	4
DlRt9 Unit1 LayerA-0	High Falls	830	32118	101	14	7	30	2969	12	169	5
DlRt9 Unit1 LayerA-1 Tool	Watts	751	26900	89	15	2	43	933	13	125	4
DlRt9 Unit1 LayerA-1 Tool	High Falls	655	29278	101	14	1	30	2880	11	177	4
DlRt9 Unit1 LayerA-1.12	High Falls	970	30671	103	14	5	34	2941	11	177	3
DlRt9 Unit1 LayerA-1.2	High Falls	849	30931	108	14	5	29	2824	12	171	3
DlRt9 Unit1 LayerA-1.3	High Falls	750	29441	114	14	5	26	2752	12	173	4
DlRt9 Unit1 LayerA-1.5	High Falls	689	30556	88	14	7	26	2927	10	174	3
DlRt9 Unit1 LayerA-1.6	High Falls	806	29413	71	13	7	24	2931	13	167	4
DlRt9 Unit1 LayerA-1.7	High Falls	801	31561	126	15	5	32	3012	11	180	3
DlRt9 Unit1 LayerA-1.8	High Falls	779	33213	105	14	5	25	3725	14	195	3
DlRt9 Unit1 LayerA-1.9	High Falls	647	30365	133	17	2	26	2874	13	171	3
DlRt9 Unit1 LayerA-1	High Falls	634	31223	97	14	7	25	3047	14	176	3
DlRt9 Unit1 LayerA-2.10	Watts	829	34978	156	16	1	18	1165	13	167	6
DlRt9 Unit1 LayerA-2.11	High Falls	660	33033	103	14	8	24	3365	13	195	3
DlRt9 Unit1 LayerA-2.12	High Falls	815	36541	176	16	3	24	3188	11	187	6
DlRt9 Unit1 LayerA-2.13	High Falls	788	32092	115	15	6	38	3011	12	179	4
DlRt9 Unit1 LayerA-2.15	High Falls	831	40910	441	28	5	39	2889	10	152	5
DlRt9 Unit1 LayerA-2.2	High Falls	674	29726	87	13	4	22	2321	13	178	4
DlRt9 Unit1 LayerA-2.3	High Falls	750	34692	150	14	3	22	3364	11	185	6
DlRt9 Unit1 LayerA-2.4	Watts	585	28189	106	15	2	23	1340	12	148	2
DlRt9 Unit1 LayerA-2.5	High Falls	724	33469	123	15	5	29	3006	13	188	4
DlRt9 Unit1 LayerA-2.6	High Falls	765	29989	122	14	6	24	2799	14	179	2
DlRt9 Unit1 LayerA-2.7	High Falls	746	32475	123	15	2	24	2984	13	180	4
DlRt9 Unit1 LayerA-2.8	High Falls	790	30148	112	15	4	25	2781	9	166	3
DlRt9 Unit1 LayerA-2.9	High Falls	675	31093	98	14	5	27	2912	13	174	7
DlRt9 Unit1 LayerA-2	High Falls	638	30960	117	16	7	22	2940	15	179	4
DlRt9 Unit1 LayerB-3 Tool	High Falls	869	30622	107	14	8	23	2967	13	181	5
DlRt9 Unit1 LayerB-3.11	High Falls	943	41500	368	27	2	30	2956	10	169	5
DlRt9 Unit1 LayerB-3.3	High Falls	654	30623	114	15	3	26	2933	12	165	3
DlRt9 Unit1 LayerB-3.4	Watts	872	29510	92	14	1	20	1373	9	142	3
DlRt9 Unit1 LayerB-3.6	High Falls	645	31523	125	16	7	26	3147	12	186	5
DlRt9 Unit1 LayerB-3.8	High Falls	697	33236	114	15	2	30	3300	14	189	5
DlRt9 Unit1 LayerB-3.9	High Falls	710	30884	99	14	6	31	2387	11	170	4
DlRt9 Unit1 LayerB-4.10	Watts	920	33444	163	17	-2	16	1101	12	154	5
DlRt9 Unit1 LayerB-4.2	High Falls	713	31664	124	16	4	29	3004	11	183	4
DlRt9 Unit1 LayerB-4.3	High Falls	827	34334	169	17	6	36	3237	14	183	3
DlRt9 Unit1 LayerB-4.5	High Falls	732	31738	85	14	1	27	2988	13	164	3
DlRt9 Unit1 LayerB-4.6	High Falls	754	32975	97	14	2	28	2995	12	179	5
DlRt9 Unit1 LayerB-4.7	High Falls	756	33760	109	14	2	26	3009	13	177	3
DlRt9 Unit1 LayerB-4.9	High Falls	989	35140	171	16	4	34	2675	11	172	2
DlRt9 Unit1 LayerB-4	High Falls	649	31329	80	13	4	24	2812	12	170	4
DlRt9 Unit1 LayerBC-5.2	High Falls	789	31831	176	18	6	33	3014	10	163	3
DlRt9 Unit1 LayerBC-5.3	High Falls	734	32950	107	14	4	23	2949	12	175	4
DlRt9 Unit1 LayerBC-5.4	High Falls	773	31059	99	9	4	33	2815	11	165	5
DlRt9 Unit1 LayerBC-5.5	High Falls	699	32785	106	14	1	26	2900	14	182	5
DlRt9 Unit1 LayerBC-5.6	Watts	751	27060	140	17	0	24	896	12	138	4
DlRt9 Unit1 LayerBC-5.7	High Falls	1286	31981	180	17	1	23	2987	13	185	4
DlRt9 Unit1 LayerBC-5	Brandywine Creek	740	28624	99	14	4	26	1783	12	152	3
DlRt9 Unit1 LayerBC-6.3	High Falls	602	32661	154	17	6	28	2574	12	181	2
DlRt9 Unit1 LayerBC-6.4	Watts	707	31261	78	13	1	23	1375	14	149	4
DlRt9 Unit1 LayerBC-6.5	High Falls	702	35537	220	20	1	35	3446	12	182	4
DlRt9 Unit1 LayerBC-6.6	High Falls	764	32543	114	15	3	28	2960	14	166	2
DlRt9 Unit1 LayerBC-6	High Falls	726	29514	101	15	4	28	2735	13	170	4

Table 5-4 (continued). XRF Data for Artifacts from DlRt 9. All Values in ppm.

Context	Source	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
DlRt9 Unit1 LayerC-7	High Falls	871	29096	108	15	3	23	2770	11	173	5
DlRt9 Unit1 Surface Tool	High Falls	710	31424	102	14	6	29	3018	15	174	6
DlRt9 Unit1 Surface	Brandywine Creek	787	26787	92	15	6	25	1743	13	149	4
DlRt9 Unit1 Surface	High Falls	721	31293	124	15	3	26	3495	14	192	3
DlRt9 Unit1 Surface	High Falls	637	33365	84	13	4	24	2963	16	182	3
DlRt9 Unit1 Surface	Watts	813	27151	93	15	4	23	1278	12	136	5
DlRt9 Unit1 Surface	High Falls	780	30797	105	15	10	28	3066	12	182	4
DlRt9 Unit2 LayerA-0.10	High Falls	509	34691	153	17	6	25	3160	12	172	8
DlRt9 Unit2 LayerA-0.11	High Falls	678	29301	114	16	3	22	2896	14	171	5
DlRt9 Unit2 LayerA-0.2	High Falls	763	32725	99	14	9	25	3042	12	177	3
DlRt9 Unit2 LayerA-0.3	High Falls	851	31942	101	14	3	32	3008	13	178	3
DlRt9 Unit2 LayerA-0.5	High Falls	816	29529	102	14	5	28	2992	14	187	4
DlRt9 Unit2 LayerA-0.6	High Falls	745	28836	90	15	3	31	2868	12	182	6
DlRt9 Unit2 LayerA-0.7	High Falls	1535	17264	153	20	2	30	2608	11	162	4
DlRt9 Unit2 LayerA-0.8	Brandywine Creek	768	31199	98	14	5	25	1900	12	149	5
DlRt9 Unit2 LayerA-0	High Falls	1023	32022	118	15	4	25	3063	13	185	5
DlRt9 Unit2 LayerA-1 Tool	Arrowstone	428	15891	65	16	9	108	489	10	174	6
DlRt9 Unit2 LayerA-1 Tool	Watts	669	28480	85	14	3	24	1351	13	139	3
DlRt9 Unit2 LayerA-1 Tool	Watts	669	28480	85	14	3	24	1351	13	139	3
DlRt9 Unit2 LayerA-1 Tool	High Falls	848	30818	101	14	5	23	2928	12	173	3
DlRt9 Unit2 LayerA-1.10	High Falls	758	30388	99	14	3	25	2984	12	180	3
DlRt9 Unit2 LayerA-1.12	High Falls	794	29772	101	14	4	33	2930	13	180	3
DlRt9 Unit2 LayerA-1.13	High Falls	724	32076	114	15	4	25	2999	14	172	3
DlRt9 Unit2 LayerA-1.15	High Falls	719	29707	120	16	4	32	2918	14	174	3
DlRt9 Unit2 LayerA-1.2	High Falls	845	29141	105	15	6	27	3050	12	176	4
DlRt9 Unit2 LayerA-1.3	High Falls	669	32458	100	14	4	30	3099	12	182	4
DlRt9 Unit2 LayerA-1.4	High Falls	880	31058	177	19	4	35	2920	11	171	4
DlRt9 Unit2 LayerA-1.5	High Falls	675	28501	91	13	5	24	2804	11	170	3
DlRt9 Unit2 LayerA-1.6	High Falls	921	31703	137	16	4	28	3047	11	184	3
DlRt9 Unit2 LayerA-1.7	High Falls	926	31864	208	20	4	25	2908	12	168	2
DlRt9 Unit2 LayerA-1.8	High Falls	913	29854	119	15	7	40	2953	13	183	6
DlRt9 Unit2 LayerA-1.9	High Falls	763	30192	122	16	4	25	2837	14	180	4
DlRt9 Unit2 LayerA-1	High Falls	601	31092	101	14	5	27	2994	11	177	8
DlRt9 Unit2 LayerA-2 Tool	High Falls	836	32736	118	13	6	23	2846	12	183	5
DlRt9 Unit2 LayerA-2 Tool	Brandywine Creek	875	31848	99	14	0	27	1887	13	161	5
DlRt9 Unit2 LayerA-2.11	High Falls	841	43532	246	19	6	33	2665	11	173	5
DlRt9 Unit2 LayerA-2.12	Watts	745	30290	508	35	16	125	909	5	172	4
DlRt9 Unit2 LayerA-2.14	High Falls	770	35969	249	22	7	31	2311	10	165	3
DlRt9 Unit2 LayerA-2.2	Watts	769	32748	96	14	1	23	1406	13	145	5
DlRt9 Unit2 LayerA-2.3	High Falls	775	33424	105	13	4	32	3065	13	179	2
DlRt9 Unit2 LayerA-2.4	Arrowstone	399	18240	97	17	12	121	549	11	199	8
DlRt9 Unit2 LayerA-2.6	High Falls	636	28044	153	17	2	27	2778	13	165	3
DlRt9 Unit2 LayerA-2.7	High Falls	971	55834	182	11	2	18	2115	11	146	4
DlRt9 Unit2 LayerA-2.8	High Falls	802	33434	148	16	3	29	3305	13	182	3
DlRt9 Unit2 LayerA-2.9	High Falls	887	38195	249	20	3	32	3412	12	167	5
DlRt9 Unit2 LayerA-2	High Falls	747	30399	101	15	2	26	2917	11	178	4
DlRt9 Unit2 LayerB-2 Tool	High Falls	762	31827	102	14	7	26	3040	14	178	4
DlRt9 Unit2 LayerB-3 Tool	High Falls	668	31640	135	16	5	25	3021	16	173	4
DlRt9 Unit2 LayerB-3 Tool	Brandywine Creek	776	36730	198	19	2	36	1777	10	146	5
DlRt9 Unit2 LayerB-3	High Falls	641	30385	91	13	1	25	3124	14	171	5
DlRt9 Unit2 LayerB-3	High Falls	794	32218	108	15	1	24	2390	10	172	4
DlRt9 Unit2 LayerB-3	High Falls	1290	32882	210	20	3	43	2432	11	168	3
DlRt9 Unit2 LayerB-3	High Falls	717	29942	101	15	6	29	2996	14	185	5
DlRt9 Unit2 LayerB-3	High Falls	803	31495	101	15	6	27	2880	14	183	4
DlRt9 Unit2 LayerB-3	High Falls	811	36439	278	23	5	27	2931	15	161	3
DlRt9 Unit2 LayerB-3	High Falls	999	30589	143	17	3	35	2891	14	184	5

Table 5-4 (continued). XRF Data for Artifacts from DlRt 9. All Values in ppm.

Context	Source	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
DlRt9 Unit2 LayerB-3	High Falls	735	32567	90	13	5	25	3228	11	183	5
DlRt9 Unit2 LayerB-3.3	High Falls	773	33159	164	17	6	27	3181	14	187	4
DlRt9 Unit2 LayerB-3.4	High Falls	593	32110	111	15	6	40	2975	11	176	4
DlRt9 Unit2 LayerB-3.5	High Falls	690	32704	115	15	6	25	3345	16	185	5
DlRt9 Unit2 LayerB-3.6	High Falls	1002	30216	123	16	3	35	2914	13	177	4
DlRt9 Unit2 LayerB-3.7	Brandywine Creek	701	31030	88	14	2	27	1773	11	147	2
DlRt9 Unit2 LayerB-3.8	High Falls	841	31202	131	16	1	31	2855	11	177	5
DlRt9 Unit2 LayerB-3.9	High Falls	676	34336	154	17	3	26	3004	12	174	3
DlRt9 Unit2 LayerB-3	High Falls	751	30623	107	14	3	27	3099	15	189	6
DlRt9 Unit2 LayerBC-4 Tool	Watts	661	28330	85	14	1	30	1317	11	140	4
DlRt9 Unit2 LayerBC-4.2	High Falls	773	33882	113	13	5	31	2764	10	180	4
DlRt9 Unit2 LayerBC-4.3	High Falls	794	30963	112	15	4	26	2876	14	172	4
DlRt9 Unit2 LayerBC-4.4	High Falls	793	34448	178	18	3	32	2939	12	169	1
DlRt9 Unit2 LayerBC-4.5	High Falls	842	29414	101	15	4	27	2772	12	177	2
DlRt9 Unit2 LayerBC-4.6	High Falls	714	31319	147	17	5	22	3067	12	183	3
DlRt9 Unit2 LayerBC-4	Watts	600	27735	98	15	2	28	1515	10	140	3
DlRt9 Unit2 LayerBC-5 Tool	High Falls	664	30104	112	12	5	34	2995	14	180	3
DlRt9 Unit2 LayerBC-5.2	High Falls	715	32714	128	16	7	30	3076	13	176	6
DlRt9 Unit2 LayerBC-5.3	High Falls	792	34440	206	19	3	33	3234	11	179	5
DlRt9 Unit2 LayerBC-5.4	High Falls	809	30549	93	14	2	27	2745	9	166	6
DlRt9 Unit2 LayerBC-5.5	High Falls	576	30139	122	16	5	22	2697	13	174	3
DlRt9 Unit2 LayerBC-5.6	Brandywine Creek	695	31104	102	15	4	22	1806	13	150	4
DlRt9 Unit2 LayerBC-5.7	High Falls	860	31916	146	15	4	46	2746	10	172	2
DlRt9 Unit2 LayerBC-5.8	High Falls	837	34297	233	20	9	36	3304	12	176	2
DlRt9 Unit2 LayerBC-5	High Falls	736	34226	93	13	6	22	3158	13	184	4
DlRt9 Unit2 LayerC-6.2	High Falls	899	31473	125	16	6	27	3056	12	176	6
DlRt9 Unit2 LayerC-6.3	High Falls	730	32157	190	19	3	24	3082	11	174	5
DlRt9 Unit2 LayerC-6.4	High Falls	831	35253	205	18	4	29	3115	10	178	3
DlRt9 Unit2 LayerC-6.5	High Falls	973	36350	321	21	4	30	3102	10	167	4
DlRt9 Unit2 LayerC-6.6	High Falls	764	40007	327	22	6	28	3318	11	180	7
DlRt9 Unit2 LayerC-6.7	High Falls	831	34818	336	27	5	30	3253	12	178	5
DlRt9 Unit2 LayerC-6	High Falls	772	32053	115	14	6	27	3410	14	183	5
DlRt9 Unit2 Surface Tool	Arrowstone	511	16552	81	16	8	115	501	12	181	5
DlRt9 Unit2 Surface	High Falls	666	29291	112	16	2	31	2660	12	173	2
DlRt9 Unit2 Surface	Watts	673	24887	73	15	-2	22	1177	9	125	3
DlRt9 Unit2 Surface	High Falls	707	29746	79	13	4	24	2958	13	180	4
DlRt9 Unit2 Surface	High Falls	644	30333	152	18	1	25	2909	13	172	4
DlRt9 Unit2 Surface	High Falls	703	29947	92	14	6	25	3020	13	187	7
DlRt9 Unit2 Surface	High Falls	1398	21369	130	18	3	29	2840	13	181	2
DlRt9 Unit2 Surface	High Falls	783	31812	98	11	7	27	2959	13	172	4
DlRt9 Unit2	High Falls	753	31448	122	15	5	23	2883	16	180	6
DlRt9 Unit2	High Falls	689	31840	93	14	4	34	3123	14	184	4
DlRt9 Unit2	High Falls	652	31742	124	15	4	24	2999	15	183	2
DlRt9 Unit2	High Falls	662	33999	176	18	7	26	3051	10	184	3
DlRt9 Unit2	High Falls	1294	34173	237	21	5	30	2830	12	182	5
DlRt9 Unit2	High Falls	649	36162	227	19	2	30	3142	13	166	4
DlRt9 Unit2	High Falls	741	29341	112	15	5	29	2837	13	171	4
DlRt9 Unit2	High Falls	839	35516	238	20	3	23	3117	12	175	3
DlRt9 Unit2	High Falls	676	34478	175	18	3	22	3171	12	175	3
DlRt9 Unit2	High Falls	724	31252	108	15	5	27	3052	15	175	2

Table 5-5. XRF Data for Artifacts from EaRu5. All Values in ppm.

Context	Source	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
EaRu5 Unit1 LayerA-0 Tool	Arrowstone	659	17936	190	22	13	124	512	11	194	5
EaRu5 Unit1 LayerA-0 Tool	Unknown	786	15747	72	17	6	82	620	9	157	3
EaRu5 Unit1 LayerA-0 Tool	Arrowstone	804	15939	62	16	7	113	504	9	184	9
EaRu5 Unit1 LayerA-0 Tool	Arrowstone	522	17082	143	19	10	127	531	13	186	7
EaRu5 Unit1 LayerA-0 Tool	Unknown	928	17966	118	19	7	96	767	8	181	3
EaRu5 Unit1 LayerA-0.2	High Falls	728	28331	99	13	2	36	2715	11	168	5
EaRu5 Unit1 LayerA-0.3	High Falls	1361	30249	168	18	0	46	2998	13	187	1
EaRu5 Unit1 LayerA-0.4	High Falls	1049	31769	141	16	3	38	3067	13	186	5
EaRu5 Unit1 LayerA-0.5	High Falls	2312	30130	188	19	3	36	3076	13	186	5
EaRu5 Unit1 LayerA-0.6	High Falls	1118	31190	100	14	5	28	3235	13	182	4
EaRu5 Unit1 LayerA-0	Unknown	570	17546	88	17	1	89	707	9	173	5
EaRu5 Unit1 LayerA-1 Tool	Arrowstone	689	16485	129	19	12	127	515	9	170	6
EaRu5 Unit1 LayerA-1.2	High Falls	946	30235	112	15	3	31	3168	13	181	2
EaRu5 Unit1 LayerA-1.3	High Falls	1307	34841	189	16	4	33	4069	12	209	3
EaRu5 Unit1 LayerA-1.4	Unknown	2347	16829	164	21	2	83	734	10	175	5
EaRu5 Unit1 LayerA-1.5	Unknown	2347	16829	164	21	2	83	734	10	175	5
EaRu5 Unit1 LayerA-1.6	Arrowstone	2061	19117	203	23	9	128	555	9	192	8
EaRu5 Unit1 LayerA-1.7	Unknown	2467	22637	441	38	10	118	848	8	178	5
EaRu5 Unit1 LayerA-1.9	Unknown	606	21710	291	28	5	85	761	6	171	3
EaRu5 Unit1 LayerA-1	High Falls	946	30235	112	15	3	31	3168	13	181	2
EaRu5 Unit1 LayerAB-1 Tool	Arrowstone	653	19794	221	24	11	124	546	9	198	7
EaRu5 Unit1 LayerAB-1 Tool	Arrowstone	1163	16930	157	21	11	124	536	10	190	8
EaRu5 Unit1 LayerAB-1 Tool	Unknown	472	18605	90	16	4	92	728	8	178	3
EaRu5 Unit1 LayerAB-1 Tool	Unknown	1281	16807	105	18	7	92	717	5	175	3
EaRu5 Unit1 LayerAB-1 Tool	Unknown	1042	17196	197	23	8	104	702	8	168	4
EaRu5 Unit1 LayerAB-1 Tool	Unknown	1819	15967	234	26	5	95	727	9	182	2
EaRu5 Unit1 LayerAB-1 Tool	Arrowstone	727	18207	83	16	12	126	549	12	191	8
EaRu5 Unit1 LayerAB-1.10	High Falls	575	35920	139	15	4	24	3842	14	203	5
EaRu5 Unit1 LayerAB-1.11	High Falls	854	32248	136	16	6	33	3145	12	183	4
EaRu5 Unit1 LayerAB-1.12	Arrowstone	486	18943	126	19	12	129	567	13	200	6
EaRu5 Unit1 LayerAB-1.2	Unknown	517	18642	170	22	6	92	771	8	176	1
EaRu5 Unit1 LayerAB-1.4	High Falls	732	33612	90	13	1	28	3113	10	185	5
EaRu5 Unit1 LayerAB-1.5	High Falls	1094	31536	113	15	7	28	2931	11	188	3
EaRu5 Unit1 LayerAB-1.6	High Falls	971	30790	172	18	7	35	2978	15	179	4
EaRu5 Unit1 LayerAB-1.7	High Falls	663	34266	104	14	2	27	3204	11	180	3
EaRu5 Unit1 LayerAB-1.8	High Falls	730	33708	113	15	4	28	3044	14	182	2
EaRu5 Unit1 LayerAB-1.9	High Falls	909	32939	97	13	6	31	3788	16	191	2
EaRu5 Unit1 LayerAB-1	High Falls	1073	32839	140	16	5	29	3709	13	194	2
EaRu5 Unit1 LayerB-2 Tool	Unknown	666	17044	99	18	5	91	712	8	172	3
EaRu5 Unit1 LayerB-2 Tool	Unknown	481	18553	179	22	6	93	721	5	168	4
EaRu5 Unit1 LayerB-2 Tool	Unknown	509	18116	133	19	5	83	719	10	170	4
EaRu5 Unit1 LayerB-2 Tool	Unknown	432	18502	151	20	5	90	712	11	177	4
EaRu5 Unit1 LayerB-2 Tool	Unknown	1011	18709	230	25	7	107	733	8	172	3
EaRu5 Unit1 LayerB-2 Tool	Unknown	503	16764	137	19	5	80	693	10	167	3
EaRu5 Unit1 LayerB-2 Tool	Unknown	385	17662	129	19	7	87	691	10	178	3
EaRu5 Unit1 LayerB-2 Tool	Unknown	669	17993	75	16	7	89	718	8	174	4
EaRu5 Unit1 LayerB-2.10	High Falls	949	30914	113	15	5	25	3041	11	185	5
EaRu5 Unit1 LayerB-2.11	High Falls	844	33556	106	14	6	31	3118	13	193	4
EaRu5 Unit1 LayerB-2.12	Unknown	728	15284	97	18	5	85	762	10	173	3
EaRu5 Unit1 LayerB-2.13	Unknown	505	19849	134	19	5	100	804	10	186	2
EaRu5 Unit1 LayerB-2.14	High Falls	2162	30620	109	13	3	30	3049	12	180	5
EaRu5 Unit1 LayerB-2.15	High Falls	811	31253	167	16	5	26	3051	11	173	4
EaRu5 Unit1 LayerB-2.16	Arrowstone	452	18393	76	15	12	126	548	15	198	6
EaRu5 Unit1 LayerB-2.17	High Falls	718	31395	121	16	6	26	2977	14	181	5
EaRu5 Unit1 LayerB-2.18	High Falls	647	34311	179	18	3	27	3296	14	179	2
EaRu5 Unit1 LayerB-2.19	High Falls	708	30269	164	18	4	49	3078	13	176	4

Table 5-5 (continued). XRF Data for Artifacts from EaRu5. All Values in ppm.

Context	Source	Mn	Fe	Zn	Ga	Th	Rb	Sr	Y	Zr	Nb
EaRu5 Unit1 LayerB-2.2	High Falls	804	32121	94	14	3	35	3028	12	183	5
EaRu5 Unit1 LayerB-2.20	High Falls	795	34711	141	15	4	26	3352	14	182	3
EaRu5 Unit1 LayerB-2.22	Unknown	443	17178	113	19	6	82	702	6	174	3
EaRu5 Unit1 LayerB-2.23	High Falls	776	32580	109	15	3	27	3754	13	199	4
EaRu5 Unit1 LayerB-2.24	High Falls	776	32580	109	15	3	27	3754	13	199	4
EaRu5 Unit1 LayerB-2.26	High Falls	714	29676	121	16	2	30	2872	9	171	3
EaRu5 Unit1 LayerB-2.28	Unknown	466	19867	133	19	7	92	746	8	176	4
EaRu5 Unit1 LayerB-2.3	High Falls	902	31457	101	14	2	26	3115	16	181	5
EaRu5 Unit1 LayerB-2.4	High Falls	893	32662	106	14	3	31	2820	13	176	6
EaRu5 Unit1 LayerB-2.5	Arrowstone	758	16179	84	17	9	122	516	10	185	6
EaRu5 Unit1 LayerB-2.6	High Falls	763	34051	111	14	7	31	3143	14	182	3
EaRu5 Unit1 LayerB-2.7	Unknown	699	18283	126	19	7	90	722	9	182	3
EaRu5 Unit1 LayerB-2.8	High Falls	627	31772	186	19	4	30	3019	10	174	4
EaRu5 Unit1 LayerB-2.9	High Falls	745	31088	84	14	5	27	3534	12	193	2
EaRu5 Unit1 LayerB-2	High Falls	768	31908	92	11	4	25	3124	13	178	4
EaRu5 Unit1 LayerB-3 Tool	Unknown	581	19192	183	22	7	85	721	6	168	5
EaRu5 Unit1 LayerB-3.11	High Falls	694	30004	115	15	5	23	2847	11	164	4
EaRu5 Unit1 LayerB-3.2	Unknown	375	20297	134	19	9	93	741	9	176	2
EaRu5 Unit1 LayerB-3.3	High Falls	1364	32956	112	14	4	30	3501	14	180	4
EaRu5 Unit1 LayerB-3.4	Unknown	274	24286	246	22	11	102	872	7	186	2
EaRu5 Unit1 LayerB-3.5	High Falls	1119	34125	151	16	5	31	2808	16	203	6
EaRu5 Unit1 LayerB-3.6	Unknown	391	26045	276	26	14	106	887	7	180	2
EaRu5 Unit1 LayerB-3.7	High Falls	909	32490	107	14	2	27	3030	13	186	5
EaRu5 Unit1 LayerB-3.8	High Falls	845	32345	147	17	5	26	3084	13	182	4
EaRu5 Unit1 LayerB-3.9	High Falls	640	31433	83	12	5	27	2959	12	176	4
EaRu5 Unit1 LayerB-3	High Falls	636	30616	147	17	8	40	2953	12	179	3
EaRu5 Unit1 LayerC-3.2	High Falls	799	34338	153	16	3	32	3039	11	179	7
EaRu5 Unit1 LayerC-3.3	High Falls	1060	31263	120	14	5	39	3244	14	183	4
EaRu5 Unit1 LayerC-3.4	High Falls	800	30253	87	14	4	25	2875	11	182	3
EaRu5 Unit1 LayerC-3.5	High Falls	680	30123	92	14	5	25	2848	14	178	5
EaRu5 Unit1 LayerC-3	High Falls	680	33503	97	14	3	26	3643	13	191	4

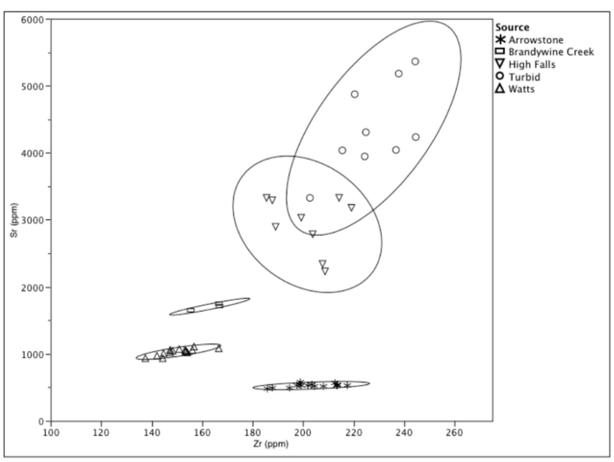

Figure 5-2. Elemental biplot of strontium and zirconium for lithic sources. Confidence ellipses are 95 percent and all values in ppm.

ellipses in Figure 5-2 are at 95 percent and all values are in parts per million (ppm). As light overlap exists between the High Falls Creek and Turbid Creek source that is due to the similar geological origin from the Mount Cayley volcanic field, however, these materials can be double checked with visual assessment- High Falls Creek is lighter in color, is coarser grained and contains more phynocrysts. What is notable is that these materials, like obsidian sources, are relatively chemically homogenous. Samples included here were collected in the widest range of localities possible to ensure that there range of variation is captured. Trace elements that are not compatible demonstrate similar results as obsidian, but this result shows that pXRF can discriminate one igneous rock source from another- be it sources proximate to each other, or separated by substantial distance.

Archaeological Sites

Of the 166 artifacts sampled from DlRt9, all were

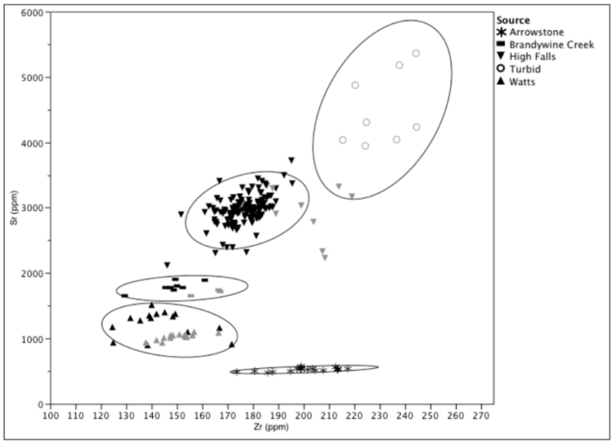

Figure 5-3. Elemental biplot of strontium and zirconium for lithic sources (lightly shaded) and artifact materials from DlRt 9. Confidence ellipses are 95 percent and all values in ppm. **Elemental biplot of strontium and zirconium for lithic sources (lightly shaded) and artifact materials from DlRt 9. Confidence ellipses are 95 percent and all values in ppm.**

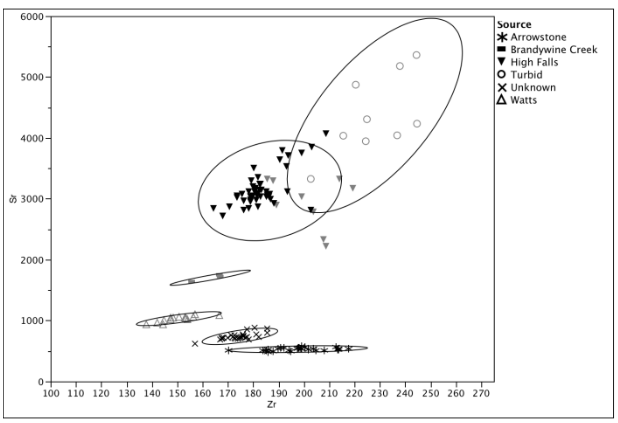

Figure 5-4. Elemental biplot of strontium and zirconium for lithic sources (lightly shaded) and artifact materials from EaRu 5. Confidence ellipses are 95 percent and all values in ppm.

assigned to a known source (Figure 5-3). Surprisingly, not one of the artifacts derives from local Turbid Creek source. This is likely due to the matching to source signatures. The next closest source, Brandywine Creek was represented by eight artifacts, followed by fifteen from Watts Point, located in northern Howe Sound. The most distant source, Arrowstone Hills, accounts for three items at this site. This and other signatures mark the first known occurrence of this material from the interior Plateau, on the Northwest Coast. Of the 87 artifacts from EaRu5, 58 assign to a known geological source and 29 originate from an unknown source (Figure 5-4). Future research will attempt to determine its geological origin and archaeological occurrence. Intriguingly, no artifacts originate from Watts Point or Brandywine Creek sources. Yet, forty-seven artifacts derive from the High Falls Creek source, 20 km south of the site in the Squamish River valley. Surprisingly, eleven artifacts come from the Arrowstone Hills source.

Discussion and Conclusion

To address the questions posed at the beginning of this paper, portable x-ray fluorescence can determine the differences between geological source materials. In this case, chemical distinction of toolstone sources from five discrete sources is possible. Trace element analysis found that these materials characterize in much the same way as obsidian sources. It can also apply these results to archaeological contexts, in this case two rock-shelter sites, in similar environmental contexts, with a very similar radiocarbon chronology. However, what is most intriguing is that these results offer new insights into the role of various lithic materials in local to regional technological organization, trade and interaction.

On the larger scale of Northwest Coast and Plateau archaeology, these results demonstrate that the peoples using these sites did not simply use local toolstone found in close proximity of these locales. Non-obsidian materials have much more dynamic role and distribution in these culture areas than previously understood. In terms of local to regional use of lithic materials, the majority of lithic material used at each site does originate from local sources on the Northwest Coast. On one hand, at DlRt9, the local High Falls Creek sources dominate the lithic assemblage, followed by Watts Point, Brandywine Creek and finally the most distant source, Arrowstone Hills. This pattern of lithic material use reflects a local use and focus of resources in and around ethnohistorically-recorded villages along the Squamish River (Bouchard and Kennedy 1986; Reimer 2012). On another, EaRu5 illustrates a different pattern, with High Falls Creek (and possibly Turbid Creek) dominating lithic material use, followed by Arrowstone Hills and Unknown source, with no use of Brandywine Creek or Watts Point materials. However, closer examination of results illuminates an interesting pattern at EaRu5 that all but one tool at EaRu5 derives from a single source- Arrowstone Hills. This is a somewhat surprising pattern, as all the other sources (except the unknown) are known to be closer. Furthermore, Arrowstone Hills is a source located on the interior Plateau, approximately 200 km distant. Access or exchange for this material crossed ethno-linguistic boundaries, and demonstrates previously undocumented occurrence of this material on the Northwest Coast. The single tool (a scraper) that does not match the Arrowstone Hills chemical signature derives from the High Falls Creek source, 20 km down river in the Squamish River. While the pattern of lithic material use at DlRt9 seems to reflect a pattern of direct procurement, a small degree of exchange, down the line, that eventually makes it way down the river systems bordering the interior Plateau onto the Northwest Coast, up into mid elevation resource use contexts, but only as curated tools. Further north, a similar pattern is observed, but amplified, with a higher number of formal tools curated and left at EaRu5. This site may reflect a trade/exchange contact point between coastal Squamish Nation and interior Plateau group as no village is located between the culturally known travel and trade route via the upper Meagher Creek over the upper Elaho River down into the Squamish valley or up and over to Jervis Inlet (Bouchard and Kennedy 2010).

The results presented here offer new ways that elemental analysis can contribute to larger issues in lithic technological analysis, by examining non-obsidian source materials using XRF, their archaeological occurrence at two similar archaeological sites, that illustrate different land use patterns over the past 1500 years on the southern Plateau and Northwest Coast. These patterns are previously undocumented, and offer a nuanced perspective to lithic materials, their geochemistry and technological organization. As a final concluding point, I would recommend that archaeologists consider the cultural value and places from which these materials derive. It is with that information that we can factually understand their occurrence and distribution. Future analysis of these materials must include those factors.

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CHAPTER 6

Toolstone Geography in the Northern Cascades of Washington and Adjacent Areas

Robert R. Mierendorf
National Park Service (Retired), U. S. Department of Interior, 810 SR 20, Sedro Woolley, WA 98284-1239 (rrmcascades@gmail.com);

Kevin E. Baldwin
1014 151st Ave SE, Bellevue WA 98007 (baldwin_kevin@hotmail.com)

Background to the Study of North Cascades Toolstone

The northern Cascade Mountain Range, or North Cascades, extends 220 km from northeast of the town of Hope, British Columbia, to Snoqualmie Pass in Washington State. The geographic center of the North Cascades is within the North Cascades National Park Service Complex (the park) and adjacent lands. The park (Figure 6-1) takes in remote alpine terrain comprising the most heavily glaciated portion of the range in the convergent headwaters of the three largest regional rivers - the Columbia, the Fraser, and the Skagit. Park lands on the western slopes extend from the border with Canada, south along the upper Skagit River; park land extends east across the Cascade crest to include the upper end of Lake Chelan. The park is managed by the National Park Service (NPS) to maintain several qualities, including its scenery, recreational enjoyment, wilderness character, naturally functioning ecosystems, and cultural and historic resources.

Research Design

Investigation of toolstone in the North Cascades is an outgrowth of the park's archaeological research design, which identifies lithic quarries, along with other toolstone procurement locations and lithic scatters, as site types that can shed new light on the pre-contact history of the mountains (Mierendorf 1986). The park and its immediately adjacent lands encompass the core area of a distinctive toolstone landscape whose rich suite of rock types offered a variety of utilitarian options to pre-contact populations. Reflecting for the most part geographic variation in bedrock lithology, this suite of toolstone types differs from the variety of toolstone used in the foothill, lower riverine valley, and littoral landscapes that surround the North Cascades. Even within the North Cascades interior, the abundance and type of toolstone in archaeological assemblages vary significantly within and between watersheds.

Archaeological evidence indicates that, hardly the unexplored wilderness it has been made out to be in the post-contact period, the North Cascades was "prospected" and "mined" by indigenous groups for its unique mineral resources over a period of nearly 10,000 years. Given the park's abundance of lithic-dominated sites, we synthesize characterizations of toolstone types in archaeological sites and in procurement locations in order to define two distinctive toolstone types of the North Cascades: toolstone of the Hozomeen chert quarry complex and of the Hannegan volcanics quarry complex.

Toolstone type is a fundamental attribute of artifact assemblage variation, and it is widely accepted as having a strong association with

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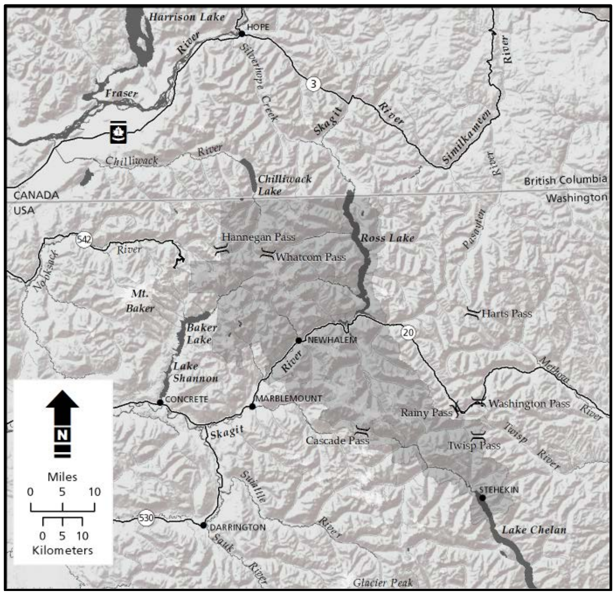

Figure 6-1. North Cascades National Park Service Complex shaded gray, showing place names mentioned in the text.

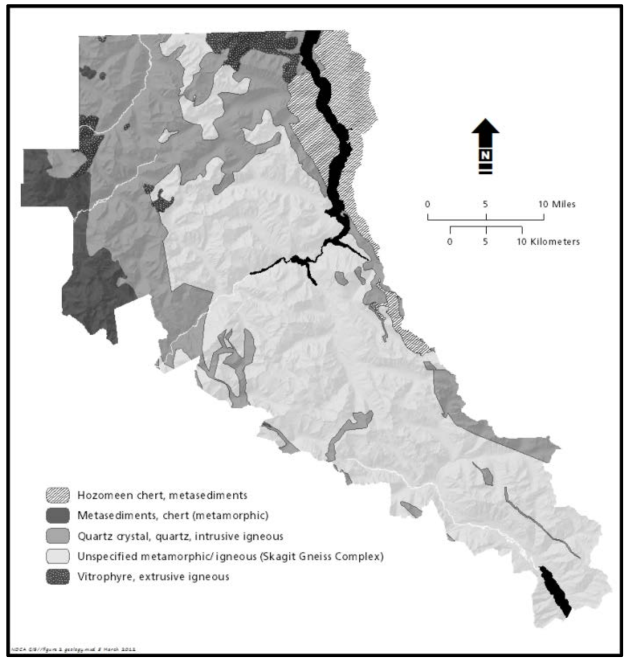

Figure 6-2. Toolstone categories found within major bedrock mapping units, based on site inventory records and archaeological research referenced in the text of this study; mapping units simplified from detailed maps in Haugerud and Tabor (2009).

foraging peoples' cultural patterns as these developed over time. The availability of toolstone constrains, to varying degrees, the organization of its use by foraging groups (Andrefsky 2009). Discriminating toolstone from different sources increases the capacity to make artifact-to-source correlations and to reconstruct aspects of subsistence, settlement, exchange, mobility, and demography. Even so, we are aware of the many unresolved issues surrounding toolstone consumption and lithic technology organization in complex foraging societies (Andrefsky 2009; Brantingham 2006). There is no single or routine method for making behavioral inferences from toolstone scattered across the landscape (Shott 2006). Here, our goal is to understand the behavioral relationships between uplands and lowlands in the study area, with the belief that upland land-use is best understood in the context of "subsistence strategies employed in adjacent foothills and valleys." (Madsen and Metcalf 2000). Also, due to constraints imposed by steep altitudinal gradients in mountains (Mierendorf 1999; Whitaker and Carpenter 2012; Zeanah 2000), pre-contact resource consumption invites research into the ways that alpine resource access, processing, risk avoidance, and transportation were regulated for optimization of benefits.

We explore three broad questions surrounding the toolstone quarry complexes:

1) In what ways did geography influence how people used North Cascades toolstone?

2) Can toolstone from these quarry complexes be linked to populations in lowland environments of the Northwest Coast or Plateau?

3) What is the chronology of North Cascades toolstone use?

We use artifact-to-source correlation and radiocarbon dating techniques to investigate the geographic circulation of North Cascades toolstone, the chronology of its use, and the routes used for access and transportation.

Five main categories of bedrock are the source of most local North Cascades toolstone (Figure 6-2). These include two small areas of extrusive volcanic rocks, the Hannegan Volcanics and the Skagit Volcanics, in the north end of the park; the Hozomeen Terrane metamorphic rocks of oceanic origin in the northeast corner; a body of Easton

Terrane metamorphic rocks along the western margin of the park; and the largest area, which is comprised of the last two categories: intrusive plutonic and metamorphic rocks of granitic origin, representing the crystalline core of the range and locally containing dikes and other formations of secondary hydrothermal rocks and minerals.

Toolstone types within these five rock categories have been identified empirically by their presence in archaeological assemblages. They include chert, metasediment (a generic descriptor covering lithologies such as mudstone, siltstone, slate, argillite, greywacke, and claystone), vitrophyre (glassy groundmass with prominent phenocrysts), dacite, fine-grained volcanics (such as basalt), granite, gneiss, quartz crystal, talc, and nephrite (nephrite-serpentinite-jadeite series). Some of these raw materials were procured from non-bedrock secondary sources rafted in glacial ice (as "float") southward from primary sources in southern British Columbia (Mierendorf et al. 1998). Most of the North Cascades however, both inside and outside the park, remains unexplored for toolstone sources and archaeological sites, so our findings here represent only an initial exploratory contribution to a larger research endeavor.

Beginning in the 1950s with the first systematic archaeological investigations in western Washington, the need to learn the sources of the various stone materials found in sites of the Puget Lowlands became apparent. At the time, it was thought that there were ". . . very few occurrences of cryptocrystalline minerals in northwestern Washington and adjacent British Columbia." (Bryan 1963:9). Many Puget Sound artifact assemblages were made from inferior quality, presumably local toolstone from unverified sources, or from "float" found in gravel-rich glacial and alluvial deposits. Typically such materials were described as dark-colored, opaque, medium to coarse-grained, and were identified as "basalt" (e. g., Bryan 1963; Butler 1961; and others). In local artifact collections and from early excavations at sites like Marymoor Farm (45KI9) and the Biderbost Site (45SN100), particularly along the eastern margins of Puget Sound, assemblages were observed to be rich in toolstone types imported from east of the Cascades (Bryan 1963; Butler 1961; Greengo and Husted 1970; Nelson 1962, 1976) where high-quality siliceous types were abundant. The relative frequency of these imports in western Washington assemblages thus became an indicator of the degree of influence when inferring cultural relations between the Northwest Coast and Plateau (Butler 1961; Nelson 1962, 1976). By showing continuity in toolstone traits between the Northwest Coast and Plateau, these early notions of toolstone geography, in turn, contributed to a broader regional discussion about the role of the Cascade Mountains in cultural developments. The existence of a "foothills or trans-Cascade region" was proposed by Smith (1956), who suggested that the "traditional Coast-Plateau divisions" are misleading when trying to understand relationships between these culture areas (Swanson 1962:152).

More recent regional studies have employed sensitive geochemical sourcing techniques on high-quality toolstone types, such as obsidian from well-known quarry complexes like Glass Buttes, Oregon, and Obsidian Cliff, Wyoming, and Bear Gulch and Timber Butte, Idaho—all procurement centers that supplied toolstone to long-distance exchange networks. In the Pacific Northwest, such toolstone types have an arguably high exchange value, and on this basis, obsidian artifact-to-source correlations have been used to infer regional exchange routes (Carlson 1994). Other studies have successfully employed artifact-to-source correlations on vitrophyre and dacite in the southern Cascades of Washington (McClure 1989, 1998), in the southern Coast Range of British Columbia (Reimer 2011), and on the Olympic Peninsula (Kwarsick 2010). In the latter case, geochemical correlations show that toolstone quality dacite from bedrock sources in southwestern British Columbia was procured from widespread secondary sources in glacial deposits as far south as the northern Olympic Peninsula (Kwarsick 2010; Reimer 2011).

Unlike the major regional obsidian quarry complexes, North Cascades quarries are restricted in geographic extent, are difficult to access by lowland populations, and are composed of highly heterogeneous source material. Toolstone from these quarries has an arguably low exchange value, and artifact-to-source correlations should signal circulation patterns that are mostly local in scale. Of the nearly two dozen toolstone types recognized in the North Cascades, we describe the two most distinctive varieties – Hozomeen chert and Copper Ridge vitrophyre of the Hannegan volcanics. Both have uncertain regional exchange value, but their procurement and use are well established in archaeological assemblages in the North Cascades area itself. The sources of these two toolstone types are geographically separated from one another by 35 km of remote, steep terrain, and both were utilized in the post-contact period by Salish bands who share cultural and linguistic histories.

Toolstone utilization is influenced by many factors, including abundance, quality, access, transport distance to consumers, exchange value, and demography. In the North Cascades, toolstone sources may have been deliberately targeted by indigenous groups seeking out specific procurement patches and outcrops in their overall land-use strategies. But the preponderance of evidence suggests that toolstone procurement here as elsewhere was embedded in other subsistence pursuits (Binford 1970), such as hunting and gathering in the mountains (McClure 1998; McClure and Markos 1987), or in cultural expressions of identity and tradition (Franck 2003; Reimer 2011; Schaepe 2003).

Methodology

In this study, we correlate artifacts from archaeological sites with the two most recognizable toolstone types, macroscopically and geochemically, found in the park. Environmental and physical characteristics of the two toolstone types are vastly different from one another.

Hozomeen chert is a macroscopically distinctive metamorphic silica found in the Hozomeen Terrane rocks, which are mapped over a considerable area of the upper Skagit River valley in northern Washington and adjacent British Columbia (Haugerud and Tabor 2009; McTaggart and Thompson 1967). The rocks formed initially as ocean-floor basalt, sandstone, shale, and chert in a deep ocean basin ca. 350-220 million years ago and underwent subsequent metamorphism. Soon after the discovery of its first quarry (Mierendorf 1987b), Hozomeen chert gained recognition as one of the dominant toolstone types in archaeological sites of the upper Skagit River valley (Figure 6-3). Quarries in the park are located on the valley bottom, on steep valley walls, and in alpine settings, but the intensively used quarry workshops are on low elevation landforms (<2000 ft asl) along the interface of the valley bottom and steep valley wall.

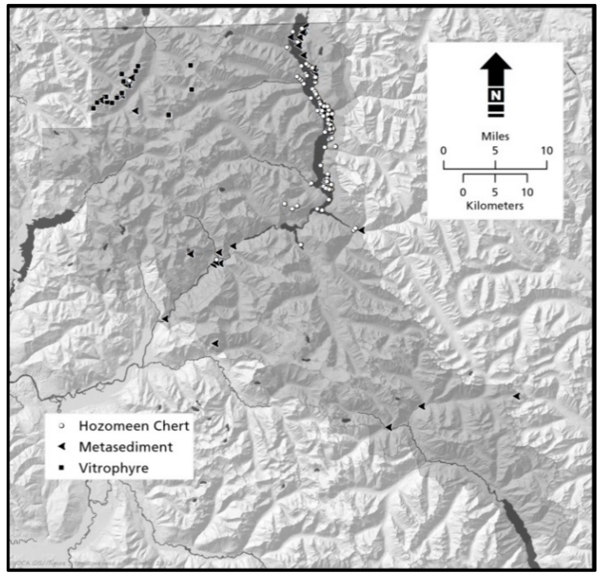

Figure 6-3. Archaeological assemblages where Hozomeen chert is dominant shown by circle, metasediment dominant by a triangle, and vitrophyre dominant by a square.

This portion of Skagit Valley (in today’s Ross Lake reservoir vicinity) is distant from the closest ethnohistorically reported permanent winter villages on the Skagit and Fraser Rivers. From these villages, direct bedrock quarry access would have entailed arduous travel into and along the Skagit Valley bottom, a travel corridor through the mountain interior that was well-used because it did not involve appreciable elevation changes. Although canoes could not access the upper Skagit Valley from either the Fraser or lower Skagit river valleys, we know that it was possible to navigate this upper reach of the river based on Custer’s 1859 exploratory journey in a dugout canoe (Custer 1866), which unbeknownst to him, carried his party past several of the ancient Hozomeen chert quarries along their route.

The second toolstone, Copper Ridge vitrophyre, is a glassy rock with prominent phenocrysts. It is associated with the Hannegan volcanics, which are restricted to a small area of the upper Chilliwack and Nooksack River headwaters (Haugerud and Tabor 2009; Staatz et al. 1972; Tucker 2006). This lithic resource is associated with the northernmost and oldest (3.7 million years) part of the rim of the Hannegan caldera (Tucker 2006), which filled with the densely welded ignimbrite still seen today on Hannegan Peak. Caldera deposits were intruded by hundreds of dikes that have compositions ranging from basaltic andesite to high-silica rhyolite (74-79 percent SiO_2), dacite (Tucker 2008), and vitrophyre. Initial archaeological reconnaissance in 1986 revealed intensive pre-contact quarrying of Hannegan volcanics at alpine outcrops on Copper Ridge (Mierendorf 1987a) (Figure 6-3). All documented quarries are >1500 m asl, in alpine and subalpine zones, and they consist of small, moderately dense lithic scatters. In contrast to the Hozomeen chert quarry complex, the Hannegan quarries are located geographically closer to permanent settlements in the Skagit and Fraser River valleys, but their access entails an arduous overland ascent through narrow valleys and into alpine terrain bounded by the Hannegan and Copper Mountain massifs. It may be inferred that access to the Hannegan quarries followed several different travel corridors through some of the most rugged terrain in the North Cascades.

For this study, geochemical and archaeological data on Hozomeen chert and Copper Ridge vitrophyre is compiled from published and unpublished journals and technical reports, and from archaeological survey and excavation data collected from 1986 to the present. Distinctive macroscopic characteristics of Hozomeen chert, aided by petrographic analysis, are used to make artifact-to-source correlations. Hozomeen chert has been excavated from intact, dated contexts at over a dozen archaeological sites in the upper Skagit River valley. X-ray fluorescence (XRF) analysis was conducted on 67 bedrock source samples from nine vitrophyre outcrops on Copper Ridge. Based on geochemical characterization of the geologic vitrophyre samples, we synthesized the XRF data of 87 flaked artifacts from archaeological sites in the Copper Ridge area (Hughes 1994 and 1995; Skinner 1998a, 1998b, 1999a, 1999b, 2003; Skinner and Davis 1996). Excavation data from one of the archaeological sites (45WH484) on Copper Ridge provided a large sample of flaked vitrophyre and dated charcoal from an intact hearth feature (Mierendorf 1999).

Toolstone Data

Hozomeen Chert of the Upper Skagit River Valley Physical and Chemical Properties.

Characteristics of Hozomeen chert toolstone are based on macroscopic description and semi-quantitative petrographic analyses. Geologic specimens were collected from bedrock and glacial gravel within the park and compared to artifacts from archaeological assemblages in the North Cascades and adjacent areas (Figure 6-4a).

The description below is based on previously published data (Mierendorf 1993: Appendix B) and from more recent unpublished investigations.

Viewed on fresh fracture surfaces, the most abundant form of Hozomeen chert is strongly color-mottled black, dark gray, light gray, or bluish-gray in the groundmass, which is permeated with a complex reticulate pattern of thin white (but sometimes black) veins (Figures 6-4b through 6-4j). Occasionally ochre and other earth tones are visible as well, and luster is dull to semi-glossy. Fracture pattern varies from smooth, glassy conchoidal to hackly conchoidal and irregular (Figure 6-4e). Although most often opaque, thin pieces (1-2 mm thick) may be translucent. Much less abundant are other macroscopically distinct varieties exhibiting color and textural combinations that differ from the dominant form. One of these is characterized by a homogeneous opaque, medium-gray groundmass that mostly lacks the reticulate pattern of veins; a “jasper” variety is opaque red and exhibits occasional vein-like mottles of gray chert (Figure 6-4d); a translucent, semi-glossy “chalcedony” (Figure 6-4h) with gradations of light gray, light green, or light blue colors and few mottles is transparent on thin margins; and an opaque white variety displays a complex network of thin, dark reticulate veins (Figure 6-4c).

Based on a semi-quantitative petrographic analysis of thin-sections, Hozomeen chert is composed of 90-95 percent microgranular quartz crystals (2 to 10 microns diameter). Minor constituents include a dusty opaque material, a phyllosilicate material, and scattered grains of calcite, carbonate, and sphene. One sample of the “jasper” variety consisted of unrecrystallized chert with dusty hematite inclusions in a planar fabric. A sample of white chert consisted of coarse, foliated recrystallized quartz grains 10-100 microns across. The chert formed in a deep oceanic basin, concentrated from silica derived from radiolaria, whose recrystallized “ghosts” are visible under magnification in the groundmass.

Veins compose 1-15 percent of the rock mass, are 10 microns to 2 mm wide, and can be described variously as crosscutting, branching, intersecting,

Figure 6-4. Photographs of Hozomeen chert quarry complex, Hozomeen chert artifacts, and macroscopic appearance of color varieties. (a) Hozomeen chert quarry complex in the upper Skagit River valley and Ross Lake area, international boundary located just north of Hozomeen Mountain, visible as prominent nunatak in upper center of photo. (b) Finished biface made of high toolstone quality Hozomeen chert from upper Skagit River valley, showing complex color mottling. Scale: 8.2 cm long. (c) Biface showing typical macroscopic attributes of Hozomeen chert, including two different color varieties and complex reticulate mottle pattern; from upper Skagit River valley. Scale: 9.4 cm long. (d) Close-up of Hozomeen chert flake tool, "Hozomeen jasper" variety, showing typical quartz vein network in microgranular matrix. (e) Close-up of fresh fracture surface of most common dk. gray color variety of Hozomeen chert, showing macrocrystalline quartz veins in microgranular matrix (photo scale ca. 3 cm). (f) Serrated Olcott biface of Hozomeen chert found during construction near Lynnwood, King County (ca. 10 cm long). (g) Lanceolate (partially-shouldered) Hozomeen chert biface found near Ebey's Prairie, Whidbey Island, Island County (Randall Schalk, personal communication). (h) Western-stemmed Hozomeen chert lanceolate (9.37 cm long) found near King Lake, Snohomish County, by landowner Charlotte Selva (courtesy of the Burke Museum, University of Washington). (i) Hozomeen chert microblade from Cascade Pass (45CH221) from component dated 7-7,500 cal B.P. (j) Corner-notched Hozomeen chert point from Grade Cr. Site (45CH640), dated 450 B.P., Lake Chelan.

curved, discontinuous, and in some cases gradational into the groundmass. Vein mineralogy is 80-90 percent quartz crystals that are slightly larger (5 to 30 microns diameter) than those of the groundmass; veins also include albite in addition to sphene and a minor amount of carbonate material. Under magnification quartz crystals in veins exhibit a comb texture, with elongated grains or unusual radiating wavy aggregates normal to the axis of the vein wall. In some samples, parallel laminations and veins are defined by a greater or lesser amount of dusty opaque material.

Quarry and Procurement Sites of the Hozomeen Chert Quarry Complex. To date, all recorded Hozomeen chert quarries are proximal to bedrock sources in today's Ross Lake vicinity (Figure 6-4a). In this core area (roughly 64 km^2), outcrops of chert are common on cliffs, rock buttresses, ridges, summits, and steep slopes. In some cases the outcrops are expressed as ribbon-chert and in other cases as massive jointed beds. Typically the chert is interbedded with greenstone and other metamorphic rocks of the Hozomeen Terrane. Bedrock procurement locations range in elevation from alpine settings (1867 m asl) to lower montane setting (470 m asl) (Franck 2000; Mierendorf 1993, 2004). At least 14 bedrock quarries are presently recorded within the Hozomeen chert quarry complex and three of these were used also as short-term encampments.

Quarries vary from extremely high-density lithic scatters with buried, intact components, to low-density single-component surface scatters marking short-term reduction loci. Typical quarry workshop debris is dominated by coarse (5-30 cm diameter), angular shatter and broken flakes in association with occasional hammerstones and early-stage bifaces. Common quarry features are hammer marks on bedrock faces or on large boulders, in the form of percussion flake scars particularly on outside corners and edges. A morphologically varied assemblage of hammerstones is found across quarries, but excavated pits have not been observed (Mierendorf 1993). It may also be noted that, within the quarry complex, many outcrops exhibiting toolstone-quality Hozomeen chert show no evidence of quarry use.

The current sample of recorded Hozomeen chert procurement locations is influenced more by the cultural resource management priorities of land-managing agencies than it is by a cultural resource research design. Consequently, in both Washington and adjacent British Columbia, there remain large tracts of land within the Hozomeen Terrane that have never been surveyed for toolstone quarries or, for that matter, archaeological sites of any kind. Our experience in this rugged terrain leads us to believe that many quarry locations remain unrecorded.

Whereas bedrock outcrops are concentrated sources of toolstone, Hozomeen chert was also procured from secondary gravel sources, particularly on moraines, glacial terraces, and alluvial fans (Bush et al. 2009; Mierendorf 1993; Mierendorf et al. 1998). As a result of natural dispersal mechanisms, usable nodules of toolstone-quality Hozomeen chert were carried beyond primary bedrock outcrops. When the Cordilleran ice sheet last filled the upper Skagit River valley, it overrode all but the highest peaks, plucking fragments of chert from bedrock and spreading them as "float" boulders and cobbles across the landscape. During the Evans Creek stade (ca. 17,000 years ago), the Skagit River was temporarily blocked by a Baker River alpine glacier (Riedel 2011). Its flow was diverted south to the upper Stillaguamish River, an event that is likely to have delivered Hozomeen chert gravels into the lower Stillaguamish-Skykomish-Snoqualmie River basins.

Riedel et al. (2010) sampled till and counted clast lithologies, including Hozomeen chert, to infer the origin and movement of glaciers in the Skagit River valley. Near the mouth of Big Beaver Valley, 1 km from the Hozomeen chert bedrock sources, Hozomeen chert clasts comprised 12 percent of ice sheet till and 4 percent of alpine till from that valley. In the Marblemount vicinity 50 km downstream from bedrock sources, Hozomeen chert is common in gravel clasts of glacial outwash terraces and in Skagit River gravel bars. Near the mouth of Baker River 70 km downstream, alpine till contained 2 percent Hozomeen chert (Riedel et al. 2010). Clasts of Hozomeen chert have been reported from as far away as the beach gravels of Camano Island (Schalk and Nelson 2010), 130 km from the closet known bedrock outcrops.

Cumulatively, these data suggest that secondary sources of Hozomeen chert toolstone extend well beyond the source bedrock and that the geographic extent of this toolstone in northern and central Puget Sound is poorly understood. Presently, the

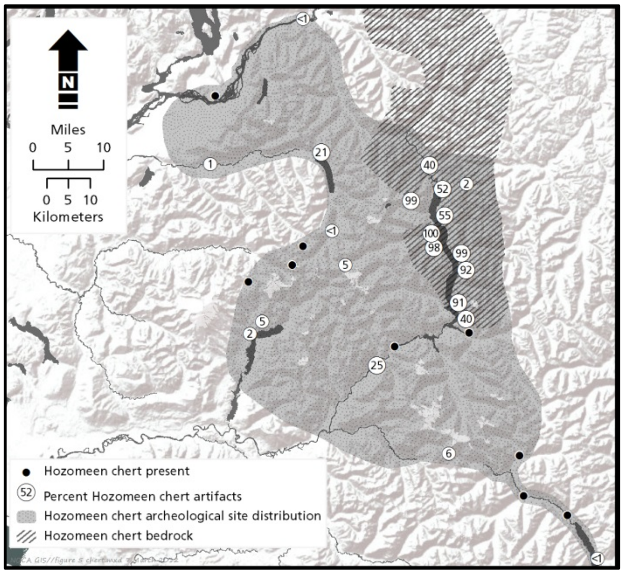

Figure 6-5. Map of archaeological assemblages in the North Cascades containing Hozomeen chert.

geography of both primary and secondary chert sources cannot be inferred with any certainty, and it is likely that more procurement locations will be identified.

Artifacts Correlated to Hozomeen Chert Sources. Hozomeen chert is the dominant toolstone in archaeological sites in the middle and southern areas of Ross Lake, particularly in the vicinity of Lightning Creek, where it comprised 95 percent of flaked stone categories in a sample (n=2447) from 44 archaeological sites (Mierendorf et al. 1998:71-78). Interestingly, this area lies within the driest part of the rain shadow created in the lee of the Picket Range. Reduced snow accumulation here created favorable wintering grounds for ungulates, which is consistent with ethnohistoric evidence for winter hunting in the upper Skagit River valley (Teit 1900). Evidence for winter hunting also comes from archaeofaunal remains and protein residues on stone tools, representing mountain goat, deer, elk, and mountain sheep (Bush et al. 2009; Mierendorf et al. 1998). In this core area, non-quarry campsites also contain abundant Hozomeen chert debitage, and some campsites (45WH262 in particular) served as centers for the production of intermediate and late-stage Hozomeen chert bifaces (Mierendorf et al. 1998). Away from this core area, the proportion of Hozomeen chert decreases rapidly while the proportion of the dominant metasediment toolstone increases to levels more commonly found elsewhere in the park.

Archaeological sites containing Hozomeen chert are mapped in Figure 6-5. The line-hatched area shows the bedrock occurrence of the Hozomeen Terrane rocks (boundaries approximate), and the shaded-stippled polygon shows the areal extent of Hozomeen chert in archaeological sites. Numerals inside circles indicate the percentage of Hozomeen chert in site assemblages. Data are from excavated archaeological assemblages where the total lithic sample exceeded 100 items (except for sites on Little Beaver ridge and Whatcom Pass, where data from surface assemblages of lithics >75 are used). Due to the map scale, no attempt was made to plot all assemblages inventoried in the Ross Lake area.

The highest percentages in Figure 6-5 are proximal to Hozomeen chert bedrock outcrops, and values exceeding 90 percent are quarries, all of which are in the upper Skagit River valley (Bush et al. 2009; Franck 2000; Mierendorf 1993, 2004; Mierendorf et al. 1998). Away from bedrock sources, the proportion of Hozomeen chert decreases to ≤20 percent at distances of 10-20 km and trails off from there at greater distances. Sites at Newhalem (Figure 6-5), located just below the Skagit River gorge, measured 25 percent Hozomeen chert due to their proximity to secondary gravel procurement sources (Mierendorf and Harry 1993).

This rapid fall-off rate in Hozomeen chert percentages matches closely other distance-decay trends reported in widespread areas. Some consider this pattern to ". . . reflect optimization of the time and energy trade-offs inherent in the procurement of stone raw materials from geographically adjacent *vs.* geographically distant sources. . . " (Brantingham 2003:489-490). In the southern Washington Cascades, rapid distance-decay in toolstone proportion was measured by tracking the distribution of artifacts sourced to the Elk Pass obsidian quarry (45LE286). This toolstone was geochemically traced across a 52 km^2 expanse of the Cowlitz watershed. McClure noted a "dramatic fall-off pattern", represented by just 14 percent obsidian in the assemblage at 45LE285, located 11 km west of the Elk Pass source (McClure 1998:68). Elk Pass obsidian has been recovered only from sites in the Cowlitz River watershed, in contrast to the North Cascades toolstone, which circulated to many watersheds adjacent to the Skagit River's.

Key data points in tracing the eastern circulation of Hozomeen chert are provided by archaeological assemblages east of the Cascade Range crest. From Cascade Pass (45CH221) it has been traced to a series of sites in the lower Stehekin River valley that includes High Bridge (45CH69) and Buckner Orchard (45CH412). The Grade Creek site (45CH640), where a late-style projectile point of Hozomeen chert was excavated (Figure 6-4j; Ozbun et al. 2005), is the easternmost of all, located midway down Lake Chelan, 120 km east of the quarry complex. In the extreme northeastern North Cascades, Reimer (2000) identified a single piece of Hozomeen chert from a site in the Cathedral Peak vicinity. There is evidence that the western margin of the Okanogan lobe of the Cordilleran ice sheet topped the Cascade crest and extended some 80 km southwest into the upper Skagit Valley (Riedel 2011), thus eliminating glacial transport as an explanation for Hozomeen chert's presence east of the Cascade crest.

Key sites marking the western extent of Hozomeen chert are at Whatcom Pass (45WH631) and on Copper Ridge (45WH484, 45WH481 and 45WH551). To the northwest, Hozomeen chert usage is documented in pithouse village sites DiRj1 (Lenert 2007) and DhRk8 (LeClair 1976; Schaepe 1999) along the Fraser River of British Columbia. Artifact photos published in LeClair (1976:Figure 16-17) along with the description "crypto-crystalline grey chert" recorded several physical characteristics distinctive to Hozomeen chert. In 1997, Dave Schaepe made the Maurer Site (DhRk8) collection available for examination, leading to confirmation that at least several bifaces in this collection are made of Hozomeen chert. Solid dots in Figure 6-5 designate the presence of Hozomeen chert artifacts where quantitative data are not available.

Outlier artifacts of Hozomeen chert extend to northern and eastern Puget Sound. They include several possible Western-stemmed lanceolate forms. Among the most distant (145 km from quarry complex) is a stemmed, partially shouldered point (Figure 6-4g) found in Ebey's Prairie on central Whidbey Island (R. Schalk and George Bishop, personal communication 2007). Schalk and Nelson (2010) report Hozomeen chert tools and debitage from a late-period shell midden on western Camano Island. At King Lake in eastern Snohomish County, a large contracting-stem and shouldered Hozomeen chert biface was collected recently from private property and donated to the Burke Museum of Natural History and Culture; it represents an unambiguous example of Western-stemmed biface technology (Figure 6-4h). In central Puget Sound, a serrated lanceolate Olcott point (Figure 6-4f) was recovered from the Lynnwood, Washington, area in western King County.

Hozomeen chert artifacts were identified by the authors in archaeological collections curated at the Hibulb Cultural Center and Natural History Preserve in Marysville and at the Burke Museum. At the former, two display artifacts (a flake tool and a lanceolate biface) from 45SN100 (Biderbost/Duvall site along the Snoqualmie River) perfectly matched reference samples of Hozomeen chert. At the latter location, the authors inspected several hundred artifacts from a much larger 45SN100 collection. Based on a nonsystematic, opportunistic sampling of the collection's level bags, nearly 5 percent of the observed lithic specimens (mostly debitage, but including some formed tools and diagnostics) were made of Hozomeen chert. Although the source locations of this toolstone were unknown to the artifact catalogers, most level-bag descriptions captured the main visual characteristics of Hozomeen chert with descriptors such as "gray chert", "gray chalcedony w/dark gray mottling", "chalcedony, gray, with black non-linear banding", and "lt. gray chert w/black & white banding and small black inclusions." Based on a much lesser effort and a smaller sample of lithic artifacts from site 45KI9A (Marymoor Farm, Sammamish River valley, 150 km from the quarry complex), also curated at the Burke Museum, we observed two artifacts (a side-notched point and a flake scraper) that matched our reference specimens. The artifacts-to-Hozomeen chert correlations for 45SN100 are inconsistent with earlier claims that toolstone from the Skagit basin was not used in the Snoqualmie River valley (Nelson 1962).

At its widest extent, Hozomeen chert was found between the Fraser River to the northwest, across the Cascade crest to the southern end of Lake Chelan in the southeast, in northern and eastern Puget Sound, and as far south as Lake Sammamish, an area covering over 25,000 km^2. Historically, this broad area encompasses portions of the territories of Coast and Interior Salish populations in both the

Northwest Coast and Plateau Culture Areas.

Chronology of Use. A compilation of 70 radiocarbon age estimates (Table 6-1) from anthropogenic contexts directly associated with Hozomeen chert shows long usage as a toolstone beginning in early Holocene times. There is a weak tendency for dates to cluster in four time periods (in radiocarbon years before present): 150-600, 1000-2800, 3600-5400, and 6100-8000.

The earliest well-dated use of Hozomeen chert comes from three excavated archaeological sites, two in the core of the quarry complex (45WH220 and 45WH224) and one at a distant alpine pass (45CH221). The first two are bedrock quarries where reduction activities ranged from removal of nodules from bedrock to cortex cleaning to core and biface blank preparation. The other is a multicomponent campsite where Hozomeen chert was recovered from below primary Mazama O tephra (6730 radiocarbon years) in association with a radiocarbon age of 7980±60 (Table 6-1). This date is consistent with the 7640 radiocarbon years before present age estimate from the earliest quarry assemblage at 45WH224. This early period of Hozomeen chert use generally coincides with the appearance of forests in the upper Skagit River valley, based on paleoecological reconstruction from data in two lake cores in the valley (Spooner et al. 2008). The abundance of dates after about 5400 years ago may indicate maximum use of Hozomeen chert in the middle and late Holocene (Mierendorf et al. 1998; Rousseau 1988). Its use continued to just prior to historic contact.

Based on morphologies of regionally time-sensitive bifaces, Hozomeen chert was fashioned into a variety of lanceolate forms affiliated with early and middle Holocene Olcott and Cascade technologies (e.g., Figure 6-4f), dated about 9,000-5,000 radiocarbon years before present. Two Hozomeen chert artifacts affiliate with Western-stemmed technology (Figure 6-4g and 6-4h) which is dated between about 11,300 and 8,300 radiocarbon years ago (Jenkins et al. 2012; Reid 2011). More recent time-sensitive types and radiocarbon age estimates attest to its use through middle and late pre-contact time periods. One late-period point is from a shell midden dated 1,130-1,700 radiocarbon years before present on the west shore of Camano Island, where a small number of Hozomeen chert toolstone artifacts was excavated, and where several beach gravels assigned to Hozomeen chert were found, suggesting procurement from a secondary source (Schalk and Nelson 2010). Another late style Hozomeen chert point was recovered from lower Lake Chelan and dated 450±60 (Ozbun et al. 2005). Generally, the temporal span represented by all Hozomeen chert time-diagnostic artifacts is consistent with the Table 6-1 radiocarbon data and it is coeval with the early spread of obsidian trade across the region (Carlson 1994).

In the late nineteenth century James Teit recorded *Nlakápamux* (Lower Thompson) elder recollections of traveling to the headwaters of the Skagit River to hunt animals and to find stone to make arrowheads (Teit 1900). The types of toolstone are not specified, and given its abundance in the area, Hozomeen chert is likely to have been one of them. A linguistic link to *Nlakápamux* use of the chert derives from the origin of the word Hozomeen, which in the *Nlakápamux* language and means “sharp, like a sharp knife” (elder Annie York cited in Akrigg and Akrigg 1986; M. Dale Kinkaid, personal communication; Mierendorf 1993). Among ethnohistoric records in the project area, Teit (1900) is unique in providing the only specific reference to indigenous procurement of toolstone in proximity to the Hozomeen chert quarry complex and its link to winter hunting of ungulates. This ethnohistoric evidence suggests that traditional knowledge of toolstone procurement in the upper Skagit River valley persisted well into the historic period.

Technological Uses. The quality of Hozomeen chert toolstone for flaking technologies varies from very poor to good and its use was conditioned by several overriding physical characteristics. Because only a small volume of most bedrock outcrops consists of good toolstone, acquiring usable nodules entailed a high degree of efficient primary reduction. The process required judicious selection of nodules and removal of waste, resulting in large volumes of quarry debris (shatter, broken flakes, and hammerstones). Because much of the chert groundmass is heterogeneous, it breaks easily along quartz veins and related metamorphic “impurities”, resulting in high failure rates. Nevertheless, due to the vast expanse of bedrock available for quarrying, the evidence reveals that large nodules of high toolstone quality were regularly procured. In tool production and use, Hozomeen chert is difficult to flake but its thin margins are sharp and durable. A controlled heat-treatment experiment on Hozomeen chert samples collected from several quarries in North Cascades National Park (including 45WH224) showed no significant improvement in flaking qualities and in some cases, flaking quality noticeably decreased (Nelson 1995). Nelson observed that chert of high quality prior to heat treatment was most likely to be improved, but he concluded that the energetic costs of treatment far exceeded any increase in workability. He also noted that visible changes in the chert following heat treatment were insufficient for identification of heat treatment in artifacts (Nelson 1995).

Pre-contact inhabitants of the upper Skagit River valley relied on Hozomeen chert to produce large to small bifaces, multidirectional flake cores and flake tools, and microblades from prepared cores. Evidence of blade production from a “Levallois-like” core or other macroblade technologies (Ozbun and Fagan 2010) on Hozomeen chert is entirely lacking. Stages of biface manufacture were often spatially separated, with early-stage reduction being characteristic of quarry procurement locations and late-stage reduction located at temporary base camps within a few kilometers of the quarries (Iversen et al. 2012; Mierendorf et al. 1998). Despite the evidence of extensive quarrying in the valley, Hozomeen chert was less used for projectile points compared with metasediment toolstone, based on a sample of 117 diagnostic bifaces (Mierendorf et al. 1998). This may reflect the importance of Hozomeen chert for use as bifacial cores and more generalized, portable tools associated with a highly mobile toolkit (Kelly 1988; Rasic and Andrefsky 2001). The microblade core and microblade artifact categories (n=38 in the aggregated lithic assemblage from Ross Lake) each revealed Hozomeen chert to be the dominant toolstone (61 percent and 80 percent, respectively) (Mierendorf et al. 1998) in this technology. At DgRg2 along the Skagit River near Hozomeen, Rousseau (1988) documented use of Hozomeen chert for situational expedient tools consisting of minimally retouched flakes that functioned as cutting and scraping tools. Also in the Skagit River valley about 32 km further south, at a small late period work station (45WH239), Bush et al. (2008) conducted detailed edge-wear analysis that revealed tool edge modifications consistent with use of Hozomeen chert flake tools for processing plant materials. At a large nearby site dated 5,000 years old (45WH241), Bush et al. (2009) excavated a complex of six cookstone hearths, burned mammal bones, and abundant Hozomeen chert flaking debris and tools. To date, this is the only full-scale excavation in the quarry complex of a large hunting-related campsite that functioned also as a quarry.

Vitrophyre of the Hannegan Volcanics

Physical and Chemical Properties. Vitrophyre, or porphyritic obsidian, is a volcanic rock with a glassy groundmass in which small feldspathic crystals (phenocrysts) are embedded. Phenocrysts, typically 1-3 mm long, occur randomly in the matrix and disrupt the otherwise isotropic, conchoidally fracturing groundmass. Toolstone-quality vitrophyre has few phenocrysts, displays fracture properties similar to those of obsidian, but accounts for only a small portion of source material observed in outcrops (Figure 6-6).

Hand specimens of geologic and artifact vitrophyre samples (n=154) from the park's collection were characterized macroscopically. Geologic specimens (n=67) were collected and sampled from nine named outcrops (designated by Roman numerals i through ix) on Copper Ridge in the northwest corner of the park. The artifact specimens (n=87) were selected from 20 pre-contact archaeological sites located either on Copper Ridge or within 7.5 km of Copper Ridge. Based on macroscopic observations of unweathered fracture surfaces of outcrops and geologic samples, the vitrophyre of Copper Ridge falls into two distinct macroscopic types (Figure 6-6c and 6-6d).

Type 1 is a nearly opaque black to greenish-black glassy matrix, found in massive or blocky habit. Thin margins (1-2 mm thick) are occasionally translucent with a dark greenish-gray color. Fracture pattern is conchoidal, subconchoidal, uneven, or hackly, and the luster grades from dull to vitreous. Phenocrysts tend to be large (typically 2-3 mm on a side) and of opaque white mineralization, which may exhibit a thin red stain on its margins. Occasionally, alternating gray bands resembling flow lines and mottled gray spherulites appear in the glassy matrix. A hydration rind of light gray color is sometimes present. Type1 vitrophyre has been recorded on the southern end

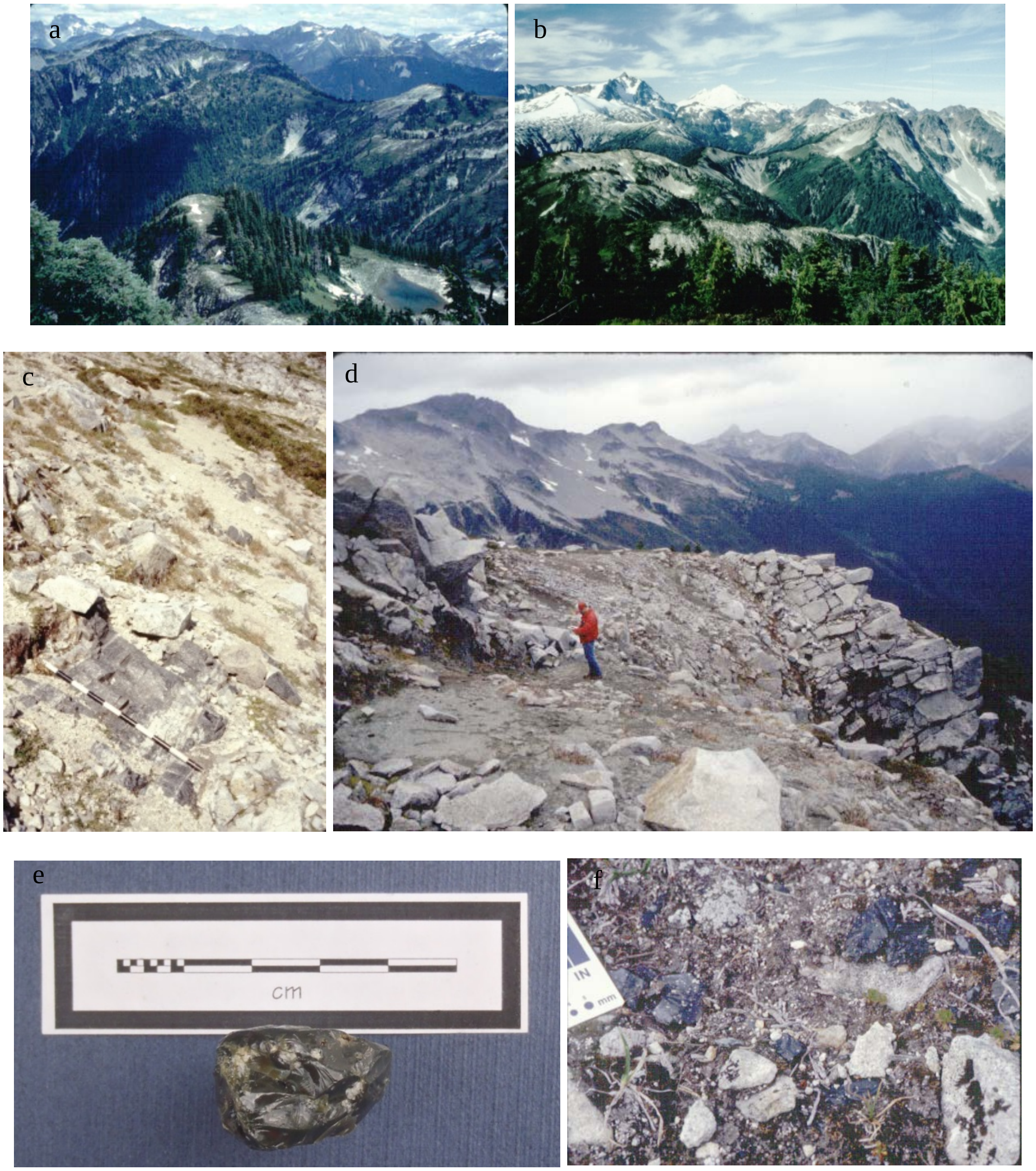

Figure 6-6. Photographs of Hannegan volcanics quarry complex outcrops, artifacts, and macroscopic appearance. (a) Hannegan volcanics quarry complex, upper Chilliwack River watershed, taken from northern end of Hannegan caldera, outcrops iv and vii of Hannegan volcanics vitrophyre and headwaters of Silesia River foreground, Copper Ridge center. (b) Upper Chilliwack River watershed and Copper Ridge foreground, in the Hannegan volcanics quarry complex, Mount Baker on the horizon photo center. (c) Outcrop i of Hannegan volcanics vitrophyre, one of several sources of geochemical Copper Ridge Variety A near the Hannegan caldera rim; 1 m thick dike appears as black groundmass exhibiting light gray bands; discontinuous outcrops visible in middle and far distance for ca. 50 m. (d) Outcrop ii is the source of Copper Ridge Variety B; dike is visible as black stratum in rock face left of figure. (e) Close-up of fresh conchoidal fracture surface on typical reniform nodule from outcrop ii, Copper Ridge Variety B. (f) In situ primary reduction scatter of broken flakes and shatter of Hannegan volcanics vitrophyre, Copper Ridge Variety A, quarry site 45WH478.

Table 6-1. Radiocarbon Chronology of Hozomeen Chert Use.

Sample Lab. Number	Site No.	Reference	Conventional Radiocarbon Age
Hozomeen Chert Radiocarbon Age Estimates			
Beta-234921	45WH239	Bush et al. 2008	150±40
Beta-249111	45WH241	Bush et al. 2009	190±40
Beta-249119	45WH241	Bush et al. 2009	220±40
Beta-40693	45WH237	Mierendorf et al. 1998	230±40
Beta-249112	45WH241	Bush et al. 2009	230±80
Beta-249114	45WH241	Bush et al. 2009	230±40
Beta-249118	45WH241	Bush et al. 2009	240±60
Beta-72999	45WH477	Mierendorf 1997	260±70
Beta-72998	45WH477	Mierendorf 1997	280±60
Beta-33522	45WH224	Mierendorf 1993	290±80
Beta-33508	45WH228	Mierendorf et al. 1998	310±70
Beta-40703	45WH304	Mierendorf et al. 1998	330±70
Beta-249113	45WH241	Bush et al. 2009	360±40
Beta-179024	03/903-19	Ozbun et al. 2005	450±60
Beta-303702	45WH253	Iversen et al. 2012	510±30
Beta-40697	45WH253	Mierendorf et al. 1998	580±80
Beta-64822	45WH262	Mierendorf et al. 1998	1020±80
Beta-73000	45WH477	Mierendorf 1997	1110±100
Beta-64821	45WH262	Mierendorf et al. 1998	1120±80
No Data	DgRg4	Bush et al. 2009	1160±40
WSU-3411	45WH477	Mierendorf 1997	1350±60
Beta-134367	45WH220	Mierendorf 2004	1360±50
Beta-249110	45WH241	Bush et al. 2009	1370±40
Beta-40702	45WH283	Mierendorf et al. 1998	1380±110
Gak-4921	DhRk8	Schaepe 1998	1410±90
Beta-53859	45WH239	Mierendorf et al. 1998	1430±120
Beta-40696	45WH241	Mierendorf et al. 1998	1430±90
Beta-64824	45WH300	Mierendorf et al. 1998	1650±70
Beta-249117	45WH241	Bush et al. 2009	1750±40
Beta-64826	45WH300	Mierendorf et al. 1998	1750±60
Beta-40701	45WH268	Mierendorf et al. 1998	1760±80
Beta-33512	45WH224	Mierendorf 1993	1830±60
Beta-40695	45WH241	Mierendorf et al. 1998	1890±90
Beta-64825	45WH300	Mierendorf et al. 1998	1940±90
N-1641	45SN100	Nelson 1976	2000±80
Beta-209505	45CH221	Mierendorf and Foit 2008	2050±80
Beta-250064	45CH221	Mierendorf and Foit 2008	2170±40
Beta-128242	DgRk10	Merchant et al. 1999	2190±100
AA-70611[1]	DiRj1	Lenert 2007	2356±33
Beta-223576	45CH221	Mierendorf and Foit 2008	2400±50
Beta-234920	45WH239	Bush et al. 2008	2460±40
Beta-128241	DgRk10	Merchant et al. 1999	2620±60
Beta-234919	45WH239	Bush et al. 2008	2740±60
Beta-27498	45WH224	Mierendorf 1993	2800±120
WSU-3814	45WH224	Mierendorf 1993	3600±130

Table 6-1 (continued). Radiocarbon Chronology of Hozomeen Chert Use.

Sample Lab. Number	Site No.	Reference	Conventional Radiocarbon Age
Hozomeen Chert Radiocarbon Age Estimates			
Beta-305571	45WH253	Iversen et al. 2012	3820±30
Beta-134368	45WH220	Mierendorf 2004	3840±120
Beta-33513	45WH224	Mierendorf 1993	3980±70
Beta-33514	45WH224	Mierendorf 1993	3980±80
Beta-33515	45WH224	Mierendorf 1993	4000±90
Beta-33516	45WH224	Mierendorf 1993	4090±90
Beta-128607	DgRk10	Merchant et al. 1999	4130±40
Gak-4919	DhRk8	Schaepe 1998	4220±100
Gak-4922	DhRk8	Schaepe 1998	4240±380
WSU-3813	45WH224	Mierendorf 1993	4470±200
Beta-33519	45WH224	Mierendorf 1993	4590±80
Beta-33521	45WH224	Mierendorf 1993	4790±70
Beta-249115	45WH241	Bush et al. 2009	5020±40
Beta-249116	45WH241	Bush et al. 2009	5030±40
Beta-33520	45WH224	Mierendorf 1993	5030±100
Beta-223577	45CH221	Mierendorf and Foit 2008	5390±70
No Data	DgRg4	Bush et al. 2009	5850±50
Beta-250065	45CH221	Mierendorf and Foit 2008	6170±50
Beta-134369	45WH220	Mierendorf 2004	6540±290
Beta-209506	45CH221	Mierendorf and Foit 2008	6730±70
Beta-214644	45CH221	Mierendorf and Foit 2008	7000±90
Beta-33518	45WH224	Mierendorf 1993	7640±150
Beta-209504	45CH221	Mierendorf and Foit 2008	7730±70
Beta-214642	45CH221	Mierendorf and Foit 2008	7980±60

[1]Radiocarbon age from Housepit 2, associated with Hozomeen chert

of Copper Ridge, in outcrop i and outcrops iii through ix.

Outcrop x, discovered later than the other outcrops and at a distance, has not been characterized macroscopically yet. In the main, samples from outcrop x resemble Type 1 vitrophyre.

Type 2 is a translucent brownish-green to grayish-green glassy matrix, found in interlocking spheroid-reniform nodules each typically less than 5 cm long. Translucent margins are common and show colors from dusky yellow gray to light olive gray. Fracture pattern is very conchoidal to conchoidal and the luster is uniformly vitreous. Phenocrysts tend to be small (typically 1 to 2 mm on a side) and of either opaque white mineralization or dark lamellar crystals resembling biotite mica. Rarely, isolated thin gray bands appear in the glassy matrix, and a light gray hydration rind is also sometimes present. Type 2 vitrophyre has been recorded only at outcrop ii some 6 km north of the Type 1 outcrop cluster.

In both types, a small percentage of phenocrysts may be replaced by open voids, as if the earlier mineralization phase chemically weathered out.

In addition to the macroscopic description, vitrophyre samples were also submitted to energy dispersive X-ray fluorescence (XRF) trace element analysis. The analysis of geologic samples (n=67) from outcrops i through ix provided data on 14 trace elements or trace-element groups, as measured in parts per million (ppm). Cluster analysis then determined that two trace elements, Strontium (Sr) and Zirconium (Zr), were most diagnostic in defining geochemical groups that had the lowest intrasource variability and the highest intersource variation (Skinner 1998b:5). Table 6-2 tabulates all Zr-Sr data for the geologic toolstone

Table 6-2. XRF Geochemical Data on Hannegan Volcanics Bedrock Samples.

Sample type	Provenience	Assigned source	Confidence	Zr (ppm)	Sr (ppm)	Catalog No.	Lab No.	Reference
Hannegan Volcanics Vitrophyre								
Geologics (n = 67)	outcrop i	Variety A	Good	184	97	18072	65	Report 98-67
				201	85	18065	108	Report 98-67
				203	109	18052	96	Report 98-67
				223	77	18099	91	Report 98-67
		Outlier	N/A	119	139	18093	85	Report 98-67
				313	137	18058	101	Report 98-67
		Unassigned	N/A	204	82	10168	179	Report 96-30
	outcrop ii	Variety B	Good	101	93	18068	111	Report 98-67
				108	90	18073	66	Report 98-67
				109	86	18087	80	Report 98-67
				112	122	18060	103	Report 98-67
				114	108	18071	114	Report 98-67
				116	108	18055	98	Report 98-67
				130	120	18048	92	Report 98-67
				138	122	18077	70	Report 98-67
		Outlier	N/A	183	64	18092	84	Report 98-67
		Unassigned	N/A	105	141	100001	145	Report 96-30
				106	75	100008	152	Report 96-30
				115	124	100003	147	Report 96-30
				116	93	100007	151	Report 96-30
				117	90	100006	150	Report 96-30
				119	103	16552	180	Report 96-30
				120	110	100002	146	Report 96-30
				124	123	100005	149	Report 96-30
				131	116	16553	181	Report 96-30
				138	126	100004	148	Report 96-30
	outcrop iii	Variety A	Good	187	66	18064	107	Report 98-67
				187	84	18085	78	Report 98-67
				189	67	18056	99	Report 98-67
				190	72	18079	72	Report 98-67
				194	72	18076	69	Report 98-67
				196	83	18062	105	Report 98-67
				197	63	18061	104	Report 98-67
				204	72	18094	86	Report 98-67
				211	89	18091	83	Report 98-67
		Unassigned	N/A	179	85	100011	155	Report 96-30
				182	67	100012	156	Report 96-30
				186	69	100013	157	Report 96-30
				189	119	100014	158	Report 96-30
				190	61	100009	153	Report 96-30
				190	64	100010	154	Report 96-30
	outcrop iv	Variety A	Good	226	113	18088	81	Report 98-67
				235	97	18080	73	Report 98-67
				243	84	18070	113	Report 98-67
				250	85	18081	74	Report 98-67
		Outlier	N/A	216	189	18057	100	Report 98-67
	outcrop v	Variety C	Good	286	102	18063	106	Report 98-67
				311	132	18075	68	Report 98-67
				314	124	18090	82	Report 98-67
				317	126	18069	112	Report 98-67
				319	131	18097	89	Report 98-67
	outcrop vi	Variety A	Good	243	90	18053	97	Report 98-67
				246	73	18082	75	Report 98-67
				263	76	18095	87	Report 98-67
	outcrop vii	Variety A	Good	223	106	18086	79	Report 98-67
				224	99	18049	93	Report 98-67
				232	103	18096	88	Report 98-67
				237	99	18083	76	Report 98-67
	outcrop viii	Variety A	Good	185	64	18059	102	Report 98-67
				186	66	18051	95	Report 98-67
		Outlier	N/A	160	56	18067	110	Report 98-67
	outcrop ix	Variety D	Good	250	171	18066	109	Report 98-67
				254	139	18050	94	Report 98-67
				257	174	18078	71	Report 98-67
				264	189	18084	77	Report 98-67
				271	174	18074	67	Report 98-67
				283	139	18098	90	Report 98-67

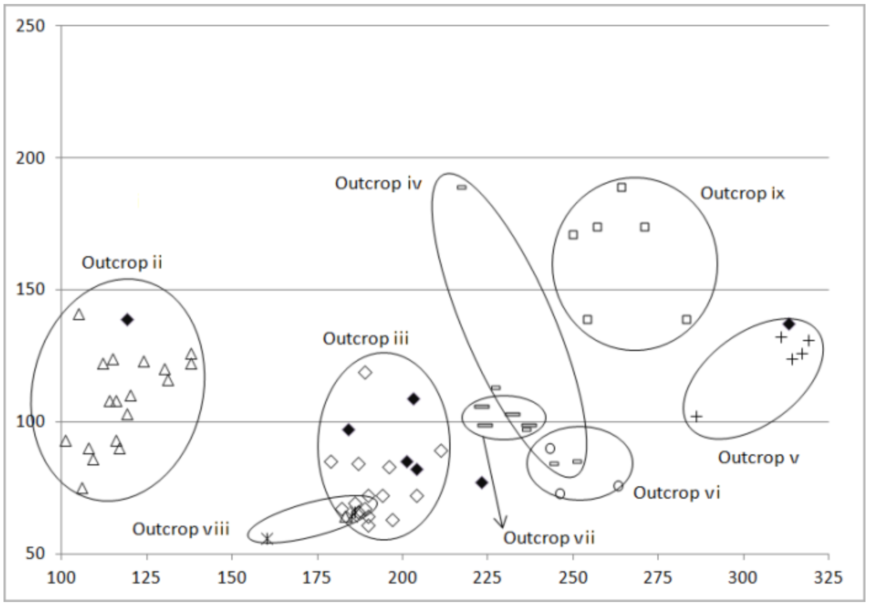

Figure 6-7. Scatterplot shows the amount of the trace elements Zirconium (Zr) on the x-axis and Strontium (Sr) on the y-axis, in parts per million, for all geologic samples collected from vitrophyre outcrops on Copper Ridge (Skinner 1998b, Skinner and Davis 1996). Eight symbols and ellipses designate outcrops: triangle--outcrop ii; diamond--outcrop iii; short bar--outcrop iv; cross--outcrop v; circle--outcrop vi; long bar--outcrop vii; star--outcrop viii; square--outcrop ix. Outcrop i (black diamond) possessed high intrasource variation obscuring visibility of the data clusters for outcrops ii, iii, and v, so an ellipse is not shown. Outcrop x is not included here as it lacks XRF data.

samples, and the same geologic XRF results are graphed in Figure 6-7.

In XRF analysis, tight Zr-Sr geochemical groupings with low intrasource variation tended to cluster on certain outcrops, while other outcrops displayed much higher intrasource variation, yielding Zr-Sr geochemical signatures that were non-diagnostic. High intrasource variation may result from two separate factors: uneven, hackly surfaces on samples may cause unpredictable reflection of the X-ray beam; and high phenocryst density in samples may interfere with the XRF process, which is diagnostic primarily for glassy and fine-grained extrusive volcanic toolstone types (Skinner 1998b:4-5).

Ignoring geochemical outliers and other anomalous XRF results, four geochemical groups were confidently identified as distinct Copper Ridge varieties and are designated as Varieties A-D (Skinner 1998b) (Figure 6-8). With few exceptions, these four geochemical source varieties correlate well with the physical outcrops on Copper Ridge and differentiate from other known geochemical signatures of Pacific Northwest glassy and fine-grained extrusive toolstone.

Six of the outcrops (i, iii, iv, vi, vii, and viii) define Variety A and are located at the southern end of Copper Ridge, where they are associated geophysically with the northern rim of the collapsed Hannegan caldera (Figure 6-6a and 6-6b). Outcrop v (Variety C) and outcrop ix (Variety D) are also located on the southern end of Copper Ridge, and the southern cluster of outcrops as a whole form a tight 2.3 km^2 geographical grouping.

Outcrop ii (Variety B) is a small exposure of vitrophyre about 1 m x 2 m in size (Figure 6-6d), located in the north-central section of Copper Ridge 6 km north of the furthest extent of Hannegan volcanics rocks as mapped by Tucker (2006). A tenth outcrop (outcrop x) was recorded in 2004 on the ridgeline connecting Copper Ridge with Copper Mountain to the northwest. Samples from outcrop x have not yet been characterized by XRF analysis. Elevations for these bedrock sources on Copper Ridge span from subalpine (1,370 m above sea level) to alpine zones (2,000 m above sea level). All outcrops except outcrop x are proximal to likely access routes running along the top of Copper Ridge, which links the Chilliwack watershed in the north with the Nooksack and Baker watersheds to the south.

Geochemical outliers and anomalous XRF results do exist in the dataset. For example, outcrop i (Figure 6-7; Table 6-2) exhibited high intrasource variation and thus yielded non-diagnostic XRF results. Outcrop i results were spread across three other well-defined geochemical groups (Varieties A, B, and C) of vitrophyre and are assumed to have

Table 6-3. XRF Geochemical Data of Artifacts Correlated to Bedrock Samples.

Sample type	Provenience	Assigned source	Confidence	Zr (ppm)	Sr (ppm)	Catalog No.	Lab No.	Reference
Hannegan Volcanics Vitrophyre								
Artifacts (n = 87)	45WH455	Variety A	Good	168	79	18046	63	Report 98-67
				178	64	18042	59	Report 98-67
				183	81	18029	46	Report 98-67
				187	68	18014	31	Report 98-67
				191	63	18025	42	Report 98-67
	45WH462	Variety B	Good	104	97	10126	5	Report 98-67
				112	101	10123.2	3	Report 98-67
				113	103	10128.4	10	Report 98-67
				115	90	10124	4	Report 98-67
				116	97	10128.2	8	Report 98-67
				119	112	10128.1	7	Report 98-67
				120	115	10128.3	9	Report 98-67
			Low	116	139	10127	6	Report 98-67
				124	138	10123.1	2	Report 98-67
	45WH478	Variety A	Good	214	108	18030	47	Report 98-67
	45WH479	Variety A	Good	188	77	18024	41	Report 98-67
				190	89	18013	30	Report 98-67
				191	68	18009	26	Report 98-67
				199	77	6716	167	Report 99-53
				205	102	18005	22	Report 98-67
				206	78	18038	55	Report 98-67
	45WH480	Variety A	Good	226	124	18044	61	Report 98-67
				234	118	18019	36	Report 98-67
				237	104	18017	34	Report 98-67
				249	102	18043	60	Report 98-67
				259	64	18036	53	Report 98-67
	45WH481	Variety A	Good	182	78	6537.1	198	Report 99-53
				186	98	18034	51	Report 98-67
				187	82	18047	64	Report 98-67
				190	77	18035	52	Report 98-67
				190	87	18022	39	Report 98-67
			Low	176	129	18003	20	Report 98-67
	45WH482	Variety B	Good	116	112	18041	58	Report 98-67
	45WH484	Variety B	Good	103	87	17388	16	Report 98-67
				106	98	17389	17	Report 98-67
				113	104	16556	12	Report 98-67
				119	93	17370	183	Report 99-53
				120	94	10085	1	Report 98-67
				120	119	17374	15	Report 98-67
				128	92	17368	182	Report 99-53
				132	109	17376	184	Report 99-53
			Low	109	150	16558	13	Report 98-67
			Small size	116	85	17383	200	Report 99-53
				118	107	17362	14	Report 98-67
		Unknown	N/A	187	179	17479	185	Report 99-53
		Unassigned	N/A	122	96	16557	175	Report 96-30
				123	101	16554	173	Report 96-30
	45WH486	Variety A	Good	190	77	18007	24	Report 98-67
		Variety B	Good	120	94	10829	169	Report 99-53
	45WH503	Variety B	Good	111	95	18023	40	Report 98-67
				114	94	18040	57	Report 98-67
				115	95	18032	49	Report 98-67
				124	107	18021	38	Report 98-67
				130	102	18039	56	Report 98-67
			Small size	128	103	18012	29	Report 98-67
	45WH505	Variety A	Good	188	73	18026	43	Report 98-67
				227	130	18020	37	Report 98-67
				238	98	18037	54	Report 98-67
				255	64	18010	27	Report 98-67
		Variety D	Low	240	149	17236	199	Report 99-53
				250	143	18031	48	Report 98-67
	45WH515	Variety B	Good	130	108	12314	11	Report 98-67
	45WH549	Variety A	Good	177	97	18008	25	Report 98-67
		Variety B	Good	113	85	18028	45	Report 98-67
	45WH551	Variety A	Good	182	75	19508	186	Report 99-53
				183	63	19510.1	188	Report 99-53
				185	78	19510.2	189	Report 99-53
				198	82	19510.3	190	Report 99-53
		Variety B	Good	114	98	19509	187	Report 99-53
		Unknown	N/A	163	250	18011	28	Report 98-67
	45WH554	Variety A	Good	223	103	18006	23	Report 98-67
				226	96	18001	18	Report 98-67
				227	111	18004	21	Report 98-67
				235	111	18015	32	Report 98-67
				252	107	18045	62	Report 98-67
	45WH555	Variety A	Good	185	90	18018	35	Report 98-67
				207	87	18033	50	Report 98-67
			Low	191	149	18027	44	Report 98-67
				257	135	18002	19	Report 98-67
	45WH631	Variety B	Good	109	93	22183.1	201	Report 03-41
			Small size	106	89	22183.2	202	Report 03-41
				117	102	22183.3	203	Report 03-41
	DgRi2	Variety B	Good	110	108	200002	192	Report 99-53
				127	88	200003	193	Report 99-53
	Hannegan Pass	Variety B	Small size	104	74	300001	204	Report 07-82
	IF	Variety B	Good	115	109	10439	168	Report 99-53
			Low	120	143	18016	33	Report 98-67

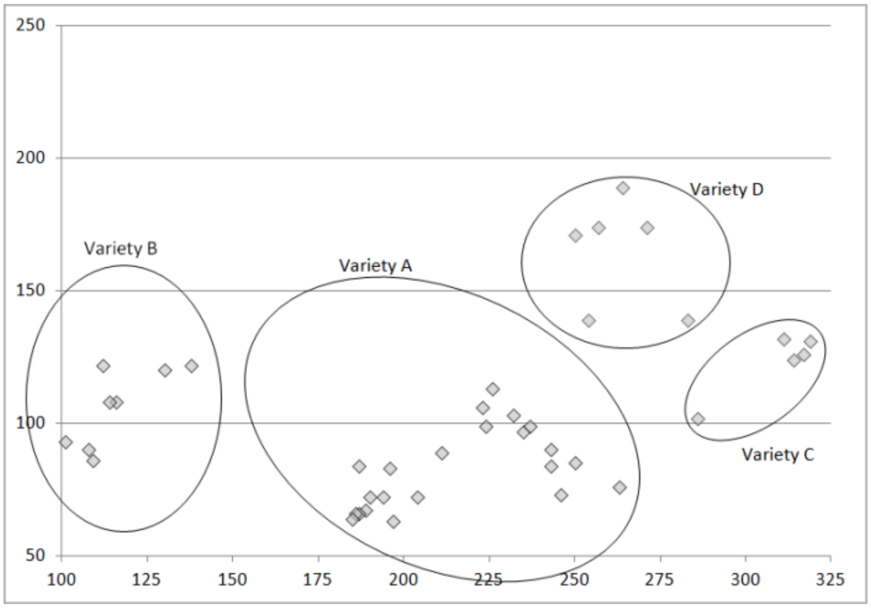

Figure 6-8. Scatterplot showing amount of the trace elements Zirconium (Zr) on the x-axis and Strontium (Sr) on the y-axis, in parts per million, for geologic samples collected from vitrophyre outcrops on Copper Ridge (Skinner 1998b). Only those samples that could be XRF-tested with reasonable accuracy are shown, and only the four main geochemical clusters are denoted by ellipses. Outliers, unknowns, and unassigned geochemical values are not shown. Variety A occupies the large central portion of the chart, having median values for both Zr and Sr; variety B is shown at left, with lower Zr values and median Sr values; variety C has elevated Zr values and median Sr values; and variety D has slightly elevated Zr values coupled with elevated Sr values.

a significant amount of measurement error. In all figures of this study, interpretive XRF results for outcrop i have been suppressed, but outcrop i data is retained for reference in Table 6-2. Additionally, most geologic specimens from outcrop ii on the northern end of the ridge produced highly diagnostic XRF results of geochemical Variety B with low intrasource variability, but a single specimen from outcrop ii produced results similar to geochemical Variety A located in the southern quarry complex (Table 6-2). Uneven surface features and the presence of phenocrysts in hand specimens may account for these anomalies.

Quarry and Procurement Sites of the Hannegan Volcanics Quarry Complex. Most bedrock quarries and procurement source locations are located proximal to the ancient Hannegan caldera at the headwaters of the Chilliwack, Nooksack, and Silesia watersheds within the park boundaries. All documented source outcrops are 1,370-2,000 m above sea level and occur in ridge, cirque, steep slope, scree, rock buttress, and alpine meadow settings covering an approximate area of 13 km^2. Presumably, vitrophyre toolstone was extracted directly from outcrops, but we have seen no clear evidence of hammer marks or percussion flake scars on the exposed vitrophyre dikes. It is likely that toolstone-quality vitrophyre was also procured from weathered nodules located close to the source outcrops. Lithic scatters representing primary reduction loci are found next to outcrops, several of which (e.g., outcrops i and ii) were discovered following initial recognition of primary flaking debris.

At the outcrops, vitrophyre of toolstone quality is relatively uncommon and several dikes contained extremely low proportions of glassy material. We observed a paucity of high-quality vitrophyre in all dike morphologies, but outcrops i, ii, and iii display the most homogeneous, high-quality toolstone.

In addition to hard-rock outcrop dikes, isolated vitrophyre gravels and cobbles are scattered on the surface of Copper Ridge, in talus, soils, and wind-deflated ridgelines. The dispersal agents for such isolated vitrophyre clasts include physical and chemical weathering, mass wasting events, and glacial transport. The Cordilleran ice sheet overrode Copper Ridge, while local Alpine glaciers reworked its contours. These agents scattered toolstone-quality vitrophyre fragments across the landscape. The presence of loose vitrophyre clasts may be due to erosion of outcrops, some now wholly obliterated or buried. Alpine slopes have eroded to the degree that original dike structures may no longer be visible, but concentrations of vitrophyre clasts do exist in scree slopes or on

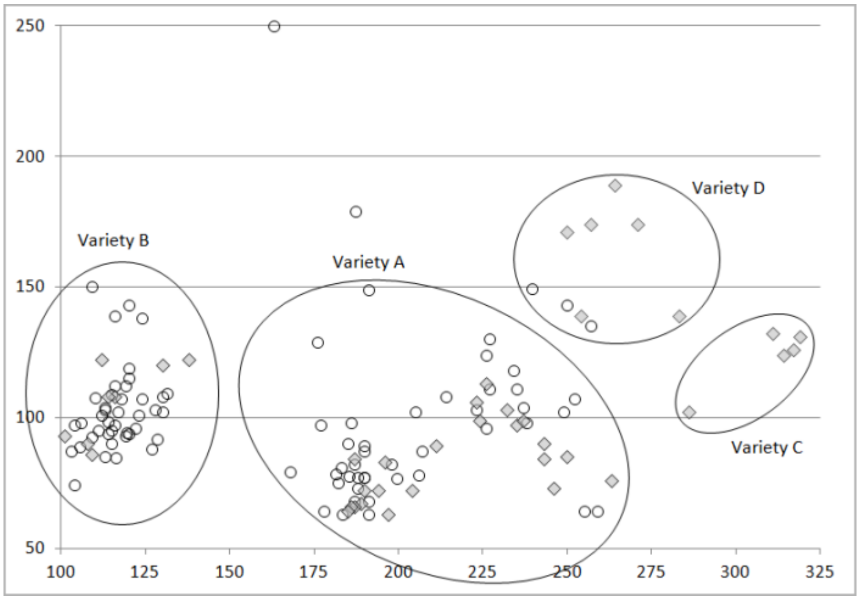

Figure 6-9. Scatterplot showing the amount of the trace elements Zirconium (Zr) on the x-axis and Strontium (Sr) on the y-axis, in parts per million, for geologic and artifact samples. Only those samples that could be XRF-tested with reasonable accuracy are shown. Geologic outliers, unknowns, and unassigned values are not shown, while all values for artifacts are shown (Skinner 1998b, 1999a, 2003, 2007; Skinner and Davis 1996). Geologic samples designated by gray diamonds, artifacts by circles; the four main geochemical source groups by ellipses.

ground surfaces below. Concentrations such as these, proximal to outcrops now buried or obliterated, may have provided secondary toolstone sources to pre-contact populations. Among the loose vitrophyre nodules that occur sporadically on Copper Ridge and proximal to it, vitrophyre of toolstone quality is almost never found. As part of this study, the numerous isolated secondary geologic clasts of vitrophyre were not recorded, geochemically characterized by XRF analysis, or macroscopically described.

Field evidence is equivocal as to the degree to which glaciers transported vitrophyre toolstone any great distance from the ridge. Vitrophyre is exceedingly rare in Chilliwack River alluvial gravels inside the park, but in one instance outside of the park, a gravel cobble of vitrophyre was recovered from the northern end of Chilliwack Lake. This specimen was correlated with Copper Ridge Variety B (Mierendorf 2004) and geochemically sourced to outcrop ii on the northern end of Copper Ridge.

We have reason to believe that the geography of Hannegan volcanics extends beyond our survey boundaries and it is possible that the unknown geochemical sources represented in the artifact XRF data (Table 6-3) are from as yet unidentified outcrop quarries, some of which may be made of fine-grained volcanics, rather than vitrophyre.

Artifacts Correlated to Hannegan Volcanics Sources. Table 6-3 lists all XRF Zr-Sr data for artifacts (n=87) from 20 archaeological sites and isolates, 15 of which are located on Copper Ridge itself. The artifact data are shown in Figure 6-9 along with the four main geologic groups (all data and geochemical groupings, Skinner 1998b, 1999a, 2003, 2007; Skinner and Davis 1996). With more research, geochemically characterized groups of geologic and artifact samples from Copper Ridge may evolve over time; the geochemical characterizations presented here must be considered preliminary.

The vast majority of artifacts (n=81) are geochemically grouped in either Variety A (n=42) or Variety B (n=39). The quarry complex at the southern end of Copper Ridge appears to have been the procurement source for artifacts of the Variety A geochemical group, while outcrop ii in the north appears to have provided toolstone for Variety B artifacts. The geochemical data suggest that the main geological procurement sources represented in the artifact sample have already been recorded and chemically characterized. Geochemical group Variety A accounts for 48 percent of all artifacts, while Variety B accounts for another 45 percent. Further subdivision of geochemical groups may be possible. For example, two separate modes may exist in Variety A (one visibly lower in Zr-Sr trace elements and the other higher), with positive geospatial correlations with known outcrops, but such interpretations must await further analysis.

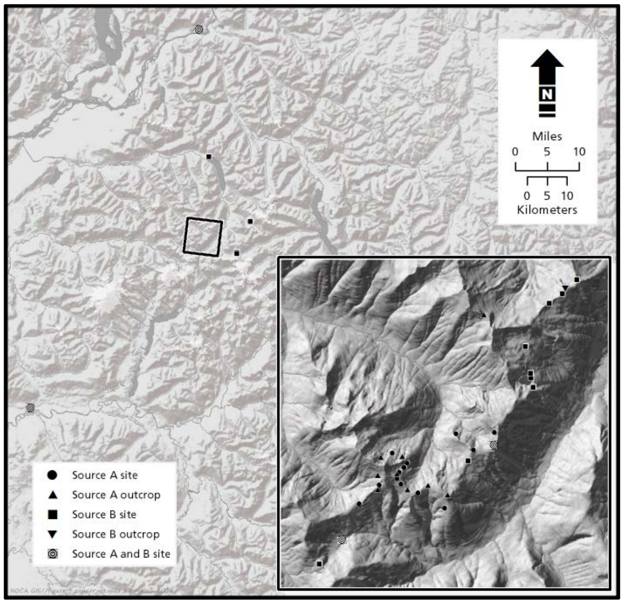

Figure 6-10. Map of Hannegan volcanics quarry complex outcrop and site locations plotted by geochemical source.

Six artifacts were not sourced to the predominant Variety A or Variety B geochemical groups. Of these, two artifacts were correlated with a Variety D geochemical group, which corresponds to the Zr-Sr signature for Copper Ridge outcrop ix. Note that one artifact (Catalog No. 18002) was assigned with low confidence to Variety A (Skinner 1998b), but its location on the scatterplot suggests placement rather in the nearby geochemical group Variety D. If valid, regrouping an artifact in this way would decrease the total count of Variety A and bring the count of Variety D up to three. Two artifacts are assigned to an Unknown geochemical group, located just above Variety A in Figure 6-9, the existence of which suggests at least one minor, unrecorded vitrophyre procurement source. Finally, two artifacts (Catalog Nos. 16554 and 16557) were unsourced in early XRF analysis of vitrophyre (Skinner and Davis 1996). Their location near the center of the Variety B ellipsis on the Zr-Sr scatterplot in Figure 6-9 would today argue for inclusion in that geochemical group.

No artifacts have yet been correlated with geochemical group Variety C (Skinner 1998b), indicating by logical extension that no artifacts can be positively sourced to outcrop v.

Four sites have artifacts correlated with both geochemical Varieties A and B. One of these (45WH549) is mid-way between the northern and southern Copper Ridge sources, and the other (45WH551) is southwest of the ridge on the Chilliwack side below Hannegan Pass. The latter is a short-term camp with a cooking hearth feature and late-period arrow points made of Hozomeen chert. The other two sites, DgRj1 and 45SK258, are distant outliers as discussed below.

Six archaeological sites containing vitrophyre artifacts are located beyond Copper Ridge and beyond any known vitrophyre sources (Figure 6-10). Three of these sites (45WH462, 45WH515, and 45WH631) are located on or near the crest of the northern Picket Range, which is the eastern divide that the Chilliwack watershed shares with the upper Skagit. Copper Ridge Variety B, from 6-10 km away, is the dominant toolstone in each of these. Artifacts from a fourth site (DgRi2), located about 6 km north of Copper Ridge at the northern end of Chilliwack Lake (Schaepe 1998b), correlate also with Variety B (Skinner 1999a). Contiguous with DgRi2 is DgRi1, the closest settlement to the Hannegan quarry complex and at a distance of 6 km, it is within one day's foraging radius of outcrop ii (Variety B). This important Chilliwack pithouse village ("*Sxótsaqel*") is tied by elder histories and geographic place names to the traditions and identity of the people who trace ancestry to those who lived in the Chilliwack Valley (McHalsie 2001:150; Schaepe 1998b).

The two distant outlier sites shown in Figure 6-10 suggest that geochemical Varieties A and B were used in lithic technologies in lowland valley settings distal to Copper Ridge. Lenert (2007) reported specimens of "obsidian" from a pithouse village (DiRj1) on the Fraser River just below Hope, British Columbia, 48 km north of Copper Ridge; Craig Skinner geochemically correlated these specimens with Copper Ridge Variety B with low confidence, due to the small size of many of the specimens (Lenert 2007:232). Sixty kilometers to the southwest of Copper Ridge, from site (45SK258) excavations in the lower Skagit River valley near Hamilton, Kopperl (2011) reported vitrophyre of Varieties A and B (geochemical correlations performed by Craig Skinner). The site is located just downstream of the largest extended village (s. báliuq^{w}) on the Skagit River reported by Skagit elders (Collins 1974:18). These two outlier sites, one each in the Skagit and Fraser Rivers, provide the first evidence in the pre-contact period of a direct link of this particular alpine toolstone

Table 6-4. Radiocarbon Chronology of Hannegan Volcanics Vitrophyre Use.

Sample Lab. Number	Site No.	Reference	Conventional Radiocarbon Age
Beta-96060	45WH484	Mierendorf 1999	1460±110
Beta-239567	45SK258	Kopperl 2011	2040±40
Beta-239565	45SK258	Kopperl 2011	2060±40
Beta-208882[1]	DiRj1	Lenert 2007	2130±40
Beta-239566	45SK258	Kopperl 2011	2160±40
Beta-214923	45SK258	Kopperl 2011	2170±50
Beta-97235	45WH484	Mierendorf 1999	2300±100
Beta-96061	45WH484	Mierendorf 1999	3400±90
Beta-96057	45WH484	Mierendorf 1999	4350±50
Beta-96058	45WH484	Mierendorf 1999	4470±70

source with lowland settlements.

The only report of artifacts made of a glassy toolstone located west of Copper Ridge is at archaeological site 45WH223. McClure and Markos (1987) describe artifacts of a material that is macroscopically identical to Copper Ridge vitrophyre. This site is 25 km west of Copper Ridge in the Nooksack River watershed.

Even more so than Hozomeen chert, the use of Copper Ridge vitrophyre decreases abruptly with distance from primary sources. Although not quantified here, the few artifacts of Hannegan toolstone at the two most distal sites mentioned above comprise much less than 1 percent of the total site assemblages by count.

Chronology of Use. Based on 10 radiocarbon age estimates from three archaeological sites, Copper Ridge vitrophyre sources were exploited since at least the middle Holocene (Table 6-4). Five of these dates are on charcoal associated with a very high density of vitrophyre flaking debris from stratified hearth matrix in a campsite (45WH484) on the ridge, located about 2.4 km southwest of the Variety B source (outcrop ii). Eleven pieces of flaking debris excavated from upper, middle, and lower hearth matrices were correlated with Variety B (Skinner 1998b and 1999a) and indicate that Variety B toolstone use began by about 4,500 years ago. From this site, no artifacts of Variety A were identified. The remaining five dates, from a site in the lower Skagit River valley (45SK258), and another in the upper Fraser River valley (DiRj1), cluster between 2,200 and 2,000 years ago; these dates overlap with those from 45WH484. Flaked vitrophyre at 45WH484 also postdates the radiocarbon age of 1460 B. P., indicating that Copper Ridge sources continued to be used into later pre-contact time periods. The approximate time of the Hannegan toolstone complex's earliest known use, 4,500 years ago, is a pivotal time in the region's cultural and economic development, marking the emergence of larger and more sedentary communities and intensified resource procurement.

Technological Use. The quality of Hannegan volcanics toolstone for flaking technologies varies from very poor to good, and its use was conditioned by the restricted availability of primary sources of toolstone quality. Due to the abundance of phenocrysts in the groundmass, the vitrophyre fractures easily so that primary reduction loci appear as debris scatters dominated by the morphological categories of shatter and broken flakes. Even so, sites often contain debitage composed of homogeneous glassy pieces indicating that toolstone quality nodules were produced by careful selection during primary reduction. Like other obsidians, Copper Ridge vitrophyre is brittle but easy to flake and produces cutting edges that are very sharp but lack durability.

Pre-contact inhabitants of Copper Ridge relied on vitrophyre to produce small, irregular flake cores and usable flakes. Due to the small size of nodules, bi-polar fracturing is the most common primary reduction technique represented. A large assemblage of vitrophyre flaking debris was excavated at 45WH484 (Copper Lake), where only one small non-diagnostic vitrophyre biface was recovered. The assemblage was otherwise dominated by broken secondary and tertiary flakes (bi-polar and pressure) correlated with Copper Ridge Variety B. The large volume of small debitage size-grades at 45WH484 (the vast majority of shatter and flake categories are less than 3 cm) reflects the small size of the nodules quarried from outcrop ii, presently the only source known for geochemical Variety B.

Discussion and Conclusions

We return to the research questions posed at the beginning to define the focus of this investigation.

The first asked about the ways in which toolstone geography influenced how people used the North Cascades. Our data show that Hozomeen chert and Copper Ridge vitrophyre toolstone dominates archaeological assemblages in sites located closest to bedrock outcrops. The toolstone's rapid proportional decrease in sites with increasing distance from each quarry complex is most consistent with localized exploitation during seasonal hunting and gathering forays by small groups. Unlike high-quality toolstone possessing long-distance exchange value (e.g., Oregon, California, Wyoming, and Idaho obsidian sources), the cultural circulation of these North Cascades types is more likely to reflect the land-use and mountain access patterns of people from the adjacent valley lowlands, than they are to reflect trade and exchange across the larger region.

The quarry complexes are within the ethnohistoric territories of Salish-speaking groups who generally shared similar subsistence and cultural traditions regarding the use of toolstone. Thus, differences in the way the toolstone complexes were used are to some degree due to the physical properties, abundances, and access conditions of each. Hozomeen chert toolstone is relatively abundant, nodules are of large size, the material is physically durable, and its cutting edges are moderately sharp. Copper Ridge vitrophyre is geographically more restricted, the toolstone is highly frangible, and its technological range is limited by the small size of raw nodules; however, its cutting edges are very sharp. The vitrophyre was used to produce small flakes from bipolar splitting of the nodules. In contrast, the chert was used in core, informal/expediency tool, and large biface technologies. This comparison suggests that the different lithic technologies at each of the quarry complexes reflect lithic raw material abundance and quality and by the fact that different toolstone types have physical properties that vary in their effectiveness for specific tool functions and tasks (Andrefsky 1994, 2009).

That the upper Skagit River valley was an important traditional hunting and plant and mineral gathering grounds is supported by archaeological, ethnohistoric, and ecological evidence (Bush et al. 2009; Lepofsky et al. 2000; Mierendorf 1993; Mierendorf et al. 1998; Teit 1900; Smith 1988). The prominent rain shadow east of the Picket Range (one of only two areas in western Washington supporting arid-loving flora, including native *Pinus ponderosa* and *Juniperus scopulorum* [Rocky-mountain juniper]) (Agee et al. 1986) and centered near Lightning Creek was preferred winter ungulate range due to low snow accumulations on the valley bottom relative to the surrounding alpine terrain. Archaeofauna recovered from excavations in this rain shadow include mountain goat, deer, mountain sheep, hare, beaver, and elk (Bush et al. 2009; Mierendorf et al. 1998) and their exploitation is consistent with Schalk's (1988) model of winter ungulate hunting below the average snowline, particularly where upland and lowland resource patches are close by (Madsen and Metcalf 2000). The upper Skagit Valley is the only large north-south trending valley to split the North Cascades down the middle and it offered a distant hunting, plant, and mineral gathering resource patch for populations in settlements of the upper Skagit Valley and adjacent valleys. For pre-contact hunting and gathering forays in the rain shadow, the congruence with a source of abundant toolstone is sure to have appreciably increased the economic payoff of each trip into the valley, and it is possible that selection of subsistence patches was conditioned by toolstone availability (e.g., Daniel 2001; Reimer 2011). Evidence suggests that the Hozomeen chert quarry complex developed over millennia during many of these short-term seasonal hunting and gathering trips, which were in turn, influenced by other culturally embedded practices and meanings (Franck 2003).

The scale of procurement effort represented by the Hozomeen chert quarry complex may be large by central Northwest Coast standards. At the most studied of the upper Skagit River valley quarries (45WH224), an estimated 69 metric tons of Hozomeen chert were detached directly from bedrock along 30 m of the rock face, creating an anthropogenically-formed bedrock overhang; in places beneath it, the deposit of flaking debris accumulated to a depth of nearly 2 m (Mierendorf 1993). Other quarrying loci in this large site appear even larger in volume.

The Hannegan volcanics quarry complex, though covering a much smaller source area and revealing a much smaller volume of toolstone, is likely to have developed out of foraging trips along the extensive system of alpine resource patches among the connecting ridgelines between massifs of the Chilliwack and Nooksack River headwaters.

This alpine terrain is second to none in its spatial and temporal congruence of high-ranked and high-return resources. Archaeological evidence of diet breadth and resource exploitation in these rich patches is not available because only one site in the Hannegan complex has been test excavated (45WH484), compared with the extensive excavations of the Hozomeen chert quarry complex. Overall, our combined field observations and detailed familiarity with the quarry complexes lead us to believe that the Hannegan quarries represent a substantially smaller scale of toolstone procurement compared to the Hozomeen complex.

Each quarry complex differed in its mode of access and distance from village populations. The Hannegan complex outcrops were accessed only after ascending alpine terrain, where travel and transport costs (due to steep elevation gradients) are high compared with those of low elevation travel corridors, such as were used to access the largest Hozomeen quarries. Regardless of the costs incurred in procurement and transport, Hannegan toolstone has been traced to three low elevation settings, one each in the Skagit and Fraser River valleys and the third and closest to the quarries, located at the north end of Chilliwack Lake is within one day's foraging radius of a pithouse village (Schaepe 1998b). This direct link between alpine toolstone and lowland settlements is consistent with the idea, which has a long history in Pacific Northwest archaeology, that some up-river groups of the western Cascades were more foothills or mountain-oriented than is generally believed (Butler 1961; Mierendorf 1999; Smith 1956; Smith 1988; Swanson 1962). Smith (1988:142) noted that among ethnohistorically described people in the North Cascades, the Chilliwack bands in particular were oriented to their mountain valley compared with other North Cascades Coast Salish groups.

Due to restricted geographic coverage and relatively small sample sizes, we believe our data under-represents to a large degree the geographic extent of Hozomeen chert quarries and artifacts. To a much lesser degree, the presence of "unknown" geochemical sources in artifact assemblages suggests that other Hannegan volcanics sources may exist, although most artifacts in our sample are assignable to Varieties A or B. These problems will no doubt be remedied in future field investigations and in geochemical analyses of any number of archaeological collections in museums and collections repositories. Prehistorians, cultural resource managers, and tribal/first nations organizations that manage lands in the North Cascades and adjacent areas should be alerted to the potential research and cultural heritage contributions to studies of toolstone geography.

The second question asked if North Cascades toolstone usage could be linked to lowland populations in the adjacent Northwest Coast and Plateau. The presence of distant Hozomeen chert "outliers" in archaeological sites located in northern and eastern Puget Sound, in the upper Fraser River valley, and in the Stehekin-Chelan basin at the east end of the range suggests that its use as toolstone was known to people resident in lowland villages of both the Northwest Coast and Plateau. From one such village, the 2,100 year old Fraser River pithouse site, *Sxwóxwiymelh* (RiRj1), Lenert correlated artifacts with the Hozomeen and Hannegan toolstone quarries. Based on its distance from the quarries, he inferred a foraging radius of 48-64 km (Lenert 2007:239) for the inhabitants of *Sxwóxwiymelh*. Like others (Brantingham 2003), we are skeptical that the maximum distance from artifact to source easily equates to a group's foraging radius. However, in the case of *Sxwóxwiymelh*, it is strategically positioned at the mouth of what is clearly the easiest overland travel route leading to the Hozomeen quarry complex (through the low Silver Hope-Klesilkwa divide), so that a foraging distance of 48 km seems entirely reasonable. It seems much less likely however, that the *Sxwóxwiymelh* village foraging radius extended 64 km to the Hannegan quarry complex. By the same reasoning, we doubt also that the Hannegan quarry complex was within the foraging radius (60 km) of inhabitants of the large 2,000 year old encampment (45SK258, Kopperl 2011) on the middle Skagit River valley near Hamilton, Washington. Both of these lowland valley settlements represent the most distant occurrences of Hannegan toolstone reported so far and we are most inclined to infer down-the-line dispersal to these two settlements through numerous intervening villages. In the specific case of *Sxwóxwiymelh*, down-the-line exchange is likely to have passed through *Sxótsaqel*, the closest Chilliwack village to the Hannegan quarry complex. Perhaps expanded research in the North Cascades and adjacent areas will show that the relative abundance of alpine resources in lowland archaeological sites is an indicator of the intensity of alpine resource use, as suggested by Reimer (2000:215) and that the most intensively used alpine resource patches are those that are closest to large lowland population aggregates (Mierendorf 1999).

The rapid fall-off with distance in the proportion of Hozomeen chert in archaeological assemblages indicates that by any measure, most of this toolstone was procured and used in the upper Skagit Valley. Assemblages containing 100-40 percent Hozomeen chert define the core zone of the quarry complex, covering about 64 km^2, where procurement from bedrock and proximal secondary gravel sources prevailed. Ten to 20 km beyond this core area, over an area several times larger, Hozomeen chert proportions vary from about 39-5 percent. At distances much beyond 20 km the proportion of Hozomeen chert plummets to 1 percent or less. Whereas the first two zones represent intensive procurement of chert from primary and secondary sources, the outmost area of use represents incidental procurement from highly dispersed secondary gravel sources or from down-the-line exchange, i.e., the slow circulation among neighboring bands and villages in lower valleys and littoral areas of Puget Sound, which we have traced at least as far south as Lake Sammamish (45KI19A). In the Chelan-Stehekin drainage, the complete absence of primary or secondary sources of Hozomeen chert means that its presence in archaeological sites up to 120 km east of the source is due to trade or down-the-line exchange.

Artifact-to-source correlations permit us to trace several routes of toolstone dispersal from the quarry complexes and in most cases they align with ethnohistoric trails. From the Hozomeen chert quarry complex, a low-gradient travel corridor to the Fraser River followed the upper Skagit River valley northwest of today's Ross Lake area over a low divide (Silver Hope-Klesilkwa) into the upper Fraser River valley near today's Hope, British Columbia. Another dispersal route to Puget Sound followed the lower Skagit River valley south and then west to its mouth. A third route west can be tracked up the Little Beaver Creek valley, over Whatcom Pass, into the upper Chilliwack Valley and then up to Copper Ridge and Hannegan Pass (Mierendorf 2004). To the east, an important trans-Cascade dispersal route can be traced along a series of sites over Cascade Pass, down Stehekin Valley to the lower end of Lake Chelan. Given the near absence of Hozomeen chert artifact-to-source data along the east slopes of the North Cascades but outside of the Stehekin-Chelan watershed, we suspect that the actual extent of Hozomeen toolstone dispersal is greater than we have been able to demonstrate here. Other Hozomeen chert dispersal routes are likely to come to light, including other trans-Cascade routes connecting the upper Skagit River valley with the Similkameen and Methow River valleys, for example.

From the Hannegan quarries, toolstone has been geochemically traced north along the Chilliwack Valley, past Chilliwack Lake, following the valley west to the Fraser River. Data are not sufficient to determine empirically the southern dispersal route(s) into the lower Skagit River valley, and although an upper Chilliwack River route crossing south into the Baker River valley fits the physiography, Hannegan volcanics toolstone has yet to be found in archaeological components excavated in the Baker River valley (Parvey 2011). Our data show a western dispersal route followed the backbone of Copper Ridge southwest as far as Hannegan Pass; from this point we infer that dispersal continued west down the North Fork Nooksack River valley, which connects in turn to a route south to the Skagit Valley following the South Fork Nooksack River. This south fork route is a likely candidate for dispersal to the Skagit River settlement (45SK258) at Hamilton, Washington (Kopperl 2011). We have not traced Hannegan toolstone east of the Chilliwack watershed into the adjacent upper Skagit River valley (Mierendorf 2004), even though its presence on the divide between the two watersheds makes it likely that there was dispersal further east. These results suggest a long time depth to the trail network that was described ethnohistorically in the area encompassing the North Cascades quarry complexes, where traditional Salish knowledge of trails is well-recorded (Boxberger and Schaepe 2001; Majors 1984) and where interactions between "... neighboring groups was facilitated by a network of mountaintop and riverside trails. Numerous trails provided access to the Nooksack and Skagit River valleys, to the south and east, and the up- and down-river sections of the Fraser River. Mountain ridgetop complexes were heavily traveled..." (Schaepe 1998b:35). Many of these routes have been mapped from information provided by Stó:lō elders (Boxberger and Schaepe 2001; Majors 1984).

Answers to the last question, about the chronology of toolstone use, derive from our compilation of 80 radiocarbon age estimates, mostly on charcoal, from sites in and adjacent to the North Cascades. Hozomeen chert has been used since the early Holocene or late-Pleistocene, and its use continued throughout the Holocene, based on radiocarbon chronologies and on its association with Western-stemmed, Olcott, and Cascade technologies (Figure 6-4). In the park and adjacent areas, its earliest use is approximately coeval with rapid colonization of newly deglaciated lands by flora and fauna and the initial appearance of open forests about 9,000 years ago (Spooner et al. 2008). By at least 4,500 years ago, use had begun of the more restricted and difficult-to-access alpine Hannegan volcanics complex. It remains to be seen if earlier use of this source will be demonstrated. It may be that mid-Holocene onset of the Hannegan toolstone is causally related to the development of resource intensification and more sedentary populations, as is widely believed to have taken place at about this time, or it may be related to other factors.

Tracing Hozomeen chert artifacts east through Cascade Pass to a series of sites along the Stehekin River valley and Lake Chelan has implications that go far beyond mere evidence of trans-North Cascades travel. Its presence in the early Holocene at Cascade Pass indicates that onset had begun of a trans-Cascade flow of information (e. g., technological and linguistic) between Northwest Coast and Plateau cultures by at least early Archaic times. Although trade routes and travel corridors connecting the Northwest Coast and Plateau in this early period are inferred to have followed major river valleys (Carlson 1994; Galm 1994), our data identify a coeval trans-Cascades route through Cascade Pass that linked northern Puget Sound and the Fraser River with the Columbia River. The use of this technically more difficult and less secure mountain route implies far greater planning depth compared with use of the low elevation valley routes. Kinkade (1990) called attention to the role of trans-Cascade overland travel in the spread of a proto-Salish language. Based solely on linguistic comparisons between Coast and Interior Salish terms, he proposed a pre-contact dispersion of a hypothetical proto-Salish language east across the Cascades from its core area between the lower Fraser and lower Skagit Rivers. A map of this inferred proto-Salish homeland (Smith 2001:21, Plate 6) as described by Kinkade shows its spatial congruence with both of the North Cascades quarry complexes.

The geography of the Hozomeen chert and Hannegan volcanics quarry complexes and their long history of use is inconsistent with the view that the North Cascades high country and interior were of little significance to pre-contact Pacific Northwest populations. To the contrary, the vast breadth of cultural connections embedded in information derived from toolstone geography, ecology, landscape history, linguistics, ethnohistory, oral traditions, and place names speaks to a deep involvement in mountain environments. Thus captured in the Salish language is the origin of the name Hozomeen, “. . . like a sharp knife”, the jagged mountain summit, the rock it is made of, and its traditional tool function (Mierendorf 1993). For many indigenous groups affiliated historically with coast and interior Salish (e.g., Nooksack, Upper Skagit, Stó:lō, Nlakápamux, Okanogan), the North Cascades mountain headwaters of the three biggest Pacific Northwest rivers converged in a shared resource area, one that remains “alive in cultural tradition and knowledge“ (Franck 2003:18).

There is much more to be learned from study of toolstone quarry complexes in the North Cascades and their linkage to traditional Salish place names, cultural heritage, and identity. Although small in comparison to the Far West’s large quarries, local toolstone complexes in remote mountain and alpine terrain possess high research potential to address questions of chronology, land use, exchange, travel, and the optimization of alpine resource collection, independent of lowland data sets. The extremes of topography and climate combine to create seasonally rich alpine resource patches which are known to have a long history of indigenous use. Exploitation that involves the acquisition and transportation of alpine resources to lowland populations requires great depth of planning in order to regulate cost, risk, and returns from distant-patch foraging (Brantingham 2006; Whitaker and Carpenter 2012). Pre-contact Northwest peoples, Plateau and Coast alike, have left an indelible archaeological record of their presence in the high country and the record is worthy of the same careful attention accorded to other portions of the Northwest Coast and Plateau.

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CHAPTER 7

Elk Pass Obsidian and Pre-contact Band Territory in the Southern Washington Cascades

Rick McClure
U.S. Forest Service, Gifford Pinchot National Forest (rhmcclurecrm@gmail.com)

At the landscape level, the embedded procurement strategies of hunter-gatherer-foragers may produce archaeological distributions of toolstone material that reflect the home ranges or territories of a specific group or band. Over the past decade, a number of studies have addressed this subject, among them the work of Jones and Beck (2003), looking at obsidian as an indicator of foraging territory in the Great Basin. Another study, by Brantingham (2003), proposed that the maximum transport distances of given raw material types are equivocally related to the geographic range of a forager group. The utilization range of obsidian from the Elk Pass geochemical source in Washington State provides a case study and application of these principles from the southwestern section of the Plateau region of the U.S. Pacific Northwest.

Located in the southern Washington Cascade Mountain Range, 125 km southeast of Seattle, the Elk Pass source location is one of only 12 documented geological sources of obsidian identified to date in the state of Washington (Figure 7-1). Compared to Oregon, with 134 documented sources, obsidian was obviously much less important as a toolstone resource to the north, in present-day Washington. All twelve of the Washington sources are small, in terms of the volume of raw material present at the locations today. The archaeological distribution of obsidian from these sources is apparently also very limited, especially when compared to some of the major sources in Oregon, such as Newberry Volcano obsidian, which has been identified in archaeological assemblages more than 900 km from the geological source (Hughes and Connolly 1999). In contrast, the archaeological distribution of obsidian from the Elk Pass source is limited to a distance of only 52 km from the geological source.

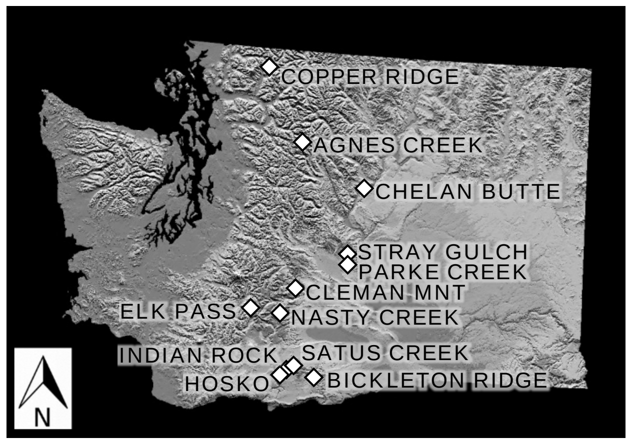

Figure 7-1. Washington obsidian sources. Adapted from "Washington Obsidian Sources" by Northwest Research Obsidian Studies Laboratory (2009). Base orthophoto courtesy U.S. Geological Survey.

The geological source of the Elk Pass obsidian has been identified as a small alpine talus field located near the crest of the Cascades in the heart of the Goat Rocks Wilderness, Gifford Pinchot National Forest, roughly 25 km south of Mt. Rainier National Park. The elevation is approximately 2,042 m above mean sea level. Obsidian nodules ranging from 7 to 20 cm in length were identified within the talus field, which is bisected by the Pacific Crest National Scenic Trail at a point just west of Elk Pass, an old trail junction. The talus field originates near the crest of a north-south trending ridge (Figure 7-2), the watershed divide between Lake Creek, on the west,

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Figure 7-2. General view of the Elk Pass Obsidian geochemical source and associated quarry site (45LE286) as viewed from Pacific Crest Trail south of the site. The view is to the north, with Mt. Rainier in the background. August 2010 photograph.

and the Clear Fork Cowlitz River, on the east. The location is 500 m west of the actual crest of the Cascade Range. Near the top of the talus field, along the crest of the ridge, are several erosional surfaces with concentrations of obsidian debitage indicating the quarrying and processing of toolstone.

Initial archaeological documentation of the obsidian source location and prehistoric quarry was conducted in 1986 and 1987, following the discovery of a reference to the site in the writings of William O. Douglas, former Chief Justice of the United States. Douglas, a life-long champion for wilderness preservation, had spent much of his youth in the Yakima area, and as a teenager had explored much of what is now the Goat Rocks Wilderness. Some of these youthful rambles are described in his memoir *Of Men and Mountains*. In a chapter entitled *Goat Rocks*, Douglas described the ridgeline tapering to the north from Old Snowy Mountain, a prominent peak along the crest of the Cascades, noting that its “farthest knob” was a hillock he had climbed “to find the obsidian rock the Indians used for arrowheads” (Douglas 1950:207). Recalling his early visits to the area ca. 1914-1918, Douglas remembered that “the obsidian lay exposed there in the sunlight, its small flaky pieces looking like bright, shiny bits of new asphalt” (1950:207). This passage is the earliest known written reference to the Elk Pass obsidian quarry, subsequently documented as archaeological site 45LE286.

During the initial archaeological investigations, conducted by Forest Service archaeologists Rick McClure and Janet Liddle, several nodules of obsidian were collected from the talus field for geochemical source characterization. The initial x-ray fluorescence (XRF) analysis of the nodules was conducted by Dr. Richard Hughes, of the Archaeological Research Facility, Department of Anthropology, University of California at Berkeley. Subsequent XRF characterization was done by Craig Skinner, Northwest Research Obsidian Studies Laboratory, Corvallis, Oregon.

Surface artifact material, consisting of debitage, shatter, and tool fragments, was observed in three non-contiguous loci, designated Area A, Area B, and Area C, where vegetation is lacking and soil erosion and deflation have occurred. It is assumed that obsidian nodules were collected from the talus field (Figure 7-3), which is comprised mainly of rhyolite material, and were then carried anywhere from 20 to 100 m to these more sheltered locations on the east side of the ridge crest for processing. Areas A through C appear to represent toolstone processing locations.

1987 field investigations at the Elk Pass site included systematic surface sampling within Area C for purposes of more detailed lithic analysis, and the excavation of a single 1-x-1-meter test excavation unit. Surface densities in Area C soil exposures average 80 obsidian artifacts per square meter, but test excavations indicate subsurface

Figure 7-3. Surface source of obsidian nodules in talus slope at the Elk Pass quarry site (45LE286). August 2010 photograph.

densities of up to 10,000 obsidian artifacts per cubic meter. A radiocarbon date of 6250 +/- 110 BP (uncalibrated) was obtained from isolated charcoal fragments found in direct association with lithic debitage at a depth of 55 cm. The vertical distribution of artifact material indicates higher concentrations of material at the lower, presumably earlier levels of the cultural deposit (Brown 2000a, 2000b:14).

Non-diagnostic debitage and shatter is by far the most common artifact category represented in the archaeological assemblage from the Elk Pass site. Lithic analysis of technologically diagnostic debitage and flaked pieces indicates obsidian core and biface reduction as the principal activities at the site, and that large flakes produced from cores were used to make bifacial blanks (Figure 7-4). There is some indication that the later stages of bifacial tool manufacture are represented in later but not in the earlier periods of site use, as indicated by the much higher frequencies of pressure flakes in the upper, presumably more recent, cultural deposits. Excessive fragmentation represented by the high counts of shatter may be attributed to the poor quality of the obsidian material (Brown 2000b:16).

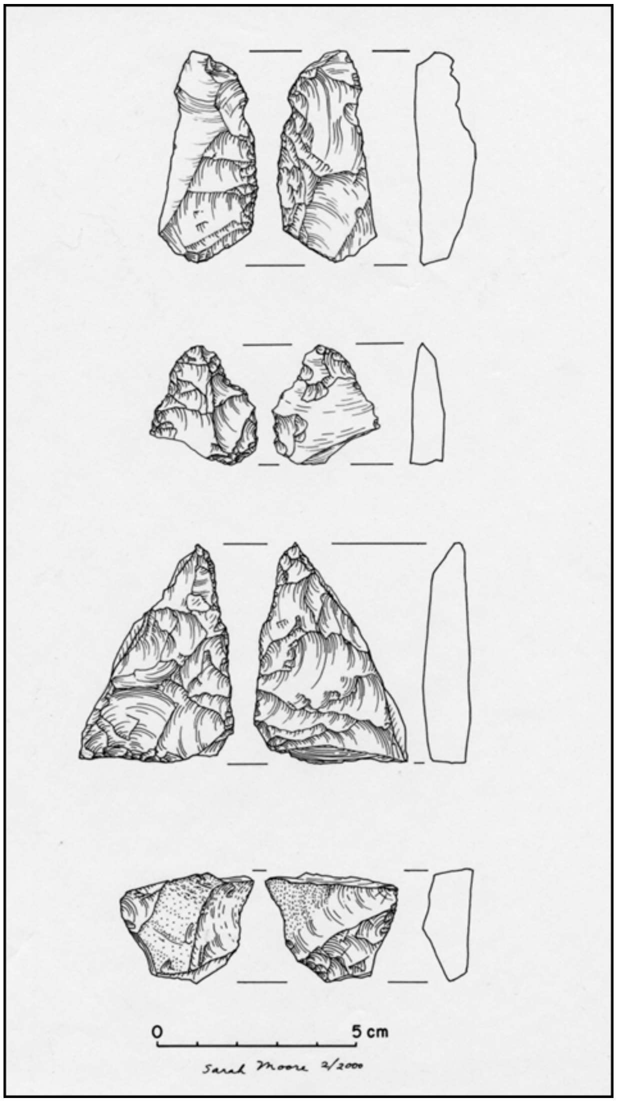

Figure 7-4. The largest of the obsidian biface blank fragments recovered in archaeological sampling at the Elk Pass quarry site (45LE286) during the 1987 field investigations. Illustration by Sarah Moore.

Four other high elevation obsidian scatters were found within 1.6 km of the Elk Pass Quarry Site, and were recorded as separate archaeological sites. XRF sourcing confirmed the presence of Elk Pass obsidian in one of these sites, 45LE250. XRF sampling of the others has not been done, but based on proximity to the source location and visual characteristics, it is assumed that all of the surface obsidian visible at these sites is from the Elk Pass source. Ethnographic data for the local Taytnapam people indicate that traditional use of the mountain landscape in the vicinity of the quarry site was associated with the seasonal hunting of mountain goats. Many Northwest native groups of the early historic period valued mountain goats for their meat, their wool, and their horns and hooves (Lubinski and Burtchard 2004:16). The pattern may have been similar to that described for the Yakama at Mount Rainier, where the men are said to have hunted goats on the flanks of the mountain, "while their women were gathering huckleberries" each summer (Smith 2006:130). Jim Yoke, a Taytnapam elder interviewed by anthropologist Melville Jacobs in 1927, provided place-names for two locations in present-day Goat Rocks Wilderness where mountain goats were hunted, and mentioned a cave where their meat was smoke-dried (Jacobs 1934:233). Information also attributed to Jim Yoke describes an Indian "goat hunters trail" ascending Lost Lake Ridge from the upper Cowlitz River Valley (Sethe 1938). This ridge would have provided direct access to the vicinity of the Elk Pass obsidian quarry.

While archaeological samples from the alpine and subalpine sites near Elk Pass are limited, projectile points represent the dominant tool type, a pattern which tends to suggest hunting as a primary activity above treeline in this part of the Cascade

Range. Projectile points include late Holocene corner-notched arrow points and larger side-notched dart points more typical of the middle Holocene. All of the examples identified to date are manufactured from cryptocrystalline silicate (CCS) toolstone, rather than obsidian, which is the most abundant lithic raw material in evidence at this handful of high elevation archaeological sites. The ethnographic pattern of land use indicates that the hunting of mountain goats was the primary purpose for visits to this part of the Cascades. Goats remain common in the Elk Pass vicinity today. These factors suggest that procurement of Elk Pass obsidian was probably ancillary to hunting objectives.

Spatial Distribution

Archaeological investigations and XRF sourcing studies conducted to date indicate that the use of Elk Pass obsidian was confined entirely to the upper Cowlitz River watershed, west of the Cascade crest. Among the earliest archaeological investigations in this area were the preliminary reconnaissance and site documentation efforts of David G. Rice, carried out from 1963 to 1967 (Rice 1964, 1969). Documenting a private collection from archaeological site 45LE271 near the community of Packwood, Rice described three "tapered stemmed" projectile points of obsidian and suggested they were possibly derived from a local source in the Goat Rocks. Rice was aware of the reference to a possible Goat Rocks obsidian source through the writings of William O. Douglas, mentioned previously. His report provides the earliest recognition that obsidian artifact material from archaeological assemblages in the upper Cowlitz watershed may have originated from a local source in the nearby Goat Rocks Wilderness. XRF analysis would later demonstrate that obsidian from this site did indeed originate from the Elk Pass source.

XRF sourcing of archaeological obsidian in the region since 1987, when the Elk Pass material was initially characterized, has indicated a relatively limited conveyance zone for the Elk Pass obsidian. Distribution appears to be restricted entirely to the upper reaches of the Cowlitz River watershed, west of the Cascade crest. To date, a total of 104 prehistoric archaeological sites have been identified in the upper Cowlitz watershed, between the crest of the Cascades and River Mile 52, at Mayfield Dam. Of this total, 23 (22.1%) of the documented sites feature artifact material identified as obsidian. Most of the artifact assemblages are characterized by high frequencies of raw materials described as CCS, microcrystalline quartz (e.g. jasper, chert, chalcedony), or local volcanic stone, such as basalt, dacite, or andesite. XRF sourcing analysis has been conducted for at least one or more artifacts from 17 (73.9%) of the archaeological sites with known occurrences of obsidian raw materials. Results indicate that at least 12 distinct sources of obsidian are represented in the prehistoric assemblages from the area, with Elk Pass obsidian the most common at just over 61% of all sourced specimens (Table 7-1).

The overall sample size of lithic artifact material from archaeological sites in the Upper Cowlitz watershed is relatively small, and the overall size of the XRF sample even smaller (n = 160). As indicated in Table 7-1, below, the results are skewed by the larger samples from those sites that have been the focus of major data recovery excavations, such as site 45LE415. The results suggest a relationship between sample size and the number of obsidian sources represented among the lithic artifact material recovered from a given site, both in terms of volume excavated and in the number of artifacts sourced. Those sites with the largest samples usually have a greater variety of obsidian sources represented.

Archaeological assemblages from the upper Cowlitz River area are typically characterized by CCS and Cascade volcanic (basalt, andesite, dacite) toolstone, with obsidian present in much smaller quantities. Archaeological sites in closest proximity to the Elk Pass source appear to contain the highest frequencies of obsidian artifact material. While most of this material appears to have come from the Elk Pass source, other, non-local geochemical sources of obsidian are also represented.

The largest sample of XRF-sourced obsidian comes from site 45LE415, located on the floor of the Cowlitz River Valley near the community of Packwood, with about 5% obsidian represented in the lithic assemblage. Elk Pass material in the 45LE415 assemblage consists primarily of middle to late stage bifacial thinning flakes and fragments. While the majority (77%) of the obsidian sampled comes from the Elk Pass source, six nonlocal

Table 1. Obsidian sources represented in artifact assemblages from the upper Cowlitz River watershed, based on XRF analyses to date.

Site	Elk Pass	Newberry Volcano	Whitewater Ridge	Obsidian Cliffs	Glass Buttes	Glass Mtn.	Wolf Creek	Tule Springs	Quartz Mtn.	Inman Creek	Cleman Mtn.	Rimrock Spring	Unknown Source	References
45LE58				1										Hughes 1987
45LE209	1	2			1				1	1			5	Hughes 1990a; Ellis et al. 1991
45LE220	27	1	1									1	1	Hughes 1990b; McClure 1992; Skinner & Davis 1998
45LE222	5	1			2									Hughes 1990b; McClure 1992
45LE223	2	2		1										Hughes 1990b; McClure 1992
45LE249	1													Hughes 1986
45LE250	1													Hughes 1986
45LE263	1													Hughes 1986
45LE285	2													Hughes 1990b; McClure 1992
45LE271	1													Hughes 1986
45LE277													3	Hughes 1986; McClure 1988
45LE289		1												McClure 1992
45LE415	83	6	10	1			1	1			1			Hughes 1990b; Mack et al. 2010
45LE417			1		3	4							2	Hughes 1991; Flenniken et al. 1992
45LE422				5										Hughes 1992; Luttrell 1992
Warfield* #2													2	Hughes 1990b; McClure 1992
Warfield* #8		1												Hughes 1990b; McClure 1992
Totals:	**98**	**13**	**12**	**8**	**6**	**4**	**1**	**1**	**1**	**1**	**1**	**1**	**13**	**160 = XRF sample**

* - Artifacts from the Warfield collection from two sites within the drawdown zone of Mossyrock Reservoir; not yet correlated with recorded archaeological sites.

sources are represented in much smaller quantities, and likely reflect materials obtained through exchange, rather than direct procurement. These include five sources from central or southeast Oregon, and one eastern Washington source.

XRF analyses of obsidian from sites located along the Cowlitz River below and to the west of Cowlitz Falls, have identified no Elk Pass material (Figures 7-5 and 7-6). Analyses of obsidian from archaeological sites on the east slope of the Cascade Range have likewise produced no evidence for material from the Elk Pass source. A general pattern of primarily westward, downstream movement of the material is indicated, into the Cowlitz River valley and up the Cispus River, a major tributary (Figure 7-6). The sole exception to the pattern is the occurrence of Elk Pass obsidian at Tipsoo Lakes, headwaters of the Ohanapecosh River near Chinook Pass, 38 km north of the source. This would either suggest transport up the Ohanapecosh drainage, one of its tributaries, or possibly along the crest of the Cascades.

Chronology of Use

Late Holocene use of the Elk Pass obsidian quarry is indicated by the presence of sourced obsidian in several well-dated archaeological assemblages (McClure 1992:78). The youngest is a component of the *Awxanapakash* site (45LE220) associated with radiocarbon dates between 430 and 500 B.P. (uncalibrated). Hydration band measurements for the sample (n=27) of Elk Pass obsidian from this site range from 0.8 to 1.1 microns. The *Akushnesh* site (45LE285) assemblage includes Elk Pass obsidian from an occupation dated between 500 B.P. and 1100 B.P. Means derived from the series of six hydration band measurements obtained for two specimens were 1.7 microns and 1.9 microns, respectively. The Judd Peak Rockshelters

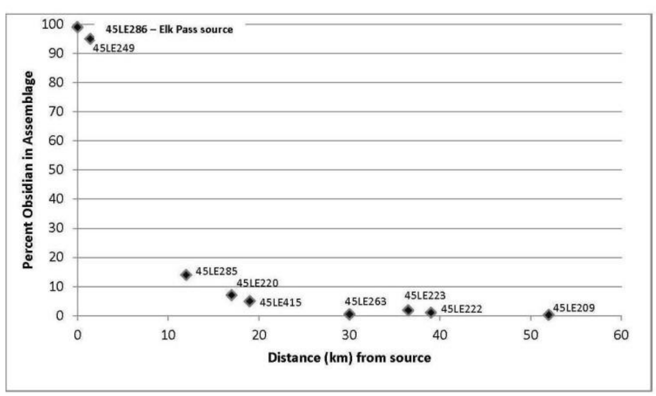

Figure 7-5. Obsidian percentages with distance from Elk Pass source (45LE286), based on excavation samples.

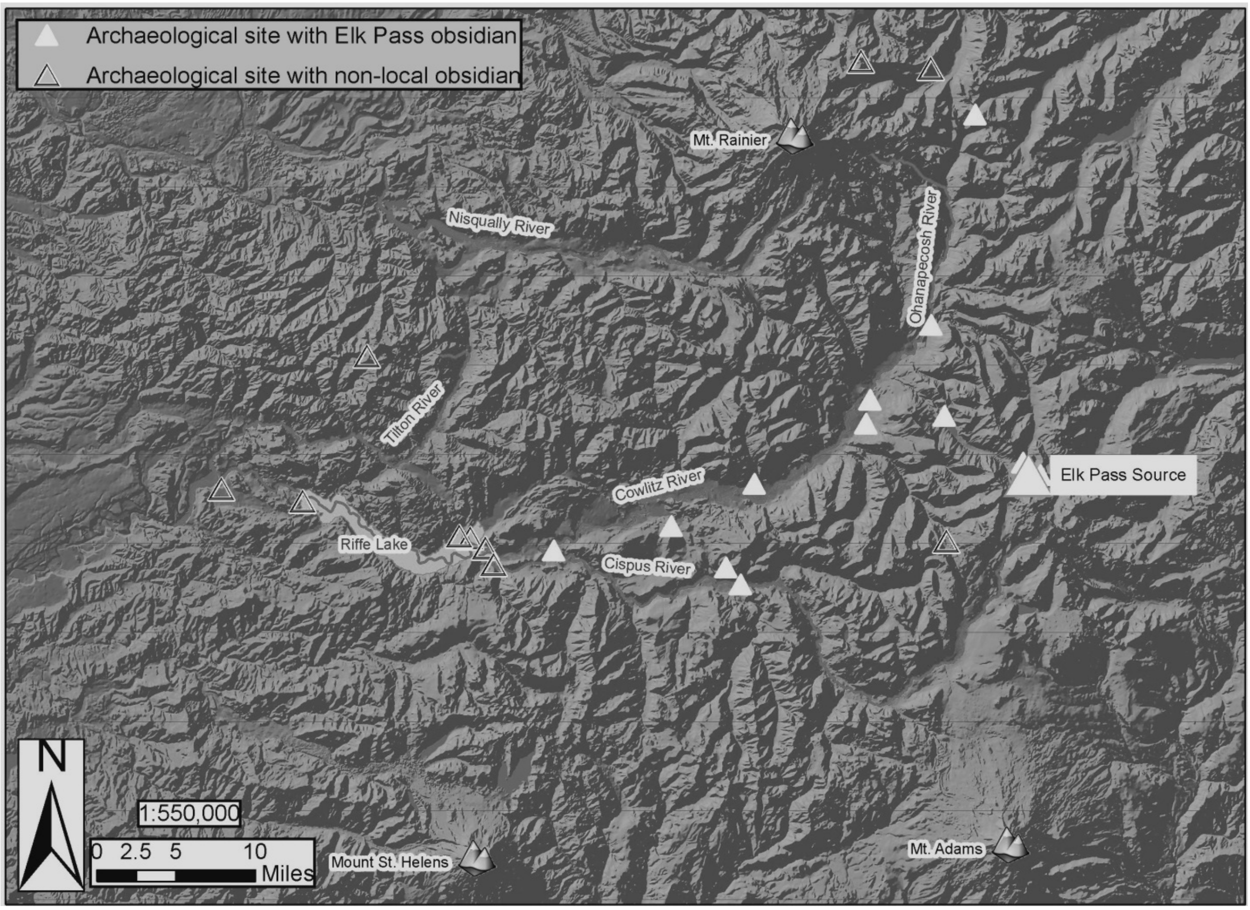

Figure 7-6. Spatial distribution of Elk Pass obsidian, upper Cowlitz River watershed. GIS map Heritage Program, Gifford Pinchot National Forest, produced by Chris Donnermeyer.

(45LE222) produced Elk Pass obsidian from a cultural stratum dating between 800 B.P. and 1100 B.P. Two pieces of debitage were subjected to hydration analysis. One specimen had no visible hydration band; the second produced two sets of measurements from different surfaces, one with a mean of 3.1 microns, the other with a mean of 4.3 microns. This artifact may represent older lithic material recycled for use by later site occupants.

Middle Holocene use of the Elk Pass quarry is indicated by the presence of sourced obsidian in Stratum II at Layser Cave (45LE223), with an associated radiocarbon date of 5200 +/- 170 B.P. (uncalibrated), and the deeper Stratum X, with an associated radiocarbon date of 6650+/- 120 B.P. (uncalibrated). Site 45LE222 produced Elk Pass obsidian from a cultural stratum dating to 5930 +/- 120 B.P., and the Elk Pass quarry itself produced a high volume of debitage in association with charcoal dating to 6250 B.P. Mean hydration band measurements from two Layser Cave artifacts were 2.5 microns and to 3.1 microns, respectively. The artifact from the earlier stratum at 45LE222 produced a mean hydration band measurement of 3.7 microns.

The earliest use of Elk Pass obsidian in the upper Cowlitz watershed is indicated from the large sample recovered during excavations at the Beech Creek site (45LE415). The early component of the site is dated to 9,200 ± 500 B.P. (Mack et al. 2010:133). Relative chronology established through obsidian hydration analysis, as well as radiometric dating, indicates very early use of both non-local and Elk Pass obsidian. Early, non-local sources include Whitewater Ridge, Wolf Creek, and Tule Springs material, all from southeast Oregon (2010:126). The frequency of Elk Pass obsidian is higher in the later components of the site, which also feature non-local obsidian from Newberry Volcano, also located in southeast Oregon. Mean hydration band measurements for the sample (n=83) of Elk Pass obsidian from 45LE415 range from 1.2 to 4.0 microns (Mack et al. 2010:130).

Elk Pass obsidian artifacts associated with radiometrically-dated components from three of the sites in the upper Cowlitz watershed (45LE220, 45LE222, 45LE223) were used to establish a tentative and approximate hydration rate for Elk Pass obsidian (Mack et al. 2010:137). The rate of hydration was calculated using the equation $M^2 = Kt$, where t is a specific point in time (e.g., radiocarbon date), M is the hydration rim thickness of an obsidian specimen from the specific dated stratum, and K is the diffusion coefficient (Michels 1973:206). A hydration rate of 1.94 microns^2/1000 years was derived from this exercise. At this rate, the hydration rim measurements for Elk Pass obsidian from site 45LE415 suggest a time span ranging from 8,224 B.P. to 758 B.P. Given the problematic variables associated with the use of obsidian hydration in absolute dating, these results at best provide a general indication that the time depth for the use of Elk Pass obsidian at this site is considerable.

Utilization Range and Group Territory

The utilization ranges for the non-local Oregon obsidians represented in upper Cowlitz assemblages are considerably greater than that indicated for the Elk Pass material. The distribution of Newberry obsidian, for example, covers much of Oregon and Washington, extending well north into British Columbia (Connelly 1999). Glass Buttes obsidian was likewise distributed throughout much of the Pacific Northwest (Steuber, this volume). In contrast, the utilization range for Elk Pass obsidian is restricted entirely to the upper reaches of the Cowlitz River watershed, west of the Cascade divide, and downstream only as far as the mouth of the Cispus River, a maximum distance of 52 km from the material source. XRF sourcing of obsidian from archaeological assemblages on the east flank of the Cascades, in the Tieton and Naches River drainages, have indicated no Elk Pass obsidian.

The utilization area for Elk Pass obsidian corresponds largely to the historic territory of the Taytnapam, a Sahaptin-speaking Plateau group that occupied the upper Cowlitz River in the early to middle 19th century. Except to the west, the boundaries of this group were largely defined by the landscape, and especially the high mountains and ridgelines that surrounded them. The western limits of the Taytnapam were in the vicinity of present-day Mayfield Reservoir, more than 50 miles up the Cowlitz River from its confluence with the Columbia. Downstream, to the west, were the Salishan-speaking Cowlitz. The farthest upriver Cowlitz villages were apparently shared with the Taytnapam (Hajda 1990:505). Three of the archaeological sites with Elk Pass obsidian correspond to historic seasonal camps or villages of the Taytnapam. These include: 45LE209, at the ethnographic site of *Koapk*, a seasonal fishing camp at Cowlitz Falls; 45LE220, at the ethnographic site of *Awxanapaykash*, a seasonal fishing camp located further upstream; and 45LE285, at *Akushnesh*, present-day Packwood Lake.

At contact, the Taytnapam were organized into eight autonomous bands (Figure 7-7). The term "band," as used by anthropologist Melville Jacobs, who worked with Taytnapam consultants in the 1920s, is perhaps best understood as simply an aggregation of family units (Jacobs 1927).

Identified bands included the *q'iyañxła΄ma*, on Kiona Creek near Randle; the *cicpacła΄ma*, on the Cispus River; the *k'wpła΄ma* ("falls people"), at Cowlitz Falls; the *wasała΄ma* at Morton; the *lalaxła΄ma*, at the mouth of the Tilton River; the *swi΄ktswiktła΄ma* ("horsetail people") at Nesika; the *nucnuła΄ma* ("nose people") at the mouth of the Cowlitz Canyon; and the *qwє΄ltła΄ma*, at Mossyrock Prairie, furthest downstream, to the west (Costima 1934, Jacobs 1927). The possibility of a ninth band, upriver from the *q'iyañxła΄ma,* is indicated by the existence of the village of *cawacas* "where the present town of Packwood lies" (Smith 2006).

According to anthropologist Allen Smith (2006), each of these bands "had a recognized geographical locus, the name of which it bore." Smith argued that each band unit could be identified with a specific winter settlement within their valley section. With regard to band territory, his consultants agreed that "tribal limits corresponded to the crests of the mountain ranges" and that particular group could "more or less effectively exploit the natural resources of rugged, forested terrain on those slopes which faced their tribal center or villages." Citing Curtis (1911:160), for his study of the Yakama, Smith notes that hunting and collecting territory was often the common property of several bands.

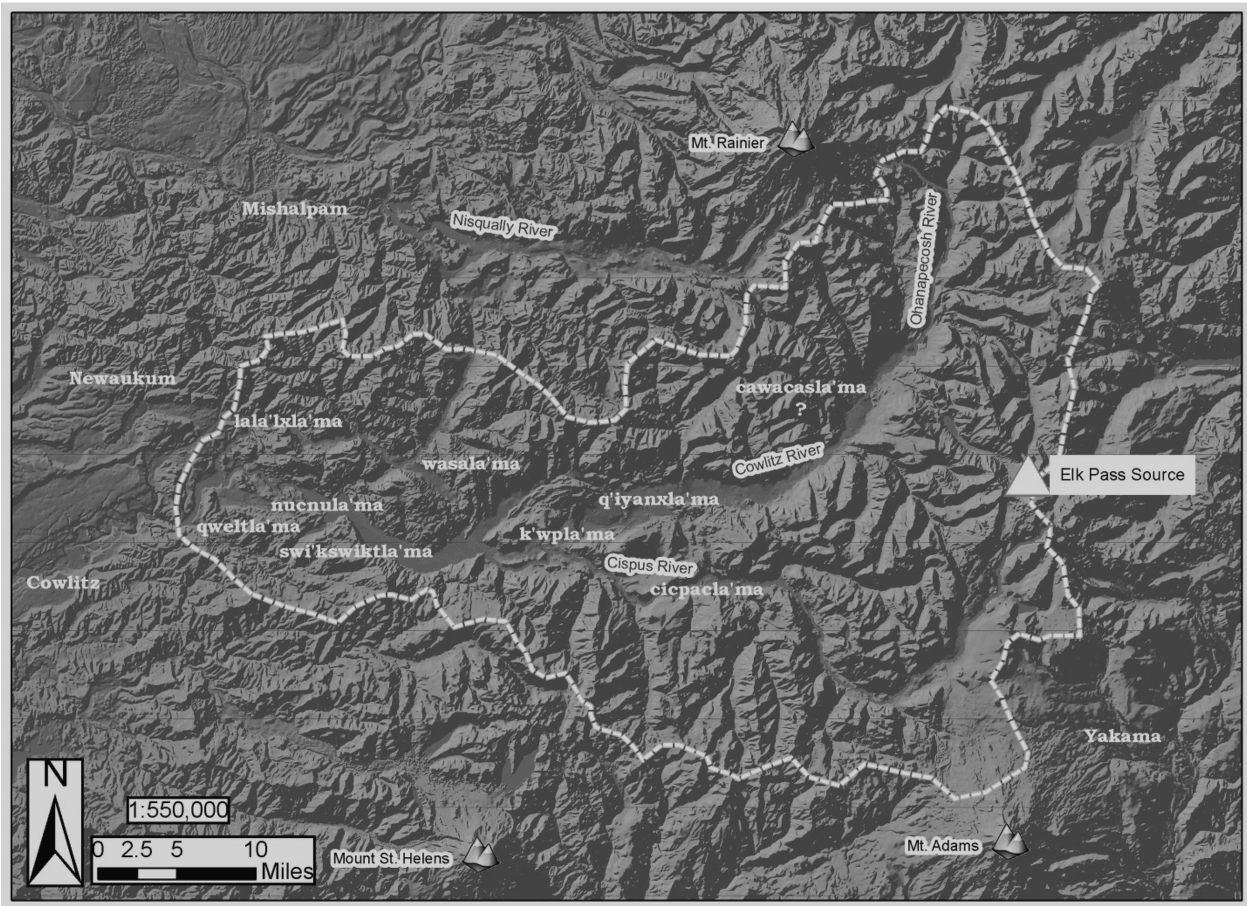

Figure 7-7. Upper Cowlitz River watershed with historic period Upper Cowlitz Taytnapam territory indicated by a dashed line. Locations of individual bands and neighboring tribal groups are also indicated. Gifford Pinchot National Forest GIS map produced by Chris Donnermeyer.

The conveyance zone for Elk Pass obsidian includes the territory of the four upriver Taytnapam bands. No Elk Pass obsidian has been identified within the territory of the other four bands, located downstream, to the west of Cowlitz Falls. The distribution of the obsidian may well correspond to the foraging territory of the ancestral population, and reflect the range of those with direct access to the source. The fact that the material does not occur within the historic territory of the four western Taytnapam bands is intriguing, and suggests the possibility that toolstone distribution may also serve an indicator of expansion or contraction of group territory through time.

On the basis of the spatial distribution pattern, two hypotheses emerge, and both merit further exploration. Both assume direct, embedded procurement as the mechanism for acquisition of the Elk Pass obsidian and simple forager/collector band organization through time. The first is that all of the upper Cowlitz area population, from Koapk (Cowlitz Falls) east and upriver, had direct access to Elk Pass obsidian throughout time, regardless of specific band affiliation. This would say something about the degree of band affinity, and perhaps group identity. The second hypothesis is that for much of the pre-contact period, the upper Cowlitz area was occupied by a single band, perhaps also suggesting lower population density and higher mobility. If populations increased in the late prehistoric period, as Burtchard (1998) has suggested, then perhaps one band eventually split to become two, then four, and eventually eight or nine by the time of contact.

The caveat, of course, in considering the relationship between historic group territory and ancestral group territory is the span of time represented by dated assemblages with Elk Pass obsidian. As we have seen, the most recent dated occurrence of Elk Pass obsidian is from ca. 430-500

B.P., about 300 years before the first historic contact with non-native people. Much can occur in three centuries' time, but there is nothing in the archaeological record, nothing in the historic record, and nothing in the oral traditions of the Taytnapam to suggest radical upheaval, population shifts, or significant changes in group composition during this period. These things would come later, in the decades after contact.

The limited spatial distribution of Elk Pass obsidian is likely related to the structure, composition, and mechanical properties of the stone. Spherulite inclusions are located throughout the matrix, and microfractures exist throughout much of the archaeological and geochemical source material observed. Preliminary replicative flintknapping experiments suggest that these physical characteristics limited the ability to control bifacial reduction, resulting in a high rate of production failure and shatter (Jeffrey Markos, personal communication 1989). These factors likely constrained utility and value. Compared to nonlocal obsidians, Elk Pass material was probably a low value lithic resource, unsuitable for trade and exchange. The general lack of finished formed tools, particularly projectile points, lends support to this material assessment.

The high value, non-local sources of obsidian represented in the area, such as Newberry Volcano, or Obsidian Cliffs, have very large ranges of utilization, and, I suspect, provide a greater challenge to the identification of direct procurement versus exchange territory. For its very differences, the Elk Pass obsidian is much more suited to the isolation of the range of a specific forager group.

Summary and Conclusions

The Elk Pass obsidian source is one of only 12 geochemically distinct primary sources of obsidian identified to date in the state of Washington. Archaeological investigations in the southern Cascade Mountain Range have shown that lithic raw material obtained from this source was used for tool manufacture throughout much of the pre-contact period. Aside from a small cluster of alpine sites near the toolstone source, Elk Pass obsidian has been identified in samples from only 11 archaeological sites, all but one of which occur within the upper Cowlitz River watershed no more than 52 km from the source location. Use of material from this source appears to have been limited. For the majority of archaeological sites where this material has been identified, obsidian represents a very small percentage of the toolstone assemblage.

The very limited investigation conducted to date regarding the distribution, character, and use of Elk Pass obsidian suggests the following as tentative conclusions: (1) Elk Pass obsidian was a low-value resource, largely unsuitable for exchange; (2) group territory within the conveyance zone of this obsidian was likely constrained by mountainous topography; (3) the source location and limited spatial distribution suggest direct access, embedded procurement by a single band or related group of bands; and (4) distribution of Elk Pass obsidian closely approximates the historic territory of the Taytnapam, and particularly the four upriver bands of this group. Although tentative, this study demonstrates the potential that similar studies of other minor sources of obsidian may offer, with respect to understanding the relationship between toolstone transport/distribution and forager/collector territory and range.

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CHAPTER 8

Columbia Hills Toolstone Geography

Ron L. Adams
Archaeological Investigations Northwest, Inc. (ron@ainw.com)

Cryptocrystalline silicate (CCS) material was extensively used as a pre-contact toolstone for millennia throughout the Columbia Plateau region of North America. This lithic material occurs in great abundance in the Columbia Hills, a group of grass-covered ridges and hills that tower above the Columbia River along the southern boundary of central Washington State in the semi-arid, eastern portion of the Columbia River Gorge. Archaeological examination of the Columbia Hills lithic landscape and analysis of lithic debris associated with pre-contact lithic procurement sheds important light on regional lithic procurement strategies and their relationship to patterns of settlement and subsistence.

This chapter discusses the results of archaeological field investigations within the Columbia Hills. Evidence of CCS toolstone procurement has been identified at sites ranging from ephemeral lithic scatters to large quarries. Analyses of lithic material from the quarries and their spatial relationship to traditional modes of settlement and subsistence are used to develop a model for toolstone procurement within this lithic landscape. By drawing on previous theories of toolstone quarrying and its relationship to settlement, this model provides important insights into past lithic procurement strategies in a geographically and culturally distinctive area that was one of the major pre-contact population centers of the Columbia Plateau region.

CCS Toolstone in the Columbia Plateau

CCS, most commonly referred to as chert, tends to be, by far, the most abundant raw material type used for making stone tools in archaeological assemblages on the Columbia Plateau (Adams and Ozbun 2011; Ozbun et al. 2002; Stevens and Galm, 1991; Dumond and Minor 1983). Large CCS outcrops are found scattered throughout the region and are associated with Miocene basalt flows that form the Columbia River Basalt group (Reidel and Hooper 1989). During the Miocene, major basalt flows were extruded across parts of Washington, Oregon, and Idaho. The flows were deformed by compression which created the Columbia Hills and other east-west trending ridges found in central Washington (Orr and Orr 1996).

Various mineralization processes associated with the basalt flows led to the formation of CCS lithic material. One of the primary processes that creates chert in this context is related to the leaching of silica minerals from water moving through the basalt. This silica precipitated in cooling joints and between basalt columns to form cherts and opals (Hess 1996:52; Lindberg 1989).

Much of the CCS in the Columbia Plateau is also attributable to the basalt flows trapping sediments and organic matter, which later transformed into CCS lithic material through mineralization processes. In the process of their formation, these basalt flows trapped sediments and organic matter that had accumulated on the surface of the previous flow since its emplacement. Successive basalt flows were separated by as much as 100,000 years, during which time soils and associated organic matter became trapped between successive flows. In some cases, basalt flows dammed rives and created large lakes that accumulated lakebed sediments that also became trapped between the basalt flows (Orr and Orr 1996). Silica leached from the basalt replaced the trapped organic matter and created fossiliferous chert, such as petrified wood, which represent some of the most beautiful and high-quality toolstone

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material found in the Columbia Hills and elsewhere on the Columbia Plateau (Edmondson 1991).

Columbia Hills Cultural Context

The Columbia Hills are situated in the eastern portion of the Columbia River Gorge in Klickitat County, Washington, rising above the north bank of the river to maximum elevations of between 500 and 900 m above mean sea level. The archaeological record of the area includes large pithouse villages along the Columbia River and a continuous human occupation for the last 8,000 years (Cressman 1960; Minor and Toepel 1986). By the Late Archaic period (2000 B.P.-A.D. 1720), this area was an important center for regional trade (particularly at The Dalles) and contained one of the richest salmon fishing locations in North America at Celilo Falls, located directly across the river from the Columbia Hills in Oregon (Butler and O'Connor 2004; Hayden and Schulting 1997).

Ethnographically, the Columbia Hills vicinity was occupied by speakers of the Sahaptin language who resided in politically autonomous winter villages on the Columbia River at the base of the hills (Ray 1936:). The villages within the immediate vicinity included *wálawitsis* at the present-day town of Maryhill, up to three apparently related villages (*wayám, wanwáwi*, and *tḱu*) at Miller Island and adjacent areas at the confluence of the Columbia and Deschutes Rivers, and *¾ mÍł* at the confluence of the Columbia River and Rock Creek. It has been estimated that a combined 3,442 people (more than 70% of whom lived in the Miller Island vicinity) resided in these villages during the winter months in the late 18th century (Boyd 1985; Hunn and French 1998:393).

While subsistence among these groups was largely centered around the large scale procurement of salmon and its storage for winter consumption, more than 50 percent of peoples' food energy was likely derived from gathered plant foods, particularly roots (Hunn 1990:176; Spier and Sapir 1930:174). A relative abundance of root species can be found on the ridge crests of the hills, especially on lithosols which have conditions favoring the growth of bitter-root and various species of edible lomatiums (Hunn 1990:93). Due to their proximity to large winter villages on the Columbia River, the Columbia Hills would have been ideally situated for procuring these important food resources.

Root collecting traditionally involved families setting up camps in the hills and mountains above the Columbia River at progressively higher elevations (as high as 1,800 m) between April and June (Hunn 1990:107; Hunn and French 1998:380-382; Spier and Sapir 1930:182). During these times, men accompanying root-gathering parties (root gathering being a subsistence endeavor traditionally undertaken by women and girls) hunted wild game, particularly deer and elk (Hunn 1990:138). Isolated projectile point finds, some associated with small lithic scatter sites, in the Columbia Hills could have been related to these hunting forays. Of particular importance and relevance to the discussion of lithic procurement, the lithosol areas where edible roots are typically found also often contain naturally outcropping CCS toolstone material. It is conceivable that men accompanying root-gathering expeditions procured CCS lithic raw material from outcrops situated on the lithosols where roots were most abundant.

In addition to their association with subsistence, the Columbia Hills are considered an important spiritual area among native groups. Within the Columbia Hills are several legendary sites that are incorporated into local Native oral traditions (Griffin and Churchill 2001:57). The Columbia Hills were also traditionally associated with vision quest activities, during which young people ventured to a remote location, maintained a vigil and accomplished tasks, such as stacking rocks, with the goal of acquiring a guardian spirit who could act as a protector throughout life (Griffin and Churchill 2001:36; Historical Research Associates, Inc. 1995:5-3; Ray 1942:235, 236; Spier and Sapir 1930:238-240). Many stacked rock features located along the crest of the Columbia Hills in the vicinity of CCS quarries and outcrops were likely created as part of vision quest activities. While these vision quests were probably not associated with toolstone procurement and flintknapping, their significance with regard to the materiality of the Columbia Hills may pertain to the cultural value of Columbia Hills CCS.

Lithic Procurement and Related Sites in the Columbia Hills

Archaeologists from Archaeological Investigations Northwest, Inc. (AINW) conducted several successive archaeological surveys of the Columbia

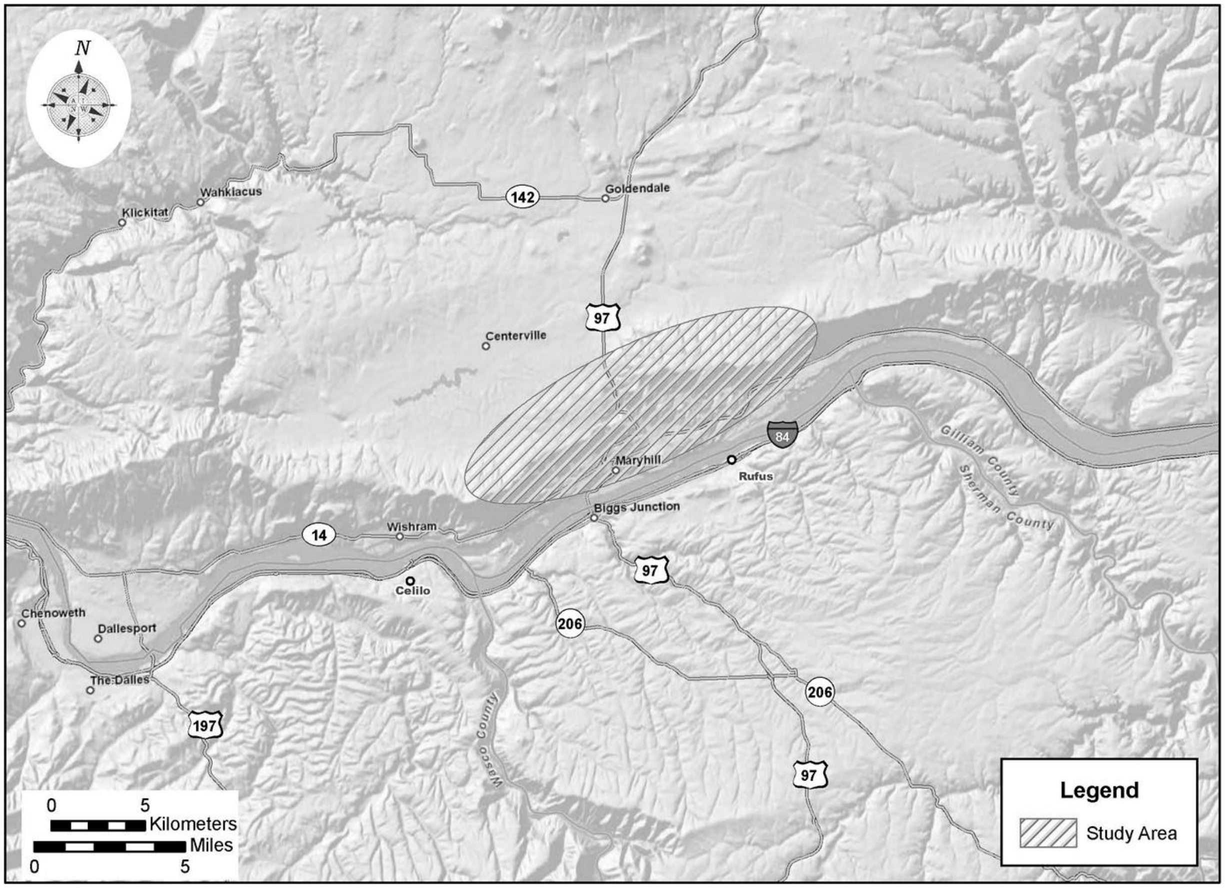

Figure 8-1. Map showing AINW study area and vicinity.

Hills for wind energy projects between 2005 and 2010 (Adams and Ozbun 2007, 2008, 2009a, 2009b; Adams et al. 2008, 2009a, 2009b, 2009c, 2009d, 2010). The surveys resulted in the identification of myriad pre-contact archaeological sites, the vast majority of which were associated with lithic procurement. A total of approximately 95 pre-contact lithic procurement and 2 apparent pre-contact camp sites were identified during pedestrian archaeological surveys that covered combined area of approximately 1,042 ha in the Columbia Hills (Figure 8-1). Subsurface archaeological testing and evaluation has been conducted at the 2 camp sites and within 24 of the lithic procurement sites.

The two sites (45KL590 and 45KL1479) identified as likely pre-contact camps were both located on the lower-mid slope of the Columbia Hills in an area containing several lithic procurement sites, including a small CCS quarry site (45KL1505) recorded during the AINW survey within 1.6 km of the camps in the same mid-slope setting. Site 45KL1479 is situated on a terrace approximately 100 m west of an unnamed creek and was found to contained large quantities of lithic debris in addition to tools associated with food procurement and processing (e.g., a pestle, projectile point fragment, biface blanks, flake tools, and a basalt chopper) (Adams 2009b). Blood residue analysis of stone tools recovered from 45KL1479 indicate that birds, deer, fish (salmon or trout), and rabbit were likely processed at the site location (Adams 2009b). Approximately 2 km northeast of 45KL1479, site 45KL590 is located on a benched landform on the mid-slope of the Columbia Hills at the location of a spring. The site also contained large quantities of lithic debris as well as faunal bone fragments and a small number of CCS stone tools (Adams 2009c). Importantly, neither 45KL590 nor 45KL1479 was situated in a locale with naturally occurring CCS toolstone material, indicating that they were most likely not directly associated with lithic procurement and making them unique in relation to the vast majority of pre-contact sites recorded in the Columbia Hills.

Spread out over distances of up to several kilometers from the probable camp locals are 95 lithic procurement sites identified in the Columbia Hills that range in size from small lithic scatter sites to large quarries with extensive scatters of CCS debitage and cores. For the purpose of illustrating this variability, the lithic procurement sites have been divided into the categories of Ephemeral Lithic Procurement Locales and Quarries.

Ephemeral Lithic Procurement Locales

The small, ephemeral CCS lithic scatter sites range from those containing an abundance of poor quality CCS material to sites comprised of very discrete, limited amounts good quality CCS material. The lithic artifacts at these locales reflect very limited lithic procurement activities and comprise the overwhelming majority of sites identified within the study area.

The assay sites containing poor quality material are often marked by the presence of abundant light and crumbly chunks of chert or opal that are easily shattered. From a distance, these sites can appear as spectacular lithic scatters. However, upon closer examination the poor quality of the material is apparent. The high water content of the opal material makes it susceptible to crumbling as it dehydrates on exposure to the atmosphere. Natural fractures caused by freezing and thawing are also common for these materials.

A small boulder-sized chunk of this type of CCS material from the Columbia Hills was tested for its suitability as a toolstone by John L. Fagan at the AINW laboratory. After striking the material once with a hammerstone, the boulder completely shattered into small, angular chunks (Figure 8-2). None of the chunks removed from the boulder were suitable for further reduction to produce tools. Indeed, among hundreds of pieces of this naturally fractured, low quality CCS material at these types of sites, there are sometimes a few flakes that have resulted from deliberate flintknapping either from the poor-quality CCS material or from a very limited quantity of better quality CCS that is often found in association. These flakes are evidence of episodes of assaying or testing lithic raw material. After gauging the quality of the easily shattered material or the limited quantities of usable CCS, pre-contact flintknappers likely moved on in search of better prospects elsewhere.

Figure 8-2. Low-quality CCS boulder after being subjected to experimental reduction in the AINW laboratory.

The remaining minor lithic procurement sites include those containing moderate quantities of medium-quality CCS or limited quantities of very good quality CCS material. These sites are found on deflated lithosols and in and around drainages where lithic material has been exposed through erosional processes (Figure 8-3). Within these areas, there is often a concentration of flakes and cores in the vicinity of a few small exposed CCS cobbles or boulders. Cultural material in even the more concentrated areas within these sites occurs in relatively low densities both on and beneath the surface, ranging between about 1 and 100 artifacts per cubic meter in test excavations. These densities indicate that toolstone material was more than likely procured periodically or even during a single episode at the small lithic procurement sites. Prehistorically, these locales may have been occasionally checked to see if good toolstone material was exposed as people passed through the area on root-gathering or hunting forays. Importantly, the high degree to which the usable CCS lithic material at these ephemeral lithic scatters was utilized illustrates the importance of the Columbia Hills as a toolstone landscape.

Quarry Sites

The largest and richest lithic procurement sites in the Columbia Hills can be classified as quarries.

Figure 8-3. Drainage exposure of CCS boulders in the Columbia Hills.

Figure 8-4. Typical example of superior-quality Columbia Hills CCS toolstone.

The quarry sites in the Columbia Hills range from expansive scatters to discrete, high-density clusters of CCS lithic material. These "hot spots" are found amongst much larger numbers of smaller lithic assay sites. Subsurface archaeological testing was conducted at significant artifact concentrations within six Columbia Hills quarry sites (45KL1131, 45KL1237, 45KL1263, 45KL1400, 45KL1401, and 45KL1505). The quarries are all associated with 1) high densities of exceptional quality CCS flakes and cores found both on and beneath the surface; 2) natural outcroppings of CCS cobbles and boulders; and 3) lithic artifacts displaying early stages of core and biface reduction technologies.

Artifact loci within the most substantial quarries contained lithic material densities of over 1,000 artifacts per cubic meter. These artifacts include flakes and cores of high quality toolstone material with clearly identifiable attributes related to conchoidal fracturing resulting from deliberate lithic reduction activities. This high quality material is characteristically caramel-brown translucent chalcedony that is very hard and durable with clean and smooth fracture surfaces (Figure 8-4). In addition, there is often poorer quality white chert that often forms a "crust" around the high-quality CCS. Thousands of fragments resulting from the deliberate removal of this white chert from the exterior of CCS boulders and cobbles also occur at Columbia Hills quarry sites.

Mining pits are found at some of the largest quarry sites in the Columbia Hills (namely, 45KL1146, 45KL1237, and 45KL1400). The mining pits are oval or circular in shape, 2-3 m in diameter, and approximately 0.5-1 m in depth. A large quarry site (45KL1400) on the crest of the Columbia Hills contains one mining pit at which CCS boulders dug from the pit appear to have been deliberately placed in a linear alignment at the pit's south end overlooking the Columbia River (Figure 8-5). The highest density of CCS debitage and cores is typically found adjacent (primarily downslope) to the quarry pits.

Quarry pits are also found at sites nearby the study area, including the Walawateese Quarry site (45KL612), which contains five quarry pits ranging in size from approximately 32 m^2 to 300 m^2. The Walawateese quarry is situated at the base of the southern slopes of the Columbia Hills and contains a very high density of CCS flakes and cores on its surface, with the greatest density occurring downslope from the quarry pits, similar to the pattern found at quarry pits higher up on the crest of the Columbia Hills (Hess 1995).

Figure 8-5. Mining pit at quarry site 45KL1400.

Archaeological test excavations at the Columbia Hills quarry sites have revealed the utility of mining for toolstone material at CCS quarries. These large quarry sites are all situated at or near the crest of the Columbia Hills, where soils are shallow. In test excavations in this environment, basalt bedrock was typically encountered between 25 and 50 cm below the ground surface (Figure 8-6). Within the basalt bedrock, CCS seams or beds are present that can be accessed with relatively little effort. The large quarry pits likely represent areas where large amounts of exceptional toostone material found in the CCS seams or beds were repeatedly excavated over a long period of time.

At sites without mining pits, the lithic material has been exposed naturally by way of stream down-cutting on the upper slopes of the hills and aeolian processes at the crest of the hills where basalt bedrock and outcropping CCS seams or beds have been exposed. At the largest quarry sites, naturally occurring cobbles and boulders can be found in these settings. At the drainages in particular, there is often an abundance of exposed large CCS cobbles and boulders that have been "mined" naturally through stream down-cutting. These drainages were likely checked periodically for toolstone material. The largest quarry in the study area (45KL1237) covers an area of approximately 36 ha marked by several deeply incised drainages around which high densities of flakes and cores litter the ground surface**.**

The smallest quarries in the study area are found at discrete locales where CCS material has been exposed on deflated surfaces at the crest of the Columbia Hills around the heads of drainages. While not extensive in size, these areas contain loci with high densities of toolstone material.

Test excavations at these small quarries reveal high densities of subsurface flakes and cores comparable to those found in the larger quarries. The high concentration of artifacts at these small quarries is illustrative of the high degree to which all sources, both big and small, of good quality CCS material were utilized prehistorically.

Figure 8-6. Shallow exposure of CCS bedrock in 1x1-m test unit at quarry site 45KL1505.

Lithic Material and Procurement Strategies

The lithic artifacts collected from archaeological testing work at Columbia Hills lithic procurement sites were analyzed by Dan Stueber and Terry L. Ozbun at the AINW laboratory to model reduction technologies represented in the assemblage. Stone tool and debitage classifications were based on technological and morphological attributes defined from flintknapping experimentation and common to the lithic technological literature (Crabtree 1982; Flenniken 1981; Holmes 1919; Titmus 1985). This discussion focuses on the analysis of lithic artifacts recovered from the two probable camp sites (45KL590 and 45KL1479) and six quarries where subsurface archaeological testing and evaluation was conducted at major artifact concentrations (45KL1131, 45KL1237, 45KL1263, 45KL1400, 45KL1401, and 45KL1505).

The artifacts consist of 2,036 CCS and 15 basalt artifacts from limited surface collections and archaeological test excavations. Of these, 420 CCS and 11 basalt artifacts were from the probable camp sites (45KL590 and 45KL1479), while the remaining 1,616 CCS and 4 basalt artifacts were collected from the quarries (45KL1131, 45KL1237, 45KL1263, 45KL1400, 45KL1401, and 45KL1505). The sites with the greatest numbers of artifacts analyzed include the large quarry sites 45KL1400 and 45KL1237, with 559 and 498 artifacts respectively. The highest densities of lithic artifacts were also encountered at these two sites, with densities up to 3,657/m^3 at 45KL1400 and 1,554/m^3 at 45KL1237 (densities extrapolated from small excavation volumes).

The analyses of lithic material from the quarries found that tools were very rare, consisting primarily

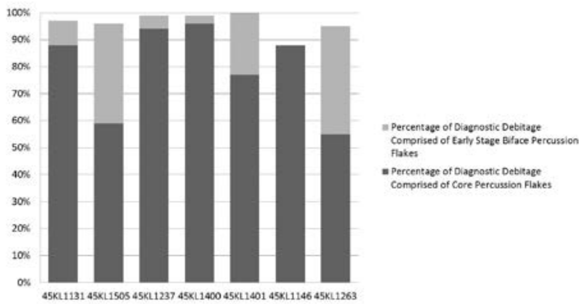

Figure 8-7. Bar graph illustrating the dominance of early-stage reduction technologies in debitage assemblages at Columbia Hills toolstone quarries.

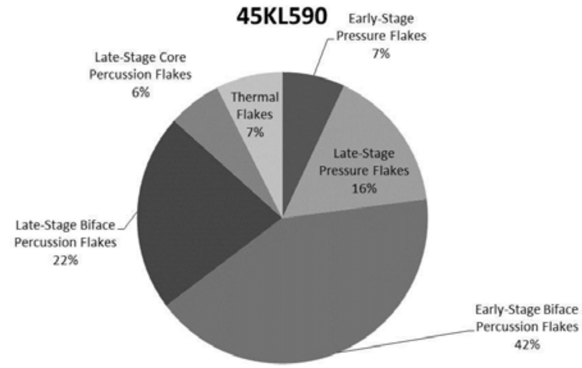

Figure 8-8. Pie chart showing the variety of reduction technologies associated with the debitage assemblage at pre-contact camp site 45KL590.

of cores and a few early-stage blanks, while lithic debitage from the sites (consisting primarily of core percussion flakes and early stage biface percussion flakes) generally reflected early stages of lithic reduction, and not the manufacture of formal tools. Between 80 and 100 percent of all recovered diagnostic lithic debitage from the quarries consists of CCS core and early stage biface percussion flakes. In contrast, debitage associated with tool-making activities of lithic reduction typically includes a much higher concentration of later stage of biface percussion flakes and pressure flakes. At the largest quarries (45KL1237 and 45KL1400), these later stages of lithic reduction comprise less than five percent of the analyzed debitage (Figure 8-7). While not formally analyzed, the lithic debitage found on the surface at the nearby Walawateese quarry also primarily consists of flakes reflecting early stages of lithic reduction (Hess1995).

The lithic material from the probable camp sites (45KL590 and 45KL1479) bore visual similarities to that from quarry sites, particularly the nearby site 45KL1505. However, these sites contained more formed tools and far fewer pieces of debitage indicative of early stages of lithic reduction. The debitage assemblages from 45KL590 and 45KL1479 are instead dominated by bifacial percussion flakes and pressure flakes. This pattern is indicative of later stages of lithic reduction and tool-making and a scenario in which earlier stages of raw material reduction were being done at the nearby quarry sites (Figures 8-8 and 8-9) (Adams et al. 2009b:11, 12).

These data suggest that formal tool-making occurred at lithic workshops away from the quarries at sites such as 45KL1479 and 45KL590. Other similar camp-type occupation sites may exist outside the study area in the Columbia Hills, given the expansiveness of the Columbia Hills lithic landscape. The proximity of the Columbia Hills quarries to pre-contact and ethnographically documented villages on the Columbia River suggest that much of the lithic material from the quarries was also taken directly to village sites for further reduction and tool-making without going through an intermediate workshop site.

Indeed, previous archaeological studies of toolstone quarrying behavior indicate that in cases where quarries were situated within close proximity (approximately 10 km or less) to residential contexts, minimal (primarily early-stage) lithic reduction activities occurred at the toolstone sources (Beck et al. 2002; Elston 1992a:798). Studies that have modeled this type of quarrying behavior are derived from “central place foraging models” (e.g., Bettinger et al. 1997; Metcalfe and Barlow 1992) which assert that the greater the distance traveled from the central place (i.e., a settlement) to obtain resources, the more cost-effective it is to conduct in-field processing of the resource. If the distance to the central place is relatively short, it is more cost effective to limit the time devoted to processing the resource in the field. When central place models are applied to lithic reduction analyses, field processing time, the increase in the resource utility due to field

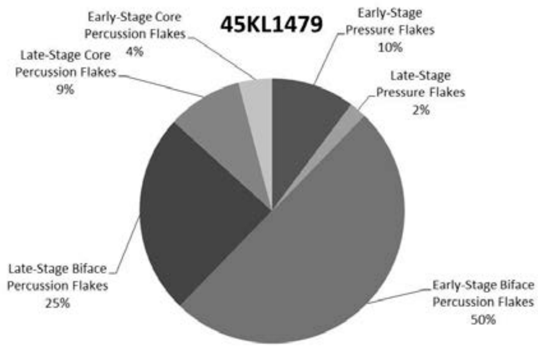

Figure 8-9. Pie chart showing the variety of reduction technologies associated with the debitage assemblage at pre-contact camp site 45KL1479.

processing, and transport distance are key components for determining the degree to which lithic reduction activities take place at the quarries proper (Beck et al 2002:492).

From the perspective of efficiency, central place models focus on the expenditures of time and energy associated with different stages of lithic reduction. According to these models, when the toolstone source is near lithic workshops of a residential site, it is most cost-effective to limit reduction to the initial stages at the quarry location due to the fact that the most cost-effective (in terms of effort) reduction occurs at the beginning of the reduction sequence and diminishes thereafter. In support of this notion, Bettinger et al. (1997) noted that the initial flakes of a biface reduction sequence typically have, on average, the greatest weight and are the most efficient in terms of increasing the utility of the core, assuming that 50 percent of the core consists of waste flakes.

When looking at the issue solely from the perspective of ease of transport, those living near toolstone quarries would not have needed to expend a lot of energy breaking down lithic material into easily transportable pieces due to the relatively light energy expenditures associated with travel between the quarries and village sites. If a village is within close proximity to a quarry, the most cost-effective option is to complete later stages of reduction at the residential workshop, given the absence of a need to break down the cores further for ease of transport. On the other hand, initial stages of reduction at the quarries could also be employed to assay the quality of the lithic raw material, so as not to incur unnecessary transport costs for unusable materials however small those costs might be due to proximity. In all cases, it is also assumed that the quarries could be visited more frequently due to their proximity, eliminating the need to transport an abundance of toolstone that has already been reduced into usable pieces at one time.

The relatively close proximity of the Columbia Hills quarries to pre-contact village sites warrants the application of the principals of central place foraging models. Archaeological evidence for human settlement within the immediate vicinity of the Columbia Hills has been dated to as early as 8,000 years before present (Cressman 1960; Minor and Toepel 1986). By the late prehistoric period (2,000 B.P.-A.D. 1720), pithouse villages were abundant along the Columbia River throughout the Columbia Plateau (Andrefsky 2004:32). Some of the largest Columbia Hills quarries (particularly 45KL1237) are situated within 5 km to the northeast of two large prehistoric pithouse village sites on Miller Island (Figure 8-10). Combined, these two sites are comprised of nearly 200 housepit features (Boxberger et al 1993:10; Strong et al. 1930).

CCS toolstone from the hills undoubtedly made its way to these settlements and the time depth and extent of nearby settlement likely accounts for the apparent intensity of lithic procurement in the Columbia Hills at a wide range of locales. Furthermore, in addition to the quarry sites within the study area, at least five other large quarry sites (including the Walawateese quarry discussed above) have been recorded in the Columbia Hills area. All of the Columbia Hills quarries are situated in the vicinity of traditional ethnographic winter village locations in an area stretching 51 km between The Dalles, Oregon in the west and the confluence of Rock Creek and the Columbia River in the east.

The quarries nearest to the river would have obviously been the most accessible and therefore most attractive for those seeking toolstone. The Walawateese quarry is located within several hundred meters of the *wálawitsis* village site at present-day Maryhill and much closer to the Columbia River (700 m from the river) than the quarries near the crest of the Columbia Hills, making it much easier to access. While the Walawateese quarry was most definitely a rich

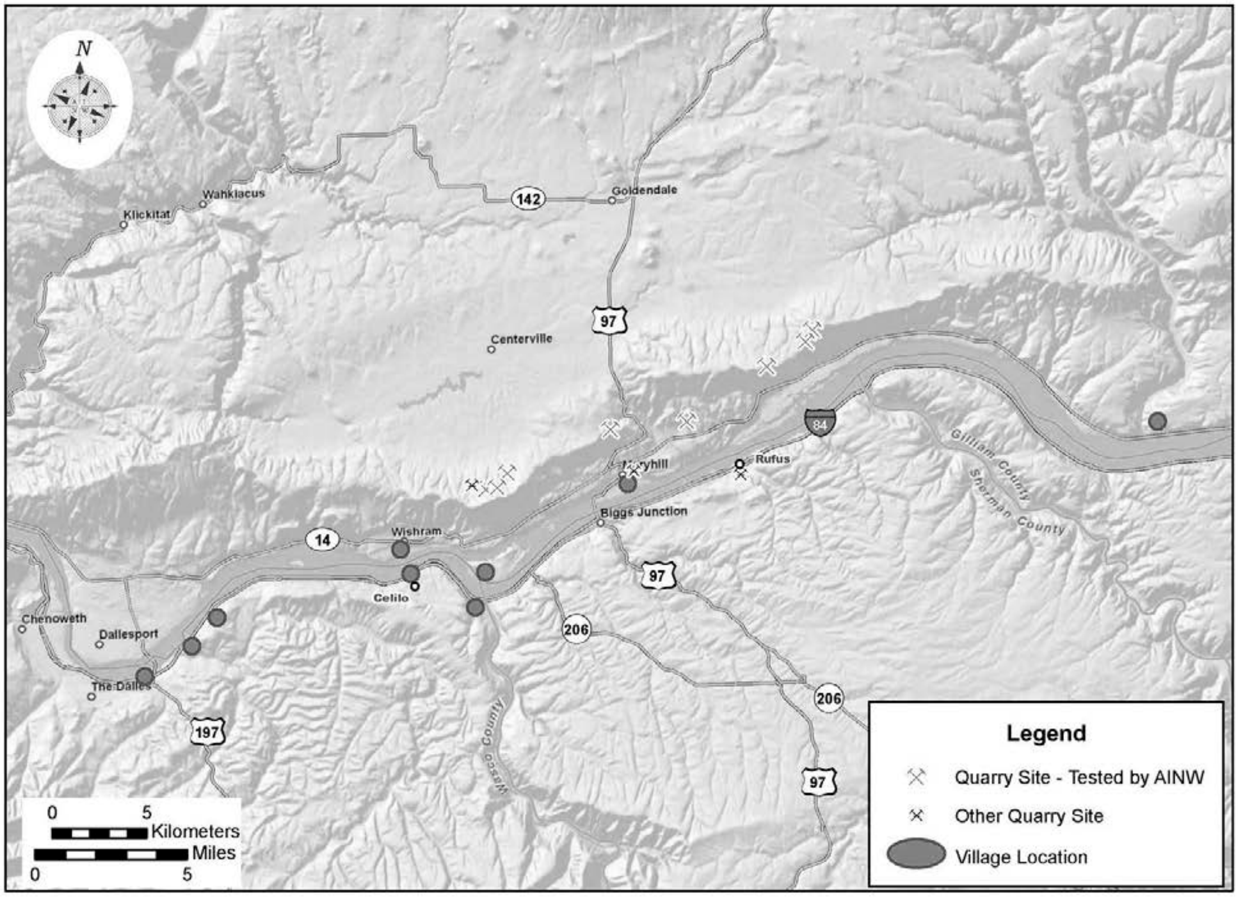

Figure 8-10. Map showing the location of ethnographic villages in relation to Columbia Hills toolstone quarry sites and other nearby quarries.

source of toolstone, the extensive quarrying of CCS material reflected in the large quarry pits at the site is likely attributable to its proximity to the river and the *wálawitsis* village. As Wilson (2007) has demonstrated, when toolstone sources are of comparable quality, the closer the source is to a central place the more likely it will be utilized extensively.

Accessing the quarries higher up in the hills would likely have involved well established trails extending from the Columbia River to the Columbia Hills and beyond. Historic maps of the area appear to depict some of the routes used to access the quarries at or near the crest of the Columbia Hills. Travel routes extending through the Columbia Hills depicted as trails on historic maps pass nearby two of the largest quarries located at the crest of the hills. Davies Pass, one of the main historic (and current) travel routes from the Columbia River through the Columbia Hills and beyond extends within close proximity to the large quarry site 45KL1400 as depicted on the 1861 General Land Office (GLO) map of Township 3 North, Range 16 East, Willamette Meridian (GLO 1861b). A trail is also depicted extending through the largest quarry site in the study area (45KL1237) from the south slope of the Columbia Hills on the 1862 GLO map of Township 2 North, Range 15 East, Willamette Meridian (GLO 1862a). However, it would have required traversing up the slopes of the Columbia Hills with an elevation gain of nearly 670 m to reach this quarry from the village sites at Miller Island in spite of the short distance (approximately 3.5 km) from Miller Island to the quarry.

Despite the geographic proximity of the quarries to settlements, establishing an iron-clad, verifiable link between the toolstone material found at Columbia Hills quarries and that found at nearby residential sites will require further analysis of lithic material. Photographic images of CCS tools from pithouse village sites on Miller Island and projectile points referred to as "gem points" from various sites between The Dalles and the John Day River depict artifacts that appear to have been made from toolstone material with visual attributes very similar to those of the CCS found at quarry sites in the Columbia Hills (Strong 1959:154-146; Strong et al. 1930). However, macroscopic comparisons of CCS samples is limited in its accuracy in comparison to the measurement of trace element concentrations through ICP-MS analyses, which have been found to be more effective in identifying the source locations of CCS toolstone (Hess 1996:77). These types of analyses have not been conducted for the CCS from sites near the Columbia Hills, although toolstone from the hills very likely made its way to the large nearby villages, particularly Miller Island given its proximity to large Columbia Hills quarries.

Modeling Columbia Hills Lithic Procurement

Taken together, the lithic material analyses and the distances from the quarries to settlements and camps strongly suggest that trips to quarry sites were relatively short and the time spent reducing toolstone at quarries would have likewise been brief. In order to better characterize the pre-contact strategies of obtaining toolstone in the Columbia Hills, it is useful to examine the other activities traditionally carried out in the area, namely foraging behavior.

As noted previously, root crops were very important sources of nutrition for native groups by the contact period. The proximity of the quarry sites to edible roots suggests that CCS lithic procurement in the Columbia Hills was often associated with foraging. In this scenario, pre-contact toolstone procurement in the Columbia Hills would have been an activity "embedded" in the seasonal subsistence round documented ethnographically in the region, much like what Binford (1979) observed among the Nunamiut, who procured toolstone during subsistence gathering forays. These strategies of lithic procurement embedded in subsistence practices are in contrast to what are referred to as "direct" lithic procurement strategies in which the main goal of the journey is to obtain toolstone.

Certainly, the CCS procurement sites located the greatest distance from camps and villages (particularly small ephemeral lithic scatters) were most likely visited primarily in association with root-gathering forays. As noted previously, the women and girls who traditionally gathered roots were typically accompanied by men who hunted in the vicinity of the root gathering grounds (Hunn 1990:138). A scenario in which the men also gathered toolstone during these root-gathering trips as an embedded practice is highly plausible.

However, the dichotomy of "direct" vs. "embedded" lithic procurement can lead to the unnecessary pigeon-holing of activities into abstract categories that may not reflect the fluidity and complexity of human behavior. Gould and Saggers (1985) observed a combination of both direct and embedded strategies of lithic procurement in ethnoarchaeological work among Western Desert Aborigines in Australia. The lithic procurement activities among the Western Desert Aborigines referred to as "direct" lithic procurement were often associated with the maintenance of long-distance social networks or were done from base camps that were occupied for subsistence purposes (Gould 1978:830-832; Gould and Saggers 1985:120, 123). What distinguished this activity from more embedded lithic procurement were statements by informants indicating that the primary goal of these forays was to obtain lithic raw material, in spite of the fact that other activities were taking place during the forays. In short, it is difficult, if not misleading, to put strict classifications of "embedded" or "direct" procurement on pre-contact toolstone quarrying.

When examining the range of lithic procurement sites that occur in the Columbia Hills, a model for lithic procurement in the Columbia Hills is perhaps best viewed as combining both direct and embedded strategies. The more ephemeral lithic scatters and smaller quarries in the Columbia Hills were likely locales in which lithic procurement was practiced in association with subsistence-related tasks or while traveling through the hills en route to areas further afield. It is also possible that very limited lithic procurement occurred during vision quests, as stacked rock features likely constructed in ritual contexts are located throughout the Columbia HIills. At the ephemeral lithic scatter sites, lithic procurement would have been limited in its duration and intensity, although certain desirable spots were likely visited repeatedly. The archaeological evidence for this type of limited-scale toolstone procurement includes lithic procurement locales with one or more of the following characteristics: relatively low densities of lithic debitage, very discrete areas with high densities of lithic debitage, and abundant CCS lithic material of poor or uneven quality.

As opposed to the embedded procurement that was likely linked to the ephemeral lithic procurement sites situated some distance from habitation sites, more direct toolstone procurement likely occurred at the quarry sites nearest to villages and camps. The most obvious candidate for direct procurement would be the Walawateese quarry which would have been the most accessible from villages on the Columbia River, particularly the *wálawitsis* village at Maryhill. The abundance of large quarry pits at the site attests to this type of use. The quarry sites within close proximity to Columbia Hills camp sites 45KL590 and 45KL1479, which include an expansive quarry containing a mining pit (45KL1400), were likely, at least occasionally, visited for the sole purpose of obtaining CCS toolstone. Likewise, direct procurement of CCS likely occurred at the large CCS quarry (45KL1237) located approximately 3.5 km from large pithouse villages at Miller Island. Not surprisingly, lithic debitage assemblages at these two large quarries contained the most substantial concentrations of early-stage core percussion flakes among the quarry sites investigated for this study (Figure 8-7).

Summary and Conclusions

The Columbia Hills represent an important source of CCS toolstone for one of the most densely populated areas within the Columbia Plateau region during the pre-contact period. This lithic landscape contains several large quarry sites and myriad smaller lithic procurement locales within relatively close proximity to large villages and seasonal camps. Analysis of lithic material from Columbia Hills quarry sites and applying the principles of central place foraging models indicate that pre-contact flintknappers procuring CCS in the hills most likely limited their activities to the early stages of toolstone reduction at the quarries, choosing to conduct later stages of reduction and toolmaking at nearby villages and camps. Much of this quarrying and assaying of CCS lithic material in the hills was likely embedded in foraging for the abundant edible roots found in the Columbia Hills lithic landscape, as root procurement was a very important aspect of the local and regional subsistence regime. However, visits to the largest quarry sites likely also occurred outside of root gathering forays as a direct procurement strategy, especially in the cases of the large quarries most accessible to villages and camps.

To conclude, this study is best viewed as an exploratory analysis of Columbia Hills toolstone geared to providing preliminary insights into the pre-contact lithic procurement strategies utilized in this landscape. Further studies could provide additional insights into the relationship between toolstone procurement and subsistence. In addition, the spiritual significance of the Columbia Hills and how it may relate to the materiality and cultural value of Columbia Hills toolstone is a topic worthy of future exploration.

To develop a more complete picture, establishing a time depth for pre-contact CCS toolstone procurement with radiometric dating and an analysis of the chemical signatures of the Columbia Hills CCS are necessary to better understand the relationship between the Columbia Hills lithic landscape and the villages and camps in which the toolstone was used, as well as how widespread this toolstone is throughout the region. In particular, establishing a chronology for quarrying in the Columbia Hills could allow for a diachronic analysis of reduction technologies to determine whether these strategies change through time and whether there is variability between the strategies used at specific quarries and workshops.

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CHAPTER 9

Estimating Biface Production Output at a Basaltic Andesite Workshop in the Blue Mountains

Kenneth C. Reid
Idaho State Historic Preservation Office (ken.reid@ishs.idaho.gov)

Matthew J. Root and Daryl E. Ferguson
Rain Shadow Research Inc. (Rainshadow@pullman.com; deferguson@pullman.com)

Introduction

The toolstone geography of the Tri-State Uplands of southeastern Washington, west-central Idaho, and northeastern Oregon is structured by the Miocene lava flows of the Columbia River Basalt Group (Camp et al. 1982). Investigation of workshops where various fine-grained volcanic (FGV) rocks outcrop as nodular clasts or tabular boulders has a long history in this region (Bryan and Tuohy 1960; Bucy 1974; Womack 1977; McPherson et al. 1981). A few studies have included experimental reduction exercises designed to better understand how bifaces or cores were made (Womack 1977; Jaehnig 1991). More recently, geochemical sourcing of FGV rocks has been explored at regional scales approximating those posited for western obsidians (Jones et al. 1997; Smith 2004; Bakewell 2005; Page 2008).

We now have a better appreciation of the variability within this suite of volcanic toolstones, and can distinguish many of them geochemically, sometimes supplemented with petrographic thin section analysis (Bakewell 2005). For example, low silica basaltic andesites of the Grande Ronde Basalt Formation can be readily distinguished from high silica andesites and dacites of the Saddle Mountain Basalt Formation (Dickerson 1998; Bakewell 2005). This chapter furthers these studies by integrating geological and geochemical results with replicative experiments to estimate temporal trends in production biface output at the Pataha Canyon workshop in southeast Washington.

Environmental Setting

Pataha Canyon lies at the northern rim of the Blue Mountains, near the edge of a forested basalt plateau and a rolling steppe formed in loess (Reid and Root 1998). The Blue Mountains form a western spur of the northern Rocky Mountains. The study area lies at the edge of the Arid Transition and Canadian zones, and is ecotonal in character. Pataha Creek is the main tributary of the Tucannon River, which joins the lower Snake River not far above its confluence with the Columbia.

The Pataha Canyon workshop (45UM110) lies at an elevation of 1,155 m at the confluence of Pataha Creek and a small channel from Iron Springs Canyon (Figure 9-1). Pataha Creek is the principal tributary of the Tucannon River and drains an area of about 124 km^2. The canyon here is about 1,000 m wide at the rim, and about 244 m in depth. The site has an effective temperature (ET) of 9.43°C. By comparison, sites along the Snake River to the north enjoy values between 13-14°C. In fact, all known winter settlements in the lower Snake basin lie in sheltered settings where ET ranges between 13-14°C. We assume that the Pataha Canyon workshop served as a warm weather seasonal camp rather than a winter settlement in prehistory.

Local physiography consists of north-trending plateau fingers and intervening valleys, locally named and mapped as ridges and gullies. The plateau is formed in basalt of middle Miocene age. Locally the flows are assigned to the "Grande

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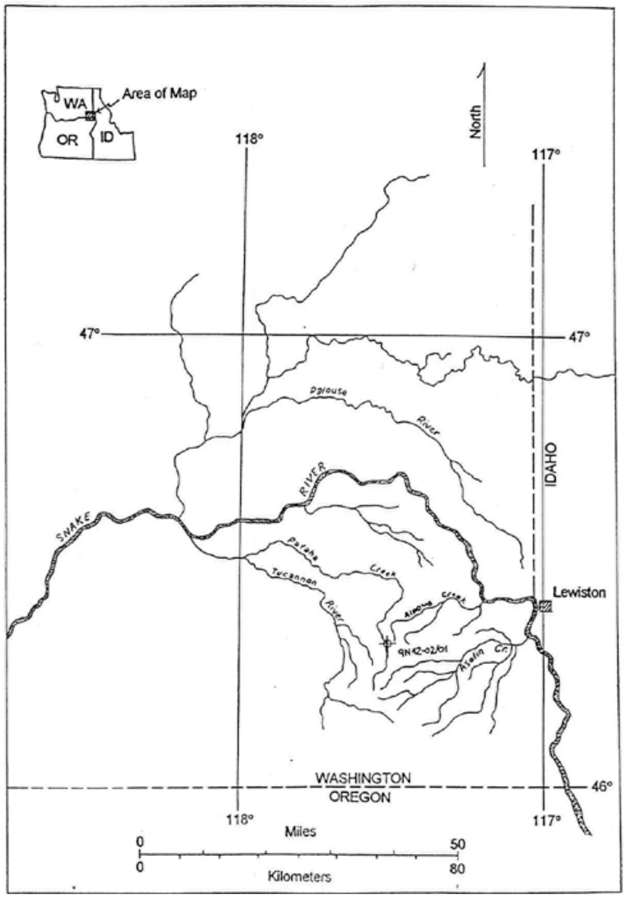

Figure 9-1. Vicinity map of the Pataha Canyon study area.

Ronde basalts of reversed magnetic polarity" (Schuster 1993). To the south, this dissected plateau is studded by several buttes and peaks. These include Huckleberry Butte (1,561 m), Mount Horrible (1,774 m), Sunset Point (1809 m), Diamond Peak (1,950 m), and Oregon Butte (1,951 m). All are subalpine in elevation and lack an upper timberline. The frequency of springs increases to the south, with an average of at least one mapped and named spring per section on the USGS quadrangles. Many are marked by lithic scatters dominated by the locally outcropping FGV toolstone.

Although native place names sometimes offer clues to how a locality was used originally, Nez Perce elder Elmer Paul glossed Pataha ("Puhtuh'puh") as meaning only "in the bushes" (Chance et al. 1987:136). The site does lie in a forest-shrub plant association where soils formed under a mix of Ponderosa pine, Douglas-fir, spirea, snowberry, and rose. Fringing this association to the north, and separating it from the more extensive steppe grasslands, was the grass-shrub association of bluebunch wheatgrass, Idaho fescue, Sandburg bluegrass, rose, lupine, and balsamroot. The steppe grassland proper, which extended northward to the Snake River, comprised a mix of bluebunch wheatgrass and Idaho fescue (Raver 1974:65).

Ethnography tells us that "making meat" was the major subsistence focus in the Blue Mountains, and archaeology has taught us that chipped stone industries flourish where the meat is being made. The principal game animals found within a day-radius of the site were deer and elk. Bears ranged the highlands to the south. Rocky Mountain bighorn remains have been identified in the upper Tucannon basin in Columbia County, and a native bighorn was killed as late as 1917 in the Asotin Creek headwaters (Johnson 1983:116). Bison bones have been recovered in cultural contexts at six sites along the lower Snake River to the north, where they date between 2,500 and 950 years ago (Schroedl 1973:25-32).

The Tucannon River is one of the shorter streams draining the Blue Mountains. However, while spawning beds in the Tucannon basin may have been fewer than those in the Grande Ronde basin, the fish were probably fatter on arrival. We suspect the prehistoric aboriginal fishery within the study area may have been more robust than suggested by historic data (Parkhurst 1950:5-9).

Toolstones

Our focus here is on workshop dynamics within the context of a delimited toolstone terrane. The bulk of our sample consists of a single toolstone, a local outcrop of basaltic andesite. However, the lithic raw materials recovered at Pataha Canyon also include several chromatically distinguishable cherts, chalcedonies, and jaspers, obsidians, and a few rhyolite specimens.

Cherts, Chalcedonies, and Jaspers. The only reported outcrop of upland chert in either the Tucannon basin or Garfield County is located in Section 15, Township 9 North, Range 41 East, at an elevation of 1,097 m. This is about 5.5 km southwest of the Pataha Canyon workshop. An accompanying map suggests an outcrop area of about 200 ha (Huntting 1942:8). The same area has been mapped by Baldwin (1989:102) as the "Big Four Lakes Outcrop," and described as follows:

> …several beds of massive and laminated black and gray chert and massive black argillite about 25 feet thick interbedded with greenstones of about the same thickness. These are overlain by several hundred feet of black and gray cherts, black and olive argillites, and light colored argillites and cherts. In all more than 1,000 feet stratigraphic thickness of cherty argillites have been exposed…The rocks collectively called cherty argillites comprise metamorphosed argillaceous sediments, pure cherts, and all gradations between the two…The cherts range from olive-green to gray and through gray to black, the latter being the most common color. They are very brittle and break with a subconchoidal fracture. They are very dense and are extremely fine-and even-grained and show no signs of organic remains (Huntting 1942:11-13).

Huntting correlated the Big Four Lakes Outcrop as an exposure of what is now referred to as the Elkhorn Ridge Argillite Formation. The outcrop is a potential source for alluvial chert gravels injected into the Snake River by way of the Tucannon (Reid 1997). We hypothesize that most of the chert tools and flakes at Pataha Canyon have their origin in gravel sources to the north.

Obsidians. Obsidian flakes from Pataha Canyon are small and few. Only 57 were recovered in the sample described below. Two flakes from the 1994 excavations were chemically sourced to Dooley Mountain in the lower Burnt River basin, and Whitewater Ridge in the upper Silvies basin (Lucas 1997)(Figure 9-2). Southern sources can probably be assumed for the remainder of the sample. Obsidian is significant in the Pataha Canyon locality chiefly as a measure of mobility and social interaction.

Fine-grained volcanics. Unlike the colorful and often lustrous cherts, chalcedonies, opals, agates, jaspers, and obsidians of the region, the Pataha Canyon toolstone offers little to enchant the rockhound or lithic connoisseur. Gray, grainy, and grubby to the eye, it is difficult for today's knappers to work, and occurs in smallish nodules. Worse yet, it is both widely distributed and chemically too uniform to distinguish from one outcrop to another. Geochemically, the Pataha Canyon toolstone is a basaltic andesite (Bakewell 1998). Geologically, it assigns to one of the north-trending sheet flows of the Grande Ronde Basalt Formation that forms the northern rim of the Blue Mountains. This formation makes up 85% by volume of the Columbia River Basalt Group. Unit N_2 of the Grande Ronde Basalt underlies the Pataha subbasin, and is locally exposed in deeply incised headwater canyons. The Pataha Canyon workshop is one of many workshops and lithic scatters recorded in similar settings on the Umatilla National Forest (Burney 1985), including nearby Teal Spring and Kelly Camp (Flenniken et al. 1991a, b). All of these workshops map to outcrops of the same Grande Ronde Basalt Formation. Geochemically, they are probably the same basaltic andesite.

Figure 9-2. Location of major fine-grained volcanic and obsidian toolstones in the Blue Mountains.

More distant basaltic andesite workshops in exposures of the Grande Ronde Basalt Formation occur at High Breaks Ridge (Dickerson 1998), Starvation Spring (Jaehnig 1992), Elk Mountain (Nisbet and Drake 1992); and Midvale Hill (Bucy 1974). Geochemical homogeneity characterizes all of these widely separated sources (Dickerson 1998; Bakewell 2004). For purposes of sourcing, this is a significant problem, because the Grande Ronde is the most areally extensive of the four units that make up the Columbia River Basalt Group. However, basaltic andesites have been geochemically distinguished from the more siliceous andesites and dacites of the Saddle Mountain Basalt Formation. A cluster of workshops around Craig Mountain shows that these high silica toolstones began to be exploited by at least 10,000 years ago.

The Grande Ronde Basalt Formation is the most extensive of the four Miocene basalt formations that make up the Columbia River Basalt Group. It includes four members with at least 120 separate flows that erupted between 17 and 15.6 million years ago. They extend over an area of nearly 12,000 km^2 in the Tri-State Uplands. Viewed regionally, the Columbia River Basalt Group comprises a coherent series of chemically related rock formations, and toolstone-quality outcrops within these flows can be modeled as a toolstone terrane (Elston 1990).

Table 9-1. Comparative Fracture Toughness Values[1] for Regional Fine Grained Volcanics Compared to Obsidians and Unheated and Heated Chert, Flint, Agate, and Jasper (data from Domanski and Webb 1992, 1998).

Obsidian	FGV	'Chert' unheated	'Chert' 300°C	'Chert' 400°C
24.01[a]	73.50[1]	48.54 (chert)	49.13	36.75
26.30[a]	70.86[2]	65.85 (flint)	38.84	37.12
27.42[a]	55. 67[3]	51.52 (flint)	37.31	34.88
25.82[b]	77.16[4]	81.96 (agate)	64.92	31.72
	89.51[5]	72.41 (jasper)	56.04	47.41

[1] Cylinders approximately 22 mm in length and 15 mm in diameter were mechanically impacted by forces ranging between 21-56 lbs, yielding fracture toughness values expressed as megapascals ($MPa.mm^{0.5}$). [a] Papua New Guinea; [b] Glass Butte, Oregon; [1, 2] Midvale Hill basaltic andesite; [3] Stockhoff dacite; [4, 5] Pataha Canyon basaltic andesite

An unanticipated finding of this study is that properties other than silica content or source-sensitive trace elements may usefully distinguish otherwise nondescript basaltic andesites. Fracture toughness testing on sample cylinders shows that this property varies in ways that can be measured and compared. Thus, the Pataha Canyon toolstone is measurably tougher than the basaltic andesite from Midvale Hill (Table 9-1), and both are much harder to work than the andesites and dacites from Craig Mountain. We speculate that FGV toolstones with low fracture toughness (Craig Mountain) came into use first, and that the tougher basaltic andesites (Pataha Canyon) became part of the regional toolstone suite later in time, as population density increased and territories contracted and stabilized.

Cultural Background

Ethnographic Setting

Pataha Canyon is remote but not isolated. The study area lies near the intersection of two major aboriginal travel corridors. One route ran from Wallula near the confluence of the Snake and Columbia rivers eastward to the Lewiston basin and Clearwater-Snake confluence, approximately following the present course of U.S. Highway 12. The Lewis and Clark expedition used this trail on their return journey to avoid the rapids and portages of the "Big Bend" of the lower Snake. For the Nez Perce, Umatilla, and Cayuse, the corridor linked the buffalo plains of Montana with the great Southern Plateau trade mart at The Dalles (Reid and Root 1998).

A second route ran north to south from the westernmost village near Almota to summer camps at Pomeroy and Dayton, thence south across the Grande Ronde basin to the Wallowa River (Chalfant 1974:117-118). This route brought the lower Nez Perce into shared summer fishing camps with parties of Umatillas, Cayuses, Walla Wallas, and sometimes even Paiutes. These multiethnic summer fishing camps suggest a mechanism for the exchange and northward distribution of Southern Plateau toolstones such as obsidians and Craig Mountain dacite.

During the first half of the 19th century, the study area was exploited by several bands of the lower Snake River Nez Perce, some of them intermixed with the Palouse. Two seasonal camps and two villages occurred in the vicinity of the study area (Schwede 1970). "Pataha" was mapped as a camp at the present site of Pomeroy. Another unnamed camp was shown on the west side of the Tucannon River 7.7 km above Marengo. A village was shown on the east side of the Tucannon opposite Marengo, and a second village was plotted 3.2 km above the mouth of Pataha Creek on the east side of the Tucannon. The latter was named *Tookeeloot'poo*; according to Nez Perce elder Elmer Paul, this was the band that lived at the mouth of Tucannon River (Chance et al. 1987:130).

Nez Perce settlement and subsistence rhythms illustrate Binford's (1980) "logistically organized collector" land use pattern. Field camps were used to bulk process seasonally abundant resources for winter stores at nearby residential bases. Toolstone acquisition was often embedded in the subsistence round. We hypothesize that the Pataha Canyon site functioned as a hunting and fishing camp and toolstone source for logistically organized collectors who wintered along the lower Tucannon or Snake. The site lies on a probable spawning stream for steelhead and spring/summer chinook, and along a travel corridor that leads from the Snake-Tucannon confluence into the Blue Mountains. It is well situated as a hunting hub and could have served as a way station for people moving up into the Blue Mountains from the lower Tucannon or Asotin Creek basins.

Prehistoric Setting

The Blue Mountains have attracted the attention of archaeologists working along the lower Snake River for more than half a century. Upland resources figure prominently in various culture historical, cultural ecological, and processual models for the region.

Rigsby (1965) postulated a Chinookan advance up the lower Columbia River within the last 2500 years. This migration forced resident Sahaptin groups upstream along the lower Snake River, and displaced the Waiilaatpu (Cayuse) into headwater hinterlands in late prehistory. Rigsby also postulated the divergence of a Proto-Sahaptian speech community into western Sahaptin and eastern Nez Perce between 3000 – 2500 years ago, with a further divergence between upper (*numipu*) and lower (*nimipu*) Nez Perce speech communities by A.D. 1800.

Brauner (1976) saw the Blue Mountains as an interaction zone between Great Basin and Southern Plateau populations during the Neoglacial, between about 4,000 and 2,500 years ago. His model postulated a mix of environmental collapse and population interaction at the regional scale at the onset of the Neoglacial. A "surge in effective precipitation" at 4000 B.P. incised channels and washed large volumes of formerly stable Mazama ash into the Snake River and its tributaries, destroying the anadromous fishery (Brauner 1976:307). Hungry fishermen tuned to the Blue Mountains for game. Here they met hunters entering the uplands from the south, and soon the shapes and notch orientations of their projectile points took on a Great Basin appearance.

Brauner's climatic forcing function was criticized by Lyman (1980), who noted healthy shellfish populations continued to flourish in the Snake River after 4000 B.P. Since the mussels require salmon hosts for a part of their life cycle, he concluded that anadromous fish probably also survived. A later revision of Brauner's argument pushed the timing of the disastrous wet interval back by about 1,500 years (Lucas 2000:50).

A recent processual model linking sedentism, demography, storage technology, and climatic cooling (Chatters 1995) draws on several archaeological and paleoenvironmental studies from the lower Snake basin. Chatters sees two discrete episodes of winter sedentism. The first, "Pithouse I" (4400–3800 B.P.), involved housepit clusters occupied by small groups and sustained by large river bottom site catchments. The second, "Pithouse II" (3500–2200 B.P.), involved a smaller number of winter settlements supported by constellations of distant field camps, often located in the forested uplands. Pithouse II "…indicates a logistically organized, delayed-return strategy that was beginning to resemble the ethnographic pattern" (Chatters 1995:349). The latter was clearly recognizable throughout the Southern Plateau by two thousand years ago. The later occupations at the Pataha Canyon workshop may have a logistical relationship to winter villages recorded near the mouth of the Tucannon River.

There is probably nothing exceptional about the Pataha Canyon workshop described here. Lithic scatters at several upland springs on the Pomeroy Ranger District have been tested or mitigated by data recovery excavations (Burney 1985; Berryman 1987; Flenniken et al. 1991a, b). The ages of most of these sites have been approximated through projectile points. A hearth at Warner Spring provided a radiocarbon age of 820 ± 70 B.P. on wood charcoal (Berryman 1987:71). Mazama tephra layers have been used to estimate the age of some levels, but it is not always clear whether the ash is considered to be a primary airfall or redeposited layer. Obsidian hydration dating has been handicapped by small samples and uncertainties about regional hydration rates (Flenniken et al. 1991b:80).

In a summary of the Washington section of the Umatilla National Forest, the Forest Archaeologist commented on the numerous “basalt” lithic scatters. The larger sites were tentatively identified as quarries, though “the source of the basalt material has not been identified” (Fulgham 1989:8). Interpretations of site function usually relied on landscape position and the nature of the chipped stone tools to argue for seasonal hunting and gathering camps. Several investigators have commented on the local availability of “fine grained basalt” and noted a local emphasis on early reduction stage sequences and biface preform production.

Field Investigations

The site was first recorded as a precontact, multicomponent, seasonal camp with an area of 7,600 m^2. The site underlies a developed recreation area and camp called Pataha Campground. Developments include road turnouts, picnic tables, fire rings, camping surfaces for tents or trailers, and a privy.

Test excavation first took place in 1994 to evaluate the damage from campground development. In 1996, a second round of testing occurred in the northern area because heavy spring rains surging out of Iron Springs Canyon flooded the area, causing extensive gullying. That flood also damaged a road in the north end of the site. Planned road repairs would further compromise the integrity of cultural deposits. Therefore, our excavations in 1997 focused on this area. The 1994 testing was limited to the North Area and included six 50-x-50-cm units and five 1-x-1-m units (Figure 9-3) with a total volume of 4.25 m^3. Three of the units formed a 1-x-3-m trench (Busskohl 1997). Artifacts from that trench are the only ones analyzed and reported here from the 1994 testing.

In February 1996, another episode of flash flooding exposed many artifacts and it was clear that the site warranted further attention. Sixteen 50-x-50-cm and two 1-x-1-m units with a volume of 4 m^3 were placed in the South Area (Figure 9-3). The recovered sample included 1,861 pieces of debitage and 13 stone tools (Lucas 1997). We do not include the 1996 debitage sample in this analysis.

Projectile points from the 1994 and 1996 investigations frame a sequence that includes a Cascade phase occupation predating 5500 ^{14}C B.P.

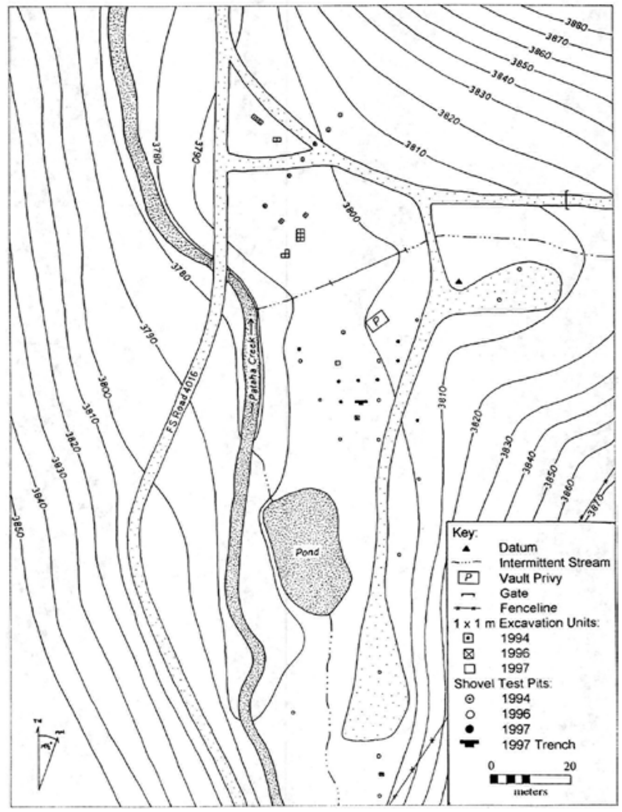

Figure 9-3. Location of the Pataha Canyon excavation units.

and a Harder phase occupation postdating 2500 ^{14}C B.P. An apparent lack of occupation was noted during the Tucannon phase, from 5500–2500 ^{14}C B.P. The occupational gap may be related to repeated overbank flooding and alluvial fan aggradation during the cool, moist Neoglacial between 4200–2500 ^{14}C B.P. when dynamic and unpredictable conditions made the site unsuitable for camping (Lucas 1997:11-12).

Lucas (1997) hypothesized that the site served as a basalt procurement locus during both the early and late occupations when knappers produced large numbers of bifacial preforms. He also noted that chert was more common in the later occupations. Plant processing was evidenced by a pestle recovered in 1996 and another in a private collection. Numerous thinning and resharpening flakes from small chert bifaces suggested a hunting field camp for exploitation of the nearby uplands.

Our 1997 fieldwork was guided by four research problems that emerged from the site testing. As summarized by Lucas (1997), these include (1) determining the depositional history of the site, including the alluvial fan in the North Area and the alluvial terrace in the South Area; (2) the sequence and chronology of occupations from radiocarbon dates, tephras, buried soils, and projectile point seriation; (3) changes through time in lithic technology, including use of different toolstones and comparative analyses of successive reduction sequences; and (4) the regional site context, including its relation to ethnographic winter villages along the Snake River and ethnographic travel routes.

Field Methods

We first partitioned the site into north and south areas. Our tests in the North Area included a 3-x-2-m block, a 1-x-3 m right-angled unit, and a 1-x-2-m deep test unit. In the South Area, 1997 tests included two 1-x-1-m units on the sloping terrace above Pataha Creek. In addition, we excavated eight 50-x-50-cm shovel tests, which were dug in 10 cm levels. We placed two of these on the west side of the southernmost 1-x-1-m unit and placed two on the east side of the unit to form two 1-x-0.5-m extensions, thereby creating a 3 m profile exposure.

Similar recovery techniques were followed during all three field seasons. We dry-screened all sediment through 8-per-inch mesh and field sorted natural clasts from artifacts. One wall of each 1-x-1-m unit was profiled, stratigraphically described, and photographed. Features were drawn and photographed in plan and profile. Charred wood and bulk sediment samples were taken for radiocarbon dating, and volcanic tephra samples were taken for microprobe analysis.

Stratigraphy

The Pataha Campground site is mapped within the Tolo silt loam, which formed under mixed conifer forests in volcanic tephra and eolian silt. The modern solum is underlain by an older, buried soil (Raver 1974:25-26).

Excavations in the North Area exposed three depositional units. The profile from the 3-x-2-m block is shown in Figure 9-4. Depositional Unit 1 is 12–26 cm thick and consists of very dark brown (10YR2/2) gravelly silt loam with matrix-supported angular to subrounded gravel and an abrupt and wavy boundary. There is extreme turbation from animal burrowing with many krotovinas.

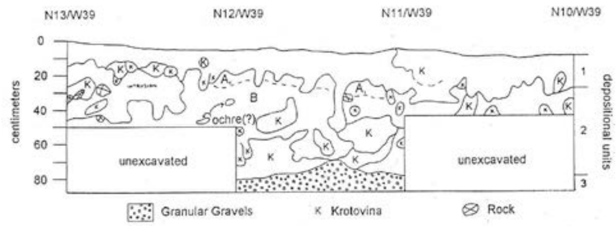

Figure 9-4. Stratigraphic profile, North Area.

Depositional Unit 2 is 19 cm thick, consisting of gravelly sandy loam with angular matrix-supported gravels and an abrupt boundary broken by many krotovina. Depositional Unit 3 is gravelly silt loam with poorly sorted clast-supported gravel. We did not reach the lower boundary and the thickness of the unit is unknown.

Depositional Unit 2 contains a truncated A-Bw solum, suggesting that black sediment in Depositional Unit 1 consists of redeposited, bioturbated A horizon sediment. The truncated A horizon is very dark brown (7.5YR 2.5/3) gravelly sandy loam with a weak fine granular structure. The Bw horizon is a brown (7.5YR 4/3) gravelly sandy loam with a weak fine subangular blocky structure.

The South Area is disturbed with the intact layers in Depositional Unit 3 beginning 35 cm below surface (Figure 9-5). The upper three levels display considerable churning from animal burrowing and possible plowing. Vertical displacement of artifacts is evident as deep as Depositional Unit 5 at 80 cm below surface. Here a glass fragment and .22 cartridge were probably introduced by burrowing animals. Depositional Unit 4 consisted of mixed and pure volcanic tephra. Microprobe analysis of glass chemistry identified it as originating in the climactic Mazama eruption at 6850 ^{14}C B.P. (Foit 1998). However, the mixed nature of the ash together with the landform position suggest that it is not a primary airfall deposit.

A study of volcanic ash in the Blue Mountains of eastern Oregon concluded that reworked Mazama deposits have been stable since 5300 ± 130 ^{14}C B.P. (Rai 1971:87-88). Down slope movement of Mazama tephra ended at the Stockhoff site in the upper Grande Ronde basin by 5750 ± 340 ^{14}C B.P. (Cochran and Leonhardy 1981:16). Deposition rates calculated for Craddock Meadow on the Silvies Plateau show that the major reworking of Mazama ash ended there by 5300 ^{14}C

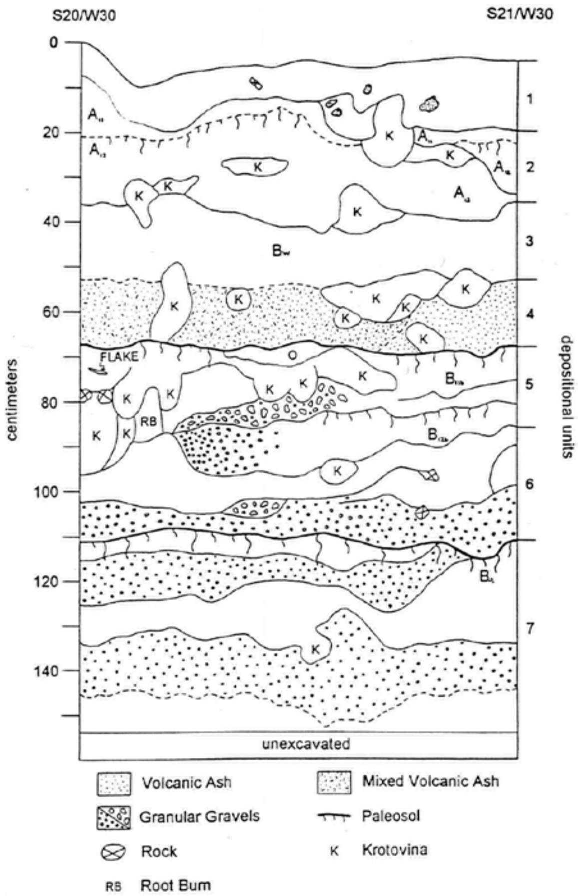

Figure 9-5. Stratigraphic profile, South Area.

B.P. (Wigand 1989:74). We therefore interpret the tephra deposits in Depositional Unit 4 to date to about 5300 ^{14}C B.P. The tephra rests on a weakly developed 2Bwb horizon. The gravelly texture of the deposits in the Bw horizon suggests that they accumulated relatively quickly with a period of soil formation before the deposition of the reworked Mazama tephra. A second weakly developed buried soil is the contact with Depositional Unit 6 and Depositional Unit 7. This is a 3Btb horizon with a moderate subangular blocky structure. The formation of this argillic horizon indicates a period of landscape stability and a pause in the prevalently active slope conditions that formed the south part of the site. We ceased excavations at 1.55 m, without reaching basal stream gravels or bedrock.

Features

One basin-shaped hearth was completely exposed in plan and section in the block in the North Area. A second precontact hearth probably coincided with the dense scatter of fire-cracked rock and charred branchwood exposed at the same level in the same block. Vitrified clinkers, chunks of heavily oxidized sediment, and historic artifacts such as cartridges and cut nails from the same context led to the field decision not to give this debris a feature number. However, three radiocarbon dates on charred branchwood are pre-contact in age.

Laboratory Investigations

Analytic Procedures

A detailed summary of the theoretical assumptions, analytic methods, and coding procedures for the lithic artifacts is found in Root and Reid (1998; see also Root 2004; Root et al. 2000). We submitted three radiocarbon samples from Analytic Unit 1 in the North Area to Beta Analytic, Inc., for conventional dating. We submitted a volcanic tephra sample to the Geoanalytical Laboratory at Washington State University. As noted, results indicate a probable source in the climactic Mazama eruption at 6850 ^{14}C B.P. (Foit 1998). We collected samples of the local basaltic toolstone from the site vicinity and submitted them for petrographic and geochemical analyses (Bakewell 1998). Finally, we submitted samples of the same toolstone to LaTrobe University in Bundoora, Australia, for fracture toughness testing (Domanski and Webb 1998). Fracture toughness comparisons were made with samples of basaltic andesite toolstone submitted from the Midvale Hill workshops in the Weiser basin, and high silica andesite or dacite from the Craig Mountain workshops in the upper Grande Ronde basin.

Radiocarbon Dates

Three radiocarbon samples were submitted from the block in the North Area (Table 9-2) for conventional dating. In addition, two small charcoal samples from within the hearth fill of Feature 1 were collected. The charred branchwood samples and the hearth samples all came from approximately the same elevation and imply that little sediment accumulated in the vicinity of the block between about 2500 and 400 ^{14}C B.P.

Two discrete occupations of artifacts and hearth debris may be mixed in Analytic Unit 1. Thus, the

Table 9-2. Radiocarbon Dates from the Pataha Canyon Site.

Sample ID	Provenience	Uncorrected Radiocarbon Age
12C	N11.41-49/W40.78-86:29-33 cm below surface	340 ± 40 ^{14}C B.P. (Beta 116,421)
12E	N11.67-70/W40.60-72:28 cm below surface	540 ± 60 ^{14}C B.P. (Beta 113,824)
Z	N10.25-36/W39.51-70:25.5 cm below surface	2470 ± 60 ^{14}C B.P. (Beta 113,823)

three radiocarbon dates mark an early event at about 2500 ^{14}C B.P., and a later event at about 400 ^{14}C B.P. Either of these ages could be assigned to the hearth basin designated Feature 1. Two charcoal samples taken from the basin fill were both too small to date by conventional means, but each has sufficient carbon for an AMS date. Another possibility is that all three of the radiocarbon dates record natural forest fires rather than cultural hearth debris. However, the samples cluster near the only recognizable hearth basin, and in the same area where fire-cracked rock is most abundant. Charred wood fragments large enough for conventional radiocarbon dating were not encountered in other units in the North Area. A wider spatial distribution of charred wood, perhaps accompanied by burn lines and evidence for intense mottling and oxidation, might be expected if the site had been swept by a natural conflagration (Connor et al. 1989). Finally, the artifacts from the 20–30 cm level do not display notable thermal damage by comparison with other levels. For these reasons, we accept the three radiocarbon ages as cultural. However, they reflect only a few of many site occupations that probably occurred in the last 2,500 years.

Projectile Points as Phase Markers

The point types in the collection fit well into the Leonhardy and Rice (1970) sequence for the lower Snake basin (Figure 9-6). Cascade, Tucannon, and Harder phases are represented, a time range that extends from at least 5000 to 2000 radiocarbon years ago (Table 9-3). The points are distributed in approximate time sequence with depth. Thus, the two lanceolate Cascade points and the Cold Springs Side-Notched basal fragment are typologically early points recovered from the 50-60 cm level. One corner-removed Alpowa type typical of the Tucannon phase was recovered from 50-60 cm, while a second Alpowa point came from 0-10 cm.

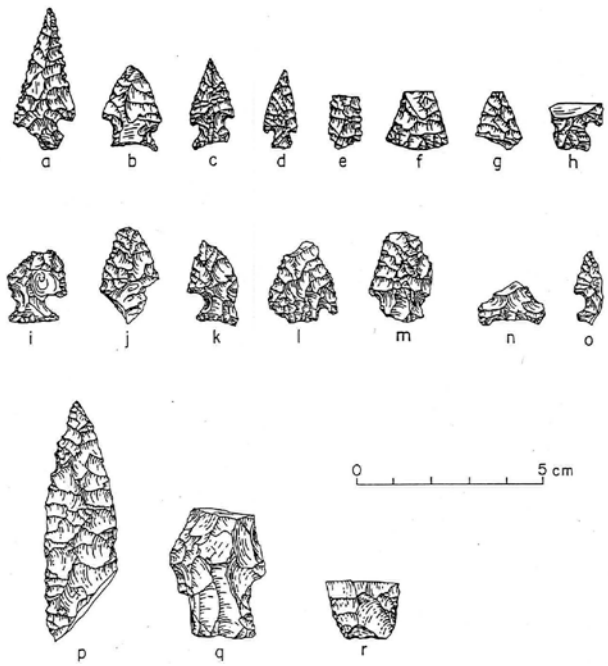

Figure 9-6. Projectile points recovered from Pataha Canyon: (a, d) Columbia Stemmed; (b, c, h, k, o) Columbia Corner-notched B; (i, m) Columbia Corner-notched A; (l) Snake River Basal-notched; (e) Wallula Rectangular-stemmed; (n) Cold Springs Side-notched; (p, r) Cascade; (q) Stemmed dart point; (f) arrow point preform; (g) arrow point fragment; (j) dart point fragment.

Table 9-3. Phases and Age Ranges for Pataha Campground Projectile Points.

Point Type	Phase Marker	Age Range (^{14}C B.P.)
Columbia Corner Notched B	Harder/Piquinin	2000 – 150
Columbia Stemmed A	Harder/Piquinin	2000 – 150
Columbia Stemmed B	Harder/Piqunin	2000 – 150
Wallula Rectangular Stemmed	Harder/Piqunin	2000 – 150
Quilomene Bar Basal Notched	Harder	2500 – 1500
Columbia Corner Notched A	Harder	2500 – 1500
Alpowa Type 01-02A	Tucannon	4000 – 2000
Rabbit Island Stemmed A	-	4000 – 2000
Nespelem Bar	-	5000 – 3000
Mankin Shouldered	-	8000 – 3500
Cold Springs Side Notched	Cascade	7000 – 4000
Cascade C	Cascade	8000 – 4000
Cascade B	Cascade	8500 – 6500

The base of what may be a lanceolate or large stemmed point came from the 40-50 cm level. Clearly, bioturbation has mixed deposits. Point types listed in Table 9-3 were defined after consulting three references: the Leonhardy and Rice (1970) cultural chronology for the lower Snake River, Lohse's (1995) review and comparison of point chronologies for the Intermountain West, and Brauner's (1976) data recovery project at Alpowa in the Lewiston Basin. The age range of 4000 – 2000 ^{14}C B.P cited by Lohse (1995: 9) for Columbia Corner Notched A has been reduced here to 2500–1500 ^{14}C B.P, which better accords with the lower Snake sequence. Finally, Brauner's Apowa Type 01-02A is so similar to examples of Rabbit Island Stemmed A, Nespelem Bar, and Mankin Shouldered, that we have listed them all. A reasonable guess is that our sample postdates or overlaps the late Cascade phase, and predates the early Harder phase.

The projectile points fall into early and late groups. The corner-notched dart and arrow points all cluster in the upper 30 cm, with most of them in the upper 20 cm. These forms are typical of the Harder phase. The corner-notched arrow points are also common in the Piqunin phase. There was no stratigraphic separation between corner-notched dart and corner-notched arrow points. This group is late Holocene in age and assigned to Analytic Unit 1. The early group of lanceolate, side-notched and stemmed dart points is late middle Holocene in age and assigned to Analytical Unit 2. No projectile points were recovered from Analytic Units 3 and 4.

Analytic Units

We defined four analytic units (AU) for the 1997 excavations based on depositional units, buried soil horizons, density modes in lithic debris, time-sensitive artifacts, and radiocarbon dates. We incorporated the 1994 and 1996 excavations into this framework using field notes, stratigraphic profiles, photographs, and unit depths.

Analytic Unit 1 is late Holocene. Projectile points and radiocarbon dates indicate it dates to the Harder and Piqúnin phases, or the last 2,500 radiocarbon years. Analytic Unit 2 dated to the end of the middle Holocene and the beginning of the late Holocene. Projectile points and stratigraphy link this unit to the late Cascade-Tucannon phase interval, or from about 5,300 to 3,000 radiocarbon years ago. All of the 1994 and 1996 collections were assigned to AU1 and AU2. Most of the 1997 collection is also assigned to AU1 and AU2, but deeper deposits in the South Area are assigned to Analytic Units 3 and 4. These are stratigraphically dated to before 5,300 radiocarbon years ago, with AU4 somewhat older than AU3. No diagnostic projectile points or radiocarbon dates were associated with AU3 or AU4. The relatively coarse nature of most of the sediments below the redeposited Mazama tephra suggests they accumulated fairly rapidly. We suspect AU3 and AU4 are middle Holocene in age, younger than the climactic Mazama eruption at 6,845 ^{14}C B.P. The landscape stability implied by the development of the 3Btb horizon, however, opens the possibility of an earlier, perhaps early Holocene, age.

Lithic Analysis

Our goal here is to explore changing rates of biface production output at one of the many basaltic andesite workshops recorded in the Grande Ronde Basalt Formation. The morphological and functional analyis of the stone tools from Pataha Canyon is summarized elsewhere (Reid and Root 1998).

We first conducted a set of reduction experiments to evaluate the basaltic andesite toolstone, and to establish experimental expectations with respect to flake types and reduction staging debris. These experiments provide an empirical model with which to interpret the archaeological flake debris. We analyzed stone tools and cores according to morphology, raw material, and production technology. We then compared the experimental and archaeological data to arrive at estimates of workshop tool production output over time. Our experiments provided empirical grounding for interpretations of the reduction technologies at Pataha Canyon. They were not exercises in "ego-graphic analogy" intended to prove that we can do what they did. In fact, we found that we couldn't do some of the things they did. However, the results provide a basis for estimating the amount of tool production and changing rates of production over time (e.g., Root 1992, 1997).

Reduction Experiments

The local pebbles and small cobbles of basaltic andesite are at best a moderate-quality toolstone. Controlled fracture in tough toolstone was considerably more difficult than with more siliceous andesites and dacites such as those from the Craig Mountain region in the Grande Ronde headwaters. This very toughness, however, may have been desirable in shaping bone or woodworking tools, or for butchering large game. Once knappers fashioned the Pataha toolstone into flake or bifacial tools, the sharp edges were probably durable.

We collected large pebbles and small cobbles from the site along with several cobbles from further up Pataha Canyon. However, we were unable to replicate the maximum size of the archaeological bifaces with the small cobbles we collected. Therefore, we also used one large flake blank from a large prepared core of andesite from Craig Mountain. Experiments included the replication of core and biface reduction technologies represented at the site. Matthew Root and Daryl Ferguson were the knappers.

Experimental replications provide empirical links between flake classes and lithic technologies. Designing experiments to interpret archaeological collections employs basic tenets of replicative systems analysis (Flenniken 1981). An advantage of such an experimental approach is that it allows us to examine *rates* of change over time, rather than merely quantifying changing *amounts* of workshop discards that resulted from knapping errors (Watson et al. 1984:159). We will return to this point in our conclusions.

The first experiment reduced six unprepared cores from small cobbles to produce flake blanks suitable for utilized or retouched flake tools. The second experiment reduced two prepared cores. We trimmed, beveled, and ground the platforms and shaped the core face to guide the removal of large blanks. In the third and fourth experiments, we shaped bifacial blanks from the flake blanks produced in prepared core reduction. We divided biface manufacture into two parts: (1) initial bifacial edging and shaping, and (2) percussion bifacial thinning. The flake blanks of Pataha Canyon basaltic andesite, however, were smaller than the largest bifacial blanks recovered from the site. Our experiments only replicated the middle part of the size range of the archaeological bifaces. We also made one biface from a 123-mm long flake blank of dacite. From this blank we produced a thinned biface 108 mm long and 38 mm wide, approximating the size of the larger archaeological bifaces. Skill levels evident in the Pataha bifaces, however, are higher than we were able to achieve.

The analytical methods and flake class definitions are detailed in Root and Reid (1998:Appendix A); Root et al. (2000); and Root (2004). All debris was size graded through four nested screens with openings of 25.4 mm, 12.7 mm, 6.35 mm, and 2.54 mm and then sorted into the raw material types. We then recorded technological flake class (defined in Table 9-4), cortex, heat-treatment, and the presence or absence of a detachment flake scar. Detachment flake scars are the ventral surfaces of flake blanks (Flenniken et al. 1991:105).

Table 9-4. Definitions of Flake Technological Classes.

Flake Class	Summary Definition
Primary decortication	Entire dorsal surface is covered with cortex.
Shatter	Cubical and irregularly shaped chunks that lack bulbs of percussion, systematic alignment of fracture scars on the various faces, striking platforms, or points of flake initiation.
Percussion bifacial thinning flakes	Flakes with bending initiations and a narrow and faceted striking platform without cortex, thin, curved longitudinal sections; extremely acute lateral and distal edge angles; at least three dorsal flake scars that originate from varying directions, 20% or less cortex on the exterior surface, and an expanding shape in plan-view.
Late-stage biface shaping (pressure) flakes	Small, thin flakes (<12.7 mm, size-grades 3, 4) with multifaceted and ground platforms, multiple scars on dorsal surfaces, are curved in long section, dog-legged or petaloid in plan-view.
Notching flakes	Flakes are circular in plan with a concave or lunate platform. In profile with the platform facing the observer and the dorsal surface upward, they have a gull-wing appearance.
Alternate flakes	Flakes are thick in relation to their length and width, are triangular in cross section, have a squared edge adjacent to the platform, have single faceted platforms, and a skewed orientation in relation to the axis of percussion.
Bipolar	Flakes with wedging initiations, shattered or pointed platforms with little or no surface area, and pronounced compression rings.
Blades and microblades	Flakes with parallel or subparallel lateral margins, dorsal arrises that are parallel or subparallel with the lateral margins, and at least two flake removal scars evident on the dorsal surface.
Uniface modification flakes	Flakes have feather terminations, single-faceted noncortical platforms; parallel to expanding lateral flake margins, a slight curve at the distal end in long section.
Simple flakes	Flakes with two or fewer dorsal flake scars that do not meet any of the above definitions.
Complex flakes	Flakes with three or more dorsal flake scars that do not meet any of the above definitions.
Undiagnostic, <6.35 mm	Size-grade 4 flakes that do not fit the definitions of biface shaping, notching, microblade, or uniface modification flakes (other flake classes are not coded for G4 flakes).

Results of Experiments

Primary decortication flakes and shatter were produced only in core reduction experiments. Only one alternate flake was produced in experiments, probably because we used rounded cobbles, not tabular pieces. Biface thinning and shaping flakes were experimentally produced only during biface manufacture with larger proportions of these flakes produced in bifacial thinning than in bifacial edging. Biface shaping/pressure flakes are usually associated with the later stages of bifacial production, such as final pressure flaking. We produced a few of these flakes during bifacial edging and thinning because we used pressure flaking to prepare platforms.

Complex and simple flakes (see Table 9-4) were produced in all technologies, but in different proportions. Simple flakes are much more common in core reduction than in biface reduction. There are slightly smaller proportions of complex flakes in the biface reduction experiments than core reduction because of the large proportion of bifacial thinning flakes (which by definition have complex surfaces) and undiagnostic flakes <6.35 mm. Thus, the relative proportions of flake technological classes vary between reduction technologies.

The proportion of flakes with cortex within each size grade also varies between technologies. Unprepared core reduction has the largest proportion of cortical debris, followed by prepared core reduction. Bifacial edging and bifacial thinning have little cortex because flake blanks with little or no cortex were used in experiments.

All reduction technologies are dominated by the smallest flakes. This is a mechanical consequence of conchoidal fracture. There are always more small pieces than large pieces. There is a steady progression, however, in the increase in the proportion of the smallest flakes from unprepared core reduction through bifacial thinning.

Though the size distribution of flakes is an important technological variable, it cannot be used in isolation to determine the technological make-up of archaeological debris aggregates. There are two reasons for this caution. First, archaeological flake debris collections consist of complex mixes of many different technologies. Second, the mode of refuse disposal has a major effect on the size distribution of artifacts in archaeological sites. As discussed below, many of the smallest flakes have probably been removed from archaeological samples due to refuse disposal patterns, site formation processes, or recovery biases. Therefore, analyses of the archaeological collection must control for size biases (Root 2004).

Archaeological Flake Debris

The analyzed archaeological sample consists of 11,480 flakes and shatter, including all debris from 1997 Rainshadow Research excavations and debris from one,1-by-1-m unit excavated by the U.S. Forest Service in 1994 (unit 40.5N 51.5W). We analyzed the archaeological flake debris according to the same analytic methods used for the experimental debris (see Root and Reid 1998:Appendix A).

Size Biases

Size distributions offer insight into site formation processes and excavation biases. Size is an important technological variable, but it must be combined with other technological data to make accurate inferences about technology (Root 2004). The size distributions of flakes from Pataha Canyon confirm that size biases are present, and must be accounted for in technological analyses.

Most flakes are in the smallest size class (<6.35 mm). Obsidian, chert, and chalcedony consist almost entirely of small flakes (Table 9-5). The basaltic andesite collection contains only 64.7 percent flakes smaller than 6.35 mm, for a ratio of flakes smaller than 6.35 mm (size-grade 4) to those larger than 6.35 mm (size-grades 1-3) of only 1.83:1 (6,956:3,793). The percentage of basaltic andesite flakes smaller than 6.35 mm in the excavated collection is considerably smaller than in any of the experimental replications. The smallest experimental percentage is for unprepared core

Table 9-5. Inventory of Flake Debris by Size and Grouped Raw Material Class, Pataha Canyon Site.

Size Grade	Basaltic Andesite		Obsidian		Chert and Chalcedony		Rhyolite		Total
	n	%	n	%	n	%	n	%	n
G1	89	0.8	0	0.0	0	0.0	0	0.0	89
G2	746	6.9	0	0.0	10	1.5	0	0.0	756
G3	2,958	27.5	2	3.5	100	14.9	2	40.0	3,062
G4	6,956	64.7	55	96.5	559	83.6	3	60.0	7,573
Total	10,749	100	57	100	669	100	5	100	11,480

G1: >25.4 mm G2: <25.4 & > 12.7 mm
G3: <12.7 & > 6.35 mm G4: <6.35 & > 2.54 mm

reduction with 72.9 percent of flakes smaller than 6.35 mm. The archaeological collection contains relatively large proportions of biface thinning and biface shaping flakes. This indicates that biface manufacture was an important activity, and furthermore that the percentage of small flakes should exceed that of unprepared core reduction. Therefore, it is likely that small flakes (<6.35 mm) produced during pre-contact tool manufacture are underrepresented due to biases from geologic mechanisms or refuse disposal patterns. Because the obsidian, chert, and chalcedony flakes are predominantly small, differential removal of some small flakes creates less of a technological bias than in the basaltic andesite flake collection.

Comparable size biases can result from refuse disposal. People usually clean-up work areas, especially on sites with long occupation spans. However, when people clear work areas, small objects are usually left. They are overlooked, too difficult to pick up, or filter down into subsurface sediments. Deposits of secondary refuse (debris removed from its place of production) are skewed toward larger objects. Deposits of primary refuse (debris left where it was produced) include both small and large items. Areas that are cleaned up lack larger items, but smaller debris remains (Schiffer 1987). Sites with short occupation spans, and especially lithic workshops, seem unlikely to experience much secondary refuse disposal. Geologic mechanisms, such as slope wash or site flooding, can also redeposit artifacts. Depending on landscape position, these can either concentrate or remove small artifacts. Given the sheet flooding and gullying parts of the site experienced in 1996, it is likely that small flakes were removed from excavated areas at Pataha Canyon by such processes in the past. This size bias must be taken into consideration in technological analyses. Nevertheless, the chert, chalcedony, and obsidian samples consist primarily of small flakes, suggesting that size biases are not present, or are at least less pronounced, for these materials.

Raw Materials

Fourteen raw material classes were identified (Table 9-6). The most common toolstone is of course basaltic andesite, procured either at the site itself or in nearby Iron Springs Canyon or Pataha Canyon. We assume that all of this material was locally gathered. Fifty-seven obsidian flakes were recovered, and these are certainly nonlocal. Two flakes from 1994 tests are from Dooley Mountain and Whitewater Ridge. In total, 669 flakes of chert or chalcedony were excavated. To study reduction technology and raw material use in detail, we defined 11 types of chert and chalcedony based on color and translucency (Table 9-6). Chert includes opaque, dense, microcrystalline siliceous toolstones. We use the common definition of chalcedony, and include all semitransparent (clear) to highly translucent mircocrystalline silicate rocks that are white, gray, brown, or red. We distinguished chert and jasper from chalcedony subjectively based on translucency. Cherts and chalcedonies are often grouped together for analysis (as is also done here). The purpose of separating these materials is to attempt to differentiate toolstones that might have distinct reduction technologies and are probably from different geologic sources. The geologic sources for these material are uncertain, but they likely were procured from interbasalt formations and from nearby river valleys, such as the Tucannan, Snake, and Grande Ronde. Another cherty outcrop 5.5 km southwest of the site includes olive, gray, and black materials. Similarly colored cherts from excavations may be from this local source. The red and green cherts, as well as the chalcedonies may come from more distant sources. The only other raw material identified in the flake collection is rhyolite, represented by only five flakes.

Though it is always the dominant material, the proportion of basaltic andesite debitage decreases through time. Conversely, the proportions of chert, chalcedony, and obsidian steadily increase through time (Table 9-7). The increases in chert and chalcedony include all varieties, both the probable near-local brown, gray, and black varieties, and red, green, and clear varieties that are probably from more distant drainages. The increase in the proportion of obsidian is similar in magnitude to the increase in chert and chalcedony. Though the proportion of basaltic andesite is lowest in the Piqúnin-Harder analytic unit (AU1), the numbers of flakes in the Piqúnin-Harder (AU1) and Tucannon-Late Cascade unit (AU2) are about the same. The number of chert and chalcedony flakes, however, increases by a factor greater than nine, and obsidian increases by a factor of 27. The use of local basaltic andesite did not decrease during the latest

Table 9-6. Chert and Chalcedony Types Listed by Technological Class, Pataha Canyon Site.

Raw Material	Primary Decort.	Shatter	Biface Thinning	Biface Shaping	Alternate	Complex	Simple	Uniface Mod.	Other G4
Black chert	0	0	0	15	0	1	0	0	11
Black-orange chert	0	0	0	8	0	1	2	1	7
Clear chalcedony	0	0	0	7	0	4	1	0	15
Gray, brown chert	0	1	2	37	1	9	7	1	49
Green chert	0	0	0	1	0	0	0	0	2
Orange jasper	0	0	0	1	0	0	0	0	2
Red chalcedony	0	2	1	44	1	8	2	0	62
Red jasper	2	5	6	22	0	13	12		43
Red/white Variegated chert	0	2	0	7	0	4	4	0	44
Tan, brown Chalcedony	0	0	1	56	0	7	0	1	42
White, pink chert	0	1	0	42		4	0	2	42
Total	2	11	10	240	2	51	28	3	319

Table 9-7. Pataha Canyon, Flake Debris Summary, Raw Materials by Analytic Unit.

	Piqúnin, Harder (AU1)		Tucannon, Late Cascade (AU2)		Pre-5600 B.P. (AU3)		Pre-5600 B.P. (AU4)	
Raw Material	n	%	n	%	n	%	n	%
Andesite	4,661	87.8	4,687	98.6	1,361	98.9	40	100.0
Chert-chalcedony	591	11.1	64	1.3	14	1.0	0	0.0
Obsidian	54	1.0	2	0.1	1	0.1	0	0.0
Rhyolite	5	0.1	0	0.0	0	0.0	0	0.0
Total	5,311	100.0	4,753	100.0	1,376	100.0	40	100.0

occupations. Rather, the use of a transported tool kit increased dramatically late in time. The latest site occupants carried chert, chalcedony, and obsidian tools with them that they repaired and resharpened on the site.

Production Technology

Technological classification of flakes and analogies to the experimental replication provide the basis for inferring production technology. A summary of the technological classification of the 11,480 analyzed flakes is presented by analytic unit in Table 9-8. These data are presented without regard to raw material, which is discussed below. Shatter and primary decortication flakes are diagnostic of core reduction. The proportions of most technological classes are about the same among all analytic units, except for the increase in biface thinning, and especially bifacial pressure flakes during the latest occupations (AU1). These changes are directly related to the increased use of chert, chalcedony, and obsidian late in time. There was little initial manufacture of the non-basaltic tools at Pataha Canyon. Production technologies evident in each analytic unit are discussed below.

Piqúnin, Harder Phase (AU1). The technological classification of flakes for the Piqúnin-Harder Phase occupations are summarized in Table 9-8. On-site reduction of basaltic andesite included core reduction, biface manufacture, and flake tool manufacture. Primary decortication flakes and shatter occur in proportions similar to those produced by experimental core reduction. Simple and complex flakes occur in roughly equal proportions, suggesting that debris from both core reduction flakes and debris from later stage reduction are present. The presence of cortical alternate flakes suggests that tabular basaltic andesite cobbles were sometimes used for core reduction or flaked directly into bifacial tools. Only two bipolar flakes were recovered. Bipolar flakes are occasionally produced in freehand core reduction (Root 1992, 1997), and these probably reflect errant blows.

The importance of biface manufacture is shown by a high proportion of percussion bifacial thinning flakes. Over three percent of the collection consists of bifacial thinning flakes, about twice the proportion produced during experimental biface manufacture. Skill level is reflected in the proportion of biface thinning flakes, with larger proportions reflecting increased skill (Root 1992). This strengthens our suspicion that our own experiments were conducted at a lower skill level

Table 9-8. Pataha Canyon, Flake Debris Summary, Technological Class by Analytic Unit.

Technological Class	Piqúnin, Harder (AU1)		Tucannon, Late Cascade (AU2)		Pre-5600 B.P. (AU3)		Pre-5600 B.P. (AU4)		Total
	n	%	n	%	n	%	n	%	n
Primary Decortication	90	1.7	81	1.7	24	1.7	2	5.0	197
Shatter	72	1.4	32	0.7	14	1.0	0	0.0	118
Biface thinning	157	3.0	114	2.4	27	2.0	4	10.0	302
Bifacial pressure	474	8.9	115	2.4	43	3.1	0	0.0	632
Notching	1	0.01	0	0.0	0	0.0	0	0.0	1
Alternate	42	0.8	32	0.7	8	0.6	0	0.0	82
Bipolar	2	0.03	2	0.04	2	0.1	0	0.0	6
Uniface modification	23	0.4	13	0.3	8	0.6	0	0.0	44
Simple conchoidal	222	4.2	154	3.2	47	3.4	5	12.5	428
Simple, other flakes	522	9.8	493	10.4	110	8.0	10	25.0	1,135
Complex conchoidal	276	5.2	119	2.5	49	3.6	3	7.5	447
Complex, other flakes	538	10.1	475	10.0	110	8.0	6	15.0	1,129
Other size-grade 4	2,892	54.4	3,123	65.7	934	67.9	10	25.0	6,959
Total	5,311	99.9	4,753	100.0	1376	100.0	40	100.0	11,480

than those of the Pataha knappers, who likely had long practice working the tough material. The proportion of biface shaping flakes is even greater than that of thinning flakes. These are predominately late stage pressure flakes indicating production of tools such as bifacial knives or dart point preforms. The relatively large proportion of biface thinning and shaping flakes indicates that production of bifacial blanks and preforms was the most important reduction activity at the site. A single apparent notching flake may have resulted from production of a serrated blade edge, possibly during resharpening, rather than from notching. There are also 17 uniface modification flakes, which indicate production or resharpening of unifacial flake tools. Their presence indicates production or maintenance of basaltic andesite flake tools at the site. However, neither here nor in the earlier deposits did we recover any of the "unifacial elongates" (Womack 1977:131-137) or "large stylized scrapers" (McPherson et al. 1981:625) that form distinctive subindustries in early Holocene deposits at workshops elsewhere in the region.

The chert, chalcedony and obsidian flake debris contrasts notably with the basaltic andesite debris. The largest single diagnostic category of all these materials is bifacial shaping flakes. These were produced during pressure flaking of thin bifacial tools such as knives and dart points. Most small flakes that are not classified as bifacial pressure flakes are undiagnostic flakes smaller that 6.35 mm. Most of these are probably from pressure flaking, but lack platforms and therefore are classified as undiagnostic. Thus, the dominant reduction technology with these materials was pressure flaking, probably during resharpening and reworking. The few bifacial thinning flakes are relatively small and may have been produced in later stage manufacture or maintenance. There are six unifacial reduction flakes, indicating flake tool modification. There are a few chert primary decortication flakes and shatter, indicating that cobble testing or core reduction did occasionally occur. Both primary decortication flakes and most of the shatter are red chert. This suggests that small cores were part of transported tool kits, or perhaps that a nearby source is present.

Tucannon, Late Cascade Phase (AU2). The technological flake profiles of the Tucannon-Late Cascade occupations are broadly similar to the later occupations (Table 9-8). The major differences are decreases in the proportions of biface thinning and biface shaping flakes, and an increase in the proportion of undiagnostic flakes smaller than 6.35 mm. The total number of basaltic andesite flakes are about the same in both analytic units. The absolute decrease in the number of biface flakes indicates a decreased importance of middle and late stage biface manufacture. Decreasing late stage biface reduction should result in a decrease in the proportion of small flakes (< 6.35 mm). Therefore, the increase in small undiagnostic flakes is unexpected. It may reflect the downward movement of small flakes due to disturbances from burrowing animals. The chert, chalcedony, and obsidian collections from these occupations are also technologically similar to the later occupations. Flakes of these materials were produced almost exclusively from rejuvenation and reworking of bifacial tools and projectile points.

Pre-5600 RCYBP (AU3 and 4). The earliest occupations also display the smallest flake densities, suggesting decreased amounts of basaltic andesite tool production. The overall distribution of basaltic andesite technological classes is essentially the same as in the overlying Tucannon-Late Cascade Phase occupations. The major change is an increase in small undiagnostic flakes. Again, this may reflect the downward movement of small artifacts from postdepositional disturbance. The sample size of Analytic Unit 4 (n = 40) is too small to reliably infer the relative importance of reduction activities, but there is no evidence to indicate significant changes from Analytic Unit 3. There are only a few chert and chalcedony flakes, and a single obsidian pressure flake. This small sample indicates infrequent resharpening of tools of these materials. During the earliest occupations, people apparently relied almost exclusively on the local basaltic andesite.

Summary of Flake Debris Analysis

All stages of bifacial tool manufacture are represented in these data. However, the final stages of basaltic andesite projectile point manufacture occurred rarely, if at all, at Pataha Canyon. Several resharpened basaltic andesite tools were recovered, indicating that some late stage debitage resulted from tool maintenance rather than initial manufacture. Primary decortication flakes and shatter of basaltic andesite are common and were produced during core reduction. Though the flake analysis did not distinguish prepared from unprepared core reduction, core analyses indicate both kinds of core were flaked on the site. Stoneworkers reduced flake blanks into percussion-flaked bifacial blanks and then into pressure-flaked bifacial tools. There is no evidence that notched dart or arrow points made of basaltic andesite were finished on the site. Most pressure-flaked basaltic andesite implements were probably bifacial cutting tools. Both replicative and laboratory experiments found that the Pataha basaltic andesite is a tough stone, difficult to shape into pressure-thinned dart or arrow points. The few andesitic projectile points we recovered may well be from more siliceous and tractable fine-grained volcanic sources. The predominance of chert and chalcedony projectile points also suggests that the local basaltic andesite was not selected for point manufacture. Unifacial modification flakes indicate that people made or resharpened basaltic andesite retouched flake tools at the site. During all occupations, chert, chalcedony, and obsidian flake debris indicate that Pataha occupants brought finished bifacial tools of these materials to the site, where they were resharpened and reworked. This indicates on-site use of tools such as bifacial knives and perhaps the repair of weaponry following hunts.

Biface Stages of Production

At Pataha Canyon, we classified all bifaces according to the stages of production defined by Callahan (1979). Stage 1 tools are flake blanks or tested tabular cobbles; stage 2, bifacial edging (Figure 9-7a, b, f); stage 3, initial thinning (Figure 9-7c, d, e); stage 4 secondary thinning; and stage 5, final shaping and edge alignment by pressure flaking. Flenniken and others (1991) have documented the staged production of basaltic tools at the Teal Spring site. Their work provides a comparative contrast to Pataha Canyon. Thus, at Teal Spring flake blanks were produced elsewhere and imported to the site. The flakes were then reduced into bifacial blanks suitable for manufacture into dart points or bifacial implements. A few blanks were made into point preforms, but most were exported from the site for use elsewhere.

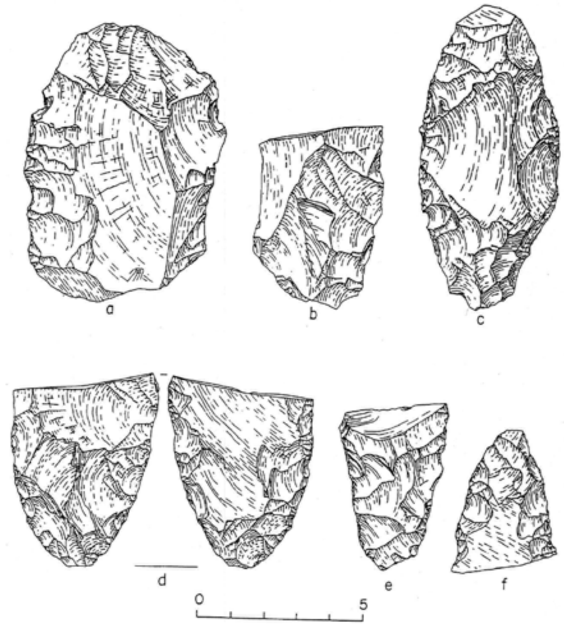

Figure 9-7. Pataha Canyon bifaces: (a, b, f) Stage 2 bifacial tool blank; (c, d, e) Stage 3 bifacial blanks.

Core Technology

We classified cores by technological types. As with other aspects of tool morphology and technology, we found significant changes between early and late occupations (Table 9-9). Unprepared cores are large pebbles and small cobbles of basaltic andesite with irregular flake removals and unprepared platforms (Figure 9-8c, f). Flake blanks were removed in an opportunistic manner, often from several platforms. Flake scars vary in size and orientation, leaving an unpatterned form. Flake initiations are Hertzian or bending with stiffness-controlled propagations, indicating freehand percussion (Cotterell and Kamminga 1987). Unpatterned, unprepared cores were principally used to produce blanks for unpatterned flake tools.

Table 9-9. Cores by Technological Class and Analytic Unit, Pataha Canyon.

	Piqúnin, Harder (AU1)		Late Cascade, Tucannon (AU2)		Early (AU 3-4) (pre-5,600 B.P.)		Site Total
Core Technology	n	%	n	%	n	%	n
Unprepared, irregular cores	11	84.6	5	41.7	1	100.0	17
Other unprepared freehand cores	1	7.7	0	0.0	0	0.0	1
Prepared bifacial	0	0.0	4	33.3	0	0.0	4
Other prepared cores	1	7.7	3	25.0	0	0.0	4
Total	13	100.0	12	100.0	1	100.0	26

Prepared bifacial cores occur only in the Late Cascade-Tucannon phase occupations. These cores are characterized by bifacially flaked platforms around only part of a cobble's perimeter (Figure 9-8a, b). The restriction of flaking to only a portion of the tool edge, and the removal of large thin flakes from one face, distinguish this technique from patterned bifacial tool reduction. Though bifacial cores may sometimes be flaked into bifacial tools, the cores from Pataha Canyon were obviously discarded without such modification. The four bifacial cores are small, but extensively flaked. The average negative flake scar length on bifacial cores is 47.3 mm, but this represents the last of many blank removals. The cores were discarded because they became too small to produce large flake blanks.

Four other prepared cores have platforms prepared by grinding or faceting, but without any of the characteristics of the more specialized bifacial flake cores (Figure 9-8d, e). The two complete cores are also small. Like the bifacial cores, they were extensively reduced and discarded because of their small size. The average negative flake scar length is only 48.5 mm. Two broken prepared cores retain evidence for removal of relatively large blanks (Figure 9-8d, e). Of the 22 basaltic andesite bifaces that retain evidence of blank form, 20 were made on flake blanks and only two on tabular cobbles. Thus, all evidence indicates that most bifaces were made on flake blanks, probably from such prepared cores.

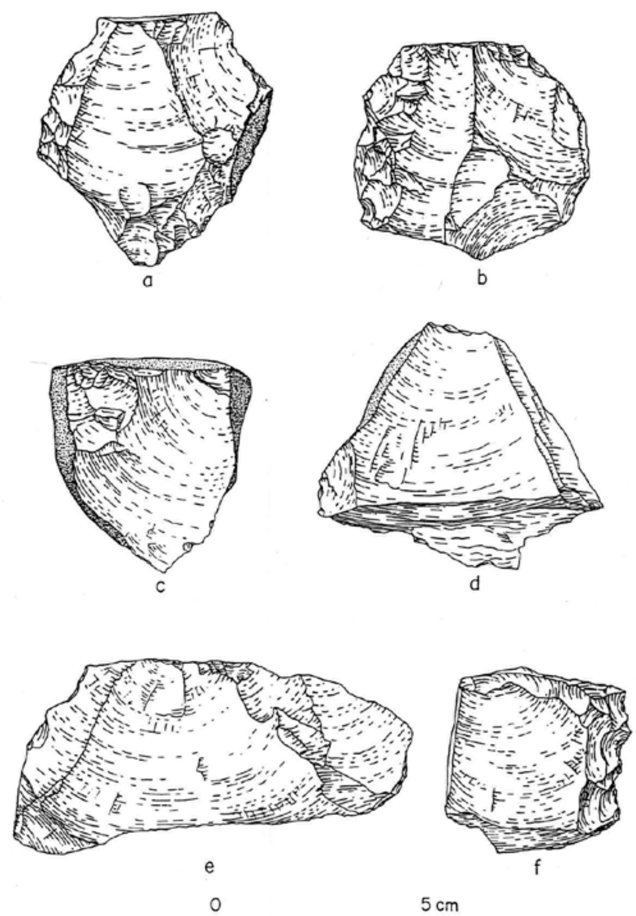

Figure 9-8. Pataha Canyon cores: (a, b) bifacial cores; (c, f) unprepared cores; (d, e) other prepared cores.

Tool Functional Classes by Analytic Unit

In order to better understand these technological patterns, we examined the distribution of tool functional classes within analytic units. The sample from the earliest occupations is small (only eight tools in AU3 and none in AU4), but the patterns of change through time are consistent. Proportions of tool functional classes suggest that early occupations were geared almost exclusively around basaltic andesite procurement and tool manufacture. The latest occupations, however, represent both hunting camps and stone procurement workshops. Functional classification of tools is summarized by analytic unit in Table 9-10.

The middle and early occupations (AU 2, 3, and 4) contain relatively few projectile points. There are no points from the pre-5600 ^{14}C B.P. horizon, and only 3 percent (n = 2) of the Late Cascade-Tucannon tools are points. Projectile points increase abruptly during the Piqúnin-Harder occupations, making up 30 percent of the collection.

Over 60 percent of the tools (5 of 8) from the pre-5600 ^{14}C B.P. unit are bifacial blanks. During the Late Cascade-Tucannon occupations, the proportion of bifacial blanks declines to 50 percent (31 of 62 tools). During the Piqúnin-Harder occupations the proportion drops to 19 percent (19 of 90 tools). There is also a slight decrease in the proportion of cores and tested cobbles from the Late Cascade-Tucannon occupations (22.6 percent) to the Piqúnin-Harder occupations (17.8 percent). Conversely, there is a slight increase in the proportion of all flake tools from the Late Cascade-Tucannon (11.3 percent) to the Piqúnin-Harder occupations (18.9 percent). The increases in the proportions of projectile points and flake tools and the decreases in bifacial blanks and cores all

Table 9-10. Stone Tools by Functional Class and Analytic Unit.

Functional Class (code)	Piqúnin, Harder (AU1)		Late Cascade, Tucannon (AU2)		Early (AU 3-4) (pre-5,600 B.P.)		Site Total
	n	%	n	%	n	%	n
Projectile points (1)	27	30.0	2	3.2	0	0.0	29
Knives							
Knives used on soft materials, short duration (3)	2	2.2	3	4.8	0	0.0	5
Knives used on soft materials, long duration (7)	0	0.0	1	106	0	0.0	1
Knives used on hard materials (12)	1	1.1	0	0.0	0	0.0	1
Bifacial knives, nfs (15)	4	4.4	4	6.4	0	0.0	8
Subtotal	7	7.8	8	12.9	0	0.0	15
Indeterminate knives or projectiles (blanks)							
Patterned bifacial tools, unknown function (44)	16	17.8	29	46.8	5	62.5	50
Flake blanks (54)	3	3.3	0	0.0	0	0.0	3
Subtotal	19	21.1	29	46.8	5	62.5	53
Light-duty bone, antler, woodworking tools							
Transverse scrapers used on hard material (17)	1	1.1	0	0.0	0	0.0	1
Utilized and retouched flakes used on hard material (22)	7	7.8	2	3.2	0	0.0	9
Subtotal	8	8.9	2	3.2	0	0.0	10
Unpatterned cutting or flake tools							
Denticulate flake tools (18)	0	0.0	2	3.2	0	0.0	2
Retouched, utilized flakes, variable materials (23)	8	8.9	3	4.8	2	25.0	13
Edge-ground flake (53)	1	1.1	0	0.0	0	0.0	1
Subtotal	9	10.0	5	8.1	2	25.0	16
Core tools: unknown functions (46)	1	1.1	0	0.0	0	0.0	1
Cores and tested cobbles							
Cores (21	13	14.4	12	19.5	1	12.5	26
Tested cobbles (31)	3	3.3	2	3.2	0	0.0	5
Subtotal	16	17.8	14	22.6	1	12.5	31
Grinding tools							
Hand stones (35)	0	0.0	1	1.6	0	0.0	1
Grinding slabs (36)	1	1.1	0	0.0	0	0.0	
Subtotal	1	1.1	1	1.6	0	0.0	2
Hammers/anvils							
Hammerstones (29)	0	0.0	1	1.6	0	0.0	1
Heavy-duty woodworking tools							
Adzes (71)	1	1.1	0	0.0	0	0.0	1
Practice pieces (56)	1	1.1	0	0.0	0	0.0	1
Total	90	100.0	62	100.0	8	100.0	160

indicate a change in the use of the site. Early in time the site was used principally as a toolstone procurement location and lithic workshop. Evidence suggests that hunting and other activities were minor site activities. During the Piqúnin-Harder occupations, however, most tools are projectile points or flake tools, with smaller proportions of bifacial blanks and cores. This suggests that late in time, the site served as a hunting camp, as well as a basaltic andesite procurement and workshop location. On the face of it, decreases in the number of recovered bifacial blanks might be taken as an indication of decreased stone tool production. However, as discussed below, analysis of flake debris indicates that this did not happen.

Estimating Changing Rates of Production

Flake debris can provide an accurate indicator of the kinds and amounts of lithic reduction at a site, because unlike tools, waste flakes are left where they fall (Shott 1994). Quantitative relationships do exist between the number and kinds of tools produced at a place and the number and technological types of debitage produced (e.g., Root 1992, 1997, 2004). These quantitative relationships are complex, but can be estimated by controlled experiments in lithic reduction.

As discussed earlier, there are probably size biases in the flake collection. Some of the smallest flakes have probably been removed by geologic or cultural processes (<6.35 mm and >2.54 mm). Thus the following exercise employs only flakes larger than 6.35 mm. Experimental production of seven thinned bifaces (stages 3 and 4) produced 25 biface thinning flakes (Table 9-11). Each tool yielded an average of 3.6 biface thinning flakes, with an average of 0.8 thinning flakes produced in bifacial edging and 2.8 biface thinning flakes produced in stage 3 and 4 thinning. We acknowledge that this experimental average is probably smaller than what would have been produced prehistorically because of our lower skill levels as knappers.

Basaltic andesite flakes larger than 6.35 mm from excavations are tallied by technological class and analytic unit in Table 9-12. More biface thinning and shaping flakes were recovered from the Piqúnin- Harder unit than from the Tucannon-Late Cascade unit, even though fewer bifacial

Table 9-11. Experimental Flake Data Tabulated by Technological Class and Size Grade, Size-grade 1-4 (All Flakes Larger Than 2.54 mm.)

Flake Technological Class, Size Grade[1]	Unprepared Core Reduction (6 replicates)		Prepared Core Reduction (2 replicates)		Bifacial Edging (6 replicates)		Bifacial Thinning (7 replicates)	
	n	%	n	%	n	%	n	%
Primary decort. G1	0	0.0	2	0.2	0	0.0	0	0.0
Primary decort. G2	5	0.7	0	0.0	0	0.0	0	0.0
Primary decort. G3	4	0.6	11	1.2	0	0.0	0	0.0
Shatter, G1	1	0.1	0	0.0	0	0.0	0	0.0
Shatter, G2	4	0.6	2	0.2	0	0.0	0	0.0
Shatter, G3	11	1.6	5	0.5	0	0.0	0	0.0
Alternate, G3	0	0.0	1	0.1	0	0.0	0	0.0
Simple flake, G1	2	0.3	2	0.2	0	0.0	0	0.0
Simple flake, G2	22	3.1	17	1.8	2	0.2	0	0.0
Simple flake, G3	82	11.7	108	11.6	42	4.0	26	2.2
Complex flake, G1	6	0.9	3	0.3	0	0.0	0	0.0
Complex flake, G2	17	2.4	28	3.0	4	0.4	4	0.3
Complex flake, G3	36	5.1	50	5.3	81	7.7	57	4.9
Biface Thinning, G1	0	0.0	0	0.0	0	0.0	0	0.0
Biface Thinning, G2	0	0.0	0	0.0	1	0.1	5	0.4
Biface Thinning, G3	0	0.0	0	0.0	4	0.4	15	1.2
Biface Shaping, G3	0	0.0	0	0.0	0	0.0	0	0.0
Biface Shaping, G4	0	0.0	0	0.0	5	0.5	24	2.1
Undiagnostic G4	510	72.9	707	75.6	914	86.7	1,033	88.7
Total	700	100.0	935	100.0	1,054	100.0	1,164	100.0

Table 9-12. Basaltic Andesite Flake Technology by Analytic Unit, Size-Grade 1-3 Only (>6.35 mm).

Technology	Piqúnin, Harder (AU1)		Tucannon, Late Cascade (AU2)		Pre-5600 B.P. (AU3)		Pre-5600 B.P. (AU4)		Total
	n	%	n	%	n	%	n	%	n
Primary decortication	88	4.7	81	5.4	24	6.1	2	6.7	195
Shatter	62	3.3	31	2.1	14	3.5	0	0.0	107
Biface thinning	142	7.6	113	7.5	27	6.8	4	13.3	286
Biface shaping	31	1.7	17	1.1	8	2.0	0	0.0	56
Alternate	39	2.1	31	2.1	8	2.0	0	0.0	78
Bipolar	2	0.1	2	0.1	2	0.5	0	0.0	6
Uniface	1	0.1	1	0.1	0	0.0	0	0.0	2
Simple	724	38.9	643	42.6	156	39.5	15	50.0	1,538
Complex	771	41.4	589	39.1	156	39.5	9	30.0	1,525
Total, G1-3	1860	100.0	1508	100.0	395	100.0	30	100.0	3,793

blanks were recovered from the late horizon. The figure of 3.6 biface thinning flakes per biface is used to estimate production. No biface shaping flakes larger than 6.35 mm were produced in experiments, and therefore, these flakes are not used in the estimates. There are of course many variables not accounted for by such a procedure, such as skill levels, variation in the number of flakes per tool, and breakage at different stages of production. Nevertheless, the exercise is instructive.

The numbers of unfinished basaltic andesite bifaces and biface thinning flakes recovered from excavations are summarized in Table 9-13. The tools include only those proveniences from which the flake debris was analyzed, including all 1997 excavations and a single 1994 Forest Service excavation unit. An estimate of biface production for each analytic unit is made by dividing the number of recovered biface thinning flakes by 3.6, after subtracting 0.8 biface thinning flakes per recovered stage 2 edged biface (thus accounting for early stage rejects).

The early unit (pre-5600 ^{14}C B.P.) has a production estimate of only 7.5 bifaces with recovery of five stage 3-4 blanks. The Tucannon-Late Cascade unit has a production estimate of 30.5 thinned blanks, though eight stage 3-4 blanks were recovered. The Piqúnin- Harder unit has an estimate of 39.2 bifacial blanks, with recovery of five stage 3-4 blanks. These production estimates allow an estimate of the number of tools successfully completed in the excavation space and exported from the site. The early analytic unit has an estimate of 2.5 bifaces. In the Tucannon-Late Cascade unit, an estimated 22.5 thinned biface blanks were successfully completed (30.5 total estimated - 8 recovered). The Piqúnin- Harder unit has an estimated 34.2 completed and exported blanks (39.2 total estimated - 5 recovered).

Thus, although fewer basaltic andesite biface blanks were recovered in excavations from the Piqúnin-Harder horizon than in the earlier deposits, more bifaces were produced than during previous occupations. Fewer broken and rejected blanks were recovered because the Piqúnin and Harder knappers were more efficient, making fewer errors than their predecessors. Analysis of the tool collections might suggest that workshop activities decreased late in time, but flake debris analysis indicates that this is not the case. More basaltic andesite bifaces were made and exported from the site during the latest occupations.

The smaller number of early stage rejects during the late occupations also suggests that those knappers practiced their craft with greater skill than

Table 9-13. Summary of Basaltic Andesite Flakes and Tools and Production Estimates for the Pataha Canyon Site (1997 Excavations and 1994 Unit "65W/00N" Only).

	Piqúnin, Harder	Tucannon, Late Cascade	Pre-5600 B.P.
Recovered edged blanks (stage 2)	1	4	0
Recovered thinned blanks (stage 3-4)	5	8	5
Recovered pressure-flaked preforms (stage 5)	1	1	0
Recovered biface thinning flakes	142	113	27
Estimated bifacial blank production	39.2	30.5	7.5
Potential bifacial blank export	34.2	22.5	2.5

did earlier knappers. Lower error rates imply greater efficiency of tool production. There is less waste of raw materials and less time is spent successfully completing a set number of tools. Increased efficiency in tool production points to changes in the organization of production. Perhaps part-time specialization, linked to increases in production efficiency (Costin 1991:37), is making an appearance at Pataha Canyon. Though full exploration of such a topic is beyond the scope of this chapter, our analyses indicate that lithic workshops in the Blue Mountains are places where such questions can be productively addressed.

One final aspect of tool production in Pataha Canyon concerns the total amount of production that occurred there throughout the past. The above analysis indicates that the excavated sample represents export of several dozen bifacial blanks from the later two analytic units. Though the excavated sample was not random, and statistical estimates of total populations cannot be made, it is likely that several thousand bifaces were made at the Pataha Canyon workshop and transported from the site. Thus, it may be instructive to compare rates of production output at Pataha Canyon with data from the contemporaneous Marshmeadow dacite workshop (35UN74) at Craig Mountain.

The Pataha Canyon site retains a relatively intact area of about 6,000 m^2. Assuming the average depth of deposits is about 1.25 m, the estimated surviving site volume is 7,500 m^3. The total excavation volume for the combined 1994, 1996, and 1997 efforts is 15.075 m^3, or about .002 of the site volume. Applying the production estimates presented in Table 9-13 to the site as a whole, and dividing the occupation span into three intervals of 2500 years each, gives us more than 17,000 bifaces produced for export during the Harder/Piqunin interval, for an average of about seven bifaces per year. During the late Cascade/Tucannon interval, about 11,200 bifaces were made for export, or about 4.5 per year. During the pre-5300 RCYBP interval, only about 1,200 bifaces were shaped for export, or about one biface every two years.

By comparison, when the debris categories at Marshmeadow are converted to rates of discard by dividing the number of blanks per stratigraphic unit into the number of years represented by the unit, rates of change over time also emerge (Table 9-14). Thus, during the early Cascade phase (SU-2,3), one production biface or elongate unifacial blank was discarded every 23 years. Between the late Cascade and early Harder phase (SU-4,5), failure and discard rates hovered around one in every eight to ten years, increasing to one in every five years in the Harder-Piqunin interval (SU-6). Thus, while the mid- to late-Holocene trend over time parallels the increasing rates of production output calculated for Pataha Canyon, these are rates at which failures accumulated, not rates at which functional workshop products left the site to equip a stone-age population.

Table 9-14. Long Term Production Patterns in FGV Blanks at Marshmeadow, 35UN95 (Compiled from McPherson et al. 1981).

Age: RCYBP	Strat. Unit	Debitage	Bifaces	Unifaces	Total Blanks
	1	254			
6700-6100	2	3,198	23	3	26
	3	6,748	69	13	82
4000-3410	4	12,233	62	12	74
3410-2260	5	21,952	103	9	112
2260- 690	6	32,584	185	26	211
	7	17,971	88	12	100
	8	10,825	38	1	39
	Totals:	105,765	568	76	644

Summary and Conclusions

The Pataha Canyon site served as a basaltic andesite procurement location and workshop, and as a field camp for upland hunting during the mid- and late Holocene. The site is the source of a moderate-quality basaltic andesite with evidence of two major reduction trajectories. First, knappers selected large pebbles and small cobbles of basaltic andesite for use as unprepared cores. They struck flake blanks several centimeters long from these cores. These were fashioned into unpatterned retouched and utilized flake tools. Knappers also selected larger cobbles for manufacture of bifacial cores and other prepared core types. They struck large flake blanks from these prepared cores, probably 8–9 cm long, from which they fashioned bifacial blanks and preforms. These percussion-flaked bifacial blanks were a major item of export from the site. Experimental replications indicated that this stone is difficult to flake. Most recovered projectile points are chert, chalcedony, and obsidian, and it is likely that the Pataha basaltic andesite was seldom used for projectile point manufacture. Instead, the bifacial blanks were probably transported from the site to other locations where they were made into bifacial knives or other types of bifacial tools that required little flaking beyond the percussion-flaked blank forms to finish them for use. Production estimates suggest that production efficiency increased during the latest occupations, when knapping error rates decreased. This suggests that changes in the organization of production occurred, and that part-time specialist knappers may have been present during the latest occupations.

The site must always have been available as a hunting camp as well as a workshop. However, late in time the emphasis on hunting grew. Increasing numbers and proportions of broken arrow and dart points litter the Piqúnin and Harder phase levels. Most of them are chert, chalcedony, and obsidian, in contrast to the general preponderance of basaltic andesite. Furthermore, most of the chert, chalcedony, and obsidian debitage consists of biface pressure flakes. Thus, broken projectile points were reworked on the site and some preforms were chipped into new tools to replace the broken ones. Use-wear analysis indicates that flake tools were used to work hard-surfaced wood, bone, or antler (Reid and Root 1998). These flake tools probably served to repair hafts during retooling, and for other wooden or bone tool manufacturing needs. The growing abundance of chert, chalcedony, and obsidian tracks an increased use of transported tool kits late in time.

The Grande Ronde Basalt Formation is the single most extensive exposure of the Columbia River Basalt Group in the Tri-State Uplands. Basaltic andesite toolstones in this formation exhibit geochemical homogeneity but variable fracture toughness. The Pataha Canyon workshop is one of many similar sites where production biface industries flourished at different times in the middle and late Holocene. The toolstone at Pataha Canyon occurs in small package sizes and is difficult to work. Nevertheless, evidence for changing rates of production derived from a replicative systems analysis of the lithic debris suggest that these sites have the potential to inform on larger regional processes.

For example, the activity shift between AU1 and AU2 coincides with an organizational shift in hunting and gathering that is evident at a broad regional level between about 3,500 and 2,500 years ago. Present evidence suggests that this development follows and is not contemporaneous with the first pithouse settlements in the region. It is manifested by the appearance of sites in upland settings that display evidence of labor investment and regular seasonal reutilization. These sites probably functioned as field camps for hunters operating out of nearby winter villages in the canyons. Locally, the dissimilar toolstone raw material profiles at the winter village of Hatiuhpuh at the mouth of the Tucannon may mask functional linkages to such upland camps and workshops as Teal Spring, Kelly Camp, and Pataha Canyon.

Table 9-15. Raw Material Profile of Bifacial or Retouched Tools from the Hatiuhpuh Settlement (45WT134) Opposite the Mouth of the Tucannon River (Data from Brauner et al. 1990:167-175).

Tool Category	Crypto-crystalline Silicates	Fine-grained Volcanics	Obsidians
Bifacial blanks and fragments	81 (94%)	1	4
Projectile Points	35 (67%)	12 (23%)	5 (10%)
Knives	5 (100%)	0	0
Drills	11 (92%)	0	1
Gravers and perforators	9 (100%)	0	0
Scrapers	51 (89%)	4	2

Thus, of the 81 bifacial blanks recovered at the winter village, only one was made from an FGV toolstone, while nearly a quarter of the 53 projectile points were (Table 9-15). All of the 52 cores from the village were made from microcrystalline silicates. The FGV projectile points from Hatiuhpuh were dart points typical of the late Cascade/Tucannon/early Harder phases. However, technological data from Pataha Canyon argues against this nearby source having provisioned these Hatiuhpuh hunters. We suspect that the high-silica andesites and dacites of the Saddle Mountain Formation that came under exploitation in the early Holocene at Stockhoff, Marshmeadow and Pilcher Creek may have continued to be valued for projectile points, even after the less tractable basaltic andesites went into production later in the Holocene.

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An earlier version of this chapter profited from comments of the volume editors.

We dedicate this chapter to the memory of Sarah Margaret Moore, who died on August 27, 2012. Her elegant line drawings have contributed here and elsewhere to a better understanding of Northwest lithic technology.

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CHAPTER 10

New Perspectives on the Stockhoff Quarry: Toolstone Procurement at a Quarry Complex in the Blue Mountains of Northeastern Oregon

Nicholas Smits
Archaeological Investigations Northwest, Inc. (nicholas@ainw.com)

Sara J. Davis
Historical Research Associates, Inc. (sara.j.davis@hotmail.com)

Introduction

The term "Stockhoff basalt" is familiar to many archaeologists who work in the Pacific Northwest. One of the largest recorded archaeological sites in Oregon, the Stockhoff Quarry site (35UN52) encompasses over 3,400 acres of land on the western flank of Craig Mountain, located about 16 km southeast of La Grande in Union County (Figures 10-1 and 10-2). The Stockhoff Quarry is named for Gene Stockhoff, who owned the land in 1955 when Alan Bryan and Donald Tuohy initiated the first archaeological investigations at the site. Working in advance of construction of a natural gas pipeline, Bryan and Tuohy (1960:489-490) conducted limited testing within the pipeline right-of-way, where they found stone tools and hundreds of flakes of "fine-grained glassy basalt." The dark gray to black, fine-grained volcanic (FGV) toolstone local to the Craig Mountain vicinity has since been known colloquially as "Stockhoff basalt" for ease of reference, even as our knowledge of the compositional variability of FGV materials in archaeological contexts has increased over the last two decades (e.g., Bakewell 1993, 1996, 2005; Bakewell and Irving 1994). Accordingly, terms such as "FGV" and "vitrophyre," which have been proposed as alternatives to the catchall term "basalt," will be used here for the sake of accuracy.

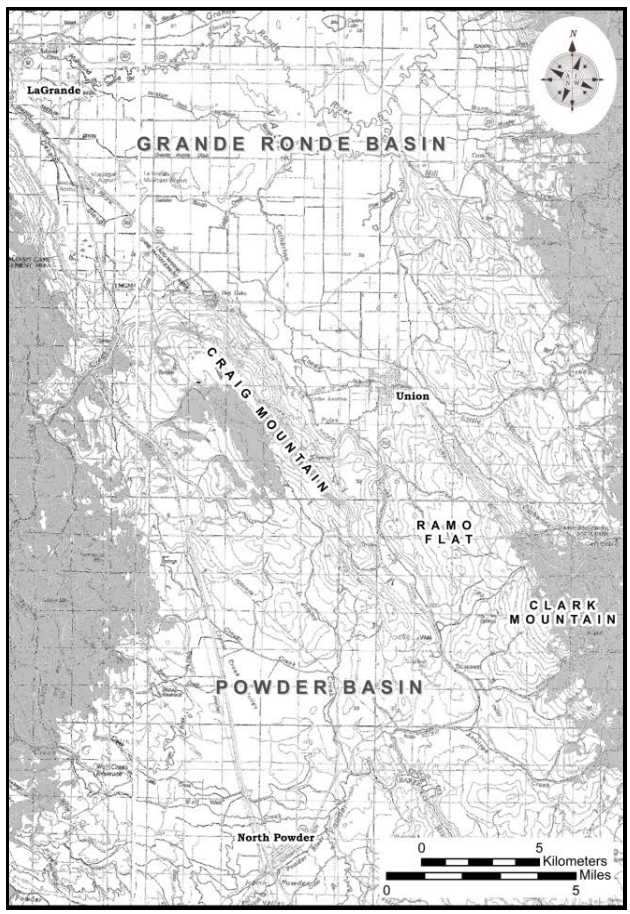

Figure 10-1. General study area showing Craig Mountain in relation to prominent features of the surrounding landscape.

In 2009 and 2010, archaeologists employed by Archaeological Investigations Northwest, Inc.

Toolstone Geography of the Pacific Northwest
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(AINW), assisted by members of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Cultural Resources Protection Program (CRPP), surveyed over 11,000 acres of private land on Craig Mountain and nearby landforms, including over 530 acres within the recorded boundary of site 35UN52. In this unique geological setting, outcrops of igneous rock range in composition from basalt to andesite to dacite and variations in between, and among them are vitrophyric toolstone sources that attracted native people for millennia (Figures 10-1 and 10-2). Excluding the Stockhoff Quarry site itself, more than 218 pre-contact archaeological resources were identified during the survey, including 28 quarry sites, 81 lithic scatters, and 109 isolated finds, as well as numerous stacked rock feature sites (Davis et al. 2010; Smits et al. 2009). Based on the survey results, it is clear that the Stockhoff Quarry site represents only part of a much larger quarry complex consisting of dozens if not hundreds of individual quarry "sites" and lithic reduction workshops across Craig Mountain and surrounding landforms.

Cultural materials were not collected during AINW's survey work, and therefore geochemical and petrographic analyses of FGV artifacts and source samples was not possible for this study. Although much of the toolstone at these sites appears similar to the naked eye, some variability in color, glassiness, and vesticularity is apparent. Fine-grained volcanic materials of various compositions are locally abundant and associated with lava flows of both the Columbia River Basalt Group (CRBG) and the Powder River Volcanic Field (PRVF), which overlap in this area. Recent geologic mapping and geochemical data indicate that Craig Mountain proper is composed primarily of dacitic materials emplaced during middle Miocene flows of the PRVF (Ferns et al. 2010). Pre-contact toolstone procurement on Craig Mountain appears to have been focused on specific sources of dark, glassy FGV material associated with dacitic and andesitic flows of the PRVF (Ferns et al. 2010:14). The chemical diversity inherent in the extrusive PRVF flows, which are more geographically restricted than the extensive and more chemically uniform CRBG flows, suggests that the FGV materials once known as "Stockhoff basalt" may represent toolstone from multiple sources that differ in chemical composition. Limited trace element data from source reference samples collected by previous researchers indicate that some of these toolstone sources on Craig Mountain may be distinguishable from each other.

Technological data based on field observations of lithic tools and debitage are generally consistent with those reported by previous archaeologists at the Stockhoff Quarry (McPherson, Coe, Day, Hall, and McGlone 1981; McPherson, Hall, McGlone, and Nachtwey1981; Womack 1977). Given an abundance of toolstone sources, pre-contact flintknappers appear to have been extremely selective. Quarrying was focused on localized sources of high-quality, glassy FGV toolstone available on Craig Mountain at elevations generally ranging from 985 to 1,460 m above sea level. Tools, debitage, and raw material sources at quarry sites indicate a focus on the removal of large flakes from cobbles and boulders for the purpose of producing bifacial cores and blanks for export. As reported for the Stockhoff Quarry (Womack 1977:7), the abundance of toolstone allowed flintknappers to be both selective and non-conservative, discarding pieces during the reduction process rather than correcting mistakes or working with flaws encountered in the material. The lithic scatter sites located away from quarries represent workshops for creating blanks for export and the occasional production and maintenance of other finished tools.

Geology and Environment

Located in the Blue Mountains of northeastern Oregon, Craig Mountain is a northwest-trending spur that separates the Grande Ronde River Basin to the north from the Powder River Basin to the south (Figures 10-1 and 10-2). Reaching 1,497 m above sea level at its summit, Craig Mountain towers over the Grande Ronde Valley, its steep northern and eastern faces shaped by faulting and landslides (Ferns et al. 2010:36). The Grande Ronde River drains the valley below as it winds its way northeast toward the border between Washington and Idaho, where it meets the Snake River some 120 km away. Elevations within the Grande Ronde basin vary between 835 and 915 m. The south- and southwest-facing slopes of Craig Mountain are more gentle, composed of undulating terrain that leads gradually down toward the Clover Creek and North Powder valleys, which are drained by tributaries of the Powder River, itself another

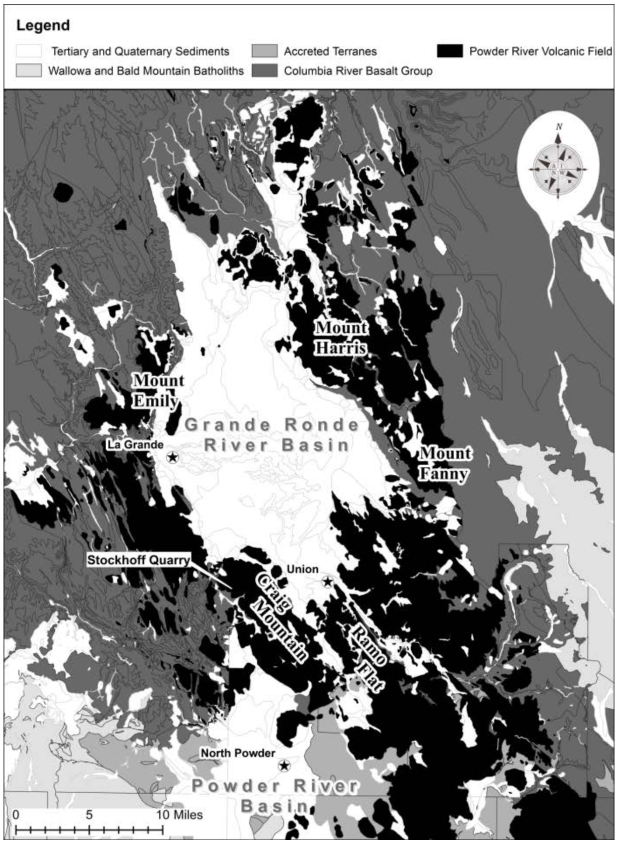

Figure 10-2. Relief map showing lithology of the Grande Ronde and Powder River basins (after DOGAMI 2009 and Ferns et al. 2010).

tributary of the Snake River. To the east of Craig Mountain, separated by Pyles Canyon, are the rolling hills of Ramo Flat and the lower slopes of Clark Mountain at the foothills of the Wallowas. To the west and southwest, across Interstate 84, are Glass Hill and Tamarack Mountain, and farther to the south and west are the Elkhorn Mountains, all part of the Blue Mountains.

The Blue Mountains are not a cohesive mountain range but instead comprise a number of smaller ranges that reflect a complex geological history. The basement rocks consist of exotic terranes accreted onto the North American continent as a result of tectonic activity during the Mesozoic era (Orr and Orr 1996:169; Orr et al. 1992:21-27). Portions of two of these terranes, the Wallowa and Baker terranes, are exposed in places within the Grande Ronde and Powder River valleys (Ferns et al. 2010:40). The Clover Creek Greenstone formation, which is Permian or Triassic in age and associated with the Wallowa Terrane, is exposed in road cuts and stream beds, particularly in the Clover Creek Valley south of Craig Mountain (Baldwin 1964:108; Ferns et al. 2010:29,41; Gilluly 1937). During the early Cretaceous, the terranes were cemented together by intrusions of the granitic Wallowa and Bald Mountain batholiths (Ferns et al. 2010:26-27; Orr et al. 1992:28).

In the middle Miocene epoch, starting approximately 17.5 million years ago, a series of vast lava flows known as the Columbia River Basalts erupted from fissures and vents in the earth, covering over 164,000 square km of what is now Oregon, Washington, and western Idaho (Hooper 1982:1464; Tolan et al. 1989:1). The Columbia River Basalt Group (CRBG), as it is known, comprises several formations representing over 300 separate flows distinguished by subtle differences in chemical and mineralogical composition (Barrash et al. 1980; Orr and Orr 1996:292-293). Of these, the most extensive formation is Grande Ronde Basalt, made up of over 120 separate flows that constitute an estimated 90 percent of the overall volume of the CRBG. Andesites and basaltic andesites of the Grande Ronde Basalt formation are exposed on the eastern edge of Craig Mountain and along Ladd Canyon on its western margin (Ferns et al. 2010). The most recent of the CRBG formations are the Wanapum and Saddle Mountain basalts, which are more silica-rich than the earlier formations (Orr and Orr 1996:295). Wanapum Basalt is exposed along the northern margin of the Powder River valley near the southern end of Craig Mountain. In general, the flood basalts of the CRBG are primarily tholeiitic (i.e., iron rich, silica-saturated) basalts, though they range in composition from basalt to basaltic andesite and andesite within the Craig Mountain vicinity (Ferns et al. 2010:17-21; Tolan et al. 2009).

Beginning approximately 14.5 million years ago, as eruptions of the CRBG waned, eruptions of the Powder River Volcanic Field began (Bailey 1990; Ferns et al. 2002:5; Ferns et al. 2010:44). Over the next 12 million years, extrusive PRVF lavas erupted intermittently from small composite and shield volcanoes, burying the older CRBG vents. Ranging in composition from olivine-rich basalt to andesite and dacite to basanite and trachyandesite, PRVF lava flows were more viscous and chemically diverse than CRBG flows (Ferns et al. 2002:5). Flows of PRVF lavas were also more siliceous and were calc-alkaline to alkaline in composition as opposed to tholeiitic basalt flows of the CRBG (Ferns et al. 2010:17, 44-46).

Approximately 13.4 million years ago, dacitic flows of the PRVF began with the eruption of Mount Emily flows along the western margin of the Grande Ronde Valley (Ferns et al. 2010:44). Dacitic and andesitic flows erupted from Mount Harris and Mount Fanny along the eastern margin of the Grande Ronde Valley, and small basaltic andesite cinder cones formed at Ramo Flat. The orientation of the vents at Ramo Flat suggests that fault zones in this vicinity may also have become active as the PRVF volcanism began (Ferns et al. 2010:44-46).

Recent geochemical data and geologic mapping indicate that most of Craig Mountain is composed of dacitic flows of the PRVF (map unit Tpd), described as "light bluish-gray to light pinkish gray, aphyric to sparsely porphyritic lava flows and domes" that outcrop as rounded, bouldery cliffs and platy flows (Ferns et al. 2010:14). In certain places, flows of black, vesicular, glassy, aphyric dacite occur between thicker flows of dacitic material. Also found on Craig Mountain are PRVF flows of andesite and basaltic andesite that "vary from dark gray, very fine to medium grained, porphyritic, vesicular lava flows, to gray, platy jointed, aphyric to light- to medium-gray fine-grained lava flows" (Ferns et al. 2010:13).

As defined by Ferns et al. (2010:13), the andesite and basaltic andesite map unit (Tpa) of the PRVF is primarily andesite but ranges in composition from basaltic andesite to low-silica dacite, and it includes what Barrash et al. (1980:17) described as "glassy basalt" of the Glass Hill sequence. This "Glass Hill basalt" was the material identified by previous researchers as the focus of past quarrying activity at the Stockhoff Quarry (Cochran and Leonhardy 1981:8). To the west of the Stockhoff Quarry, at Glass Hill, are exposures of basanite and trachybasalt (Tpbo), which are dark bluish gray to very dark gray in color, aphanitic to glassy, olivine-phyric rock that Ferns et al. (2010:12) describe as "difficult to break, rings like a bell on impact, and forms conchoidal fractures." These geochemical data highlight the variety of chemically distinct FGV materials that are present within close proximity to the Stockhoff Quarry site.

Between about 10 and 7 million years ago, regional uplift and warping occurred along the Blue Mountain anticlinorium, accompanied by subsidence of the fault-bounded Grande Ronde Valley (Ferns et al. 2010:40, 46). Folding and faulting continued into the Pleistocene, contributing to the formation of the modern topography (Ferns et al. 2010:30). Craig Mountain itself is surrounded on the west, north, and east by discontinuous fault zones (Ferns et al. 2010:36). The steep northeastern face of Craig Mountain is characterized by massive landslides and steeply tilted, fault-bounded blocks of broken rock.

Quaternary surficial deposits cover the Miocene flows of the CRBG and PRVF throughout much of the study area. To the north of Craig Mountain, the Grande Ronde basin is filled with as much as 600 m of late-Miocene, Pliocene, and Pleistocene sediment (Ferns et al. 2010:2). Across Craig Mountain, Clark Mountain, and Ramo Flat, soils are generally shallow and formed from a mixture of loess, colluvium and residuum derived from basalt and volcanic tuff (Dyksterhuis and High 1985). Lithosols are common, particularly at higher elevations. Deeper soils that formed in a mixture of loess and Pleistocene/Holocene fluvial and lacustrine deposits are present on upland valley floors. At site 35UN52, stratigraphic profiles of excavations conducted near Ladd Creek showed evidence of five major alluvial cycles (aggradation, surface stability, and erosion) since the early Holocene, the last depositional episode occurring around 100 BP (Cochran and Leonhardy 1981:3).

The current semiarid climate of the study area supports steppe vegetation characteristic of the grassland/forest ecotone. Lower elevations are inhabited by sagebrush communities that include perennial bunchgrasses such as bluebunch wheatgrass, Idaho fescue, and sandberg bluegrass (Franklin and Dyrness 1973:219). Higher elevations support Ponderosa pine communities that contain stands of western larch and black hawthorn and an understory of common snowberry, rose, arrowleaf balsamroot, buckwheat, and bitterbrush (Franklin and Dyrness 1973:168-173). Blooms of camas and "death camas" occur in the upland meadows, and riparian vegetation is present along perennial and ephemeral streams. Today, most of Craig Mountain is privately owned; land at higher elevations is used as rangeland for livestock grazing, and lower elevations are cultivated for agricultural crops.

The native vegetation of Craig Mountain would have sustained a variety of small and large mammals, many of which were hunted by native people. Historically, the lower elevations were inhabited by rabbits, squirrels, mice, rats, and gophers, and were common winter ranges for antelope, mountain sheep, and mule deer (Bailey 1936:14-15). The uplands continue to be inhabited by mule deer, elk, chipmunks, and squirrels, as well as a variety of birds including grouse, sparrow, and thrasher (Bailey 1936:23-28). Bison were also present in the past (Csuti et al. 1997:443; Francy n.d.).

Ethnography and oral history

Craig Mountain is within the ceded lands of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), in an area historically occupied by the Cayuse (*Weyíiletpuu*). The Cayuse occupied the middle and upper courses of the Umatilla, Walla Walla, Powder, and Grande Ronde river basins, while their neighbors to the north were focused on the Columbia River and lower courses of its major tributaries. The Cayuse, who traditionally spoke a distinct language, had close ties and a large degree of social interaction with neighboring groups such as the Nez Perce (*Ni Míi Puu*), Umatilla (*Imatalamláma*), and Walla Walla (*Walúulapam*), who spoke Sahaptin dialects (Kinkade et al. 1998:61-62; Rigsby 1969:73-75; Stern 1998:395; Suphan 1974:101, Walker 1998:420). These groups all used the mountainous upper reaches of major rivers-including the Grande Ronde River valley-during the summer months, often using the same resource locations at the same time (Stern 1998:396-397; Suphan 1974:101; Walker 1998:420). In the historic period, southern Plateau groups including the Cayuse and Nez Perce traveled together by horse across the Rocky Mountains to join communal buffalo hunts and interact with people of the Great Plains (Stern 1998:396).

The Cayuse fished, gathered vegetable resources such as roots, berries, and medicinal plants, and hunted on a seasonal round basis. Fish (both anadromous and local) made up approximately 50 percent of their diet, plants another 25 to 40 percent, and game the remaining 10 to 25 percent (Steinmetz 2003:8). Winter months were spent along the major rivers at lower elevations. Subsistence during the winter was focused on stored roots and bulbs, dried fish and game, and some fresh meat. In April, the first plant roots of the season, cous (biscuit root) followed by camas, became available at lower elevations. These roots were supplemented by spring chinook salmon caught in nearby rivers. Roots at lower elevations were available until roughly mid-July (Stern 1998:396-400, Suphan 1974:100, 112).

As vegetable resources became available at higher elevations, smaller (often family) groups moved to the uplands where the summer was spent fishing, hunting, and gathering plants (Stern 1998:397,400; Suphan 1974:113). Foodstuffs were dried and cached, to be collected on the return trip to winter villages. The Cayuse typically moved to the Grande Ronde Valley in late June. In mid-August, groups in the Grande Ronde Valley moved higher into the Blue Mountains for more intensive hunting, often using fire to drive game in communal hunts. Plants such as bitterroot, cous, chokecherry, wild onion, celery, and balsamroot, along with a number of species of fish and game, continue to be culturally significant “first foods” for members of the CTUIR (Anastasio 1972:119; Quaempts et al. 2007).

Oral histories on file with the CTUIR indicate that permanent villages were located in the nearby Grande Ronde Valley (Steinmetz 2002:4). Early non-Indian visitors to the area reported villages of a dozen lodges or drying sheds near fisheries on the Grande Ronde River (Stern 1998). These settlements were likely smaller than those on the major rivers during the winter, and possibly reflecting this, Suphan (1974) reports no villages in the Grande Ronde Valley, only resource locations. Ethnographic information regarding the wide variety and abundance of plant and animal resources available on Craig Mountain and in the adjacent valleys indicates that procurement of toolstone, although important, was one of many reasons for native people to visit these uplands as part of their seasonal round.

Previous archaeology

The Blue Mountains are considered part of the southern Plateau, for which numerous cultural chronologies have been developed (e.g., Ames et al. 1998; Chatters 1989; Chatters and Pokotylo 1998; Leonhardy and Rice 1970). The Blue Mountains are also at the periphery of the northern Great Basin and have been characterized as a frontier zone where pre-contact cultural interactions occurred between Plateau and Great Basin groups (Brauner 1976; McPherson, Hall, McGlone, and Nachtwey 1981:713-720). In his study of linguistic relations on the southern Plateau, Rigsby (1965) argues that the Cayuse moved into this upland area within the last 2,500 years in response to migrations of Chinookan-speaking and Sahaptin-speaking populations along the Columbia and Snake Rivers.

A summary of previous archaeological investigations at the Stockhoff Quarry is presented below. The boundary of site 35UN52 encompasses over 3,400 acres across the western slopes of Craig Mountain, and it includes areas where raw material was procured for toolstone as well as workshop areas where the stone was further reduced and made into tools, among other activities. For the most part, previous archaeological investigations at site 35UN52 have focused on a relatively narrow corridor adjacent to Ladd Canyon and Interstate 84, where pipelines and transmission lines have been constructed through the area.

Although not part of this study, other FGV toolstone quarry sites are known to exist nearby. The closest recorded example is the Union Golf Course Basalt Quarry Site (35UN250), located at the north end of Ramo Flat near the city of Union (Jaehnig 1997). Major workshops in the vicinity include Marshmeadow and Ladd Canyon (Jaehnig et al. 1996; Reed and Reed 1980; McPherson, Hall, McGlone, and Nachtwey 1981), Ladd Marsh (Ogle et al. 2006; Steinmetz 2002), and Pilcher Creek (Brauner 1985). Also nearby are stratified archaeological deposits and pictographs at Pagliarulo Rockshelter (Mead 1975) and a late pre-contact bison kill site known locally as "the Buffalo Jump" (Francy n.d.), both located outside of the city of Union. "Basalt" tools and debitage were reported at all of these nearby sites.

Bryan and Tuohy (1960)

The "Stockhoff Basalt Quarry" was identified in the mid-1950s by Bryan and Tuohy (1960), who excavated eight 1-x-1-m test units within the right-of-way for a natural gas pipeline. In total, Bryan and Tuohy (1960:489) found 165 tools and "hundreds" of flakes on the ground surface and in shallow, widely dispersed archaeological deposits. The tools were described as projectile points, cores, blanks, bifaces, scrapers, and choppers, and all of the artifacts were "fine-grained glassy basalt" with the exception of a few obsidian flakes and one flake of jasper. A sample of charcoal from one of excavation units yielded a radiocarbon date of 2600±200 years BP. Bryan and Tuohy (1960:489-490) also identified a possible "habitation mound" within the site on the west side of what is now Interstate 84, which runs through Ladd Canyon.

Bryan and Tuohy (1960:487,490) noted that quarrying activity was focused on rounded nodules and tabular slabs of the fine-grained glassy material, which they described as occurring "in a layer of elongated oval to flat cobbles." The vesicular texture of the quarry material indicated to them that it was from the surface of a flow, and it was visually distinct in comparison to adjacent basalt flows, which were of different textures and contained macroscopic minerals. Petrographic analysis by Andrei Isotoff, then a geology professor at Idaho State University, indicated that "the glassy groundmass is composed of microlites of sodic labradorite showing trachytoid texture, and a few phenocrysts of augite are seen in the section" (Bryan and Tuohy 1960:490).

All of the tools (n=165) in Byran and Tuohy's (1960:490-500) assemblage were percussion flaked. No evidence of pressure flaking was observed on the debitage or tools of FGV material, although evidence of pressure flaking was observed on the few obsidian artifacts at the site. Artifacts of FGV material from Bryan and Tuohy's (1960:490-500) excavations were classified primarily by form and secondarily by bifacial or unifacial reduction technology. Large bifaces, which they called "blades" and "blade blanks," were large ovate or leaf-shaped specimens that made up over 44 percent (n=73) of the assemblage. Only two of these were categorized as finished "blades," the rest were unfinished "blade blanks." Also of note was a lack of hammerstones at the site.

Photographs of the artifacts described by Bryan and Tuohy (1960:Figures 3 and 4) suggest that the tools classified as projectile points were likely bifacially and unifacially reduced blanks in a later stage of reduction than the larger "blade blanks" they identified. The projectile points also appear to be quite thick, with large flakes removed by percussion and little evidence of the finish-work to complete this type of tool. This is not to say that a projectile point must be finished using pressure flaking (Bucy 1971:14), rather that the artifact photographs presented by Bryan and Tuohy (1960) do not exhibit the expected attributes of finished points. Bryan and Tuohy (160:491) do caution that some of the unifacially reduced projectile points may represent unfinished forms.

A comparison of their data from the Stockhoff Quarry with those from other quarry sites on the Columbia Plateau, Great Basin, and elsewhere in North America led Bryan and Tuohy (1960:506) to conclude that the primary activity at this site was the initial reduction of stone material and the manufacture of expedient tools to be used on site. Importantly, Bryan and Tuohy (1960:506) argued that pre-contact flintknappers at the Stockhoff Quarry were not producing bifacial blades and blanks primarily for export, but were instead utilizing flakes from the initial reduction of raw material for the production of a wide variety of expedient tools. They acknowledged the possibility, however, that "at least some of the large bifaces were exported in their 'unfinished' state for use as heavy-duty multi-purpose tools," and that the large numbers of "unfinished specimens" at the Stockhoff Quarry could be interpreted as "blanks" and "rejects" (Byran and Tuohy 1960:506,509 citing Holmes 1919).

Womack (1977)

In 1975, Eastern Oregon State College began excavations at the "habitation mound" at site 35UN52, which turned out to be a 20th century refuse deposit (Womack 1977:3). Controlled surface collections and test excavations were then conducted at the site on the east side of Interstate 84, yielding over 670 tools and 3,900 flakes of FGV material (Womack 1977:v). Ten 3-x-3-m units were excavated on an ancestral floodplain of Ladd Creek, where relatively deep archaeological deposits were encountered. Stone tool types attributed to the Cascade Phase (8000 to 4500 BP) were found above and below a deposit of Mazama tephra. Based on a lack of tool types post-dating the Cold Springs Phase (6000 to 4000 BP), Womack (1977:145) argued that the quarry site was used as a source of toolstone by 8000 BP and no later than 4000 BP.

According to Peter Hooper, then chair of the Geology Department at Washington State University, the FGV material at the Stockhoff Quarry was "probably an andesite" emplaced during a localized eruption of "andesitic lavas occurring at the same time that the more common Columbia River basalts were extruded" (Womack 1977:15). Womack (1977:15) noted that the fine-grained material used as toolstone occurred as "cobbles from both colluvial and lag deposits [that] are generally tabular and only moderately rounded." Acknowledging that the material was probably not basalt in composition, Womack (1977:16) used the term "basalt" for the sake of continuity with earlier researchers.

Based on technological analysis of artifacts and replication experiments, Womack (1977:27) defined the stages of a biface reduction system for the Stockhoff Quarry site. Womack's sequential stages of biface manufacture consist of 1) removing the cortex from a flake or cobble, 2) thinning the artifact, 3) forming the final outline of the artifact, and 4) finishing the edge and hafting element (if present). Womack (1977:59) also defined five categories of debitage associated with biface manufacture, consisting of decortication flakes, thinning flakes, biface thinning flakes, multiple removal flakes, and non-diagnostic shatter.

Of the 671 tools analyzed by Womack, 77 percent (n=520) were bifaces or biface fragments, and variation among these bifaces was interpreted to represent the sequential stages of biface manufacture (Womack 1977:5, 28). Analysis of the debitage supported Womack's conclusion that the primary function of the quarry site was the production of bifaces for export. Womack (1977:146) also noted that in the vicinity of raw material sources, biface blanks and debitage were indicative of initial reduction and earlier stages of biface manufacture, whereas the terraces located a short distance from toolstone sources were used as workshop areas for further reduction and/or manufacture of formed tools. Many of the artifacts observed by Womack (1977:7) were considered to be "rejects," meaning they were broken during manufacture or had a flaw and were discarded.

Womack observed very little evidence of core preparation and thought this could be explained by the overwhelming abundance of raw material at the Stockhoff Quarry. If a pre-contact flintknapper found a flaw in the stone or made a mistake, little effort would have been spent trying to correct it. Instead, the piece would have been discarded in favor of a new one. Many of the boulders also exhibited flake scars and evidence of battering consistent with the “block on block” technique, whereby large flakes are produced by striking the platform of a cobble or boulder against an anvil. Womack (1977:32) concluded that the main function of the Stockhoff Quarry was the production of bifaces from large, relatively thick flakes taken off of source materials, and that later stages of reduction to complete formed tools would have been done at workshops away from the quarry locations.

Western Cultural Resource Management, Inc. (1980)

In 1980, Western Cultural Resource Management, Inc. (WCRM), conducted surveys, testing, and data recovery excavations for the Pan Alberta Natural Gas Pipeline project, focusing on proposed impacts to the Stockhoff Quarry (35UN52), Ladd Canyon (35UN74), and Marshmeadow (35UN95) sites (McPherson 1980; McPherson, Coe, Day, Hall, and McGlone 1981; McPherson, Hall, McGlone, and Nachtwey 1981; Reed 1980; Reed and Reed 1980). An extensive survey was conducted to determine the areal extent of site 35UN52, and the resulting boundary was defined based on the distribution of surface artifacts as well as topographic extrapolation (Johnson et al. 1980:2; Reed 1980). This larger site boundary encompasses over 3,400 acres and includes nine defined artifact concentrations, the largest of which completely encompasses the area where Womack (1977) conducted his earlier fieldwork. The site was also found to contain an historic component that included two extant buildings, three collapsed structures, two corrals, and a segment of the Oregon Trail (Reed 1980).

As part of the testing regime, WCRM excavated ten backhoe trenches adjacent to the pipeline corridor and in areas of alluvial and colluvial deposition between the pipeline and Interstate 84 (McPherson 1980:Map 3). The areas where trenching occurred were divided into three topographic zones consisting of the hilltop, hillside, and valley bottom zones (McPherson 1980:11). Subsequent data recovery excavations at site 35UN52 consisted of 32 excavation units (measuring 2x2-meters each) located within and near the pipeline corridor (McPherson, Coe, Day, Hall, and McGlone 1981). The results of testing and data recovery fieldwork indicated that the site was repeatedly occupied between 7660 BP (perhaps as early as 10,700 BP) and the historic period, and that the most intense occupation occurred between 6700 BP and 5800 BP (McPherson, Hall, McGlone, and Nachtwey 1981:713-716). These dates of occupation were based on site stratigraphy, radiocarbon dates from charcoal samples, Mazama tephra deposits, and projectile point typology (Cochran and Leonhardy 1981; McPherson, Coe, Day, Hall, and McGlone 1981; McPherson, Hall, McGlone, and Nachtwey 1981).

According to McPherson, Hall, McGlone, and Nachtwey (1981:713-720), pre- and post-Mazama occupation at site 35UN52 was focused on procurement of toolstone and the production of bifaces for export. They interpreted the presence of flake tools as evidence of limited meat processing at the site prior to the eruption of Mount Mazama ca. 6700 BP. Between 6700 and 5800 BP, an abundance of other tool forms (projectile points, bifaces, cores, scrapers, edge-ground cobbles, flake tools, groundstone, and possible net weights) provided evidence for an array of other activities, including hunting, gathering, and processing of plant and animal foods on a seasonal basis. The site appears to have been occupied to a diminished extent between 5750 and 4000 BP, when activities were more narrowly focused on toolstone procurement, lithic reduction, and animal processing, with no direct evidence of plant processing. Between 4000 and 650 BP, the site continued to be occupied for the purpose of toolstone procurement and biface production with a secondary emphasis on animal butchering and hide processing. During the same period, evidence of plant processing increased at nearby Marshmeadow, where camas processing tools became increasingly specialized after 2200 BP. Based on projectile point types, McPherson, Hall, McGlone, and Nachtwey (1981:718) suggest a temporary shift from southern Plateau to Great Basin cultural affiliation or influence during this period. Between about 650 and 100 BP, toolstone continued to be procured from the Stockhoff Quarry, with little evidence of other activities, which appear to have been shifted to other nearby sites.

An analysis of flaked stone tools and debitage led McPherson, Hall, McGlone, and Nachtwey (1981:713-720) to conclude that lithic procurement and reduction activities at site 35UN52 were focused on the production of bifacial blanks for export, and that the technology used to produce these tools was relatively unchanged over time, although the bifaces produced between about 4000 and 650 BP tended to be smaller in size than the ones produced before 4000 BP. The lack of technological change reflected that "the reduction of basalt in a technomorphologically constant manner through time was the most efficient means of reducing the toolstone…though populations on the site were not necessarily homogenous" (McPherson, Coe, Day, Hall, and McGlone 1981:346). McPherson, Coe, Day, Hall, and McGlone (1981:118-147) also revised Womack's (1977) biface reduction scheme, as they regarded Womack's four stages to be too subjective. Instead, they proposed a quantitative classification system whereby four stages of bifacial reduction were defined based on a measureable "sinuosity index" combined with the method of percussion ("hard hammer," "soft hammer," and "pressure flaking"). In general, McPherson, Hall, McGlone, and Nachtwey (1981:716) found that the Stockhoff Quarry site was primarily a quarrying and tool manufacturing locale that was utilized for at least 10,000 years.

Other Studies

Since the early 1980s, site 35UN52 has been revisited by archaeologists for several cultural resource compliance projects (Jaehnig et al. 1996:62; James 2009; Ozbun 1999; Ozbun et al. 2000; Peak and Associates 1989). Most of these projects were narrow, linear corridors for cable, fiber optic, or pipeline alignments that parallel the interstate. None of these projects involved archaeological excavations or analysis of substantial numbers of artifacts.

Survey methods and results

In 2009 and 2010, archaeologists employed by AINW, assisted by members of the CTUIR CRPP, conducted an archaeological survey of over 11,000 acres of Craig Mountain and surrounding landforms for a proposed wind farm development. The surveyed area was not a single, contiguous study area but rather multiple areas of various sizes connected by linear corridors and access roads. The pedestrian survey was performed by three crews of archaeologists using parallel transects spaced 30 m apart. More closely spaced transects ranging from 5 to 15 m apart were used when artifacts or features were encountered and in areas where archaeological resources were considered likely to be present based on topography or proximity to certain natural resources (e.g., permanent water sources, natural outcrops of FGV material, camas meadows). The pedestrian survey was supplemented by shovel testing in areas of alluvial and colluvial deposition.

The Oregon State Historic Preservation Office defines archaeological sites as "ten or more artifacts (including debitage) likely to have been generated by patterned cultural activity within a surface area reasonable to that activity" (SHPO 2007:9). Archaeological features—with or without associated artifacts—are also considered archaeological sites. In Oregon, archaeological isolates comprise nine or fewer artifacts. Not including the Stockhoff Quarry (35UN52), more than 218 pre-contact archaeological resources were identified during the survey for this project, including 28 quarry sites, 81 lithic scatters, and 109 isolated finds (Davis et al. 2010; Smits et al. 2009). Although some of these sites also contained stack rock features, sites composed solely of individual or multiple rock features are not included in this total.

In the field, the survey crews counted the number of artifacts present at isolates and smaller sites and estimated the numbers of artifacts present at larger sites. Field crews also noted the probable function(s) for each resource and documented the range of tools types and lithic materials represented at each resource based on the attributes of artifacts observed. No cultural materials were collected during the fieldwork, and therefore petrographic and chemical analysis was not possible for this paper. The survey-level data are presented here at a necessarily basic level, and despite their limitations have much information to impart.

Included in the pedestrian survey were over 530 acres within the recorded boundary of site 35UN52. The methods used for surveying land within the Stockhoff Quarry site were the same as the methods

Figure 10-3. Overview of a quarry site on Craig Mountain. The view is toward the southeast along the main ridgeline of Craig Mountain.

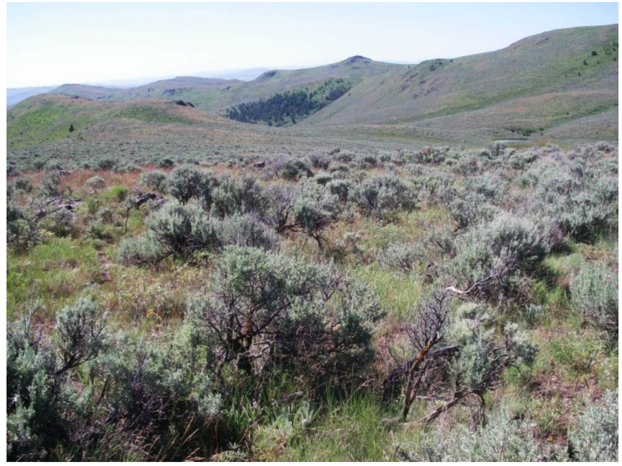

Figure 10-4. Overview of another quarry site on Craig Mountain. The view is toward the south.

used for the rest of the project, with the exception that shovel testing was not done within the site boundary per Oregon SHPO guidelines. The survey results indicate that site 35UN52 contains discrete concentrations of surface artifacts or single items separated by large areas of land where no artifacts are present on the surface, similar to the distribution of archaeological sites and isolates across the rest of Craig Mountain.

Quarry Sites

The 29 archaeological sites classified as quarries (including site 35UN52) exhibited evidence of lithic procurement focused on geological deposits of FGV material that occur mainly as tabular, sub-rounded to sub-angular cobbles and boulders, and in some locations as bedrock outcrops. Toolstone was procured from primary geological deposits consisting of boulders and cobbles eroded from weathering lava flows as well as bedrock outcrops, and from secondary deposits including colluvial and fluvial deposits. No evidence of mining or subsurface extraction was observed, as boulders and cobbles of high-quality FGV material were exposed on the ground surface (Figure 10-5). Culturally modified and unmodified boulders and cobbles of this raw material were abundant within the quarry sites. These sources of toolstone would have been attractive because of their excellent conchoidal fracture characteristics, sharp and durable edges, and large size. Large-sized lithic raw materials facilitate long use-lives of stone tools by allowing production of oversized tools that could be resharpened and reworked many times. Large initial size as a planned design concept has been identified as a component of pre-contact technological strategies at other toolstone sources in Oregon (Ozbun 1991).

Archaeological quarry sites were identified across Craig Mountain and were concentrated along the northwest-trending spine of the mountain's main ridgeline at elevations greater than 985 m above sea level (Figures 10-3 and 10-4). Less extensive evidence of quarrying was also observed at the northwestern foot of Clark Mountain, just above Ramo Flat. The quarry sites recorded during the survey ranged in size from less than 0.5 acre to over 100 acres, with an average size of about 11 acres. Field estimates of the numbers of artifacts at each site ranged from 22 to over 7,000 artifacts per site, the vast majority of which consisted of FGV debitage. The artifacts were generally sparsely distributed across the ground surface. High-density artifact concentrations were observed near the source material at some but not all of the quarry sites.

Within the recorded boundary of site 35UN52, the distribution of cultural materials observed on the ground surface was similar to the distribution of sites and isolates observed throughout the rest of the 11,000-acre survey area. That is to say that the recorded boundary of the 3,400-acre Stockhoff Quarry includes large areas between artifact concentrations and isolated artifacts where no cultural materials are present on the ground surface. The 530 acres of the Stockhoff Quarry surveyed by

Figure 10-5. Negative flake scars on boulder of raw material at a quarry site on Craig Mountain.

Figure 10-7. Negative flake scars on large cobble of raw material at a quarry site on Craig Mountain.

AINW, mainly on ridges and slopes where sediments are shallow, stand in contrast to the more well-known portion of the site where dense, stratified archaeological deposits have been the focus of previous research (Cochran and Leonhardy 1981; Womack 1977; McPherson, Hall, McGlone, and Nachtwey 1981). These observations also reflect the way in which the 3,400-acre site boundary was originally recorded using topographic extrapolation (Johnson et al. 1980:2; Reed 1980). Based on the distribution of quarry "sites" identified across Craig Mountain and nearby landforms, it is suggested that the Stockhoff Quarry be considered part of a larger quarry complex.

The quarry "sites" represent locations where FGV materials were procured, assayed for quality,

and systematically reduced to create cores and blanks suitable for export (Figure 10-6). Many of the cobbles are tabular in form and were reduced directly into large bifaces by beveling the angular or square margins. Immovable boulders of raw material frequently displayed large negative flake scars and signs of battering (Figure 10-7). Often, the edges of the boulders did not appear to support the correct angles for removal of flakes with a hammerstone. Step fractures were common in the debitage and on the negative flake scars visible on raw material. These observations are best explained by use of the "block on block" technique described by Womack (1977), whereby large boulders served as either cores or as anvils to strike cores against, or both (Figure 10-8). The large flakes removed from boulders were used to produce large bifaces, which then served as bifacial cores or blanks. Very few finished tool types were observed at the quarry sites—these consisted of a total of two scrapers, one pressure-flaked biface midsection, and some possible flake tools (edge-modified or edge-damaged flakes).

Tools classified as bifaces and bifacial blanks had flakes removed from two opposing sides, typically around the margin of the piece, by percussion flaking (as opposed to pressure-flaking). Incomplete reduction of "rejected" bifaces or blanks appeared to have been the result of breakage or other manufacturing errors; however, many bifaces recorded during the fieldwork appeared complete. Bifaces observed within the quarry sites tended to be large (between 10 and 20 cm in length)

Figure 10-8. Negative flake scars on boulder of raw material showing evidence of "block on block" technique.

with long flake scars extending towards the center of the artifact (Figures 10-9 and 10-10). The large bifaces appear to be similar to the bifacial blanks described by Womack (1977) and might have been more easily transported than multidirectional cores or other core forms. Primary geologic cortex was present on many of the bifaces and cores at both quarry sites and lithic scatter sites.

Unidirectional, multidirectional, and bifacial core reduction strategies were all represented in the assemblage of cores, from which flake blanks and flake tools were made using direct freehand percussion on cobbles and boulders. Cores were common at quarry sites and tended to range in size from 10 to 30 cm in diameter. In the field, tools that displayed more than one negative flake scar were classified as cores, while materials exhibiting a

Figure 10-9. Biface at a quarry site on Craig Mountain.

Figure 10-10. Biface at a quarry site on Craig Mountain.

single flake scar were classified as tested raw material. (One of the "quarry" sites included here was composed of tested raw material and relatively few flakes and may represent a "prospect" locale rather than a quarry [see Wilke and Schroth 1989].) Very few cores were found that were exhausted or were small in size.

Debitage present on the ground surface at the quarry sites included waste flakes from the testing and initial reduction of raw material. The majority of debitage at the quarry sites represented early-stage core and biface percussion reduction. The flakes tended to be large in size with large cortical platforms and few dorsal flake scars. Only one obvious hammerstone (an imported quartzite cobble) was recorded at a quarry site, suggesting that perhaps local FGV materials were used as expedient hammerstones.

Lithic Scatters

The 81 lithic scatter sites were accumulations of flakes and flaked stone tools that, unlike quarry sites, were not located in areas where lithic raw material was directly procured. Instead, the focus of these "workshops" was on the reduction of FGV material and the early stages of production of bifacial blanks and cores for export, and to a lesser extent the later stages of tool production and maintenance. Some of the lithic scatters were found in association with stacked rock features, generally located on ridgetops and along ridgelines. Some of the lithic scatters were found in association with historic-period artifacts. Small numbers of obsidian and cryptocrystalline silicate (CCS) artifacts were observed at a handful of sites. When present, artifacts of imported obsidian and CCS tended to represent late-stage tool production and maintenance.

Although the survey-level data are not sufficient for tallying early and late-stage flakes of specific reduction technologies, generalizations can be made regarding the presence of core reduction flakes, bifacial thinning flakes, and pressure flakes. The early stages of tool production were well represented by core reduction flakes and early stage percussion bifacial thinning flakes. Primary geologic cortex was present on debitage at most of the lithic scatter sites, reflecting close proximity to the sources of raw material. Debitage representing late stages of stone tool production was less common than other flake types at lithic scatter sites and included late stage biface percussion flakes and pressure flakes.

Finished tools observed at the lithic scatter sites included projectile points, worked flakes, and an occasional scraper. Of the 27 projectile points identified at lithic scatters, 25 were of FGV material and 2 were obsidian. The projectile points were typically isolated finds and included a single lanceolate or "Cascade" point, 11 corner-notched points, 2 side-notched points, and 13 points which were either midsections or tips where no type could be identified. Metric data from the projectile points were collected in the field and used to attempt to distinguish darts from arrows. Numerous researchers have addressed this question, and three formulas were attempted using the projectile point data from this study (Bradbury 1997; Hildebrandt and King 2012; Shott 1997). These formulas variously use shoulder width, maximum width, neck width, and maximum thickness attributes, not all of which could be measured on each artifact depending on how it had broken. Seventeen of the points had a consistent measurement (shoulder width) that could be used to compare them. According to Shott's (1997) formula, 10 were dart-sized points and 7 were arrow-sized points. Hildebrandt and King's (2012) Dart-Arrow Index could be applied to seven of the projectile points, and in each of these instances the results were the same as those obtained using Shott's (1997) formula.

Numerous artifacts were recorded in the field as flake tools or worked flakes. Flake tools are defined as exhibiting some type of wear indicative of use, while worked flakes are defined as having been altered to create or resharpen an edge for use as an expedient tool but showing no evidence of wear. Wear or polish as evidence of use is difficult to determine on FGV artifacts, particularly in the field, and no artifacts were collected during the survey.

Available geochemical data

Geochemical and petrographic analyses are required to accurately classify and source FGV materials from archaeological contexts. The results of these types of studies conducted elsewhere illustrate the compositional variability among toolstone sources that were once described as "basalt" (Bakewell 1996, 2005; Bakewell and Irving 1994). Igneous rocks are classified by their major element compositions according to total alkalis (Na_2O+K_2O) versus silica (SiO_2) by weight percent (Le Maitre 1989; Le Bas and Streckeisen 1991:830). Variability in trace element composition may then be used to distinguish samples from different geochemical sources. Geochemical analyses are often supplemented with petrographic techniques to identify minerals in thin section. Geochemical variability among FGV materials may not be detectable to the naked eye, however, and thus accurate classification cannot be done using visual attributes alone. It should be reiterated that cultural materials were not collected during the survey fieldwork reported here, which precluded geochemical and petrographic analyses of artifacts and source samples for this study.

Despite its potential, geochemical sourcing of FGV artifacts is not without limitations for the purposes of archaeological inquiry. Chemical compositions of lava flows, particularly the less viscous flows of the CRBG, may be relatively homogeneous over widespread areas. Although lava flows with calc-alkaline affinities tend to be less chemically homogenous than tholeiitic flood basalts, materials from both types of flows may be distributed over fairly extensive areas. Lava flows of the PRVF, which are chemically heterogeneous and geographically restricted, may provide a good opportunity for geochemical sourcing of FGV on a scale suitable for the archaeological study of local and regional patterns of toolstone acquisition, use, and trade.

Recent geologic mapping, based partially on geochemical data, indicates that Craig Mountain proper is composed primarily of dacitic materials of the PRVF (Bailey 1990; Oregon Department of Geology and Mineral Industries [DOGAMI] 2009; Ferns et al. 2010). Andesite and basaltic andesite from PRVF and CRBG flows are also present in the vicinity. Table 10-1 shows the number of acres surveyed by AINW and the archaeological resources identified according to the geologic map units defined by Ferns et al. (2010). Most of the archaeological survey was on Craig Mountain itself, and of the 11,219 total acres surveyed, 69 percent (7,746 acres) is mapped as Mount Emily dacite. Of the 28 newly identified quarry sites, 27 are located in areas mapped as dacite or undifferentiated andesite and dacite, and 1 quarry site is located in an area mapped as a landslide deposit. The majority of lithic workshops, represented by lithic scatters and perhaps isolates, are also located in areas mapped as dacite, but unlike quarry sites they occur in other areas as well. Although the resolution of the geologic mapping data is not appropriate for site-specific analysis, the data do show that quarry sites tend to be focused in areas where dacitic materials are known to occur. Most of the 3,400-acre Stockhoff Quarry site (not included in Table 10-1) is also mapped as dacite of the PRVF, although some areas within the site boundary are mapped as Wanapum and Grande Ronde basalts of the CRBG as well as a variety of quaternary surficial deposits (Ferns et al. 2010).

In their geologic study of the upper Grande Ronde basin, Ferns et al. (2010:63) report the results of X-ray fluorescence (XRF) analysis of over 1,100 source samples. Their database incorporates geochemical data presented by previous researchers (e.g., Bailey 1990), revising and expanding our understanding of the extent of the PRVF (Ferns et al. 2010). Based on their reported geographic coordinates, 52 outcrop samples used by Ferns et al. (2010) were from our general study area, including two whole-rock samples from within the boundary of site 35UN52. No other XRF samples coincide with the locations of the 29 quarry sites; however, several of the reported samples were taken from locations very near the Stockhoff Quarry and other quarry sites on Craig Mountain. All of these XRF samples were classified as dacite of the PRVF, and the samples taken from the Stockhoff Quarry vicinity were assigned to the Glass Hill Volcanic Group formation of the PRVF (Ferns et al. 2010:Appendix). Trace element data are also presented by Ferns et al. (2010); however, it is not known if any of the whole-rock XRF samples collected by geologists would have been suitable for use as toolstone.

For his doctoral dissertation, Bakewell (2005) conducted geochemical and petrographic analyses of artifacts and source samples from vitrophyric toolstone sources across the Pacific Northwest, including four samples from the Stockhoff Quarry and Craig Mountain. Bakewell (2005:53-54) hypothesizes that cultural groups exerted proprietary control over particular sources of toolstone, to the extent that the distribution of artifacts and geochemically distinct sources of toolstone could be assumed to correspond with geopolitical boundaries. In other words, Bakewell's (2005:59) hypothesis was that a given "cultural area" would contain only one type of vitrophyric toolstone, which would originate from a source within that cultural area. Geographic areas occupied by more than one cultural group would be expected to have more than one source of vitrophyric toolstone, and in geographic areas containing multiple toolstone sources but few cultural groups, only a few of the available toolstone sources would have been utilized.

Using petrographic observations and statistical discrimination on geochemical data from 112 samples, Bakewell was able to differentiate among what he calls "Coast Salish toolstone," "Shuswap toolstone," and "Southern Plateau toolstone." Of the 60 cases of Southern Plateau toolstone, 2 were cobbles from the Stockhoff Quarry and 2 were boulders from Craig Mountain (Bakewell 2005:61,115). Using petrography alone, it was impossible to distinguish Stockhoff Quarry/Craig Mountain toolstone from other sources in the "Cayuse area," although these sources could be differentiated from those in other areas of the southern Plateau (Bakewell 2005:74). Geochemically, Bakewell (2005:113) was able to differentiate sources of "Cayuse toolstone" from "Nez Perce toolstone" and "Paiute toolstone." "Cayuse toolstone" (n=31 cases) consisted of dacitic and andesitic materials, also characterized by Bakewell (2005:118) as "Stockhoff-type andesites and dacites." In addition to the previously mentioned samples from Craig Mountain (n=4), identified as siliceous andesite, the Stockhoff-type andesites and dacites included source samples from Mesa Hill (n=1), Alder Springs (n=1) and Anderson Springs (n=1), and artifacts recovered from Beaver Meadows (n=1), Boulder Gorge (n=1), Crane Flats (n=4), Larkspur Springs (n=1), Malheur (n=3), Sanger Mine (n=3), Westwall (n=8), Beech Creek (n=2) and a site in the North Cascades (n=1).

Bakewell (2005) succeeds in discriminating geochemical sources of toolstone from geographically and culturally disparate regions of the Pacific Northwest. His intention was not to distinguish among toolstone sources on a more local scale. Bakewell (2005:53,118-119) acknowledges the presence of a variety of chemically distinct sources of vitrophyric toolstone in the Powder River basin and in the Blue Mountains. He also notes that Powder River dacites are compositionally similar to Powder River andesites and to "Stockhoff materials at Craig Mountain" (Bakewell 2005:118-119). According to Bakewell (2005:119), "Cayuse toolstone" was represented by too few samples to characterize their sources individually, and no assumptions were made regarding temporal span for this perceived pattern.

Comparing his data with geochemical data reported by Bailey (1990) for the PRVF, Bakewell (2005:157) states that only 1 of the 142 locations reported by Bailey matches the geochemical signature of "Cayuse toolstone." Bakewell (2005:157) concludes that although the PRVF provides a wide range of vitrophyric toolstone sources, "archaeological toolstones used in the region are distinctively different from the Powder River Volcanics." In other words, based on geochemical information available at the time, Bakewell did not consider the PRVF to be a major source of toolstone for pre-contact groups. In support of his "one group-one vitrophyre" hypothesis, Bakewell (2005:118) interprets these results to mean that relatively few sources of geochemically distinct toolstone were used in the Powder River basin. Bakewell's interpretation of "Cayuse toolstone" also contradicts ethnographic information indicating that, at least by the historic period, the Cayuse and their allies often lived and traveled together, and they sometimes used the same resource locations at the same time (Stern 1998:396-397; Suphan 1974:101,147).

Since Bakewell's study, more recent geochemical and archaeological data have become available. Geochemical data and geologic mapping of the Grande Ronde basin has expanded our understanding of the extent and composition of the PRVF (Ferns et al. 2010), which includes the dacitic and andesitic materials at Craig Mountain. In addition, the results of AINW's archaeological survey show that quarrying activity on Craig Mountain was not restricted to one portion of the Stockhoff Quarry or even to the 3,400 acres within site 35UN52. Instead, evidence of pre-contact toolstone procurement extends across most of Craig Mountain and onto nearby landforms like Ramo Flat and Clark Mountain, also within the PRVF. These newly identified archaeological resources represent a significant increase in the sample size of toolstone quarry sites associated with the PRVF, and they suggest that many more quarry sites are likely to be present in other areas of the PRVF that have not yet been visited or surveyed by archaeologists. While not definitive, visual attributes of FGV materials at the quarry locations reported here suggest that there may be some geochemical variability in these local toolstone sources.

Unpublished trace element data from source samples collected by William Lyons indicate that some of these FGV toolstone sources may be distinguishable from each other (William H. Lyons, personal communication 2012; Craig E. Skinner, personal communication 2012). Lyons' source samples were collected along a linear route on the steep, south-facing roadcut above Interstate 84, where the highway enters Ladd Canyon at site 35UN52. Lyons also collected samples from locations between the eastbound and westbound lanes of the interstate. According to Lyons, whole-rock major element compositions were not determined for his samples, which consisted of dark-colored FGV with macroscopic phenocrysts. Craig Skinner of Northwest Research Obsidian Studies Laboratory conducted XRF analysis on 25 of Lyons' source samples. According to Skinner, trace element data indicate that the samples represent three geochemical sources; most of the samples are from a single source (n=22), while fewer samples are attributed to the second (n=2) and third (n=1) sources. Skinner also notes that the visual variability among samples from the main source is greater than the variability between the

Table 10-1. Acres Surveyed and Archaeological Resources by Geologic Map Unit (after Ferns et al. 2010)

	Geologic Map Unit			Acreage		Archaeological Resources				
	Unit	Description	Formation or Member	Acres Surveyed	%	Isolate	Quarry	Lithic Scatter	Total	%
Quaternary Surficial Deposits	Qa	Alluvium		229	2	5	0	5	10	4.6
	Qcf	Colluvium and Talus Deposits		354	3	2	0	4	6	2.8
	Qls	Landslide Deposits		427	4	3	1	5	9	4.1
	Qu	Undifferentiated Surficial Deposits		58	1	1	0	1	2	.9
	Other	Lacustrine, Alluvial and Fluvial Deposits		140	1	0	0	0	0	0
Columbia River Basalt Group	Tbf	Basalt	Wanapum Basalt	39	0	3	0	0	3	1.4
	Tcg	Basalt and Ferro-Andesite	Grande Ronde Basalt	57	1	2	0	1	3	1.4
	Tms	Sedimentary Rock Interbeds	Between Wanapum and Saddle Mountain Basalt	93	1	0	0	0	0	0
Powder River Volcanic Field	Tob	Olivine Basalt Sheet Flows	Little Catherine Creek	399	4	3	0	0	3	1.4
	Tpa	Andesite and Basaltic Andesite	Sawtooth Crater	628	6	0	0	1	1	.5
	Tpb	Basalt of Little Catherine Creek	Little Catherine Creek	838	7	3	0	1	4	1.8
	Td	Dacite Flows and Domes	Dacite of Mount Emily	285	3	11	3	4	18	8.3
	Tpd	Dacite	Dacite of Mount Emily	5605	50	47	18	47	112	51.4
	Tpgd	Undifferentiated Andesite and Dacite	Dacite of Mount Emily	1856	17	29	6	12	47	21.6
Wallowa Terrane	TRPwc	Clover Creek Greenstone	Clover Creek Greenstone	210	2	0	0	0	0	0
TOTAL				**11,219**	**100**	**109**	**28**	**81**	**218**	**100**

three sources, again demonstrating that visual attributes may not correspond to geochemical variability. These data, although limited, are intriguing. If distinct geochemical signatures are detectable in source samples from a relatively small portion of site 35UN52, then it may be possible to distinguish geochemical sources of toolstone from other parts of Craig Mountain and the PRVF.

Conclusions

The results of a recent large-scale archaeological survey indicate that the Stockhoff Quarry (site 35UN52) represents part of a much larger quarry complex consisting of numerous toolstone procurement locations and lithic reduction workshops across Craig Mountain and surrounding landforms. Pre-contact toolstone procurement on Craig Mountain appears to have been focused on sources of dark, glassy FGV material associated with dacitic and perhaps andesitic flows of the PRVF. Recent geochemical data suggest that "Stockhoff basalt" may in fact represent multiple geochemical sources of toolstone that can be attributed to the chemical heterogeneity of PRVF lava flows. Limited trace element data from samples collected by previous researchers demonstrate that at least some of these toolstone sources are distinguishable from each other.

Geochemical analyses of FGV artifacts and source materials from quarry sites on Craig Mountain are required to determine if these preliminary conclusions are supported. If so, the results would have implications for the archaeological study of diachronic trends in toolstone procurement and reduction strategies, mobility patterns, exchange networks, and interaction spheres in this part of the southern Plateau. Lithic technological analysis and flintknapping experimentation would also provide information regarding variability in reduction methods and sequences and assist in elucidating these research themes. Stone tools and debitage of visually similar FGV materials have been observed at nearby archaeological sites (e.g., Ladd Canyon, Ladd Marsh, Marshmeadow, Pagliarulo Rockshelter, Pilcher Creek) as well as sites that are farther afield (Andrefsky 1995; Brauner 1985; McPherson, Hall, McGlone, and Nachtwey 1981; Mead 1975; Ogle et al. 2006; Ozbun 1999; Ozbun et al. 2000; Reid 1997; Reed and Reed 1980). It is hoped that as more geochemical and archaeological data become available, they will contribute specific information about the relationships among these sites in the Blue Mountains and perhaps elsewhere on the southern Plateau.

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CHAPTER 11

Ancient Trade Routes for Obsidian Cliffs and Newberry Volcano Toolstone in the Pacific Northwest

Thomas J. Connolly
University of Oregon Museum of Natural and Cultural History (connolly@uoregon.edu)

Craig E. Skinner
Northwest Research Obsidian Studies Laboratory (cskinner@obsidianlab.com)

Paul W. Baxter
University of Oregon Museum of Natural and Cultural History (pbaxter@uoregon.edu)

Obsidian has been recognized throughout the world as an important trade commodity in societies dependent on lithic tools, in regions as diverse as the Mediterranean, Micronesia, Asia, and the Americas (Ammerman 1985; Ayres et al. 1997; Baugh and Nelson 1987; Braswell 2003; Carlson 1994; Glascock 2003; Glascock et al. 2006; Grier 2003; Kuzmin and Glascock 2007; Kuzmin et al. 2008; Santley 1984). In the Pacific Northwest of North America, obsidian and other goods were distributed via a far-reaching trade network, involving the Columbia and Fraser river systems and the intervening coastal zone from southern British Columbia to Oregon (Anastasio 1972; Carlson 1994; Hayden and Schulting 1997; Ray 1939; Stern 1998). Hayden and Schulting (1997) note commonalities in exotic materials, crafted prestige items, marine shell ornaments, and sculpted bone and stone artifacts throughout a "Plateau Interaction Sphere," distributed between important economic centers, including principal exchange nodes at The Dalles on the lower Columbia River and at the Thompson-Fraser river confluence in southern British Columbia. Taking a coastal perspective, Ames and Maschner (1999:170) similarly note a southern Northwest Coast "obsidian exchange network" that includes lands bordering the Salish Sea (Gulf of Georgia-Strait of Juan de Fuca-Puget Sound), and extending south to the lower Columbia River region. In addition to economic connections, they note a number of distinctive cultural traits shared throughout this region, including cranial re-shaping, anthropomorphic stone bowls, common artistic motifs in carved pumice, antler, and clay, whale bone and zoomorphic clubs, and other artifacts (also see Connolly 1992; Duff 1956; Wingert 1952).

Charting the geography of exchange networks has been facilitated by the use of x-ray fluorescence and other techniques which provide inexpensive and non-destructive means of identifying diagnostic trace element profiles of both subject artifacts and their geologic sources. As a result, geochemical "fingerprinting" of artifact obsidian has become standard practice in archaeological studies, and, especially in regions where obsidian is abundant, extensive source data have been compiled.

Carlson (1994) has noted that a significant proportion of artifact obsidian from sites in southern British Columbia has been traced to Oregon sources (Figure 11-1). Artifact obsidian at these sites derive predominantly from source localities near the headwaters of Oregon's Deschutes and John Day Rivers, including Obsidian Cliffs, Newberry Volcano, Glass Buttes, and a "John Day" source that is likely the widely distributed geochemical type most commonly

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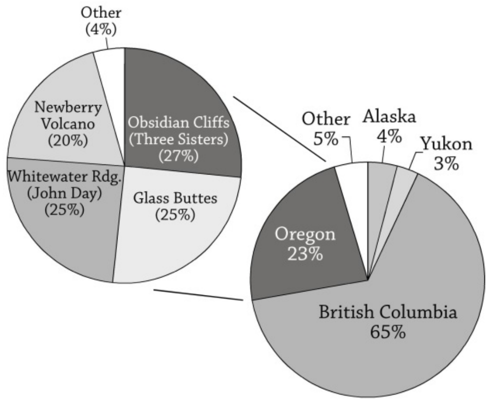

Figure 11-1. Proportion of British Columbia obsidian artifacts by source area (after Carlson 1994).

identified in Oregon as Whitewater Ridge (Skinner 2008). Hughes and Connolly (1999) have previously shown that obsidian systematically quarried from one of these sources—the Newberry Volcano obsidian flows in central Oregon—was used most extensively in the Deschutes River basin to the north, and commonly distributed in trade farther north along the spine of the Cascade Range and then throughout the region bordering the Salish Sea. The present research, similar in scope and design to the earlier Newberry Volcano study, is aimed at mapping the geographic distribution of obsidian quarried from the culturally important Obsidian Cliffs source. We find that, apart from a slightly more westerly bias, material from the Obsidian Cliffs exhibits similar geographic, and possibly temporal, distributions as the Newberry obsidian, suggesting that both were parts of the same economic network, primarily employed by consumers to the north.

The Newberry Volcano Obsidian Quarries: A Review

Newberry Caldera is at the center of the massive Newberry shield volcano. Located about 40 miles east of the Cascade Range crest, it marks the hydrologic divide between the Columbia River Plateau to the north and the Great Basin to the south. The caldera saw regular residential use in the early Holocene, most notably at the Paulina Lake site (Connolly 1999). About 7600 years ago the caldera was buried by nearly a meter of airfall tephra from the eruption of Mt. Mazama, a major Cascade Range Volcano; this event was soon followed by extensive eruptive activity within the Newberry Caldera itself. These events dramatically changed the landscape in the caldera neighborhood, creating a biotic desert that would have significantly diminished its biotic values for hunter-gatherer communities. On the other hand, among these eruptive events were numerous obsidian flows, including the geochemically indistinguishable Interlake, Central Pumice Cone, Game Hut, and East Lake flows. These were extruded between ca. 7000 and 3000 years ago, and together make up the Newberry Volcano geochemical type (Connolly and Hughes 1999; Hughes 1988; Laidley and McKay 1971; Skinner 1983).

Other chemically distinguishable obsidian flows are present in the caldera, including the Buried Flow (exposed prior to ca. 7600 years ago but rendered largely inaccessible by subsequent volcanic activity), and the Big Obsidian Flow, which erupted about 1300 years ago (Friedman 1977; Linneman 1990; MacLeod et al. 1995; MacLeod and Sherrod 1988). Obsidian from neither of these sources commonly occurs beyond the immediate vicinity of Newberry Volcano (Hughes and Connolly 1999), which suggests that these obsidians, most accessible in early Holocene times and during the most recent millennium, respectively, experienced fundamentally different economic circumstances than the Newberry Volcano geochemical type. Many sites have been identified within the caldera, and most—particularly those of middle and late Holocene age—are quarry stations or satellite lithic workshops dominated by early and middle stages of lithic reduction and the production of large bifacial blanks (Ozbun 1991).

Although the caldera apparently saw some residential use in the early Holocene, there is no evidence for sustained occupations during middle and late Holocene times, when activities in the caldera appear to have been focused almost exclusively on toolstone procurement and the production of quarry blanks for transport away from the quarry source (Connolly 1999). The extent of lithic reduction activities in the caldera is indicated by massive quantities of lithic reduction debris, especially notable in light of a general absence of domestic features and a paucity of evidence for hunting, harvesting, food processing, and other subsistence activities. The tool assemblage is dominated by large quarry blanks and preforms, with only modest occurrences of other tool classes (Figure 11-2). This contrast suggests that obsidian toolstone procurement in the caldera during middle Holocene and later times was not simply an activity embedded into a complex of hunter-gatherer routines, but a targeted activity on a scale that suggests a commercial enterprise.

Questions relating to the trajectory of Newberry Volcano obsidian beyond the caldera were addressed by Hughes and Connolly (1999), with the development of a contour map illustrating the distribution of Newberry Volcano obsidian (Figure 11-3). Contour values were generated by using the proportion of Newberry Volcano obsidian to all sourced specimens from each site where it was present. Ten-percent contour intervals were used, with the lower limit set at 20%, since the decreasing frequency of data points at the outer limits of the map made the contouring increasingly unreliable. Beyond the 20% contour interval, occurrences are simply represented by dots.

The results show a strongly directional distribution of Newberry obsidian to the north, traveling primarily through the Deschutes River basin. Some Newberry obsidian continued north, possibly along the spine of the Cascades, and into the Salish Sea (Puget Sound-Gulf of Georgia) region. This movement was no doubt facilitated by proximity of the Newberry source to the regional trading center at The Dalles, which provided a distribution point throughout the larger Columbia Plateau or southern Northwest Coast interaction spheres. By contrast, there is little suggestion that Newberry obsidian was conveyed in any quantity to the south.

The Obsidian Cliffs Quarry

More recently, we had the opportunity to examine a complex of sites at the northeast shore of Suttle Lake, located on the east flank of the Cascade Range about 55 miles northwest of Newberry Caldera. Like the Newberry sites, those at Suttle Lake exhibited the features of quarry-related lithic reduction workshops, with dense lithic reduction debris and a tool assemblage dominated by mid-stage bifaces (Figure 11-4). However, the obsidian reduction debris was derived exclusively from Obsidian Cliffs, an important source located on the

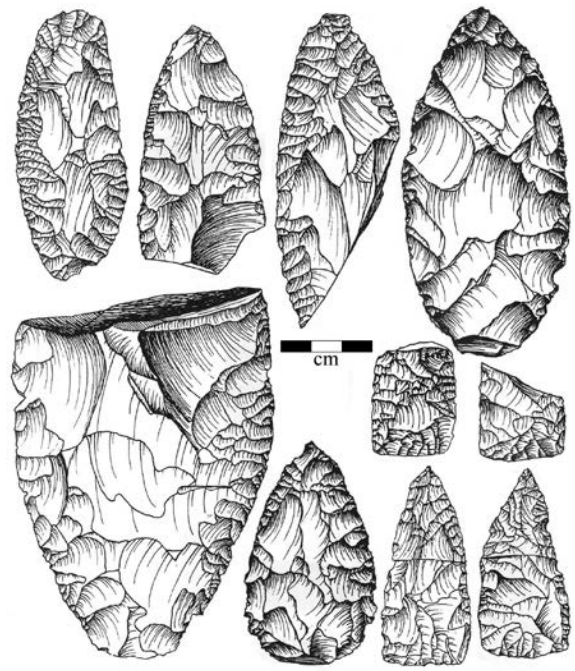

Figure 11-2. Newberry quarry bifaces from sites 35DS219 and 35DS34 (from Connolly 1999).

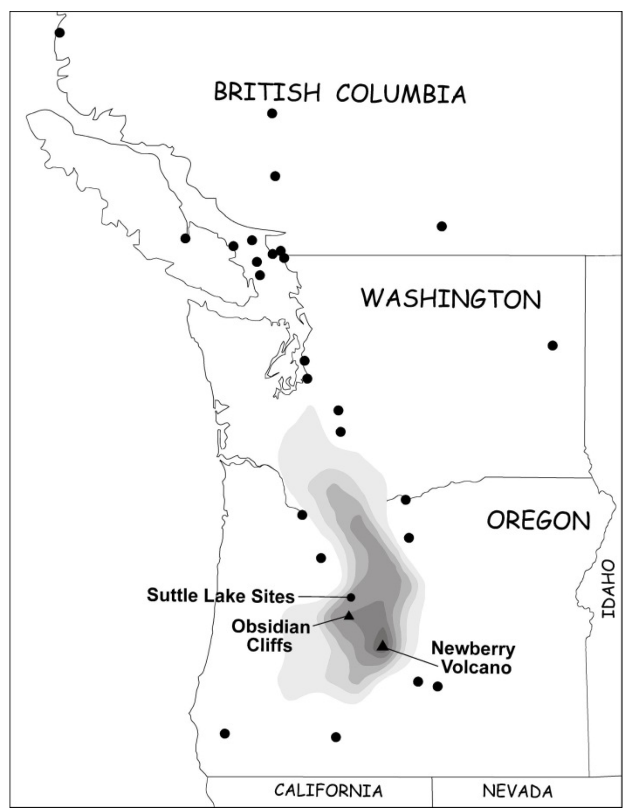

Figure 11-3. Distribution of Newberry Volcano obsidian beyond the Newberry Caldera, and the relative positions of the Obsidian Cliffs quarry and the Suttle Lake/Lake Creek site complex.

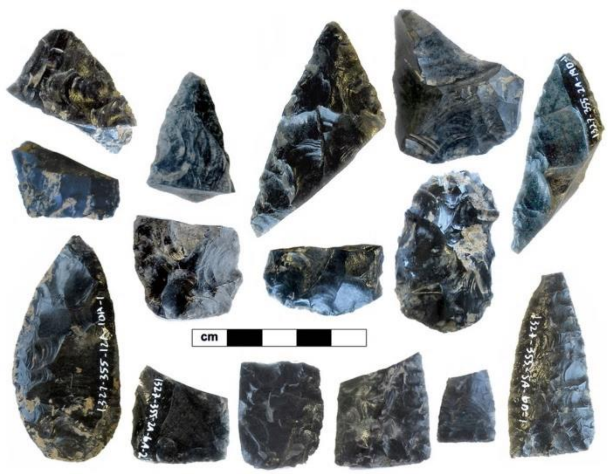

Figure 11-4. Bifaces of Obsidian Cliffs obsidian from the Suttle Lake/Lake Creek site.

west flank of the North Sister mountain peak in the High Cascades about 15 miles south of Suttle Lake.

Obsidian Cliffs obsidian has been found at many archaeological sites, particularly in western and central Oregon, and it is clear that this was a major toolstone source throughout the post-glacial period (Skinner 1995; Skinner and Winkler 1991, 1994; Musil and O'Neill 1997). It has been noted at the Paulina Lake site (within Newberry Caldera) in components dating between 11,000 and 7000 years ago (Connolly 1999), and at the 10,000 year old 45KT1362 site in central Washington (Galm and Gough 2000), and at Cascadia Cave in the South Santiam River drainage, where 96% of characterized obsidian from the nearly 9000 year-long occupation sequence is from Obsidian Cliffs (Baxter 1986, 2007). Numerous archaeological sites of the High Cascades near Obsidian Cliffs appear to be lithic reduction stations related to quarrying activity (Fagan et al. 1992; Jenkins 1988; Jenkins and Churchill 1988; Minor and Toepel 1984; Winthrop and Gray 1985).

Based on reported occurrences of Obsidian Cliffs material in the Oregon Cascades, it appears that Obsidian Cliffs material, like the Newberry Volcano obsidian, was primarily carried northward. Skinner and Winkler (1994) report that Obsidian Cliffs material represents about 85% of obsidian at sites on Willamette National Forest lands in the McKenzie River subbasin west of the Cascade crest, and 72% of obsidian in the Clackamas and Santiam sub-basins to the north (cf. Kelly 2001, 2003). This proportion decreases dramatically to the south; although Obsidian Cliffs is located near the head of the Middle Fork Willamette subbasin, toolstone from this source is just 34% of identified obsidian in the Middle Fork basin. In the Umpqua Basin to the immediate south, just 8% of identified obsidian is from Obsidian Cliffs (Skinner and Winkler 1994).

To more systematically evaluate the distribution dynamics of this widely used obsidian, we produced a comprehensive map. For this effort, we relied primarily on the obsidian sourcing data bank of co-author Craig Skinner's Northwest Research Obsidian Studies Lab, as well as a small amount of published data from other sources. We identified a total of 550 distinct sites in Oregon, Washington, and British Columbia from which at least one artifact of Obsidian Cliffs material was identified.

As with the Newberry data, a distribution and density contour map was then generated, in a two step process, using the percentage of Obsidian Cliffs material identified in each assemblage where it was present. We elected to limit our mapping universe to sites from which 20 or more obsidian specimens had been sourced. As a result, our final sample used for contouring was reduced from 550 to 188 sites. We used Surfer mapping software to produce a contour map with 5% contour intervals, using site latitude and longitude for X and Y coordinates. The lowest contour value was set at 20%, as the decreasing frequency of data points at the outer limits of the map made the contouring increasingly unreliable. Occurrences beyond the 20% contour were simply represented by dots to indicate presence (Figure 11-5).

As expected, the Obsidian Cliffs obsidian shows a strong northerly bias, nearly matching that previously mapped for the Newberry Volcano source, and reinforcing attention to the Cascade uplands as a possible transport corridor. Apart from a small amount of Obsidian Cliffs material that travels down along the crest of the Cascade Range and into the upper North Umpqua River drainage, there is little movement south. By contrast, most Obsidian Cliffs material travels north along the spine of the Cascades, and is commonly found in the Willamette Valley to the west and northwest. In the southern and Central Willamette Valley, Obsidian Cliffs glass could also have been procured from local secondary deposits of McKenzie and Willamette river gravels. It apparently follows main river systems draining the western Cascades,

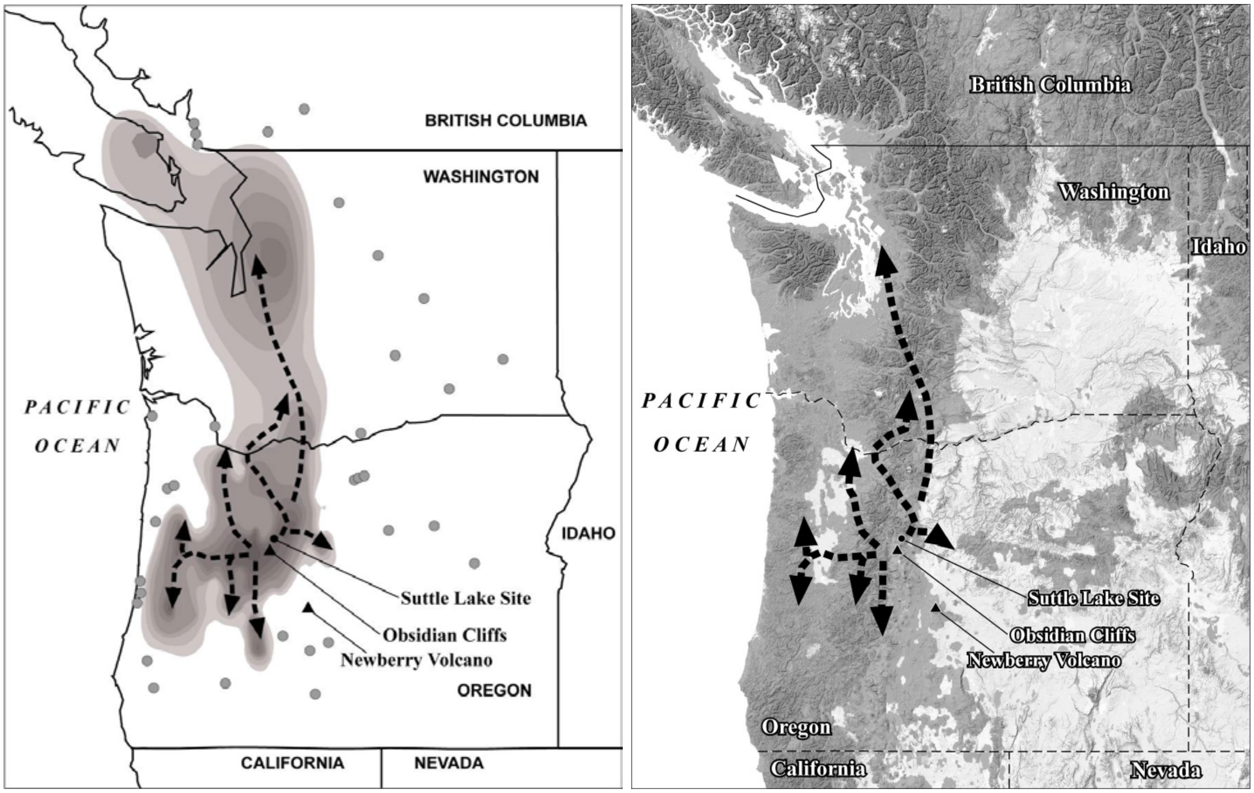

Figure 11-5. Left: Contour distribution map of Obsidian Cliffs (OC) obsidian, based on percentage of OC to all sourced specimens in 188 sites. Dots represent additional occurrences where OC obsidian accounts for less than 20% of the total sample. Right: Inferred Obsidian Cliffs distribution routes overlying a landform map (base map modified from Google maps).

probably a reflection of critical travel routes. Principal corridors include the McKenzie, Santiam, and Clackamas river systems. The appearance of Obsidian Cliffs obsidian in the northwest Umpqua Basin appears to reflect a link to the Yoncalla via their Kalapuya linguistic relatives in the Willamette Valley, rather than movement of material down the Umpqua River. Movement of material north of the Columbia River appears to follow the Cascade Range to the Puget Sound area and regions even farther north, possibly passing through trading centers at The Dalles or in the Portland Basin.

Chronology and Social Context of the Newberry and Obsidian Cliffs Quarries

Although Newberry Volcano obsidian dominates in the Deschutes Basin sites, Obsidian Cliffs material is also common, and, at a number of residential sites in the basin, is the predominant material type (Jenkins and Connolly 1994, 1996). In the western Cascades where Obsidian Cliffs obsidian is most common, Newberry Volcano obsidian regularly co-occurs with it (Skinner and Winkler 1994). This regular co-occurrence suggests that even though these two sources served slightly different geographies, both functioned as companion elements within a larger, common economic community.

Because the obsidian flows of the Newberry Volcano geochemical type are post-Mazama in age, toolstone procurement from these quarries was necessarily an activity in the post-Mazama period (middle and late Holocene). More specifically, most intensive quarrying activity appears to have occurred after ca. 4000 years ago, and prior to ca. 1000 years ago (Connolly 1999:237; Davis and Scott 1991:53) During this time there appears to have been a specialized production of bifacial implements for export from the quarries. Numerous biface caches sourced to both Newberry Volcano and Obsidian Cliffs have been identified in central Oregon and in the Cascade Range (Bennett-Rogers 1993; Marschall 2004; Scott et al. 1986; Swift

1990; Winthrop and Gray 1985). The biface caches, which feature both high numbers of bifaces and uniform production qualities, support the interpretation of obsidian as a commoditized product that was a factor in intergroup commerce, and not simply procured for local needs (Figure 11-6).

In his review of trade and exchange in British Columbia, Carlson focused on obsidian because it is a trackable commodity. To be sure, obsidian is not terribly abundant at BC sites, and, not surprisingly, most obsidian in BC sites is from BC sources. However, Carlson found that nearly a quarter of traced obsidian in British Columbia sites is from Oregon sources. Of these, four are most prominently represented, including Newberry Volcano, Obsidian Cliffs (which Carlson identifies as the "Three Sisters" source), Glass Buttes, and one from the John Day area, almost certainly the source most commonly identified as Whitewater Ridge (refer to Figure 11-1).

We have drawn on data in this study from the Obsidian Cliffs and Newberry Volcano sources. We know that both sources are near the southern limits of the Columbia Basin, and near the northern edge of the Great Basin. The other two sources commonly found in British Columbia are similarly located near this important hydrologic and cultural boundary. Though we have yet to systematically examine the distribution of obsidian from these more easterly sources, we predict that they, too, will be found to be quarried most intensively by southern Columbia Plateau communities for distribution northward.

The emergent model suggests that a small number of prominent obsidian sources located near the Columbia Plateau-Northern Great Basin boundary were most intensively quarried by people to the north, serving as an important commodity in a regional exchange system that extended well into British Columbia.

In reviewing the use history of the Newbery Volcano obsidian quarries, Connolly (1999) found diminished use during the last millennium, indicating changes to the interaction sphere by which obsidian was earlier distributed. This change may correlate to settlement pattern changes documented on the southern Columbia Plateau; as noted by Endzweig (1994:12), "[t]he high density of archaeological sites recorded along the John Day River as contrasted with its limited treatment in ethnographic and historic accounts supports the impression of a population reorganization" during the last millennium. Archeological surveys have documented the presence of many housepit village clusters throughout the southern Columbia Plateau, extending along the middle and upper drainages of the Deschutes and John Day rivers (Hibbs et al.1976; Polk 1976; Endzweig 1994); for example, Jenkins and Connolly (1994) found that the Paquet Gulch site, a large village with 75 to 100 housepits not far from the Deschutes River town of Maupin, was occupied as early as ca. 2500 years ago but produced little evidence for occupation within the last ca. 1300 years. Endzweig (1994) reports that housepit sites on the upper John Day were most intensively occupied between ca. 2600 and 900 years ago; many sites continued to be regularly used after this time, but probably not as residential places. This pattern varies notably from the settlement distribution documented historically, in which residential centers where arrayed along the Columbia River corridor (Murdock 1938; Rigsby 1965; Suphan 1974). When fur trade or military parties encountered southern Columbia Plateau

Figure 11-6. Bifaces of Obsidian Cliffs obsidian from the Paul's Fire Cache site.

Sahaptins in the upper Deschutes and John Day regions during the early nineteenth century, they were generally at temporary hunting camps and accompanied by horses (Young 1899; Fremont 1887).

The apparent withdrawal from residential centers in the upper Deschutes and John Day basins during the last millennium may not have been abrupt, and may have been a response to multiple factors. Dumond and Minor (1983) see a reorientation of focus on the middle Columbia River from upstream to the downriver Chinook area after ca. 1000 BP, possibly in response to growing economic opportunities along the Columbia River corridor. Lewis and Clark marveled at the constant trade activity along the river, and Clark's remark that The Dalles vicinity was "the great mart of all this country" is well known (Thwaites 1905:4:289). The Lower Columbia area was but one important center for a region-wide Pacific Northwest/Northwest Coast exchange network. Throughout the region economic activity was controlled and managed by powerful elites, representing resource-controlling corporate households and lineages who maintained their position in part by their central role in the wide-ranging exchange economy (Ames 2006; Ames and Maschner 1999; Sobel 2006, 2012).

Another factor may have been an increasing level of hostility between southern Columbia Plateau Sahaptins and Northern Paiutes over the course of the last millennium (Kelly 1932; Murdock 1938; Ray 1938; Spier and Sapir 1930; Steward 1938; Sutton 1986; Teit 1928) that led to the abandonment of small, isolated and vulnerable hamlets in favor of larger and more secure population centers (Endzweig 1994; Jenkins and Connolly 1994; Connolly 1999).

Whatever the motivations, it is clear that by the time of contact what had been the major Plateau obsidian sources were firmly within lands occupied by the Northern Paiutes, who had established residential centers in the upper Deschutes, John Day, and Crooked River basins (Stewart 1939; Fowler and Liljeblad 1986; Figure 11-7). Lewis and Clark reported that, in 1805, the name given for the Deschutes River by the Columbia River Indians was "the river on which the Snake Indians live" (Thwaites 1905:3:147). While there are notable exceptions (Couture et al. 1986; Hunn 1990), the documented attitude of hostility between Plateau

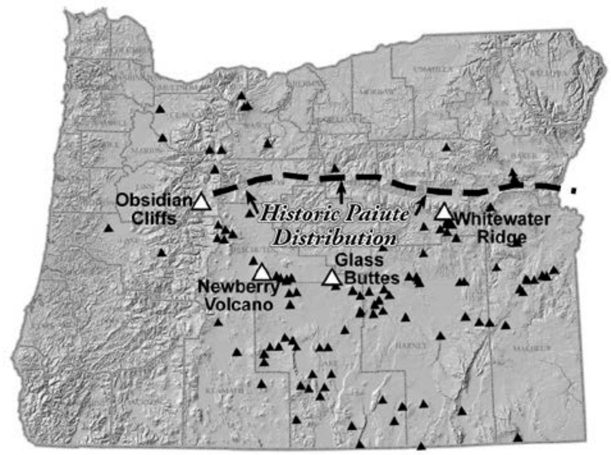

Figure 11-7. Location of the major Plateau prehistoric obsidian sources, in relation to Paiute territory at contact.

Sahaptins and their Paiute neighbors to the south must have had some impact on access to and procurement of obsidian from these sources by Plateau consumers (cf. Connolly 1999:242-243).

While access to some of the southernmost obsidian sources may have been diminished for southern Plateau folks during the last millennium, trade activity was accelerating along the Columbia River corridor (Dumond and Minor 1983; Hayden and Schulting 1997). How this change in the obsidian trade within the last millennium affected economic dynamics west of the Cascades remains largely unexplored, but one possible change is an elevated role of west-side obsidian, possibly including Obsidian Cliffs, and most notably the Inman Creek material from the Willamette Valley. Inman Creek obsidian was probably originally extruded from Western Cascades vents in the upper Middle Fork Willamette River basin, but is now widespread in Pleistocene-deposited Willamette River gravels.

A dramatic increase in the occurrence of obsidian at later Willamette Valley sites was first noted by Pettigrew (1980:66-67), who suggested that this increase may have been related to introduction of the bow and arrow, estimated to have occurred in the valley within the last ca. 2000 years. Since the Inman Creek obsidian most readily available in the Willamette River gravels occurs primarily as pebble-sized nodules, obsidian would have been of relatively limited use for the production of stone dart tips, which were typically reduced from larger bifacial preforms. The much smaller arrow points, by contrast, were frequently made on flakes, immediately making the local obsidian a significantly more valuable raw material. A manifold increase in the occurrence of projectile points in the Willamette Valley in later sites has also been noted as evidence for an increasing concern with security (Aikens et al. 2011:308-309; Jacobs et al. 1945:191-193; Zenk 1976:5-6).

From the present study, another possibility emerges for the dramatic increase of Willamette Valley obsidian in later sites. Diminished access for consumers along the Columbia River corridor to eastern Oregon obsidian sources may have enhanced its market value. One of the larger samples of sourced obsidian from the Willamette Valley is from the cluster of sites bordering the former channel of Mill Creek, in the vicinity of the modern I-5/Oregon Highway 22 interchange near Salem. The sites represent mostly continuous use throughout the past ca. 6000 years, with intense use periods between ca. 5000 and 3500 years ago and again during the last ca. 2000 years. Of 466 tested obsidian artifacts, 98% were sourced to either Obsidian Cliffs or the local Inman Creek sources. Of this number, 92% were Inman Creek obsidian, and 8% were from Obsidian Cliffs, but they were not equally distributed through time.

A number of obsidian hydration studies have suggested that Inman Creek obsidian hydrates at a relatively slow rate on the valley floor. Minor (1977, 1985) proposed hydration rates of $1.3\mu^2/1000$ years for the Portland Basin and $1.6\mu^2/1000$ years for the upper Willamette Valley, based on small sets of paired hydration values and radiocarbon dates. Connolly and O'Neill (2004) suggest a rate of $1.9.0\mu^2/1000$ years for Inman Creek obsidian in the upper Willamette Valley, based on Inman Creek obsidian from radiocarbon-dated contexts at the Chalker site (35LA420). This rate, which we apply to the Mill Creek sites, is slightly faster than Minor's preliminary rate, but still considerably slower than other Oregon obsidians, including Obsidian Cliffs. Based on their research on hydration rates for many eastern Oregon obsidians, Pettigrew and Hodges (1995) have found that Obsidian Cliffs and Newberry Volcano obsidians hydrate at comparable rates. Adjusting the experimentally induced hydration rate for Newberry Volcano obsidian reported by Friedman and Long (1976) and Friedman and Obradovich (1981) to the effective hydration temperature calculated for the Salem recording station, provides a hydration rate of $3.6\mu^2/1000$ years that we apply to the Obsidian Cliffs material. Calibrated ages are shown in Figure 11-8.

The use of Obsidian Cliffs material exhibits a gradual increase through time, but about 45% of obsidian from this source at Mill Creek predates ca. 1500 BP, and 55% occurs after that time. By contrast, about 84% of Inman Creek material appears to post-date ca. 1500 BP, representing a dramatic surge in the use of this local material. Looking beyond the valley, Inman Creek obsidian also appears to have assumed a position of importance in regional trade; at villages on the lower Columbia occupied only during the last millennium, the proportion of Inman Creek obsidian far exceeds that of eastern material (Sobel 2006). The implication is that Inman Creek obsidian was commoditized during the last ca. 1500 years, enhancing its value and range of distribution in the Willamette Valley/Lower Columbia region. Whether this is a function of enhanced trade opportunities in the lower Columbia Basin or of diminished access to eastern Oregon obsidians, or both, remains unresolved at present.

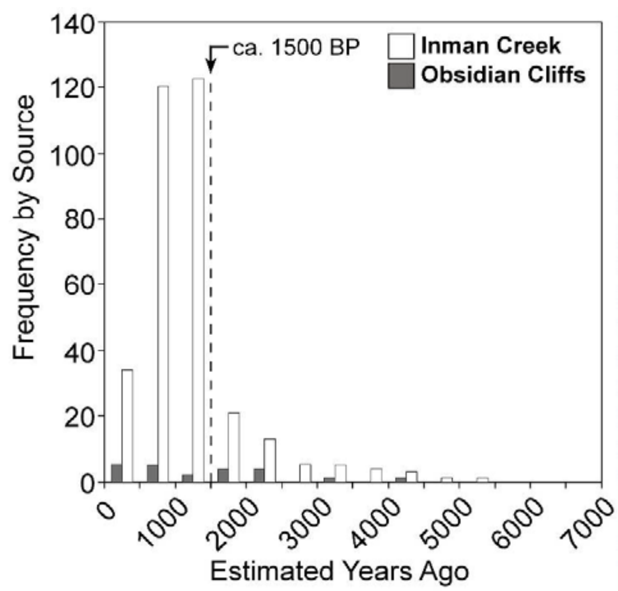

Figure 11-8. Relative proportions of Inman Creek vs. Obsidian Cliffs obsidian through time at the Mill Creek sites, central Willamette Valley.

In summary, Obsidian Cliffs, like obsidian from Newberry Volcano, was not only an important local toolstone material, but was a commoditized product systematically quarried and shaped into uniform, transportable forms and transferred to distant consumers through a regional exchange network with centers on the lower Columbia River and the Salish Sea regions. Though systematic studies have yet to be pursued, it is likely that several other eastern Oregon obsidian sources located near the southern rim of the Columbia Plateau region (most notably Glass Buttes and Whitewater Ridge) also primarily served northern consumers who participated in this exchange network. Further, it appears that during the most recent millennium, changing social dynamics may have reduced access to these eastern sources by northern consumers, while at the same time the intensity of commerce on the lower Columbia River accelerated. These factors may have served to enhance the value of the Willamette Valley's Inman Creek obsidian.

We are still some distance from fully understanding the driving forces of these regional economic patterns, but it is clear that understanding local chronologies and social dynamics depends on placing them within a much broader regional economic context.

Acknowlegements: Photographs of the Paul's Fire Cache biface were provided by Ann Bennett Rogers; Kevin Bailey aided in sorting and editing the Obsidian Cliffs source database file.

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CHAPTER 12

Glass Buttes, Oregon: 14,000 Years of Continuous Use

Daniel O. Stueber
Archaeological Investigations Northwest, Inc. (dan@ainw.com)

Craig E. Skinner
Northwest Research Obsidian Studies Laboratory (cskinner@obsidianlab.com)

For at least fourteen millennia Glass Buttes, one of the largest obsidian sources in Oregon, has been a source of high quality toolstone for Native American flintknappers. In the last century non-native historic and modern flintknappers as well as rock hounds have also used this resource for its abundant, colorful and high quality obsidian. This paper will discuss the quantity and quality of Glass Buttes obsidian, archaeological work that has been done there, the prehistoric and modern use of the resource, new archaeological findings, and the Bureau of Land Management protection plan for this valuable resource.

Obsidian was a commodity and trade item used extensively by Native American and First Nations people of North America. In the United States, the state of Oregon has in excess of 100 geochemical obsidian sources, more than anywhere else on the continent (Northwest Research Obsidian Studies Laboratory 2012) (Figure 12-1). The ancient use of these obsidian resources has added to a rich archaeological record throughout Oregon, the Pacific Northwest and Great Basin. Over the last thirty years, the use of x-ray fluorescence (XRF) characterization methods has enabled researchers to understand the movement of obsidian tools and toolstone across the landscape (Skinner 1983; Hughes 1983; Carlson 1994). Blood residue extraction, another recently developed technique (Neuman 1990; Williams 1990; Fagan 2011), aids research in understanding game hunting strategies used by ancient hunters and how they have changed over time. The Glass Buttes Source Complex, with its nine geochemical varieties identified by Craig Skinner (Ambroz et al. 2001; Northwest Research Obsidian Studies Laboratory 2012), is one of, if not the largest obsidian source in Oregon (Figures 12-2 and 12-3). Glass Buttes has a rich archaeological record that has provided, using XRF and blood residue extraction, new information to our understanding of this very important resource.

Figure 12-1. Oregon obsidian sources with Glass Buttes Source Complex circled.

Glass Buttes lies within the ethnographic range of the Northern Paiute people and was an important resource for Native People for thousands of years (Mack 1975; Loy 2001; Lebow 1990). Due to its abundant high quality and often-colorful obsidian, Glass Buttes is still used today as a toolstone source by modern flintknappers as well as a material

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Archaeology Press, Simon Fraser University, 2015

source for geologists and rock hounds. Modern use of Glass Buttes has impacted this important resource but it continues to be highly significant as a subject of geological and archaeological research as well as a Mecca for rock hounds and practitioners of traditional arts and technologies.

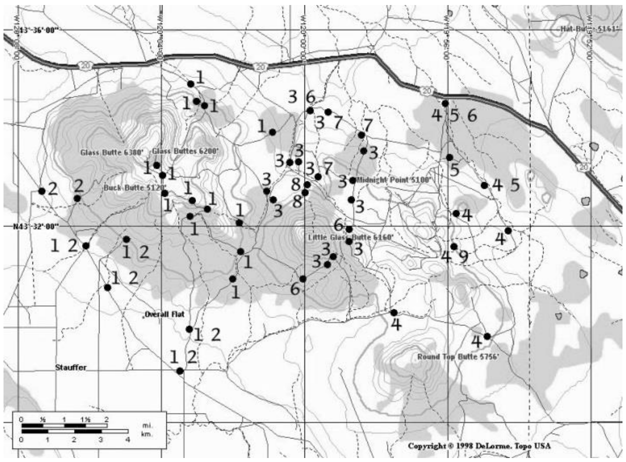

Figure 12-2. Glass Buttes main geochemical varieties 1-9 source locations.

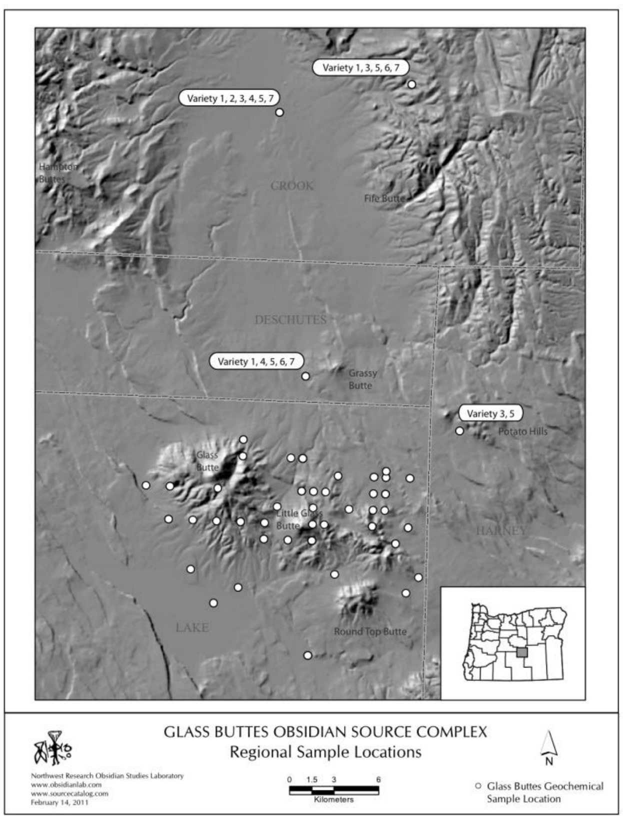

Figure 12-3. Glass Buttes extended geochemical obsidian source variety locations.

Geologic Setting

Glass Buttes is located primarily in south-central Oregon's Lake County, along U.S. Route 20 between the cities of Bend and Burns. It is situated in the High Lava Plains, on the northern edge of the Great Basin, and is in the Bureau of Land Management (BLM) Prineville District (Figure 12-1). Five million year old Glass Buttes, a large rhyolitic volcanic center, is generally between 900 m to more than 1800 m in elevation and is dominated by Little Glass Butte, and Glass Butte at 1945 m elevation (Mack 1975; Churchill 1991:1; Orr et al. 1992; Loy 2001). Ancient lakebeds, lava ridges, cinder cones, and intermittent springs typify the area (Mack 1975). Obsidian at Glass Buttes is found in an area of approximately 746 km² (Northwest Research Obsidian Studies Laboratory 2012), and occurs as surface float pebbles and cobbles and primary geologic sub-surface veins (Skinner 1983; Churchill 1991:1). This obsidian occurs in a variety of colors including: translucent and banded black, red, mahogany, gold sheen, silver sheen, gray-green banded, rainbow and banded or mottled multi-color combinations (Skinner 1983). Sub-surface obsidian in some areas is available in very large blocks or boulders, some weighing 45 kg or more (Figure 12-4).

Figure 12-4. Large quarried obsidian.

Geochemical studies of source obsidian by Ambroz (1997), Ambroz et al. (2001), and Northwest Research Obsidian Studies Laboratory (unpublished research, 2012) has identified nine geochemical varieties at a number of primary and secondary source locations within the Glass Buttes Complex and in the basins to the north and south of Glass Buttes. These sources are found primarily in northeast Lake County (Figure 12-2), with Glass Buttes geochemical varieties 1, 2, 3, 4, 5, 6 and 7 occurring in two locales in southeast Crook County, geochemical varieties 1, 4, 5, 6 and 7 occurring in southeast Deschutes County, and geochemical varieties 3 and 7 occurring in northwest Harney County (Figure 12-3).

Mining and Geothermal Exploration

Glass Buttes is within an area geologically mapped for its mercury mining and geothermal exploration potential (Johnson and Ciancanelli 1984; Loy 2001). Mercury mining, perlite mining evaluation and geothermal exploration have taken place in the Glass Buttes area. The Oregon Department of Environmental Quality (DEQ) reports that mercury-bearing cinnabar was first discovered at Glass Buttes in 1933, and small-scale mining and exploration was carried out until 1957. From 1957 through 1970, the Jackson Mountain Mining Company conducted larger mining operations, producing 500 flasks of mercury between 1967 and 1970 (Oregon Department of Environmental Quality 2012). Remnants of the mining operations and tailing piles can still be seen to the east of Glass Buttes, but these areas should be avoided as mercury contamination in the mining areas renders them unsafe to visit. These areas were slated by the DEQ for environmental cleanup in 2001, but action has yet to be undertaken by the BLM (Oregon Department of Environmental Quality 2012).

According to the University of Nevada Reno’s Great Basin Center for Geothermal Research, Magma Energy was the first company to explore Glass Buttes for its geothermal potential. “Exploration activity in and around Magma's 3607 ha (8,914 acre) property (lease at Glass Buttes) began in 1974 and continued through the early 1980's. Work included numerous drilled temperature gradient holes, geologic mapping, an electrical resistivity survey and a soil-mercury survey. Initial work was sponsored by the Oregon Department of Geology and Mineral Industries and later by the geothermal lease holders Vulcan Geothermal Group and Phillips.” (Great Basin Center for Geothermal Energy 2012).

In 1975, Mack conducted a cultural resources inventory for the BLM (Mack 1975). A geothermal plant has not yet been built at Glass Buttes. However, in 2010 ORMAT Nevada conducted further geothermal exploration adjacent to Magma’s Glass Buttes project with a $4.5 million dollar grant from the U.S. Department of Energy (Great Basin Center for Geothermal Energy 2012). At the time of this writing no further information on the ORMAT geothermal project was available.

The Supreme Perlite Mining Company laid mining claims within the Glass Buttes area in 1988. Between 1988 and 1989, four test pits were excavated and exploratory drilling took place within a 40-acre designated area, south of U.S. Route 20 and east of Glass Butte. In 1990 a cultural resource survey was conducted by Churchill (1991). Subsequent development for perlite mining has not been undertaken (Supreme Perlite Mining Company, personal communication 2012).

In the mid-1960s a single, private obsidian-mining claim was established at Glass Buttes. Several individuals have held the “grandfathered” claim since the claim was made, and is still in effect to date.

Previous Research

A number of archaeological projects have taken place in the Glass Buttes area (Mack 1975; Crowley-Thomas 1983a. b; Griffin and Soper 1984; Soper and Griffin 1984; Enneberg 1987; Churchill and Jenkins 1989; Churchill 1991; Sharp et al. 1998; Skinner and Thatcher 2003; Jenkins 2005; Jenkins and Connolly 2006). The four largest archaeological projects of the Glass Buttes area are surveys by Mack (1975) and Churchill (1991), obsidian studies carried out as part of the FGV Western Fiber Build Project (Skinner and Thatcher 2003; Sharp et al. 1998), and the Jenkins and Connolly (2006) testing and evaluation project.

Churchill’s survey, conducted in 1990, covered 480 acres for the Supreme Perlite Mining Company’s proposed mine, as previously discussed. Churchill (1991) recorded 14 archaeological sites and two isolated artifact finds. The 14 archaeological sites contained a number of bifaces, unifaces, cores, and a hammerstone. Of the two isolate finds, one is a projectile point fragment that resembles an Elko Eared series point; the other is a biface (Churchill 1991:2:1-4).

Jenkins and Connolly's 2006 testing and evaluation project, was conducted under an Oregon Department of Transportation contract for the FTV Western Fiber Build Project, a fiber optics communications line survey paralleling U.S. Route 20. Work included excavation of 197 test probes and three 1-x-1-m test units at five sites. Four of the sites were small lithic scatters, but the fifth was a huge 800-x-200-m area of dense and discreet chipping stations containing thousands of flakes, early stage biface fragments and 40-60 cm deep deposits. Early stage reduction of quarry blanks and flake "rough outs" were the major activities at all five sites using locally obtained obsidian cobbles of Glass Buttes varieties 1 and 2. Obsidian XRF sourcing of 74 specimens that included six tools, an unmodified cobble, and 67 flakes, indicated most were derived from Glass Buttes varieties 1, 2 and 3. Two of the specimens, both bifaces, were made of Silver Lake/Sycan Marsh and Brooks Canyon obsidian. The Silver Lake/Sycan Marsh obsidian source is located about 95 km to the southwest, and the Brooks Canyon obsidian source is located 11 km west of Glass Buttes. The only specimen recovered with chronologically diagnostic attributes, was an Elko Corner-notched projectile point base fragment made of Glass Buttes 1 obsidian. Although no radiocarbon dates were obtained, obsidian hydration analysis of 100 samples of obsidian suggests that these sites were used over a long period of time, extending from a few hundred years ago and back several thousand years into the terminal Pleistocene (Jenkins and Connolly 2006: 57-62). The scope of this project, including subsurface testing and obsidian characterization and hydration analysis, makes it one of the more comprehensive projects that have been conducted at Glass Buttes to date.

Mack (1975) conducted the largest survey of the Glass Buttes area to date under a contract with the Bureau of Land Management for proposed geothermal leasing, as previously discussed. Covering a 30-square-kilometer area around Glass Buttes, the survey identified and documented 131 archaeological sites and 15 isolated artifact finds. Mack describes the archaeological sites as campsites, large and small knapping stations, hunting blinds, rock walls and quarries (Mack 1975:7; Churchill 1991:1:8). Projectile point types recovered during this survey range in age from approximately 13,000 B.P. to 900 B.P. based on standard chronological assignment of the types and indicate continuous human use of the area for that period (Mack 1975:46). These projectile point types as listed by Mack include: a fluted Clovis point, Western Stemmed and foliate points, Northern Side-Notched, Pinto, Humboldt, Elko, and Rose Spring series points (Mack 1975: 78-84).

Re-Evalution of Artifacts From the 1975 Mack Survey

In 1975, Mack collected and identified 77 tools that include 48 projectile points, one crescent, three drills, one graver, seven scrapers, five stemmed knives, eight bifacial knives, and four unifacial knives. Seventy-three are made from obsidian or fine grain volcanic material (FGV), and four are made from cryptocrystalline silicate material (CCS). At the time of the 1975 Mack survey XRF geochemical sourcing of obsidian was in its infancy and was not a consideration. Blood residue extraction and analysis from stone tools was also in its early stages and not readily available to researchers. Both of these research tools are now commonly used for archaeological analysis.

In 2011, analysis was conducted on 41 of the obsidian and FGV projectile points, on loan from the University of Oregon Museum of Natural and Cultural History. These artifacts are listed in Table 12-1 and have been assigned numbers from 1 to 41 for the purposes of the analysis and discussion below (Figure 12-5). The artifacts were selected based on their chronological type associations and technological criteria, including attributes diagnostic of stone tool manufacture, use and rejuvenation (Flenniken 1981; Flenniken and Raymond 1986; Titmus and Woods 1986; Stueber 2010). Technological analysis indicated that the damage, breakage patterns and flake scar patterns were consistent with projectile points that exhibit damage due to use impact fractures and/or characteristics of rejuvenation to extend use-life. Blood residue extraction and analysis was conducted by Archaeological Investigations Northwest, Inc. (AINW). XRF geochemical sourcing was conducted on 40 of the same projectile points by Northwest Research Obsidian

Table 12-1. Obsidian source and blood residue results for selected projectile points recovered at Glass Buttes by Mack (1975).

No.	Site or Isolate and Catalog No.	Projectile Point Type	Break Type or Evidence of Repair	Obsidian Source	Distance From Source	Blood Residue
1	35LK326/1	Clovis	bending	Witham Creek	120 km	
2	35HA81/5	Crescent		Buck Spring	40 km	
3	35LK318/4	Western Stemmed	bending, burin	Chickahominy	32 km	Bear
4	35LK318/3	Western Stemmed	bending	Bear Creek	160 km	
5	Isolate 3	Western Stemmed	rejuvenation	Glass Buttes 4		
6	35LK92/1	Western Stemmed	bending	Wagontire	24 km	Bear
7	35LK322/1	Cascade	bending	Glass Buttes 3		Deer, Rabbit
8	35LK278/1	Cascade	rejuvenation	Big Stick	32 km	Bovine, Rabbit
9	35LK345/1	Cascade	rejuvenation	Cougar Mtn.	80 km	Camel
10	Isolate 10	Cascade	rejuvenation	Tough Butte	64 km	
11	35LK384/1	Cascade	bending, facial burin	Tank Creek	40 km	
12	35LK374/1	Cascade	rejuvenation, bending	MLGV*	144 km	
13	35LK365/1	Humboldt	bending	Glass Buttes 1		
14	35LK322/3	Humboldt	bending	Glass Buttes 3		
15	35LK293/3	Northern Side- Notched	rejuvenation	Venator FGV*	136 km	
16	35LK311/1	Northern Side- Notched	bending	Riley	32 km	Bovine, Deer
17	35HA77/1A	Elko series	rejuvenation, bending	Buck Spring	40 km	Chicken
18	35LK307/1	Rose Spring	rejuvenation, bending	Carlon (Bald Butte)	32 km	
19	35LK384/2	Elko	bending	Glass Buttes 9		
20	Isolate 4	Gatecliff Split Stem	bending	Riley	32 km	
21	35LK385/3	Elko	rejuvenation	Tank Creek	40 km	
22	35HA77/1B	Rose Spring	bending	Round Top Butte	40 km	
23	Isolate 9	Elko	bending	Burns	64 km	
24	35LK315/1	Elko	bending	Glass Buttes 3		
25	35HA82/1	Fragment	bending	Glass Buttes 4		
26	35LK306/1	Elko	bending	Glass Buttes 3		
27	35LK306/2	Elko	bending	Glass Buttes 3		
28	35LK299/2	Elko	bending	Chickahominy	32 km	
29	35LK366/1	Gatecliff Split Stem	bending, facial burin	Buck Spring	40 km	Rabbit
30	35LK305/3	Fragment	bending	Glass Buttes 7		Chicken
31	35LK359/1	Western Stemmed	bending	Glass Buttes 1		
32	35LK314/1	Distal Fragment	bending, facial burin	Rimrock Spring	40 km	
33	35LK383/1	Distal Fragment	rejuvenation, bending	Cougar Mtn.	80 km	Camel
34	35LK3172	Medial fragment	bending	Spodue Mtn.	90 km	
35	Isolate 14	Fragment	bending	Riley	32 km	
36	35LK284/2	Fragment	bending	Glass Buttes 1		
37	35LK313/1	Fragment	bending	Variety 5	32 km	
38	Isolate 12	Fragment	bending	Tank Creek	40 km	
39	35HA80/1	Rose Spring	bending	Buck Spring	40 km	
40	35LK301/1	Rose Spring	bending	Carlon (Bald Butte)	32 km	
41	35HA95/4	Rose Spring	bending	Whitewater Ridge	115 km	

* MLGV=Massacre Lake/Guano Valley; FGV=Fine Grained Volcanic

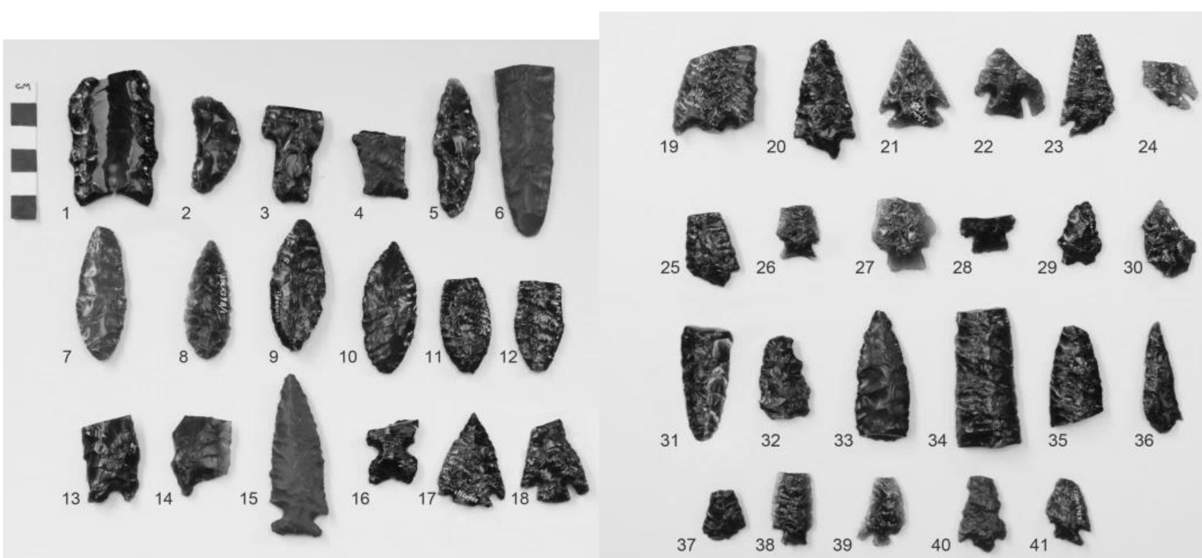

Figure 12-5. Projectile points recovered at Glass Buttes by Mack (1975) and selected for obsidian source and blood residue analysis.

Studies Laboratory. No obsidian hydration studies were performed for this project. Geochemical sourcing and obsidian hydration for the Clovis point recovered during the 1975 Mack survey (Artifact 1) was conducted in 2002 by Northwest Research Obsidian Studies Laboratory (Rondeau 2007a).

Results for the geochemical characterization and blood residue analyses provide great insight into the use of Glass Buttes by prehistoric hunter-gatherers. Obsidian tools found at Glass Buttes represent 19 distant sources: Witham Creek, Buck Spring, Chickahominy, Bear Creek, Wagontire, Big Stick, Cougar Mountain, Tough Butte, Tank Creek, Massacre Lake/Guano Valley, Venator Fine-Grained Volcanic, Riley, Carlon (Bald Butte), Variety 5, Tank Creek, Round Top Butte, Burns, Rimrock Spring, Spodue Mountain, and Glass Buttes geochemical varieties 1,3,4,7, and 9 (Table 12-1 and Figures 12-5 and 12-6).

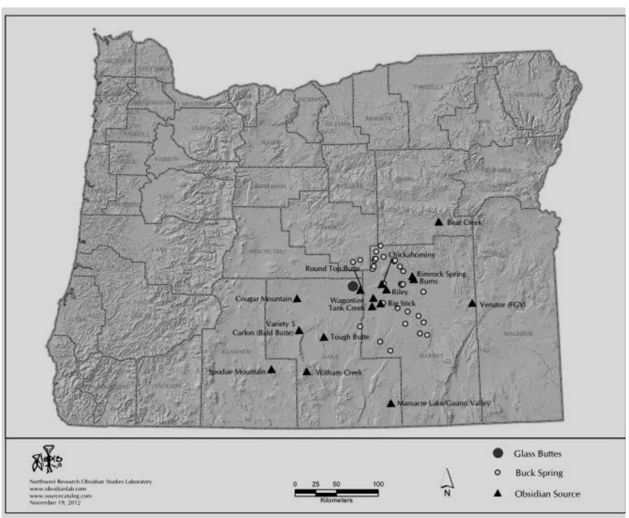

Figure 12-6. Obsidian and FGV source locations for the Mack 1975 artifacts.

Blood residue extraction and analysis was conducted on 41 artifacts (Figure 12-5) recovered during the 1975 Mack survey. The artifacts were tested using antisera from 18 species including human. Ten of the artifacts tested positive for blood residues, with three of the 10 artifacts each testing positive for blood residues from two types of animals. The species identified in the positive results include: bear, bovine (bison), camel, chicken (grouse, turkey, quail) deer (white tail deer, mule deer, elk) and rabbit. These results and the corresponding artifacts are shown in Table 12-1 and Figure 12-5. A foliate Cascade point with rejuvenation evidence at the distal portion (Artifact 9), and the distal fragment of a dart point (Artifact 33), both tested positive for camel blood residue. These positive results suggest that these two projectile points were used to hunt North American camels, which became extinct at the end of the Pleistocene. Archaeological sites at Fossil Lake (Minor and Spencer 1977) and Paisley Caves (Jenkins et al. 2012), Oregon, and in southwestern Canada (Kooyman et al. 2012), among other places in western North America, have produced evidence for the existence of this extinct species in association with human activity.

The artifacts collected during the 1975 Mack survey included five Western Stemmed points. Current research at sites containing Western Stemmed points indicates that they are contemporaneous with Clovis points and preceded the period of Clovis technology (Fagan 1988, 1996; Jenkins et al. 2012; O'Grady et al. 2012). The analyses of 41 artifacts from the 1975 Mack survey collection represent a time span from the terminal Pleistocene to the late Holocene, and provide a clear picture that Glass Buttes was a destination for the inhabitants of the region for millennia. These analyses show that a large portion of the artifacts can be traced to 19 distant obsidian sources (Figure 12-6). Two additional distant obsidian sources, Silver Lake/Sycan Marsh and Brooks Canyon, were identified by Jenkins and Connolly (2006) for artifacts they found at Glass Buttes.

Twenty five percent of the Mack survey artifacts had positive results from the blood residue analysis giving an indication of the variety of fauna that was being hunted in the area during this long period of use. In spite of all the available obsidian in the larger region, 13 sources within a 50 km radius (Figure 12-1), the range of chronological types (Figure 12-5 and Table 12-1) and number of artifacts from distant obsidian sources as well as the blood residue evidence, indicate that Glass Buttes was a preferred obsidian source with locally available game hunting opportunities.

Paleoindians Use of Glass Buttes

Paisley Caves

The Paisley Caves, located in the Summer Lake Basin of south-central Oregon, have been established through rigorous scientific investigation as having the oldest human DNA in North America. These dates, obtained from human coprolites, range in age from approximately 1,242 cal B.P. to 14,600 cal B.P., with the oldest dates being 1,600 years older than Clovis. The Paisley Caves have also produced Western Stemmed projectile points dated as old, or older than, Clovis. The well stratified deposits in Paisley Caves have yielded a wealth of other archaeological materials including sinew and plant fiber threads, leather, basketry, cordage, rope, and wooden pegs, as well as butchered animal bones (including camel) (Jenkins 2008; Gilbert et al 2009; Jenkins et al. 2012). The Paisley Caves are approximately 95 km southwest of Glass Buttes and have yielded seven flakes of Glass Buttes obsidian, most of them from deeply stratified deposits. One flake of Glass Buttes 3 was found in Level 33, approximately two to three meters from a large mammal bone, possibly horse or camel, that dates to 14,404 cal. yrs B.P. Another flake of Glass Buttes 2, from Level 39, is three meters away from a specimen with a date of 13,772 cal. B.P. (Dennis Jenkins personal communication). These data indicate that Pre-Clovis peoples made their way from Glass Buttes to the Paisley Caves.

Clovis

At the time of Churchill's 1990 survey (Churchill 1991) the only fluted Clovis projectile point (Bradley et al. 2010) that had been found at Glass Buttes was during the Mack (1975) survey. Since that time, two additional Clovis artifacts have been found at Glass Buttes. In addition, obsidian Clovis artifacts from other sites have been sourced to Glass Buttes.

In 2002, XRF geochemical sourcing conducted on the 1975 Mack survey Clovis point identified Witham Creek as the obsidian source (Rondeau 2007a). The Witham Creek source is located approximately 120 km south, as the crow flies, from Glass Buttes, but a much farther trek for a Clovis-armed traveler (Figure 12-7).

Recently, two more obsidian Clovis artifacts have been found at Glass Buttes. The Sand Flat Clovis, a point fragment, was found to the east of Little Glass Butte, and was sourced to Sugar Hill in northern California, about 160 km to the south (Figure 12-8) (Rondeau 2007b). The second artifact, a fluted Clovis preform, was found south of Glass Butte at Round Top Butte, and was correlated with Big Stick, about 32 km to the east (Scott Thomas personal communication; Rondeau 2007b).

Figure 12-7. Clovis point recovered during the 1975 Mack survey.

Figure 12-8. Sand Flat Clovis.

There are 39 Clovis artifacts made from Glass Buttes obsidian, now identified, from various sites. The Cottage Grove Clovis, found in the Willamette Valley near Cottage Grove, Oregon, was in the collection of the man that reported its find and who died in the 1920s (Minor 1985:35). This complete Clovis artifact has flute flakes covering its entire length on both faces and is made from Glass Buttes 3 obsidian (Ozbun et al. 1997; Connolly et al. 1994; Ozbun and Stueber 2001). This Clovis point was found approximately 240 km west of Glass Buttes (Figure 12-9).

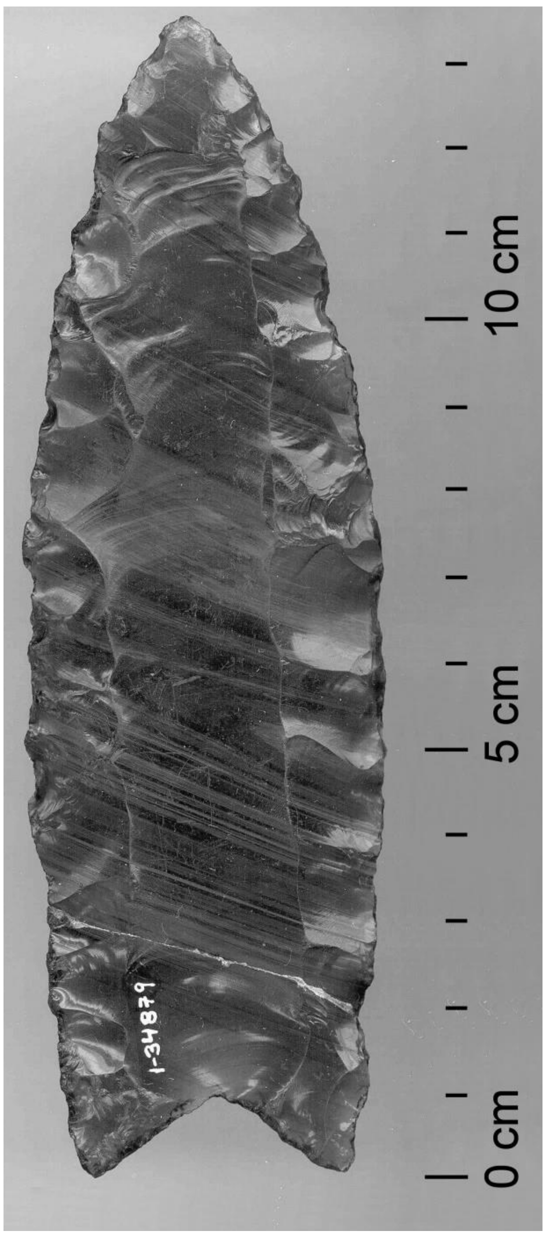

Figure 12-9. Cottage Grove Clovis.

The Ilse site Clovis, a base fragment which sources to Glass Buttes 1, was found at Rimrock Lake, northeast Harney County, about 24 km to the east of Glass Buttes (O'Grady and Thomas 2011). The Sheep Mountain site Clovis, a base fragment, sourced to Glass Buttes 1, was found 24 km east of Glass Buttes (O'Grady et al. 2009). An obsidian Clovis point and two associated Clovis artifacts sourced to Glass Buttes 4 were found at the Cal Schmidt site in Harney County (Spencer and Schmidt 1989).

The Dietz Clovis site, located in the northwestern portion of Alkali Basin, Lake County, Oregon, is the largest Clovis site in the Pacific Northwest, and has been studied and reported by a number of researchers (Fagan 1988, 1990, 1996: Pinson 2011; O'Grady, et al. 2012). Earlier obsidian sourcing assigned three of the Clovis artifacts, a point and two flute flakes, to Glass Buttes, and also indicated that 30 artifacts, 17 Clovis points and 13 fluted preforms and flute flakes, were from the Buck Mountain obsidian source in northern California (Fagan 1996). Recent re-evaluation of the putative Buck Mountain Clovis artifacts by O'Grady and the Northwest Research Obsidian Studies Laboratory (2012) has resulted in a reassignment of the source as Glass Buttes geochemical varieties 3 and 6. Thus, based on the recent XRF analysis, 33 of the Dietz Clovis artifacts are now sourced to Glass Buttes (O'Grady, et al. 2012). This abundance of evidence clearly establishes Glass Buttes as an important toolstone source for Clovis toolmakers.

Non-Paleoindian Glass Buttes Artifacts from Distant Archaeological Sites

Archaeological research in recent decades has provided evidence for the wide geographic distribution of obsidian from Glass Buttes. Glass Buttes obsidian has been found in sites from the northern California coast, throughout Oregon, southern Washington and as far north as southwest British Columbia, eastern Vancouver Island, and the Gulf Islands of British Columbia (Table 12-2 and Figure 12-10). Moore (2009) names Glass Buttes as one of the Great Basin toolstone sources and, because of its high quality material, uses it as a standard by which other obsidian sources are judged (Moore 2009). It is likely that other sites that have not had XRF characterization studies may contain Glass Buttes obsidian artifacts (Ambrose et al. 2001). See Table 12-2 for a list of sites where Glass Buttes obsidian artifacts have been found.

Table 12-2. Sites and areas where Glass Buttes obsidian has been found with references and distance from the source.

LOCATION	REFERENCE	DISTANCE
Fort Rock Basin, OR	Skinner et al. 2004	136 km
Buffalo Flat, OR	Oetting 2004	136 km
Bone Cave, OR	Ferguson and Skinner 2005	130 km
Malheur Headwaters, OR	Cadena 2012	130 km
Ashland, & Southern Willamette Valley, OR	Ozbun and Stueber 2001	240 km
Celilo, OR	Ozbun et al. 1998	230 km
Wildcat Canyon, Lower Columbia River, OR	Carlson 1994	230 km
Meier Site, Portland Basin, OR	Sobel 2011	335 km
Broken Top Site, Portland Basin, OR	Ellis and Fagan 1993	300 km
Cathlapotle/Clahclehlah, Lower Columbia River, WA	Sobel 2001, 2011	335/280 km
Mt. Adams, WA	Hughes 1990	400 km
Judd Peak, WA	McClure 1989	400 km
Umpqua/Eden Site, OR	Skinner et al 1999	300 km
Gold Hill Site, OR	Hughes 1990	250 km
Gunther Island, CA	Hughes 1978	425 km
Vancouver Island and Lower Fraser River, BC	Carlson 1994; Arcas 1994	770 km
Departure Bay Site, BC	Carlson 1994; Arcas 1994	885 km
Park Farm Site, Pitt Meadows, BC	Carlson 1994; Wilson 2009	850 km

Historic and Modern Use

Theodore (Ted) Orcutt, or Mus-su-peta-na (Up River Boy), was a Karuk Indian born February 25, 1862 in northern California, near the Karuk Indian settlement of Weitchpec on the Klamath River. In 1876, at age 14, Ted began studying flintknapping with his Karuk uncle, Mus-sey-peu-ua-fich (Up River Coyote), who was a master flintknapper. As Ted's skill grew he became well known as a maker of the famous wealth blades used in the White Deerskin Dance. Ted had already been flintknapping for 32 years when, in 1911, Ishi "the last Yahi" met Alfred Kroeber (Harwood 2001; Kroeber 1961).

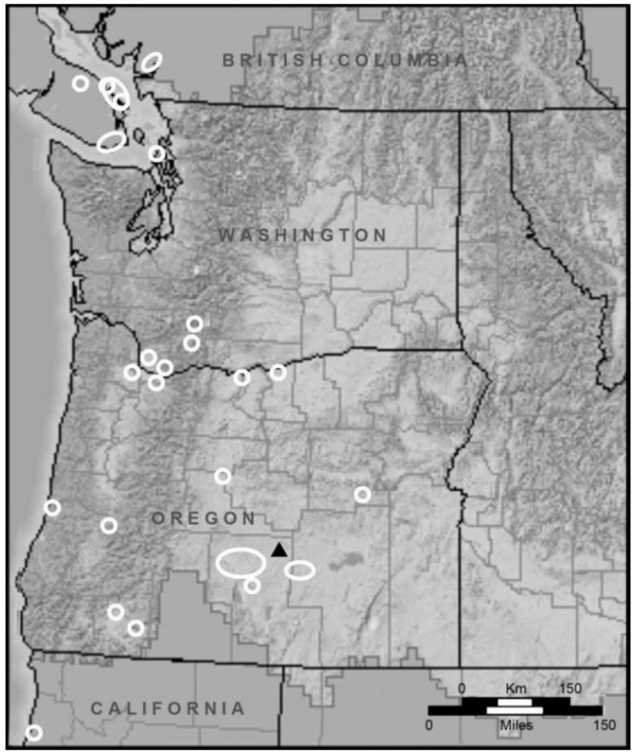

Figure 12-10. Distribution of Glass Buttes obsidian artifacts discussed in this chapter. Glass Buttes is marked with a triangle.

Figure 12-11. Karuk flintknapper Ted Orcutt circa 1940.

From the 1920s through the 1940s Ted made many trips to Glass Buttes to gather large pieces of obsidian and rough out bifacial cores for wealth blades and to fill his many flintknapping orders. Forbes (1936) writes that sometime within the first three decades of the 20th century he accompanied Orcutt on quarrying forays at Glass Buttes, carrying obsidian out on packhorses. He describes watching Orcutt make large bifaces, some 76 cm (30 in) or more in length (Forbes 1936; Mack 1975; Skinner 1983; Harwood 2001) (Figure 12-12).

Glass Buttes continues to be an important locale for obtaining high quality obsidian for the production of stone tools, as it has been for more than 14,000 years. Don Crabtree, widely acknowledged as the father of American lithic technology studies, and author of numerous articles, made collecting trips to Glass Buttes along with renowned lithic technologists Gene Titmus and J. Jeffrey Flenniken (Woods 2010). Many of the scenes in the Crabtree film series, *The Tools of Early Man*, were filmed at Glass Buttes. The first author personally accompanied the great lithic technologist and writer, Errett Callahan, on obsidian collecting trips to Glass Buttes. Since 1985, the annual Glass Buttes Spring Break Knap-in has taken place in March, with as many as 100 flintknappers attending yearly, and collecting obsidian at specific locations.

Protection

Although modern flintknappers tend to focus their knapping and quarrying activities to specific locales, as requested by the BLM, the impact is apparent. There is no specific protection plan written for Glass Buttes other than the rock hounding use policy in place on all BLM lands in the Code of Federal Regulations (CFR) under 43 CFR 8365, "Rules of Conduct" on public lands. It states that you are allowed to collect "reasonable amounts" for "non-commercial" purposes, not to exceed 113 kg (250 pounds) of raw material (not partially or completely prepared specimens) per person, per year. Sadly, some people unreasonably exploit this resource and take many hundreds of pounds at a time.

Researchers have made consistent types of recommendations regarding the archaeology of Glass Buttes over the years. Mack recommended a systemic inventory of a number of sites and test excavations at 41 sites at Glass Buttes for the high potential for providing chronological as well as resource use and site activity patterns (Mack 1975: 49-50). Churchill (1991: 78-110) recommended 14 sites as valuable cultural resources eligible for nomination to the National Register of Historic Places (Churchill 1991).

Lebow et al., in their 1990 Cultural Resource Overview for the BLM Prineville District, recommended that the Glass Buttes area be intensively surveyed and the sites be evaluated for inclusion in the National Register of Historic Places as a district (Lebow et al.: 187-188).

In spite of damage to ancient archaeological deposits from modern use, there is still tremendous archaeological potential at Glass Buttes as seen by the work of O’Grady’s and Thomas’s Clovis Quest Project in locating potential Clovis workshops (Scott Thomas, personal communication 2010, 2012). Other areas for future research include more extensive survey and sub-surface testing of sites in light of the 2006 work of Jenkins and Connolly, and the possibility of identifying additional lithic technological traditions and pre-Clovis activity. Advances in XRF technology make the re-evaluation of the geochemistry of artifacts at a number of sites important for the potential to gain new information, as was done at the Dietz Site (O’Grady et al. 2012). There is still much to learn about Glass Buttes.

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CHAPTER 13

Differential Selection of Lithic Raw Materials by Prehistoric Hunter-Gatherers in the Upper Yellowstone River Valley, Montana/Wyoming

Jacob S. Adams
Department of Anthropology, Washington State University (jacobsadams@gmail.com)

Douglas H. MacDonald
Department of Anthropology, University of Montana (Douglas.Macdonald@mso.umt.edu)

Procurement strategies of lithic raw materials are an integral part of the lithic technological organization of prehistoric hunter-gatherers. With the early beginnings of lithic technology studies**,** a debate emerged in the archaeological literature regarding the organizational and scheduling events of procuring lithic raw materials (Binford 1979; Gould and Saggers 1985). Differential patterns of raw material procurement were observed in middle range studies (Binford 1980; Schiffer 1972) and were utilized by archaeologists to estimate the organizational strategies of individuals in prehistory. However, these early debates occasionally neglected the most important part in the equation of lithic raw material procurement, the raw material source. As suggested by Andrefsky (1994a, 1994b) and Elston (1992), various extrinsic attributes are important to examine to understand lithic technological organization of hunter-gatherers, including lithic raw material morphology, quality, and availability. An examination of these attributes in the form of a quantitative gravity model (Wilson 2007), coupled with the ethnographic data, can provide a means of differentiating raw material procurement strategies.

In this paper**,** we attempt to evaluate the context in which prehistoric hunter-gatherers conducted lithic raw material procurement activities in the Gardiner Basin, Montana/Wyoming, in light of Binford's (1979) embeddedness concept. In so doing, we examine two raw material procurement areas in Yellowstone National Park, Wyoming: Obsidian Cliff obsidian and Crescent Hill chert. These two sources of stone were used most frequently by prehistoric hunter-gatherers that lived at two archaeological sites in the lowest, driest portion of Yellowstone National Park, Montana, the Yellowstone Bank Cache Site and the Airport Rings Site (Figure 13-1). At both of the archaeological sites, Obsidian Cliff obsidian represents the most common lithic raw material, with Crescent Hill chert representing the second most common material.

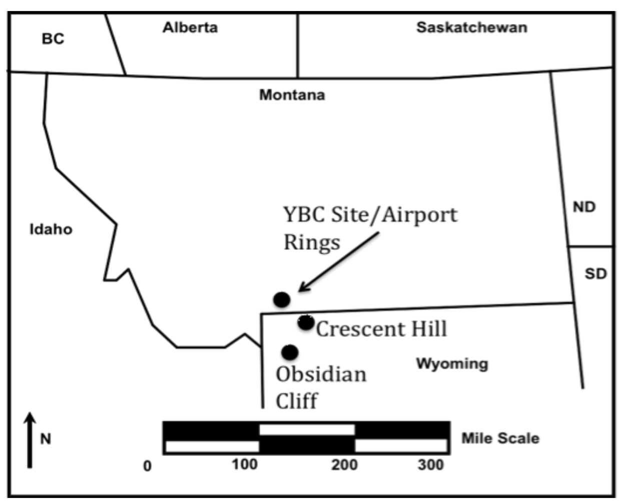

Figure 13-1. Location of areas discussed in text.

To evaluate the overall advantages of procuring material from one source over the other, various attributes were quantitatively examined in a gravity

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model. The remainder of this paper provides an overview of procurement strategies in the lithic technological organization literature. Subsequently, both raw material procurement areas in northwestern Wyoming will be discussed regarding basic attributes in the context of the two archaeological sites in the Gardiner Basin, Montana. Lastly, we review the arguments for why this provides a good case study for looking at differential procurement of raw materials.

Raw Material Procurement Strategies

With the genesis of lithic technological organization, the organizational and scheduling events of procuring lithic raw material has become a major topic of debate in the archaeological literature. During Binford's ethnoarchaeological work**,** he examined raw material procurement strategies among the Nunamiut and the Alyawara (Binford 1979, 1980; Binford and O'Connell 1984). He defined two types of procurement strategies, embedded and direct. Embedded strategies represent the procurement of raw materials when other tasks are being performed (e. g. subsistence tasks). Ethnographically, Binford (1979:259) provides an example of this among the Nunamiut:

> …a fishing party moves in to camp at Natvatrauk Lake. The days are very warm and fishing is slow, so some of the men may leave the others at the lake fishing while they visit a quarry in Nassaurak Mountain, 3. 75 miles to the southeast. They gather some material there and take it on top of the mountain to reduce it to transportable cores. While making the cores they watch over a vast area of the Anaktuvuk valley for game.

As seen from the example above there was no special trip for the procurement of raw material but instead it was "embedded" within a subsistence task, and even when the material was being reduced, it was accomplished at a location where hunting was the main site activity, not lithic reduction. The embeddedness concept represents the behavioral strategies of the Nunamiut and shows that procurement of raw materials was of secondary importance to hunting game. Direct strategies, on the other hand, assume that individuals travel for the specific task of obtaining raw material with no subsistence tasks in mind (Gould 1985) (see Figure 13-2).

With the two strategies of raw material procurement posited, a debate in the archaeological literature emerged between Lewis Binford (Binford 1979, 1985, 1989; Binford and Stone 1985) and Richard Gould (Gould 1985; Gould and Saggers 1985) regarding the soundness of these terms. Binford (1979:259, emphasis in original) states that, "*very rarely, and then only when things have gone wrong, does one go out into the environment for the express and exclusive purpose of obtaining raw material for tools.* " However, Gould et al. (1971) propose that direct procurement of raw materials occurred commonly among aborigines in the central desert of Australia.

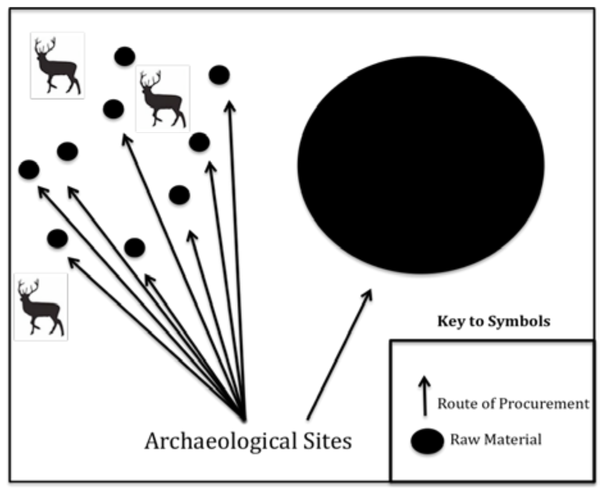

Figure 13-2. Embedded compared to Direct Procurement.

Gould and Saggers (1985) argued this point by examining the procurement strategies of aborigines of the central desert of Australia and the amount of variability in material types observed at archaeological sites. They posit objections to Binford's view that procurement is only associated with subsistence activities and suggest that the procurement of raw materials may be tied to social factors that may reflect the technological needs of individuals, for instance, establishing kinship networks to accommodate for the risk of living in the harsh desert environment. From their standpoint there were specific trips for the sole purpose of obtaining lithic raw material, deemed the "righteous-rock" argument. Gould and Saggers (1985:120) state that:

> In contrast to the Nunamiut, there is ample evidence that Western Desert Aborigines made special efforts to visit lithic sources. Usually as part of a visit to an adjacent site, but sometimes, too, in order to obtain raw material that was known to have superior technical properties.

That said, both Binford and Gould agree that embedded raw material procurement is the most common of the strategies. This makes the most sense from a standpoint of overall task management and efficiency when moving on the landscape. However, Seeman (1994) looked at early Paleoindian lithic use at the Nobles Pond site in Ohio and concluded that procurement of raw materials was a “disembedded” task. He states that, “the acquisition of lithic raw material was not embedded in subsistence behavior, but rather, was a specialized activity required by the particular demands of band aggregation in a location far removed from sources of acceptable lithic materials” (Seeman 1994:273).

Attributes of Raw Material Procurement

Since the Binford-Gould debate, as well as important studies by Schiffer (1972) and Andrefsky (1994a, 1994b), the study of technological organization and lithic raw material procurement has emerged as a major research focus for archaeologists in North America (Andrefsky 2008; MacDonald 2009; Nelson 1991). Comparing lithic raw material sources is often difficult and can be subjective in nature. However, there are certain attributes that can be examined to determine the overall quality of a source and the economic value of exploiting the source. Elston (1992) postulates several “extrinsic cost factors” that remove some of the subjectivity of the examination of quality of a raw material source. These extrinsic cost factors include quality, abundance, distribution, and mode of occurrence of lithic raw material on the landscape. In a similar thread, Andrefsky (1994a, 1994b) has viewed the roles raw material size, shape, quality, and availability play in hunter-gatherer decision-making strategies. There are also human “factors” in the decision-making involved with the procurement of raw materials such as difficulty of terrain (Raven 1992; Wilson 2007). These factors deal with social organization, mobility patterns, provisioning strategies, and territorial limits (Wilson 2007). Both “extrinsic cost factors” and human factors will now be examined in regard to Obsidian Cliff and Crescent Hill.

Obsidian Cliff vs. Crescent Hill

Obsidian Cliff is an obsidian source in northwestern Wyoming that was continuously visited throughout prehistory for the purpose of obtaining high quality lithic raw material. Regional studies of lithic raw material use indicate the importance of obsidian from Obsidian Cliff as a toolstone source in prehistory (Davis et al. 1995; MacDonald and Hale 2011; Scheiber and Finley 2011). That said, the material was not just localized to the Greater Yellowstone Ecosystem, but has been found across North America. For instance, 300 kg of Obsidian Cliff obsidian was found cached at a Hopewell site 680 km away in the midwestern United States (Davis et al. 1995:57).

In regard to quality, Obsidian Cliff represents an extremely homogenous, isotropic source of raw material (Figure 13-3). As seen from the example shown here, hunter-gatherers went to great lengths to obtain the material in prehistory. When a stone is highly siliceous, homogeneous, and isotropic in character, it can be considered a valuable commodity for peoples manufacturing stone tools (Cotterell and Kamminga 1987). Andrefsky (2005:24) states that, “stones most suitable for flintknapping are those that are brittle and do not have direction-dependent properties such as bedding planes, fissures, cracks, or inclusions…natural glass or obsidian is probably the best example of this kind of material. ”

Figure 13-3. Obsidian Cliff obsidian.

Not only is the quality of obsidian at Obsidian Cliff very high, availability of the stone was also great, with the material found in abundance across approximately a square kilometer area in northwest Wyoming (Davis et al. 1995). Across this area, obsidian is available in large nodules that have eroded out of the cliff face, material in the cliff face, as well as access to bedrock at the top of the outcrop area. The overall distribution of the material is also ideal, with the outcrop area representing a densely concentrated source on the landscape. For the human factor of the equation, distance plays a major role in how far people were willing to go to obtain materials. In the case of Obsidian Cliff, it was likely only accessed during snow-free times, due to the substantial accumulation of snow on the Yellowstone Plateau in winter.

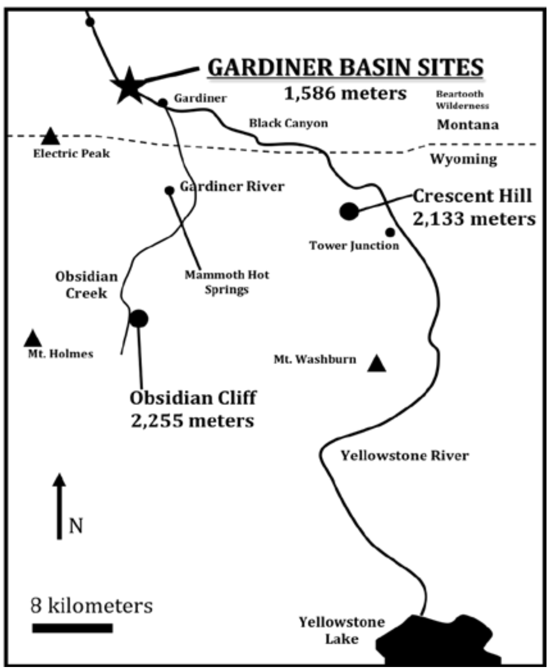

Figure 13-4. Location of procurement areas in regard to sites.

In relation to the two sites in our study, Obsidian Cliff is located approximately 41 kilometers south of the Yellowstone Bank Cache Site and Airport Rings Site (discussed below) and would have been accessed following the Yellowstone River upstream, then heading south following the Gardiner River (Figure 13-4). To gain access to Obsidian Cliff from the Gardiner Basin there is an approximate elevation gain of 669 meters, with the most elevated part of the journey being from the Gardiner Basin to the Swan Lake Flat area. From that point on, a fairly constant elevation prevails along Obsidian Creek to the cliff itself (see Figure 13-4).

There are two contexts in which Crescent Hill chert occurs within its source area of northwestern Wyoming: 1) eroding from hill tops or knobs; and 2) as chert lenses within the Crescent Hill columnar basalt formation (Adams 2011) (see Figure 13-5). Geodes are found ubiquitously across the landscape, displaying a high quality fibrous chalcedony precipitate. Chert found within the Crescent Hill basalt formation and eroding from hilltops presents itself in a variety of colors and textures. The chert ranges in colors of purples, reds, greens, and browns. Overall, the quality of the material is extremely variable, with very high quality milky white chalcedonies surrounding a macrocrystalline structure, to homogenous red jaspers, to coarse-grained poor quality green cherts.

Figure 13-5. Crescent Hill chert.

In regard to quality, Crescent Hill chert is extremely heterogeneous with a continuum ranging from fine-grained to almost unworkable coarse-grained materials. Even though these materials are not as isotropic in character as obsidian, they still provide options for individuals procuring raw materials.

Looking at the abundance of Crescent Hill, it is fairly limited compared to Obsidian Cliff; it is not a dense source but rather patchy across the landscape (see Figure 13-6) and occurs in nine distinct locations. On average, distance between the nine procurement areas is approximately 1. 6 kilometers, which emphasizes the sporadic nature of the chert on the landscape, and highlights the search costs for the raw material. The material is available within outcrop areas, eroding from outcrop areas as well as in the morphological form of tabular and rounded amorphous nodules on hilltops, varying in size and quality. Crescent Hill chert does not occur in a dense concentration as Obsidian Cliff does, but is dispersed across the landscape in different geological contexts.

Based on its availability as described above, locating the highest quality Crescent Hill materials would have been a difficult task at best. The overall density of the material should be considered low, as it is scattered across an 8. 6-km^2 area.

Figure 13-6. Extent of Crescent Hill chert procurement area.

As with Obsidian Cliff, Crescent Hill is also located upon the Yellowstone Plateau, limiting its access to warm weather months. To gain access to Crescent Hill from the sites in our study near Gardiner, Montana, people would have followed the Yellowstone River eastward through the Black Canyon of the Yellowstone approximately 32 kilometers until feeder streams allowed for upland access to the source. To access the source, an overall elevation gain of between 395-750 m would have occurred (MacDonald et al. 2010). Of the two sources, Crescent Hill would have been the easiest to access from the Gardiner Basin, but the lithic material was less abundant and more difficult to find on the landscape. In terms of material quality, Crescent Hill chert is also characterized as an inferior stone to Obsidian Cliff obsidian. Both sources provide raw materials, but hunter-gatherers would have had to weigh the economics of procuring them (see Table 13-1).

While the above discussion provides a subjective evaluation of the two lithic materials attributes, we use a gravity model to quantitatively

Table 13-1. Attributes of Raw Material Procurement Areas.

Factors	**Obsidian Cliff**	**Crescent Hill**
Quality	High quality, isotropic, homogeneous material	Low-High quality, heterogonous material
Abundance	High	Low-Medium
Distribution	Consolidated to one area	Patchy

assess the two raw material procurement locations. Gravity models are often used in economic contexts to evaluate the attractiveness of one region over another for marketing purposes. For instance, an entrepreneur will evaluate the costs and benefits of numerous factors prior to establishing a new business in one location or another. The type of people living in the area, the other businesses around the area, and the type of neighborhood are all important factors in the business decision. Wilson (2007) applied a similar model she refers to as the attractiveness equation, to evaluate the benefits of procuring one lithic raw material source over another. It allows a quantitative, economic, cost-benefit analysis to be applied to a source area (Figure 13-7). This model has had very few, if any, uses in the archaeological literature, but is highly pertinent to examining raw material procurement strategies in quantitative terms.

$$A(s)=\frac{(\text{quality})(\text{extent of source})(100)}{(\text{difficulty of terrain})(\text{cost of extraction})}\times\frac{\text{size}}{\text{scarcity}}$$

Figure 13-7. Wilson's (2007) Attractiveness Equation.

The equation determines the overall attractiveness of one raw material source over another by looking at variables such as quality of material and difficulty of terrain to obtain the material. These variables are summarized below in Table 13-2 for prehistoric hunter-gatherers living in the Gardiner Basin of Montana. Quality is ranked numerically on a scale from very poor to excellent (see Wilson 2007 for further discussion). Extent of source is characterized in regard to size in meters, ranging from small to very extensive. Size looks at the morphological dimensions of the largest pieces of raw material available at the outcrop. Scarcity looks at the amount of raw material at a procurement location and ranges from very abundant to scarce. Difficulty of terrain looks at the

Table 13-2. Quantitative Evaluation of Major Lithic Raw Material Sources for Occupants of Gardiner Basin Sites after Wilson 2007.

Source	Quality Rank (0-16)	Extent of source (1-4)	Size (max dimension in cm)	Scarcity (1-4)	Difficulty of Terrain (calories)	Cost of Extraction (1)	Attractiveness Score
Obsidian Cliff	16	4	100 cm	1	2080 cal	1	307. 7
Crescent Hill	8	2	25 cm	3	1600 cal	1	8. 3

number of calories per kilometer necessary for an individual to walk to a source location. Lastly, cost of extraction takes into account the cost of extracting material from the actual source area (Wilson 2007). In the end, an overall attractiveness score is calculated for the lithic raw material source based on the source's location compared to the sites in question (in this case, the Gardiner Basin).

As reflected in Table 13-2, we quantified the six extrinsic cost factors of the two lithic raw material procurement sources used most frequently by inhabitants of the Gardiner Basin, Montana, in prehistory (results discussed below). Based on this assessment, Obsidian Cliff yielded an attractiveness score of 307. 7, while Crescent Hill achieved a score of 8. 3. In every case, except for difficulty of terrain, Obsidian Cliff was deemed superior to Crescent Hill chert, dominating in all categories, including material quality, extent of source, material size/morphology, scarcity, and cost of extraction. The very high overall attractiveness score may explain that the high extrinsic values of Obsidian Cliff obsidian likely encouraged hunter-gatherers to differentially prefer it during prehistory, despite the closer proximity and increased ease of access of Crescent Hill chert (see Figure 13-8).

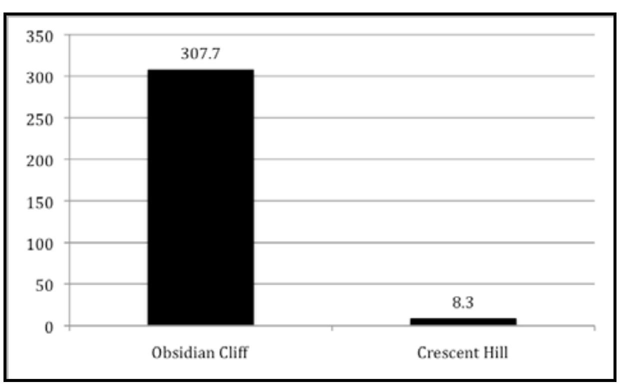

Figure 13-8. Bar graph showing attractiveness scores.

As discussed below, these two lithic raw material types—Obsidian Cliff obsidian and Crescent Hill chert—dominate the archaeological assemblages in the Gardiner Basin. To determine the source provenance of artifacts from collections, it was necessary to implement characterization studies (Hughes 2008a, 2008b, 2008c). The volcanic Obsidian Cliff obsidian was geochemically-identified through energy-dispersive x-ray fluorescence (edxrf). This technique penetrates the surface of a rock specimen and allows for the characterization of trace elements for specific volcanic sources of rock. Archaeological specimens can then be directly linked to their geologic sources via edxrf. For this study, Hughes (2008a, 2008b, 2008c) examined a total of 60 obsidian and dacite specimens from the study area, including 27 Late Archaic artifacts (MacDonald and Maas 2011:67) and 33 Late Prehistoric artifacts (Livers 2011:83).

In regard to Crescent Hill chert, 139 hand samples from the procurement area were collected and matched to artifacts in the assemblages using macroscopic visual traits. Macroscopic traits outlined by Luedtke (1992) were taken into account, including translucency, luster, texture, structure, as well as the morphological appearance of the specimen. A detailed look at the structure or fabric of the hand samples was also recorded noting inclusions, stringers, striations, streakers, and mottles (Adams 2011). This allowed for a reliable method of associating artifacts at the archaeological sites back to their original provenance.

The Archaeological Sites

Given the extrinsic cost factors discussed above, we can predict that hunter-gatherers of the Gardiner Basin of Montana/Wyoming would have differentially preferred to use Obsidian Cliff obsidian compared to Crescent Hill chert. At prehistoric sites in the Gardiner Basin, we should expect to see increased use of the obsidian versus chert. As such, we now look at the differential use of lithic raw material and two sites located in the Gardiner Basin of Yellowstone National Park in Montana (Adams et al. 2011). Each site has well dated hearth features that allow for a comparison of lithic raw material use between the Late Archaic (3,000-1,500 B. P.) and Late Prehistoric (1,500-300 B. P.) time periods. For a complete overview of these sites, see MacDonald (2007), MacDonald et al. (2010), MacDonald and Maas (2011) and Livers (2011).

The Yellowstone Bank Cache Site is located along the upper banks of the Yellowstone River in the Gardiner Basin portion of Yellowstone National Park, Montana. The site is representative of "…an intensive series of Late Archaic occupations, suggesting patterned subsistence and land-use in the Upper Yellowstone River Valley during the Late Archaic period" (MacDonald et al. 2010). With a correlation between four radiocarbon dates, as well as three Pelican Lake projectile points, there are solid data to support Late Archaic occupations. A total of 18 prehistoric features were identified during survey and excavation. Four of the roasting pit features were excavated, yielding a total of 1,490 lithic artifacts and 1,391 faunal remains.

Overall, the substantial amount of lithic artifacts and faunal remains that were recovered at the sites indicate that this was an area associated with intensive lithic reduction and subsistence activities (MacDonald et al. 2010). From the lithic assemblage at this site, the Late Archaic features indicate variable use of both Crescent Hill chert and Obsidian Cliff obsidian (Figure 13-9). One outlier was the high presence of more than 400 Crescent Hill chert flakes, side by side, with a similar amount of obsidian flakes in Feature 36 at YBC. The overall trend for these lithic data from the Late Archaic features at YBC is approximately 25 percent Crescent Hill, nearly 65 percent Obsidian Cliff, and a remainder of other material types.

The Airport Rings Site is a Late Prehistoric site with 11 stone circles situated on a terrace above the Yellowstone River in the Gardiner Basin of Yellowstone National Park (Livers 2011). In 2008, the University of Montana excavated three stone circles identifying three subsurface hearth features, two of which exhibited Late Prehistoric

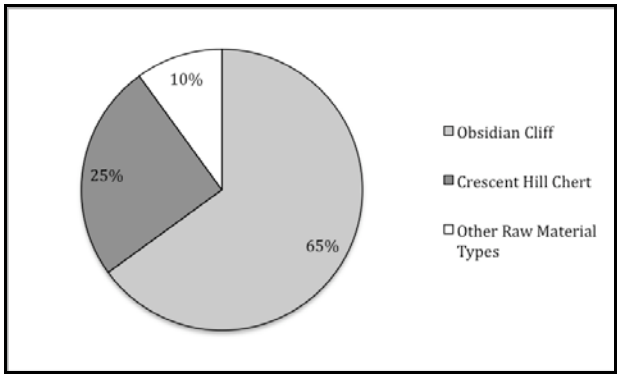

Figure 13-9. Use of Crescent Hill chert and Obsidian Cliff obsidian at Yellowstone Bank Cache site during the Late Archaic.

radiocarbon dates. Livers and MacDonald (2010) point out that the site is a "multi-component, stratified, tipi ring site consisting of two occupation levels, with both Late Prehistoric dates (300-400 B. P.) and a Middle Archaic date (5300 B. P.). " As with the YBC Site, Obsidian Cliff obsidian and Crescent Hill chert were the most prevalent raw material types in the archaeological assemblage from the Airport Rings Site (Figure 13-10). However, during this period there is an even stronger trend toward the use of obsidian. Overall, obsidian accounts for 80 percent of the assemblage with Crescent Hill chert representing only 13 percent, with a remainder of other raw material types.

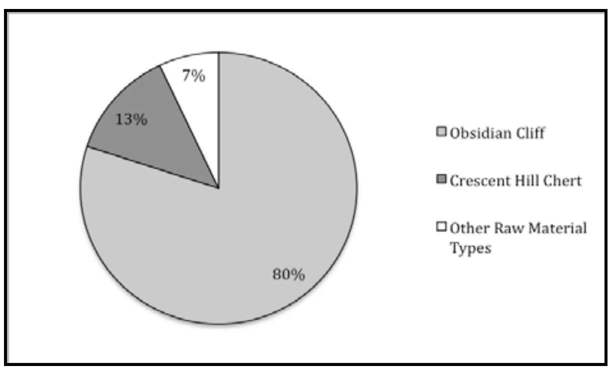

Figure 13-10. Use of Crescent Hill chert and Obsidian Cliff obsidian at the Airport Rings site during the Late Prehistoric.

Summary and Conclusions

Hunter-gatherers from the Gardiner Basin used the Yellowstone Plateau—including Obsidian Cliff and Crescent Hill chert—seasonally, incorporating trips to Yellowstone Lake to the south during warmer months (Nabakov and Loendorf 2002:67-68; see Figure 13-3). The most convenient route to the lake was via the Yellowstone River Valley which took hunter-gatherers past the Crescent Hill chert source directly south to the lake. However, it is clear that many hunter-gatherers chose to use the Gardiner River to Obsidian Creek route to get to the lake, with the main reason likely being the attraction of Obsidian Cliff along the way. The high percentages of Obsidian Cliff obsidian at archaeological sites along the northern shore of Yellowstone Lake—80 percent on average (MacDonald et al. 2012)—support this likely travel route. While this activity can be interpreted as a form of embedded procurement within a seasonal round, hunter-gatherers clearly diverged from the expected and easier travel route to the lake in order to have access to Obsidian Cliff obsidian. Thus, while Crescent Hill chert was clearly an embedded (casual collection) phenomenon on a logically-advantageous travel route to Yellowstone Lake, the choice of collecting Obsidian Cliff obsidian was intentional and more akin to direct procurement.

When evaluating Obsidian Cliff obsidian and Crescent Hill chert, in regard to raw material attributes, it is clear that Obsidian Cliff represents the logical choice for hunter-gatherers in prehistory. It is of the highest quality raw material found, high in abundance and densely consolidated, making it easy to find. Crescent Hill, while comparatively easy to access on travel routes along the Yellowstone River, is extremely variable in quality, low-medium in abundance, and scattered across the landscape. For travel to and from the raw material procurement locations, they both would have been very similar, with the trip to Crescent Hill probably a bit less strenuous and conveniently on the way to the popular Yellowstone Lake. This makes the examination of the variables influencing the procurement of raw material an important factor in hunter-gatherer decision making.

In the archaeological contexts it is apparent that obsidian was the preferred raw material type. As indicated by the hearth features, this trend increases significantly from the Late Archaic to the Late Prehistoric. At the YBC Site, during the Late Archaic, the overall mean average of Crescent Hill chert was 25 percent; at the Airport Rings Site during the Late Prehistoric the average tapered down to 13 percent. Obsidian, on the other hand, at the YBC Site during the Late Archaic had an overall mean of 65 percent and increased at the Airport Rings Site to 80 percent during the Late Prehistoric. Another line of evidence in regard to the cultural use of Crescent Hill chert and Obsidian Cliff obsidian is from the projectile points found in the Gardiner Basin; with 93 points being recovered, obsidian accounts for 67 percent with Crescent Hill chert accounting for 20 percent of the total collected points.

Not only was Obsidian Cliff obsidian the preferred material, its heightened quality, availability and other extrinsic cost factors likely pushed it into the realm of direct procurement. The attractiveness of the material forced people to reconsider traveling southward into the Yellowstone Plateau along the major waterway—the Yellowstone River—and instead using the more difficult and less intuitively advantageous route along the Gardiner River and Obsidian Creek. While Crescent Hill chert procurement was likely an embedded phenomenon during the occasional use of the Yellowstone River Valley corridor, obsidian from Obsidian Cliff clearly was directly targeted during prehistory, as witnessed by the significantly greater use of it at the Late Archaic and Late Prehistoric sites discussed above in the Gardiner Basin.

With the overall geographic distribution of the material, Obsidian Cliff obsidian was not just sought after by local hunter-gatherers, but also by other people from other regions as well. In this sense, Obsidian Cliff obsidian became a trade commodity, not just a material to be used in stone tool manufacture.

Crescent Hill may be the second most abundant material type in the archaeological contexts in the Gardiner Basin, but it is a far second from Obsidian Cliff. It is extremely variable in quality, scattered, and patchy across the landscape, which would make it a non-destination area to procure raw materials. For these reasons, Obsidian Cliff obsidian was preferred by residents of the Gardiner Valley in Montana despite it being more distant and more challenging in terms of travel routes compared to Crescent Hill chert. The results of the gravity model applied above confirm that Late Archaic and Late Prehistoric hunter-gatherers of the Gardiner Basin weighed the extrinsic cost factors of lithic raw material procurement and preferred to collect and use Obsidian Cliff obsidian, going out of their way to procure it during their travels within the Yellowstone Plateau.

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CHAPTER 14

Obsidian Use in the Willamette Valley and Adjacent Western Cascades of Oregon

Paul W. Baxter and Thomas J. Connolly
University of Oregon Museum of Natural and Cultural History (pbaxter@uoregon.edu; connolly@uoregon.edu)

Craig E. Skinner
Northwest Research Obsidian Studies Laboratory (cskinner@obsidianlab.com)

Introduction

Interaction spheres recognized throughout the Plateau (Hayden and Schulting 1997) and Pacific Northwest Coast (Ames and Maschner 1999; Carlson 1994; Galm 1994; Hughes and Connolly 1999) have been seen as critical in the evolution of the complex Northwest Coast cultural expression (Ames 1994:213). Tracking such exchange archaeologically is complicated to the extent that it involved perishable or consumable goods that have left no trace. But commodities such as obsidian, which is both commonly present in archaeological contexts in the region and easily traceable to source, provide an important tool in mapping long-distance economic links.

Previous obsidian characterization studies have speculated that the distribution of obsidian in western Oregon was due to direct procurement and trade (Musil and O'Neill 1997; Skinner and Winkler 1991, 1994). Ames (1994) argues that the maintenance and persistence of Chinook corporate households along the Columbia River required the acquisition and production of many resources to attract and retain members (Ames and Maschner 1999:148). Chiefs and other elites of the household were dependent on a prestige-based socio-economic system to expand their influence (Ames 2006; Silverstein 1990). One vital route to increased prestige was the control of trade, particularly in wealth and sumptuary goods. Such goods are "often of exotic or rare raw materials…not locally available or only in small amounts" (Ames and Maschner 1999:180). On the Northwest Coast, one such material is obsidian, which is visually distinctive, easily redistributed, and could be used to create more prestige goods for the household's elites.

Because of its trackability, obsidian characterization studies have been integral to defining interaction spheres extending well into prehistory (Ames 1994:223). The issue we explore here is the extent to which people of the Willamette Valley participated in the regional exchange networks. The large site-to-site variations seen in the frequencies of Inman Creek and Obsidian Cliffs obsidians, especially in the lower Willamette Valley, imply their distribution as commodities, rather than natural deposition. The implication is that Willamette Basin peoples were active participants in regional socio-economic interaction spheres

The basis for this analysis is a large body of obsidian geochemical characterization data from the Willamette Basin of northwest Oregon (Figure 14-1). The bulk of the obsidian data was collected by the Northwest Research Obsidian Studies Laboratory (Skinner 2011), but was then augmented from various published and unpublished sources. Archaeological investigations sponsored by the Willamette National Forest (Kelly 2001; Lindberg-Muir 1989), a gas pipeline through the

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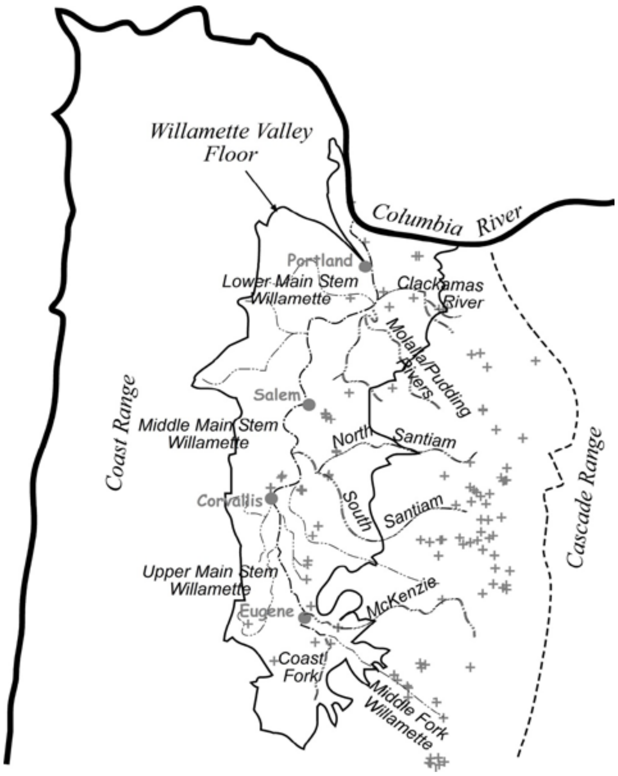

Figure 14-1. Location of the Willamette Basin study area with subbasins, cities, and sites (+) noted. The Willamette Valley is outlined at approximately 150 m (500 ft) elevation.

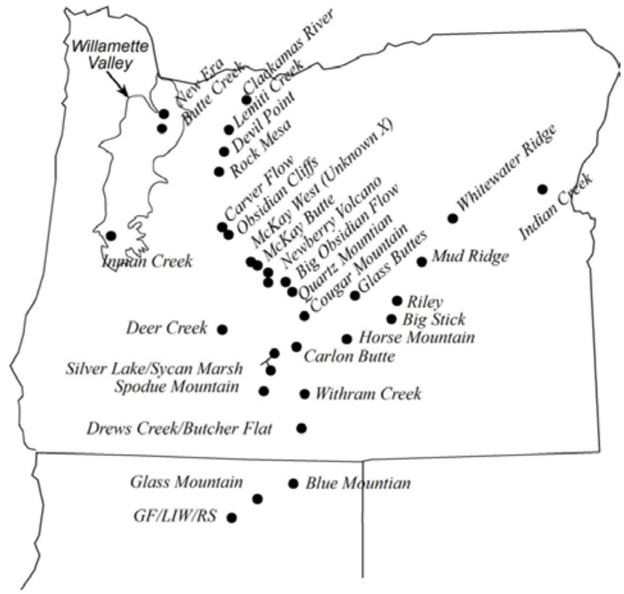

Figure 14-2. Location of obsidian sources identified in the study assemblage.

valley (Fagan et al. 1996), and a number of highway projects (Connolly nd; O'Neill et al. 2004) produced the majority of the data. It is generally true that these data were largely collected opportunistically to address resource management concerns rather than to meet the criteria of an overarching research design. Thus sampling criteria varied, coming from well controlled excavations, reconnaissance shovel probes, and single-visit surface collections, and the artifacts include both debitage and shaped-tools.

We drew on a total of 5624 specimens from 251 sites and isolates representing 32 known sources that were available for this study. However, because we rely on proportional data for this study, we eliminated sites with fewer than ten sampled specimens, a tactic which reduced the total to 5240 artifacts from 116 sites, representing 27 sources (Tables 14-1, 14-2, and 14-3).

Within the study assemblage, 45 percent of the obsidian is from Obsidian Cliffs in the Cascade Range, 31 percent is from the Willamette Valley's Inman Creek geochemical type, and 15 percent comes from five smaller Willamette Basin sources. Together, 90 percent of the characterized obsidian comes from sources in the Willamette hydrologic basin (Figure 14-2).

The Setting

The Willamette Valley is a large structural basin which lies between the Cascade and Coast mountain ranges in northwest Oregon. Beginning in the south at an elevation of about 120 m (400 ft), the river meanders north for approximately 209 km (130 mi) to its confluence with the Columbia River in the Portland Basin. Along the way it collects the outflow of 14 tributary rivers, nine from the Cascades, and five from the Coast Range. The extremely flat plane, which varies from 32 to 64 km (20-40 mi) wide, is the bottom of Pleistocene Lake Allison formed by Missoula Flood waters which repeatedly inundated the valley between 15,500 and 13,000 years ago (Orr et al. 1992). As Pleistocene glaciers retreated, lake levels declined, and great volumes of outwash cut a new course for the Willamette River as it deposited outwash gravels. Scattered within the gravels of the Middle Fork, McKenzie and main-stem Willamette Rivers are cobbles and pebbles of Inman Creek and Obsidian Cliffs obsidian. The extent of the secondary dispersal of Inman Creek and Obsidian Cliffs obsidian is not completely understood, but pebbles

Table 14-1. Frequency of Geochemical Obsidian Sources Represented in the Assemblage.

Geographic Source Group	Geo. Src Grp Overall Count	Geo. Src Grp Study Count[1]	Obsidian Types	All Sourced Artifacts Count	All Sourced Artifacts percent Group	All Sourced Artifacts percent Total	Study Assemblage Count	Study Assemblage percent Group	Study Assemblage percent Total
Willamette Valley	1780	1665	Inman Creek	1719	97	30.6	1608	97	30.7
	31.7%	31.8%	Butte Creek	59	3.3	1.05	57	3.4	1.09
			New Era	2	0.1	0.04	0		
Cascade Range	3282	3066	Obsidian Cliffs[2]	2489	76	44.3	2330	76	44.5
	58.4%	58.5%	Devil Point	476	15	8.46	436	14	8.32
			Clackamas River	267	8.1	4.75	259	8.4	4.94
			Carver Flow	34	1	0.6	33	1.1	0.63
			Rock Mesa	8	0.2	0.14	8	0.3	0.15
			Lemiti Creek	8	0.2	0.14	0		
Upper Deschutes Basin	222	197	Newberry Volcano	126	57	2.24	110	56	2.1
	3.95%	3.76%	Quartz Mountain	30	14	0.53	26	13	0.5
			Cougar Mountain	28	13	0.5	26	13	0.5
			McKay Butte	24	11	0.43	22	11	0.42
			McKay Butte West	11	5	0.2	11	5.6	0.21
			Big Obsidian Flow	3	1.4	0.05	2	1	0.04
Klamath Basin	226	220	Silver Lake/Sycan Marsh	172	76	3.06	170	77	3.24
	4.02%	4.2%	Spodue Mountain	47	21	0.84	43	20	0.82
			Deer Creek	4	1.8	0.07	4	1.8	0.08
			Drews Creek/Butcher Flat	1	0.4	0.02	1	0.5	0.02
			Carlon (Bald Butte)	1	0.4	0.02	1	0.5	0.02
			Witham Creek	1	0.4	0.02	1	0.5	0.02
Harney Basin	11	7	Big Stick	3	27	0.05	3	43	0.06
	0.2%	0.13%	Glass Buttes	4	36	0.07	2	29	0.04
			Riley	2	18	0.04	1	14	0.02
			Horse Mountain	1	9.1	0.02	1	14	0.02
			Mud Ridge	1	9.1	0.02	0		
NE Oregon	6	2	Whitewater Ridge	4	67	0.07	2	100	0.04
	0.11%	0.04%	Indian Creek	1	17	0.02	0		
			Wolf Creek	1	17	0.02	0		
NE California	8	8	Glass Mountain	4	50	0.07	4	50	0.08
	0.14%	0.15%	GF/LIW/RS	3	38	0.05	3	38	0.06
			Blue Mountain	1	13	0.02	1	13	0.02
Unknown	89	75	Unknown	89	100	1.58	75	100	1.43
	1.58%	1.43%							
Total	5624	5240		5624			5240		
Percent	100	100			100	100		100	100

[1]The study subset consists of only those sites with a sample of 10 or more characterized artifacts.
[2]Secondary source of Obsidian Cliffs and Carver Flow obsidians are the McKenzie and Willamette Rivers gravels.

Table 14-2. Percent of Subbasin[1] Obsidian By Obsidian Type.

Obsidian Type	Lower Willamette	Tualatin	Middle Willamette	Upper Willamette	Coast Fork	Clackamas	Molalla - Pudding	North Santiam	South Santiam	McKenzie	Middle Fork Will.	Total
Willamette Valley												
Inman Creek	67.81	31.6	88	64.2	43.9	0.62	22.7	23.4	1.9	1.11	22	
Butte Creek			1.2			0.62	21.3					
Cascade Range												
Obsidian Cliffs	14.59	36.8	6.77	31.6	48.5	30	51.1	43.6	83.9	87.6	37.9	
Carver Flow	0.858		1	2.7		0.21				0.48	0.11	
Rock Mesa										1.27		
Devil Point	1.717		1.59	0.64		5.97	3.11	30.3	13.5	7.62		
Clackamas River	3.004					51.6	0.44					
Upper Deschutes												
McKay Butte								0.23		0.48	2.22	
Newberry Volcano	1.29	31.6	0.2	0.26	1.52	3.09	0.44	0.23	0.57		8.09	
Big (Buried) Obs. flow											0.22	
Quartz Mountain	0.43					0.41					2.55	
Cougar Mountain									0.19		2.77	
McKay Butte West (Unk X)						2.26						
Klamath Basin												
Deer Creek											0.44	
Silver Lake/Sycan Marsh	0.43		0.4	0.39							18.2	
Spodue Mountain	1.72		0.2								4.21	
Witham Creek											0.11	
Drews Creek/Butcher Flat											0.11	
Carlon (Bald) Butte								0.11				
Harney Basin												
Horse Mountain						0.21						
Glass Buttes	0.86											
Big Stick	1.29											
Riley			0.2									
NE Oregon												
Whitewater Ridge						0.41						
NE California												
GF/LIW/RS	0.86		0.2									
Glass Mountain	1.72											
Blue Mountain											0.11	
Unknown	3.43		0.2	0.26	6.06	4.53	0.89	2.07		1.43	1	
Total Percent	100	100	100	100	100	100	100	100	100	100	100	
Total Study Sample	233	19	502	779	66	486	225	871	527	630	902	5240
Percent Study Assemblage	4.45	0.36	9.58	14.9	1.26	9.27	4.29	16.6	10.1	12	17.2	100
Number of Sites	5	1	7	15	3	12	2	22	11	19	19	116

[1]Willamette Basin subbasins arranged west side, north to south, then east side, north to south starting with Clackamas.

Table 14-3. Percent of Obsidian Type by Subbasin.

Obsidian Type	Lower Willamette	Tualatin	Middle Willamette	Upper Willamette	Coast Fork	Clackamas	Molalla – Pudding	North Santiam	South Santiam	McKenzie	Middle Fork Will.	Number of Sites	Total
Willamette Valley													
Inman Creek	9.83	0.37	27.5	31.1	1.8	0.19	3.17	12.7	0.62	0.44	12.3	61	100
Butte Creek			10.5			5.26	84.2					5	100
Cascade Range													
Obsidian Cliffs	1.46	0.3	1.46	10.6	1.37	6.27	4.94	16.3	19	23.7	14.7	106	100
Carver Flow	6.06		15.2	63.6		3.03				9.09	3.03	10	100
Rock Mesa										100		1	100
Devil Point	0.92		1.83	1.15		6.65	1.61	60.6	16.3	11		42	100
Clackamas River	2.7					96.9	0.39					10	100
McKay Butte								9.09			90.9	9	100
Upper Deschutes													
Newberry Volcano	2.73	5.45	0.91	1.82	0.91	13.6	0.91	1.82	2.73	2.73	66.4	35	100
Big (Buried) Obs. Flow											100	2	100
Quartz Mountain	3.85					7.69					88.5	10	100
Cougar Mountain									3.85		96.2	10	100
McKay Butte West (UnkX)								100				1	100
Klamath Basin													
Deer Creek											100	2	100
Silver Lake/Sycan Marsh	0.59		1.18	1.76							96.5	19	100
Spodue Mountain	9.3		2.33								88.4	11	100
Witham Creek											100	1	100
Drews Creek/Butcher Flat											100	1	100
Harney Basin													
Carlon (Bald) Butte								100				1	100
Horse Mountain						100						1	100
Glass Buttes	100											2	100
Big Stick	100											1	100
Riley			100									1	100
NE Oregon													
Whitewater Ridge						100						1	100
NE California													
GF/LIW/RS	66.7		33.3									2	100
Glass Mountain	100											1	100
Blue Mountain											100	1	100
Unknown	10.7		1.33	2.67	5.33	29.3	2.67	24		12	12	31	100

[1]Willamette Basin subbasins arranged west side, north to south, then east side, north to south starting with Clackamas.

and cobbles were carried far down the valley (Skinner 2011).

The Willamette Valley is bordered on the east by the Cascade Range, which includes the very old, deeply eroded Western Cascades and the much younger volcanic rocks of the High Cascades. There are well over 150 volcanic vents in the high Cascades, a number of which are associated with obsidian sources (Orr et al. 1992:141-148).

At the time of contact, the Willamette Valley was home to at least 13 named Kalapuyan groups whose tribal territories coincided closely with the Willamette River tributary subbasins. The dialects of the lower valley have been grouped into the Tualatin-Yamhill language, the Central Kalapuya language which included eight to twelve dialects, and the Southern Kalapuya language of the upper Willamette Valley and northern Umpqua River Basin grouped the dialects of the Yoncalla (Jacobs et al. 1945; Zenk 1990). Each dialect was localized in a cluster of winter villages established along a creek or in a restricted area near the Willamette River. These groups constituted autonomous economic, cultural, and political units and were identified by name (Jacobs et al. 1945:145). Access rights to certain resources were limited to members of the winter village group, but the territory of the larger community provided access to riverine, lowland, and upland habitats (Zenk 1976:17-18).

As reported, the local exchange center that served as a point of contact between the Kalapuya and Clackamas River Chinook was at Willamette Falls, the location of modern day Oregon City. The area was controlled by the Clackamas Chinook, the easternmost of four Lower Columbia River Chinook tribes. In the Portland Basin lived the Multnomah Chinook, and the Cathlamet and Lower Chinook downriver to the west (Silverstein 1990:533-535).

The Tualatin and other Kalapuya groups, Chinookans, and northern Oregon coastal groups, participated in a regional economic and political network (Zenk 1976:5). Such trade gave the Kalapuya access to fisheries not available above the falls in the Willamette Valley (Zenk 1976:34). Various ethnographic informants emphasized the importance of trade and listed the foodstuffs exchanged by tribe to include the Kalapuya's camas, the Tualatin's wapato, the Molala's smoke-dried meat, and the Clackamas' smoke-dried fish, eels, and pounded dried salmon (Zenk 1976:35-36). Trade is also noted in historic accounts, such as the observation by Alexander Henry (the Younger), who, upon entering the Willamette valley on January 22, 1814, reports encountering a group of seven "Yam he las" on their way to the falls with "bags of raw Cammoss" to trade. This same party was met three days later, "this time loaded with dried salmon" (Coues 1897:812, 819). Other commodities traded at Willamette Falls included *Dentalium* shells, bone and shell beads, ornamental jewelry including feathers, tobacco, animal skins, and slaves (Zenk 1976:52). As Zenk (1976:5-6) notes, the Tualatin "brokered in slave trading" and "occasionally conducted slave-raiding expeditions to the southern Willamette Valley and the central Oregon coast."

The archaeological record also provides evidence of sophisticated interaction and exchange between the Kalapuya and surrounding peoples. In 1922 George Wright described the contents of a mound near Albany, in the upper valley. In addition to a necklace of copper beads was a 55.8 cm (22 in) long bone "sword or sacrificial knife" shaped like a "canoe paddle" with a handle decorated with faces resembling "Alaskan art" (Wright 1922). Wright was certainly clearly describing a whale bone club, an iconic Northwest Coast artifact. At Fuller and Fanning Mounds on the Yamhill River in the lower valley some burials displayed the high status mark of cranial flattening, and exotic grave goods, including two whale bone clubs (Murdy and Wentz 1975:349-374; Woodward et al. 1975:402), and a ceremonial blade made of Klamath Basin Silver Lake/Sycan Marsh obsidian (Hughes 1990:51, 54). At a Harrisburg mound in the upper valley, *Dentalium* and other marine shell beads, as well as copper beads and possibly a bearskin robe, accompanied an individual with a flattened cranium, while at a mound near Shedd, also in the upper valley, grave goods included an obsidian ceremonial blade which measured 25.5 cm long (Laughlin 1941). At the nearby Calapooia Midden site, two males were buried with a whalebone club (Roulette et al. 1996). At the Lingo Site, near Junction City in the upper valley, burials were excavated which were accompanied by *Olivella* shell beads, and pendants of abalone and other marine shell (Cordell 1975). While preservation in the acidic Willamette Valley soils has been a problem, the archaeological record, like the ethnographic record, clearly indicates that the Kalapuya participated in regional exchange, including exotic prestige items. Importantly, not all excavated sites have produced exotic artifacts, indicating differential access, and signaling local social status inequality, exclusive trading partnerships, or both.

Obsidian Frequency in the Valley

Willamette Valley

Inman Creek, Butte Creek, and New Era obsidians occur in the study area, but no New Era obsidian is represented in the Study Assemblage (Table 14-1). The exact location of the primary source of <u>Inman Creek obsidian</u> is thought to have been in the Mount David Douglas region of the High Cascades, but has yet to be found, and may be buried or entirely eroded. The secondary source of Inman Creek obsidian is the gravels of the Middle Fork and main-stem Willamette Rivers, where it has been found as far north as the Clackamas River (Skinner 2011). Inman Creek obsidian was first characterized from obsidian obtained at Inman Creek, a small stream in the southwest corner of the Valley, where a deposit of obsidian nodules ranging from 1 to 15 cm in diameter was found. It has two chemically distinct forms, Inman Creek A and

Inman Creek B (Skinner 1983:306), but these appear to almost always co-occur and are treated here as a single type. It is the second most frequent archaeological obsidian in the Basin, and is identified at 61 of the 116 sites in the study assemblage (at 29 of 34 sites below 150 m (500 ft) elevation). Sites in the Middle Fork, Upper, and Middle Willamette River subbasins produced 68 percent of the Inman Creek obsidian artifacts. Butte Creek obsidian is reported from five sites on the Clackamas and Middle Willamette main-stem rivers, and from one site on Butte Creek, a tributary of the Pudding River. It accounts for less than 3 percent of obsidian at four sites, but rises to 36 percent of obsidian at a site on Butte Creek, so that it represents 21 percent of the archaeological obsidian from the Mollala-Pudding Rivers subbasin. The presence of a large proportion of cortex, and its limited distribution, suggested the as yet un-located source is on Butte Creek.

Many High Cascades sites are mid-range biface blank reduction localities for Obsidian Cliffs material (Connolly et al. 2008), and at Newberry Volcano large bifaces were also commonly produced (Connolly 1999). Caches of Obsidian Cliffs and Newberry Volcano biface blanks have been found in the Western Cascades and Central Oregon (Bennett-Rogers 1993; Winthrop and Gray 1985). Biface blank production reduced volume and weight for foot-transport. The river gravel source of Inman Creek obsidian suggests that cortex was present due to local acquisition, but it can be speculated that transport of obsidian by canoe would make volume and weight less critical factors. The generally held idea that the presence of cortex flakes at a site is evidence of a relatively local source may be true for Obsidian Cliffs obsidian, but may not reliably indicate local procurement for obsidians that are more likely to have been moved by water transport.

Cascade Range

Obsidian Cliffs obsidian is the most frequently identified obsidian type in the basin, accounting for 45 percent of archaeological obsidian. As a group, Cascade Range obsidians account for 59 percent of the study assemblage (Table 14-1). Obsidian Cliffs obsidian was quarried at the primary source, a flow on the northwest slope of the North Sister peak, and collected from glacial till deposits and McKenzie River gravels. It was one of the most important obsidian sources in the Pacific Northwest because of its quantity and quality. Obsidian Cliffs is a massive Pleistocene obsidian-rhyolite flow approximately 2.4 km (1.5 mi) long with 70 to 90 m (230-300 ft) high terminal cliffs (Fierstein et al. 2003; Skinner 1983:265). Obsidian Cliffs obsidian appears at 106 of the 116 sites in the study (at 28 of 34 sites at less than 152 m (<500 ft) in elevation and is the highest percentage of obsidian in eight of the ten subbasins in the Willamette Valley. Devil Point obsidian is a major source in a small area of the Western Cascades, appearing at 42 of the 116 study sites. It has been found at a small primary source in the North Santiam drainage, about 8 km (5 mi) west of Mount Jefferson, and at a single secondary location a few kilometers away at Grizzly Creek. The majority of this regionally minor source is reported from sites within a 35 km^2 (13.5 mi^2) area centered on the primary source location. Some 85 percent of Devil Point obsidian was found above 914 m (3000 ft) in elevation. Clackamas River obsidian is named for the northeast Willamette Valley subbasin where it was first reported, but its source has since been located on the east side of the East Fork of Hood River, northeast of Mount Hood, about 41 km (25 mi) from the Clackamas River headwaters. It has been identified at ten sites, all in the northern valley, in the Clackamas, Lower Willamette River, and Molalla-Pudding Rivers subbasins. Ninety-seven percent of the Clackamas River obsidian in the Willamette Basin was found in the Clackamas River subbasin, where it ranges from 39-82 percent of site obsidian at four sites, and is 52 percent of archaeological obsidian in the Clackamas subbasin. Carver Flow obsidian has been found at ten sites located throughout the basin, but never rises to more than 3 percent of the obsidian in any subbasin. The majority, 64 percent, was recovered in the Upper Willamette River subbasin. Rock Mesa obsidian has been found at a single site, which lies above 914 m (3000 ft) in the McKenzie drainage; here it accounted for 13 percent of the site's obsidian.

Upper Deschutes Basin

These obsidians constitute less than 4 percent of the study assemblage, but include a number of regionally important sources. None are present in the Willamette Basin in large frequencies. Newberry Volcano obsidian was found at 35 sites. Twenty three percent of Newberry Volcano obsidian is found at 13 sites in the lower valley, 5 percent at 3 sites in mid-valley, and 73 percent at 19 sites in the upper valley. At 23 of the 35 sites it is less than 10 percent of site obsidian. At three sites it is more than 20 percent of site obsidian, one in the Upper Valley, and two in the Lower Valley. Quartz Mountain obsidian is reported from ten sites, with 12 percent of it at the north end of the valley and 88 percent at the south end in the Middle Fork Willamette River drainage. McKay Butte obsidian is found at nine sites, one in the North Santiam subbasin and eight in the Middle Fork subbasin. Big (Buried) Obsidian Flow obsidian is found at two sites in the Middle Fork Willamette River subbasin and McKay Butte West obsidian at one site in the Clackamas drainage. Cougar Mountain obsidian was reported from one site in the South Santiam drainage and nine sites in the Middle Fork Willamette River drainage. Altogether, of the obsidians associated with the upper Deschutes drainage, 69 percent were found in the Middle Fork Willamette subbasin.

Klamath Basin obsidians are also very important regionally, but are only minimally present in the Willamette Basin where they account for just over 4 percent of the study assemblage. Ninety-six percent of the Klamath Basin obsidian was found in the Middle Fork drainage. The most important source was Silver Lake-Sycan Marsh obsidian. It appears at 19 sites and represents 77 percent of Klamath Basin obsidians. All other obsidians from that area co-occur with Silver Lake–Sycan Marsh obsidian, except at a single site in the Middle Willamette River subbasin where Spodue Mountain obsidian was found. Spodue Mountain obsidian accounts for 20 percent of these obsidians, and is reported from 11 sites. All these obsidians occur in sites south of the Middle Willamette except for one site in the Lower Willamette subbasin where Klamath Basin obsidians accounted for 10 percent of site obsidian.

Harney Basin obsidians are represented by seven artifacts recovered from four sites. All are in the lower valley.

Northeast Oregon obsidians are represented by two Whitewater Ridge artifacts recovered from one site in the Clackamas drainage.

Northeast California obsidians number eight artifacts reported from three sites, one each in the Lower, Middle, and Middle Fork Willamette River subbasins.

The obsidians from the Harney Basin, Northeast Oregon and Northeast California are present in the Willamette Basin in very small amounts – 17 artifacts at seven sites. Of these, ten were found at the Meier site, a Chinook village site in the Portland Basin. Future obsidian data will give further hints as to the mode and vector of arrival of these pieces, but it can be speculated that larger more important sites will have attracted a wider variety of these exotic obsidians, especially if they are located near a major thoroughfare like the Columbia River.

Inman Creek and Obsidian Cliffs Obsidian

At 31 percent and 45 percent respectively of all characterized obsidian, Inman Creek and Obsidian Cliffs obsidians are clearly the most important archaeological obsidian sources in the Willamette Basin. All other obsidians are limited in frequency or distribution. As mentioned earlier, archaeological obsidian often follows a distance decay model, becoming less frequent with distance from the source. This has been connected with down-the-line exchange, obsidian decreasing as some is kept and the excess moved on. Defining the distance to the source in the Willamette Valley is complicated by the fact that Inman Creek and Obsidian Cliffs obsidians are found throughout the gravels of the Middle Fork Willamette, McKenzie, and main-stem Willamette Rivers. However, the primary sources of those obsidians were in the Cascades at the head-waters of the Middle Fork Willamette and McKenzie Rivers. If their distribution followed only hydrologic laws of particle deposition, then nodules should be smaller and fewer with downstream-distance, reducing the frequencies of both Inman Creek and Obsidian Cliffs obsidians at sites in the lower valley. We suggest that an explanation is required for perturbations to a linear down-the-line decrease in their distributions, the most parsimonious being human agency.

In order to test for linearity in distance-to-source frequency, correlation coefficients for obsidian frequency by site location for the 116 sites in the study assemblage were calculated. Using the UTM Northing position for each site, linear correlation coefficients for Inman Creek and Obsidian Cliffs obsidian frequencies are calculated at $r^2=0.14$ and $r^2=0.05$ respectively. Correlations this close to zero are strong evidence that the frequencies of these two obsidians are not following a natural hydrologic distribution.

Contour Mapping by Source Frequency at Sites

The study sample consists of 5240 samples from 116 sites. Of these, 10 sites have no Obsidian Cliffs obsidian, 55 sites have no Inman Creek obsidian, and 52 sites have both sources present. Using Golden Software's Surfer 8 program, contour maps using the frequency of the three categories of Inman Creek, Obsidian Cliffs and All Other were prepared.

The frequency of Inman Creek obsidian generally increases to the west of the basin (Figure 14-3). In the south it fluctuates between 20 percent and 80 percent, at Corvallis it is 80-100 percent, at Salem it ranges from 40-70 percent, drops to as low as 20 percent at the confluence of the Clackamas River, then Jumps to 70-80 percent in the Portland Basin. At some northern valley sites the Inman Creek and Obsidian Cliffs frequencies are about equal.

As would be expected, the two major obsidian types in some ways appear to mirror one another (Figure 14-4). The distribution of Obsidian Cliffs obsidian is relatively high, 70-80 percent, between Eugene and Corvallis, and is very high in the upper McKenzie and South Santiam drainages where it is 100 percent of obsidian at some sites. It drops off in the North Santiam subbasin, and to the north of that is spotty, growing at specific sites to as much as 70 percent, but being almost absent at others. This pattern is also seen on the Willamette main-stem north of Corvallis where Obsidian Cliffs obsidian drops at most sites to a frequency of 30 percent or less, and drops even lower in the Portland Basin.

The distributions of all other obsidians show four foci: the Upper Middle Fork Willamette River drainage, the North Santiam River headwaters, the Molalla-Pudding Rivers subbasin and Clackamas River subbasin (Figure 14-5). As stated above, 80 percent of Klamath Basin obsidians, and 88 percent of the Upper Deschutes Basin obsidians are reported to occur at archaeological sites in the Middle Fork Willamette River drainage. The Central Western Cascades of Oregon is the source

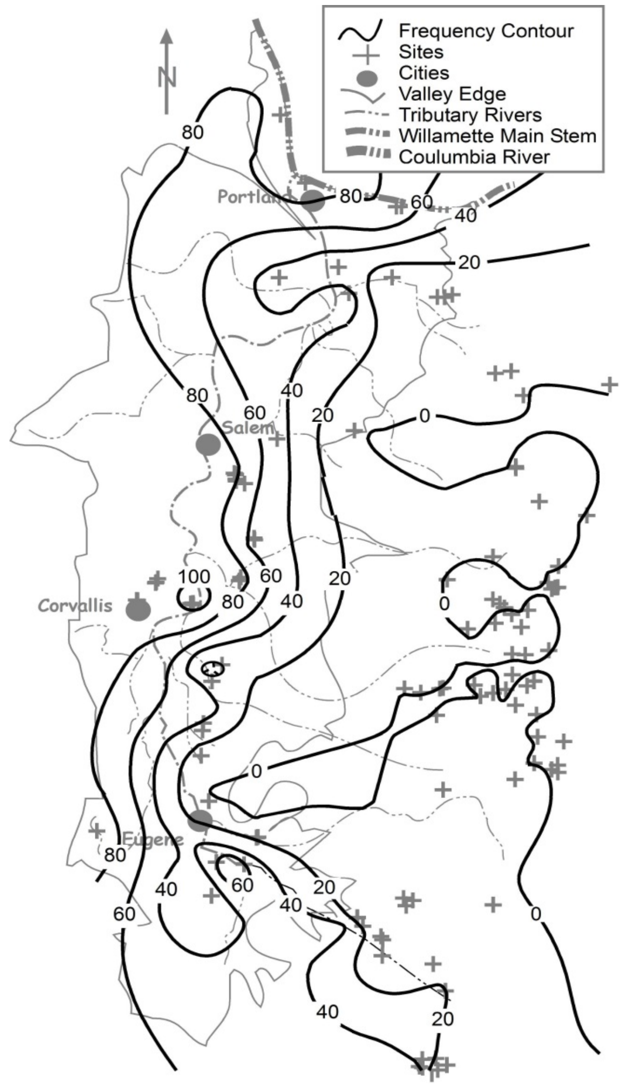

Figure 14-3. Distribution of Inman Creek obsidian across 116 sites in the Willamette Basin. Inman Creek obsidian is focused along the Willamette River, but shows considerable variation between neighboring sites, and is dominant in the Portland Basin.

location and single use area of Devil Point obsidian, 84 percent of Butte Creek obsidian is reported from archaeological sites in the Molalla-Pudding Rivers subbasin, and 97 percent of Clackamas River obsidian was reported from Clackamas River subbasin archaeological sites.

To this point the analysis of the distribution of obsidian types in the Willamette Basin has no temporal control. Within this study assemblage 93 sites include obsidian hydration measurements. Various researchers have developed hydration rates for obsidians found within the Willamette Basin

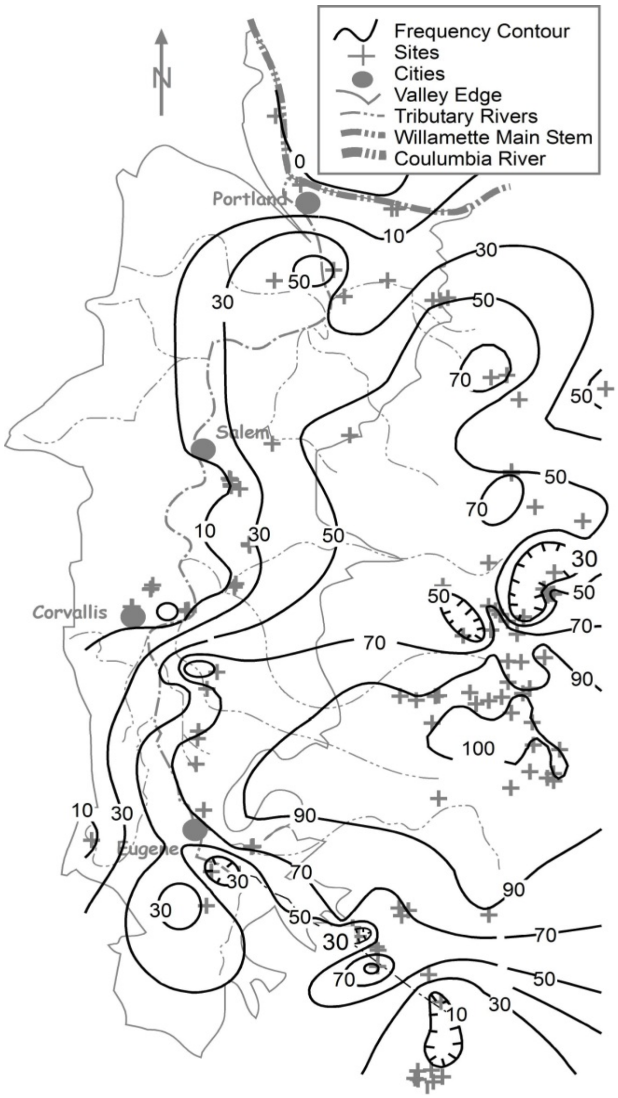

Figure 14-4. Distribution of Obsidian Cliffs obsidian across 116 sites in the Willamette Basin. Obsidian Cliffs obsidian is focused in the Cascades in the eastern basin, but shows considerable variation between neighboring sites. It is 70-90 percent of obsidian at some sites in the upper valley, drops below 30 percent in mid-valley and gains to frequencies as high as 50 percent at some sites in the lower (northern) valley.

(Baxter 2008; Burchard 1994; Connolly n.d.; Connolly and Byram 1999; Jenkins 2000; Minor 1985; Pettigrew and Hodges 1995; Skinner 1995; Wilson 1994). Unfortunately, micro-environmental variation makes a basin wide application of hydration rates untenable at this time.

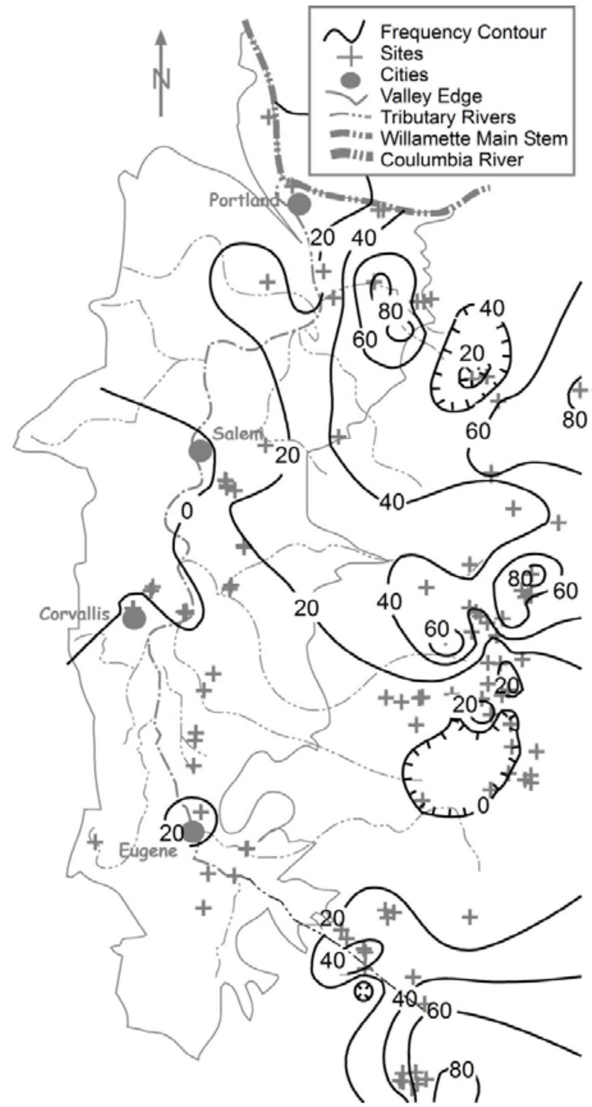

Figure 14-5. Distribution of all obsidians other than Inman Creek and Obsidian Cliffs obsidians across 116 sites in the Willamette Basin. These obsidians are most frequent in the upper valley in the Middle Fork subbasin, in mid-valley in the upper reaches of the North Santiam subbasin, and in the lower valley in the Mollala, Pudding River and Clackamas subbasins.

However, on the valley floor, larger projects at the south end of the valley (O'Neill et al. 2004:208), at mid-valley (Connolly n.d.), and at various locations on the valley floor (Wilson 1994), have worked out hydration constants for Obsidian Cliffs and Inman Creek obsidians which can be applied with at least some confidence. O'Neill et al. (2004:208) found that Inman Creek obsidian hydrated at $1.9\mu^2$/1000 years at the south end of the

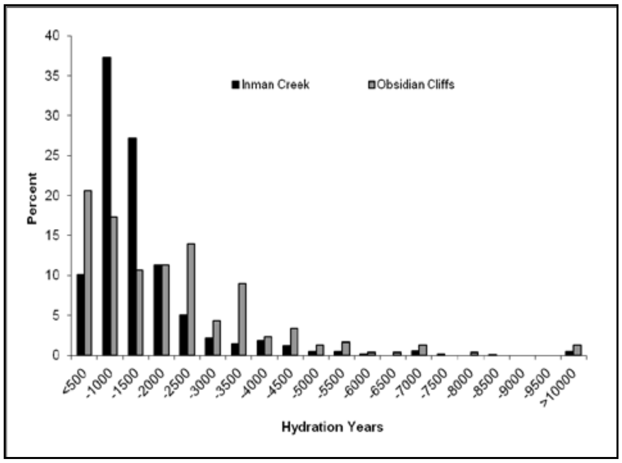

Figure 14-6. Frequency of Inman Creek and Obsidian Cliffs obsidian on the valley floor (<500 ft elevation) by hydration years.

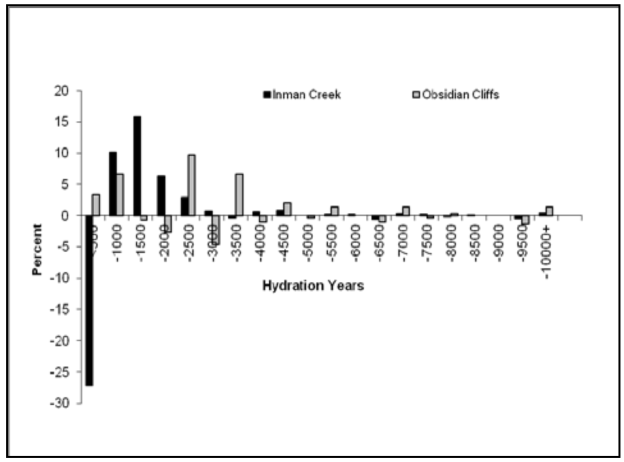

Figure 14-7. The average increase of each obsidian type by 500 year increment at valley floor sites (calculated by subtracting the previous 500 year increment frequency from the next increment frequency).

valley. At Salem, the rate was also found to be about $1.9\mu^2$/1000 years (Connolly n.d.). Obsidian Cliffs obsidian has been shown to hydrate at a much faster rate, with hydration constants estimated at $4.0\mu^2$/1000 years (Wilson 1984:20) and $3.6\mu^2$/1000 years (Connolly n.d.).

In order to make some estimates about obsidian distribution in the basin over time, this study will confine itself to the valley floor below 152 m (500 ft) in elevation. Within that limitation, there are 34 sites with source obsidian that has also been submitted for hydration rim measurement. Looking at only Inman Creek and Obsidian Cliffs obsidians, within the 34 sites on the valley floor, Inman Creek obsidian (n=892 artifacts) measurements comprise 74.8 percent of the measured hydration rims, while Obsidian Cliffs rims (n=301 artifacts) make up 25.2 percent of the total.

Hydration rim measurements, using the hydration constants of $1.9\mu^2$/1000 years for Inman Creek obsidian, and 3.6 μ^2 /1000 years constant for Obsidian Cliffs obsidian were compared (Figure 14-6). Of the total Inman Creek archaeological obsidian, 91.6 percent occurs during the last 2500 years, while of the Obsidian Cliffs archaeological obsidian, 73.7 percent appears during that time. Between 2500 and 500 years ago, Inman Creek obsidian use on the valley floor increased 11 fold (>2500 = 8.4 percent, $\leq$2500 = 91.6 percent) while Obsidian Cliffs obsidian use just about tripled (>2500 = 26.3 percent, $\leq$2500 = 73.7 percent). A combined 87 percent of the Inman Creek and Obsidian Cliffs obsidian on the valley floor appears between 2500 and 500 years ago.

The average increase of each obsidian type by 500 year increments shows variation between the two obsidian types (Figure 14-7). Obsidian Cliffs obsidian use jumped about 3500 years ago but then has an uneven presence after that. Inman Creek obsidian use steadily increased beginning at 2500 years ago, and dominated between 2000 and 500 years ago. However, after 500 years ago, while demand for all obsidian declines, Inman Creek obsidian use drops precipitously. It may be too facile to see this as a proxy for the valley's well known population decline, but it is intriguing.

Contour mapping of obsidian frequencies for the 34 valley floor sites shows the same patterns as were seen in the entire 116 site study (Figure 14-3). In the upper valley the two dominant obsidians are present in high frequencies, depending on the particular site, in the mid-valley it is almost entirely Inman Creek obsidian, and in the Lower Valley again the dominance varies by individual site. At both ends of the valley, other obsidians are a factor, being as much as 30 percent of site obsidian at particular sites in the upper valley and as much as 80-90 percent at particular sites in the lower valley.

These contours demonstrate that obsidian frequency at any given site is not dependent on local obsidian. Unmistakably, different sites in the lower valley are being supplied with differing obsidian types. If site obsidians are not obtained locally, the great site-to-site differences suggest social behavior, perhaps village-to-village connections in the form of trading partners.

Evidence for this can be found at the Chinook village sites of Cathlapotle, Meier, and Clahclellah (obsidian characterization data for these three sites comes from the Northwest Research Obsidian Laboratory data base). The Meier site is one of the 116 sites in this study. It lies northwest of the City of Portland, west of the Multnomah channel, near Sauvie Island. At that site, 75 percent of archaeological obsidian is Inman Creek. Across the Columbia River in Washington at the village of Cathlapotle, Inman Creek obsidian accounts for 86 percent of site obsidian, and 64 km (40 mi) upstream at Clahclellah, 43 percent of site obsidian is Inman Creek obsidian.

Further, Obsidian Cliffs obsidian is less than 1 percent of site obsidian at the Meier site and Cathlapotle, but constitutes 22 percent of obsidian at the upstream Clahclellah village. Clackamas River obsidian, so prominent at 52 percent of the Clackamas River subbasin obsidian, is just 4 percent of the Meier site obsidian, 3 percent at Cathlapotle, and strangely, it is just 4 percent at Clahclellah which is quite near the source. All of these Chinook village occupations date to after 1000 years ago, when the dramatic increase in obsidian frequencies began to occur.

Summary and Discussion

This paper has summarized the obsidian characterization data from 5240 artifacts collected from 116 sites in the Willamette Basin. Clearly the people of the Willamette Basin had contacts with far flung regions, but local resources were the core of the obsidian used, such that if the Willamette Valley and Cascade Range sources are grouped, they account for over 90 percent of obsidian use in the Willamette Basin.

Obsidian type distribution does not conform to a classic distance-decay model, suggesting that human transport was an important factor in the distribution of cultural obsidian. Contour mapping of obsidian frequencies of the 116 site sample showed that in the Lower Valley frequencies of Obsidian Cliffs and Inman Creek obsidians could be about equal at some villages, but at others, one obsidian type could be very high and the other low or missing.

This uneven distribution at sites was further investigated by applying obsidian hydration dating to a sample of 34 sites. Using obsidian hydration rates developed on the valley floor, it is estimated that 84 percent of the valley's obsidian use occurred after 2500 years ago. At that time Inman Creek obsidian use increased dramatically, but plummeted within the last ca. 500 years. Obsidian Cliffs obsidian followed a similar, but less spectacular trajectory, although with an earlier rise in use, beginning perhaps 1000 years prior to the precipitous rise in Inman Creek obsidian use. Contouring obsidian distribution at those 34 valley floor sites showed the valley's site-specific, uneven obsidian use distribution even more clearly.

Long distance movement of resources in organized Interaction Spheres moved various goods, including obsidian, throughout the region (Ames and Maschner 1999; Anastasio 1972; Carlson 1994; Galm 1994; Ray 1939). The "trackability" of obsidian through geochemical trace element characterization has mapped the movement of obsidian significant distances, and the frequencies of distant obsidian types over more local obsidians has shown that it was a commodity, not just a resource.

The high frequency of specific obsidian types at different Lower Willamette and Portland Basin sites can be explained as the use of an as yet unlocated source of obsidian nodules or as a function of the system of exchange which was being employed. The economic system involved may not have been simply down-the-line exchange, but rather one of redistribution. The frequency of obsidian at the Chinook sites suggests obsidian was a sought-after trade commodity. Chinook society was ranked and political organization was headed by a hereditary Chief, who's leadership rights and duties lay in a single village, but "through proper marriage alliances, control of trade and skillful and effective diplomacy, an individual chief could exert influence over a wide area" (Silverstein1990:541).

At Clahclellah, only 1074 obsidian flakes were recovered, while the assemblage contained 342,317 CCS flakes (Minor et al. 1989). Households at Clahclellah were obtaining obsidian from remote locations, but obviously not simply to fulfill a utilitarian toolstone need. A comparison of household use of obsidian at Cathlapotle and Clahclellah (Sobel 2006; 2011) showed that all households at both sites had access to obsidian and used it in the same way. This fact, on its face, might suggest that obsidian was not a prestige item. However, higher prestige households "acquired and consumed more obsidian than did lower prestige households" implying that access to and local distribution of obsidian was not even across the social landscape, and "that household prestige was intimately related to household involvement in long distance exchange systems" (Sobel 2006:192). Obsidian itself may or may not have been regarded as a prestige item, but its uneven distribution among houses of different status serves to mark households with greater amounts of obsidian as prestigious by virtue of their greater access to exotic exchange products. Long-distance trade increased household prestige by giving it access to prestige items and resources that could be turned into prestige items, as well as encouraging regional alliances that increased household prestige (Sobel 2006:192).

Large households evolved in an economically diverse landscape that required synchronized task organization, but to make them persist, they had to be seen as successful so as to attract new members (Ames 2006:31). Success breeds success. This understanding of Chinook political, social and economic organization argues that involvement in economic activities at the community, local, and regional levels was not a choice, but a necessity. Household survival depended on household prestige (Ames and Maschner 1999:150). The acquisition and redistribution of prestige items such as obsidian, a toolstone that is visually easily identified, added to the ability of households to attract and keep members.

Among the Kalapuya, exchange was accomplished as reciprocal gift-giving. Upon arrival, visitors presented goods to the village headman or host, who kept some and dispersed the rest to the villagers. Before departure, villagers presented "gifts" to the headman or host, who passed them on to the visitors. Returned home, the visitors shared the "gifts" with their village (Zenk 1976:52-53). It is likely that exchange-based relationships existed between specific villages where headmen were trading partners. The use of the term "gifts" highlights a greater truth, that the exchange was not strictly an economic transaction, but a negotiation of status; on some level the obsidian, shells, and woodpecker scalps were only the medium. Aside from any utilitarian advantage that might be present in obsidian, the fact that Chinook elites and commoners, and in a down-the-line manner, the Headmen and members of surrounding tribes, could raise their status by contact with prestige items must have been a powerful inducement to increase obsidian frequency in one's village.

Creating stable, long term economic relationships to ensure household survival was in the best interests of all concerned. About 2500 years ago in the Willamette Valley, obsidian use began to increase in frequency, and it can be speculated, in value as a medium of prestige. Villages with local access to obsidian accordingly rose in importance, while others worked to increase access through organized quarrying parties and trade alliances.

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CHAPTER 15

Upper Klamath River Obsidian Use Frequencies: Distance-To-Source and Additional Variables

Joanne M. Mack
University of Notre Dame (Joanne.M.Mack.13@nd.edu)

The Southern Cascades of south-central Oregon and northeast California, like the Klamath Basin and Modoc Plateau to the east and the Central Cascades to the north, provide many discrete sources of obsidian toolstone. The archaeological sites of the Upper Klamath River Drainage System lie just west, northwest, and southwest of these sources, providing a unique opportunity to test assumptions concerning obsidian acquisitions and use. Commonly in this area and throughout the world anthropologists presume that a community will use the obsidian sources closest to them, and if a source is relatively close to the community or core territory, individuals will acquire the obsidian through direct travel to the source (Heizer 1949, 1974). If the sources used by a community exist at a greater distance, roughly greater than 20 km, the community will use trade or exchange to obtain obsidian (Erlandson et al 2011; Kroeber 1925). However, distance may not be the only variable to influence the sources used and the mechanism of conveyance (Hughes 2011). The variables may include toolstone quality, time, tool class, culture contact, cultural boundaries or related constraints, and cultural preferences. Another commonly held assumption has been that over time, the sources acquired and their mechanism of conveyance may change based upon the level of cultural organization and complexity (Hughes 2011). It is assumed that early cultures were organized as small bands moving widely over a considerable territory, acquiring obsidian incidentally as they moved through a rather large territory hunting and gathering (Binford 1979). As groups of hunter-gatherers became larger and less mobile, perhaps regularly moving through a smaller territory their direct access to a variety of obsidian sources would be more restricted and less casual in the course of a seasonal round (Ericson 1982). By the Late Prehistoric Period when communities were tied to particular villages most if not all of the year, their acquisition of obsidian would require more planning and the likelihood of direct travel to a source or sources would not be possible or be severely restricted. Therefore, over time one would expect the use of fewer sources if several were available reasonably close. In this area, the Late Paleo-Indian Period sites would be predicted to use the greatest variety of sources. In the Archaic Period, communities would be predicted to have a somewhat smaller range of mobility, resulting in more restricted access to obsidian, thus use of fewer sources. The Late Prehistoric Period sites should have the least variety. The first step in assessing whether or not the assumptions concerning distance and time are valid for the Upper Klamath River Drainage System requires sourcing of obsidian artifacts. Therefore, a small sample study of obsidian distribution and frequency of obsidian sources was completed, and the results indicate the assumptions related to the acquisition of obsidian due to distance and time may not be valid for this area.

The use of obsidian for tools within the area of the Upper Klamath River Drainage System occurs throughout a period of at least 9000 years (Anderson and Cole 1964; Cole nd; Cressman and Olien 1962; Cressman and Wells 1961; Leonhardy 1967; Mack 1983, 1991, 1995, 2004, 2005, 2007; Newman and Cressman 1959; Nilsson et al. 1989; Wallace and Taylor 1952). In the last 35 years, a small sample of obsidian artifacts and debitage

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(n=470) from 50 of 176 known archaeological sites and 7 isolates within the Upper Klamath River Drainage System have been sourced using X-Ray Fluorescence (XRF) analysis (Hughes 1986; Jensen 1987; Mack 1983, 2005, 2007, 2008; Nilsson 1988; Nilsson et al. 1989; Oetting et al 1996; Schaefer 1995). Using distance and geology, it is reasonable to expect that the inhabitants of archaeological communities of the Upper Klamath River, which are located just west of the Klamath Basin and northwest of the Medicine Lake Highlands, had access to several obsidian source locations throughout the last 9000 years. Only one source location (Glass Mountain within the Medicine Lake Highlands) was not available until sometime after A.D. 900 (Donnelly-Nolan et al. 1990). Though small, the results of the analyses point to some unexpected use frequencies of the potentially available obsidian source locations of the region, which encompasses part of south-central Oregon and northeast California. Even though the usual measure of “distance-to-source” would lead one to expect some greater variation in use of source locations, the frequency of one source in all the obsidian assemblages tested regardless of their location within the Upper Klamath River drainage dominates. The source is the Medicine Lake Highlands, in particular, the locality of Grasshopper Flat/Lost Iron Wells/Red Switchback (GF/LW/RS). Neither chronology, assemblage location, nor the functions of the obsidian artifacts in this area change the dominance of Medicine Lake Highland obsidian significantly (Mack 2011).

For this study, the Upper Klamath River Drainage System is defined as the Upper Klamath River and its tributaries from Keno, Oregon on the east to Interstate 5 on the northern edge of Shasta Valley in northern California on the west (Figure 15-1). The northern boundary is roughly Highway 66 in the vicinity of the Jenny Creek drainage east to Hayden Mountain, where it bends northward to cross the middle course of Spencer Creek. The southern boundary is south of the California-Oregon border and includes the headwaters of Shovel Creek, Rock Creek, Bogus Creek, and the Shasta River, a major tributary of the Klamath River, which flows into the Klamath just west of Interstate 5 and includes the only major tributary valley in the study area. To the east of the study area the Klamath River flows through a small portion of the western Klamath Basin; to the west,

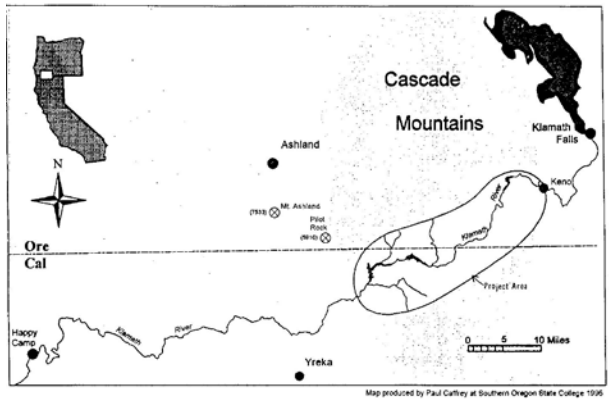

Figure 15-1. Upper Klamath River drainage system project area.

the river begins to cut through the Klamath Mountains of northern California. Thus the research area for this obsidian study is the stretch of the Klamath River and its tributaries, which cut through the Cascades Mountains, both the High Cascades and the Western Cascades (Figure 15-1). The boundaries of the Upper Klamath were originally conceived based upon geology and areas where archaeological survey and test excavations produced scientifically documented obsidian artifacts either from sites or as isolated finds since 1952 (Mack 1990).

The obsidian recovered for the study comes from slightly over 49 archaeological sites and 7 isolated finds. The sites include village sites, large and small campsites, and lithic scatters, which are the result of various types of activity or special use. Archaeological research indicates human use and habitation of the Upper Klamath River drainage begins at least 9000 years ago (Mack 1991). During the earliest pre-contact period, the canyon’s inhabitants likely travelled throughout the Upper Klamath River drainage from regions surrounding the canyon, while continuing to use surrounding areas as well. During the Archaic Period, the area’s inhabitants exploited the varied resources of the canyon on a seasonal basis, occupying the canyon and outlying areas during the times at which the canyon’s resources were at their peak and then moving seasonally into other areas. The settlement pattern of the canyon shifted during the Late Prehistoric or Pacific Period with the development of housepit villages upon the terraces and benches of the river and along major tributaries. These housepits represented a year-a-round occupation, though this does not necessarily mean that entire families would remain in the village all year (Mack 1990). Many of the people living in the villages left during various points in the year to hunt, gather, and trade, often in the surrounding uplands. For example, the upland immediately to the south of the canyon requires only a half-hour or less to reach from the river terraces and benches below, not necessitating major relocations of families. The uplands to the north also take less than an hour to reach by foot from the river terraces and benches.

The initial obsidian analysis focused upon formed artifacts, particularly projectile points. Richard Hughes completed the first X-Ray Fluorescence analysis done on obsidian artifacts from sites along the Upper Klamath River in 1977 (Mack 1979). Beginning in the late 1980s, in addition to formed artifacts, core fragments, worked flakes, utilized flakes, and debitage were also included in the sourced samples. The end result is a higher proportion of formed artifacts, especially projectile points, in the sample of sourced artifacts from the study area. Richard Hughes (1986, 1987, 1988, 1994a, 1994b, 1995, 1996a, 1996b 1997, 1998, 1999a, 1999b, 1999c, 2001, 2006a, 2006b, 2014) completed the vast majority of the X-Ray Fluorescence analyses from 1977 to 2006. However, Northwest Research Obsidian Studies Laboratory analyzed a few specimens in 1996 (Skinner et al. 1996). Slightly more than half of the assemblages sourced date to the Late Prehistoric Period, based upon associated radiocarbon dates, obsidian hydration, and the presence of time-sensitive projectile points (Desert Side-notched, Tuluwnt Series, and Rose Spring Series). Slightly less than half represent the earlier Archaic Period occupation of the area also based upon associated radiocarbon dates, obsidian hydration, and time-sensitive artifacts (Clilipudi Corner-Notched, Elko Series, Siskiyou Side-Notched, McKee Uniface, Houx Series, and Northern Side-notched). As surface collections can only be dated by time-sensitive artifacts, projectile points are the primary artifact type sourced from those collections.

Results of XRF Analysis

The results of the X-Ray Fluorescence analyses reveal the obsidian artifacts within the study area come from 13 distinct sources or source groups

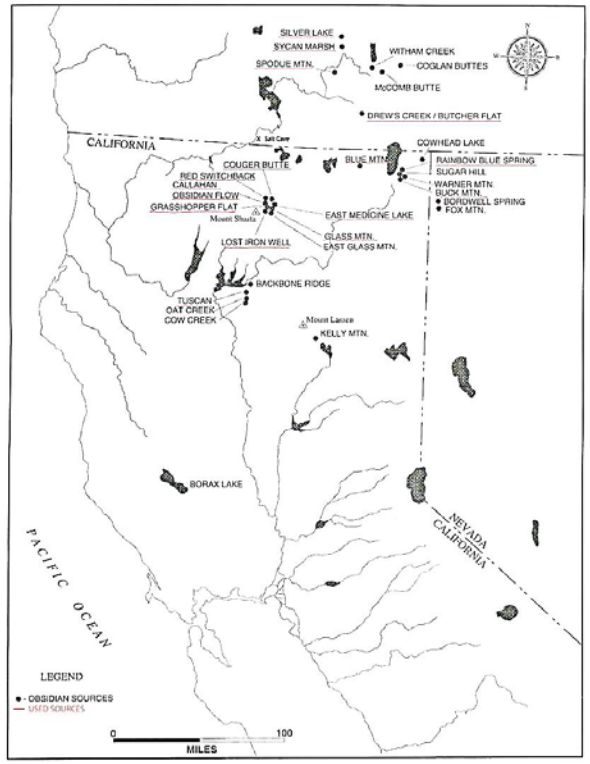

Figure 15-2. Locations of obsidian sources in study area.

(Figure 15-2). Of these 13 sources, six are located in the Medicine Lake Highlands (Figure 15-2). The remaining seven sources are located in areas northeast, east, and south of the canyon. Sources within the Medicine Lake Highlands vary in distance from roughly 55 to 74 km to the southeast of the Upper Klamath River, measured from the location of Salt Cave (Schaefer 1995). The distances to the sources would vary somewhat depending upon whether the point of measurement is upriver or downriver of Salt Cave and whether the point of measurement is north of the river or south of the river. The specific sources from the Medicine Lake Highlands represented in order of frequency are:

1. Grasshopper Flat/Lost Iron Well/Red Switchback: 54-69 km southeast; n=361
2. East Medicine Lake-two localities (Yellowjacket and Stony Rhyolite): 75 km southeast; n=23
3. Callahan Obsidian Flow: 55 km southeast; n=22
4. Glass Mountain: 71 km southeast; n=6
5. Cougar Butte: 69 km southeast; n=2

6. Railroad Grade: 58 km southeast; n=2
7. Generally sourced to the Medicine Lake Highlands: 54-75 km southeast; n=10 (Skinner et al 1996)

Of these six, the obsidian from Grasshopper Flat/Lost Iron Wells/Red Switchback was most common, at 86 percent of the specimens from the Medicine Lake Highland sources. Three percent sourced more generally to the highlands. In the earliest analysis reported by Hughes (Mack 1979), artifacts were sourced to the Medicine Lake Highlands generally, but these specimens were reanalyzed by Hughes in 1999 and identified to the Grasshopper Flat/Lost Iron Well/Red Switchback location within the Medicine Lake Highlands. The X-Ray Fluorescence analyses reported by Skinner, Davis, and Thatcher in 1996 uses different source groupings for the Medicine Lake Highlands sources. Therefore, some of these sourced specimens are grouped into a general category for the purposes of this study. East Medicine Lake and Callahan each represent five percent of the total number of specimens sourced to the Medicine Lake Highlands. Glass Mountain, Cougar Butte, and Railroad Grade all have a small representation in the sample, one percent or less for each.

The non-Medicine Lake Highland glasses are in order of frequency:

1. Spodue Mountain: 58-87 km northeast; n=18
2. Warner Mountains-two localities (Buck Mountain and Blue Spring): 156 km east; n=9
3. Silver Lake/Sycan Marsh: 119-133.5 km; n=9
4. Drews Creek/Butcher Flat: 113.5 km northeast; n=4
5. Blue Mountain: 96.5 km east; n=2
6. Massacre Lake/Guano Valley: 135-214 km southeast and east; n=1
7. Tuscan: 117 km south; n=1

Spodue Mountain's frequency is equivalent to 3.8 percent of the sample. Though the Spodue Mountain source is approximately 87 km northeast of the Upper Klamath River, nodules of this obsidian have been redeposited in the Sprague River and Williamson River, which are much closer to the Upper Klamath River (Hughes and Mikkelsen 1985, Hughes 1886b:311-312). Thus Spodue Mountain obsidian could be obtained within 55 km of Salt Cave on the Klamath. Silver Lake/Sycan Marsh and the Warner Mountains sources are 2.1 percent, and the remainder of the source localities, Drews Creek, Blue Mountain, Massacre Lake/Guano Valley, and Tucsan are one percent or less.

Though the frequency of each obsidian source location is not completely unexpected based upon the distance between the source location and the Upper Klamath, there are some surprises. Of the 470 sourced specimens, clearly Medicine Lake Highlands' glasses dominate with 90 percent of the total. Of these, it is not surprising the majority come from Grasshopper Flat/Lost Iron Wells/Red Switchback sources located on the western side of the highlands. The Red Switchback locale is one of the four closest source locales to the Upper Klamath River at 55 km. But there are three other source locations also roughly 55 km from the measuring point on the Upper Klamath River: Callahan Obsidian Flow, Railroad Grade, and Spodue Mountain. The low frequency of specimens from the Callahan Obsidian Flow (4 percent) is surprising because it is in the northwest corner of the highlands, directly south of the Red Switchback locale. Only two specimens (less than 1 percent) source to Railroad Grade on the north edge of the highlands, which may be explained by the source's poor quality even though it is one of the closest sources. Spodue Mountain obsidian accounts for slightly more than four percent of the obsidian in the study area even though it is found within the Sprague River and Williamson River as a secondary deposit, which is also within 55 km of the measuring point of Salt Caves on the Upper Klamath River.

Distance- to- source also does not explain the fact that some of the more distant sources both from the Medicine Lake Highland and the non-Medicine Lake Highland sources have higher percentages of frequency than closer sources. Comparing sources, which are roughly 72 km from the Upper Klamath one notes a slightly higher frequency of the East Medicine Lake source (six percent), the most distant of the Medicine Lake Highland sources. The frequency of Glass Mountain and Cougar Butte, located in the Medicine Lake Highlands, are both represented by one percent or less. Glass Mountain is a recent extrusion of obsidian and has not been available until the most recent part of the Late Prehistoric, which probably explains its low frequency in Upper Klamath archaeology sites.

There are three sources, which fall between 97 and 122 km miles from the Upper Klamath with low frequencies, which is not surprising, but there is one distant source, which has a frequency higher than expected. The Warner Mountains obsidian source frequency is 2.1 percent; it is a distant source at roughly 156 km from the Upper Klamath study area. The Warner Mountains source locales matches in frequency Silver Lake/Sycan Marsh, which is a somewhat closer source and exceeds in frequency several other closer sources. Drews Creek, with a frequency of one percent represented by four Late Prehistoric projectile points, and Blue Mountain, with a frequency of 0.5 percent, are closer to the Upper Klamath River, at 112.5 and 96.5 km respectively. Only the two most distant sources occur at a lower frequency: Massacre Lake and Tuscan, both at approximately 0.225 percent. It should be noted that Massacre Lake obsidian cobbles can be found on the Madeline Plans, which places it at approximately 135 km from the Upper Klamath (Young 2002). The Tuscan source here refers to a multi-locational source situated along the northern and northeastern edge of the Sacramento Valley. Only one specimen is sourced to this locale, a projectile point excavated from Paradise Craggy Village just north of Yreka near the confluence of the Shasta and Klamath Rivers (Mack 2007). One must conclude that distance-to-source is not the only factor to explain the obsidian source frequencies within the Upper Klamath River Drainage, though it would seem to explain the dominance of the Grasshopper Flat/Lost Iron Wells/Red Switchback source, especially since the Red Switchback locale is one of the closest sources.

The frequency of the 13 sources used does vary somewhat based upon time. Projectile points being time-sensitive provide the easiest specimens to use for age estimates, though obsidian hydration and association with radiocarbon dates has also been used to estimate the age of many other types of sourced specimens. Of the time-sensitive projectile points sourced, there is one specimen not from the Medicine Lake Highlands which dates to the Late Paleo-Indian period, a possible Windust projectile point made from Spodue Mountain obsidian. Only eight of 65 Archaic Period projectile points (Northern Side-notched, Houx Series, McKee, Siskiyou Side-notched, Clikipudi Series, Elko Series and Excelsior) do not source to the Medicine Lake Highlands. These source to only three other locations: three from Spodue Mountain, four from Silver Lake/Sycan Marsh, and one from Tuscan. Medicine Lake Highlands' sources, Spodue Mountain, the Warner Mountains, Silver Lake/Sycan Marsh, and Drews Creek were used to make 125 Late Prehistoric or Pacific Period projectile points (Tuluwnt Series, Desert Side-notch, and Rose Spring Series) found within Upper Klamath River assemblages, of these 19 were sourced to the non-Medicine Lake Highland sources. Based upon this sample, the greatest variety of sources used occurs during the Late Prehistoric Period.

Non-projectile point artifact categories include only 20 artifacts not sourced to the Medicine Lake Highlands' sources. They include two biface fragments, a worked flake and a piece of debitage from Silver Lake/Sycan Marsh, one almost totally unworked cobble-core from the Massacre Lake/Guano Valley source, three pieces of debitage, a knife fragment, two worked bifaces, two drill midsections, and a worked flake from Spodue Mountain, three small debitage pieces and a large biface from Buck Mountain (one of the Warner Mountain source locales), and a biface fragment and worked flake from Blue Mountain. None of the used sources found in the study area represent any particular tool class in this sample. Therefore, the use of a particular source for a particular tool class does not seem to exist in the study area.

The non-projectile point artifacts of non-Medicine Lake Highlands sources almost all occur within the uplands within the Upper Klamath River Drainage, whereas 15 of the 19 Late Prehistoric Period projectile points occur in sites on the river terraces and benches, particularly village sites. Of the eight Archaic Period and one Late Paleo-Indian Period projectile points of non-Medicine Lake Highlands' obsidian, seven occur in the uplands. In contrast, artifacts dating throughout the 9000 years of occupation of the Upper Klamath made of Medicine Lake Highlands' obsidian occur both upriver and downriver of Salt Cave on the terrace and bench sites and in the upland sites, and they occur both north of the river and south of the river in equal abundance. This suggests that in the Late Prehistoric Period finished projectile points of non-

Medicine Lake Highland obsidian will be found on the river terraces and in village sites, while the few non-Medicine Lake Highland obsidian artifacts from the Archaic will primarily be found in the upland sites. These trends may change when a larger sample of artifacts from sites within the Upper Klamath River Drainage are sourced.

Conclusion

With the limited current evidence these 470 specimens provide, Medicine Lake Highlands' obsidian, particularly Grasshopper Flat/Lost Iron Wells/Red Switchback, dominates whether sites are upriver or downriver of Salt Cave or north or south of the river, which meets the assumption of distance-to-source. What is surprising is its overwhelming dominance, with locales within the Medicine Lake Highlands as close to Salt Cave as the Grasshopper Flat/Lost Iron Wells locality passed over. In addition, the frequency of Warner Mountain obsidians exceeds the frequency of all non-Medicine Lake Highland sources, which are much closer to the Upper Klamath River, with the exception of Spodue Mountain. It is also equal in frequency to the Silver Lake/Sycan Marsh source, which is approximately two-thirds closer to the Upper Klamath River. Clearly some obsidian sources were more commonly used even when they came from a greater distance. The two major assumptions concerned with distance to source are not upheld by the sources used overtime. Instead of greater variety of source use in the pre-village time period (Paleo-Indian and Archaic), the greater variety occurs during the Late Prehistoric, and some sources appear to be preferred even though they are located at a greater distance. Therefore, distance alone cannot explain the frequencies of obsidian used within the Upper Klamath River Drainage. A much larger sample of artifacts from the study area will be analyzed in the next few years, which may or may not confirm the trends described here.

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