CHAPTER 1

Toolstone Geography and the Larger Lithic Landscape

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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 nearly 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

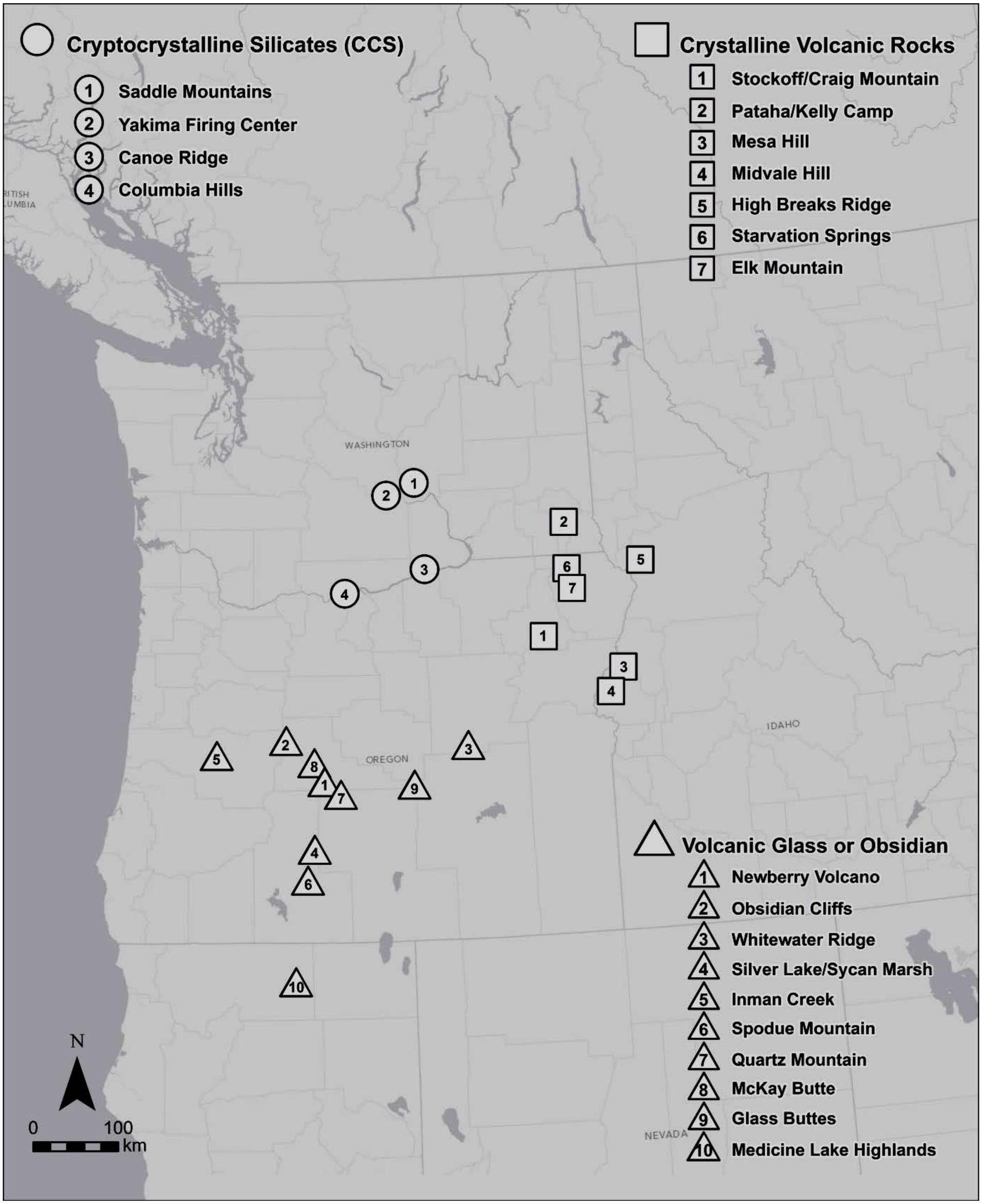

Figure 1. Geographic distribution of toolstone sources mentioned in the text.

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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