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

Toolstone Geography of the Pacific Northwest
Edited by Terry L. Ozbun and Ron L. Adams, pp. 76-106
Archaeology Press, Simon Fraser University, 2015

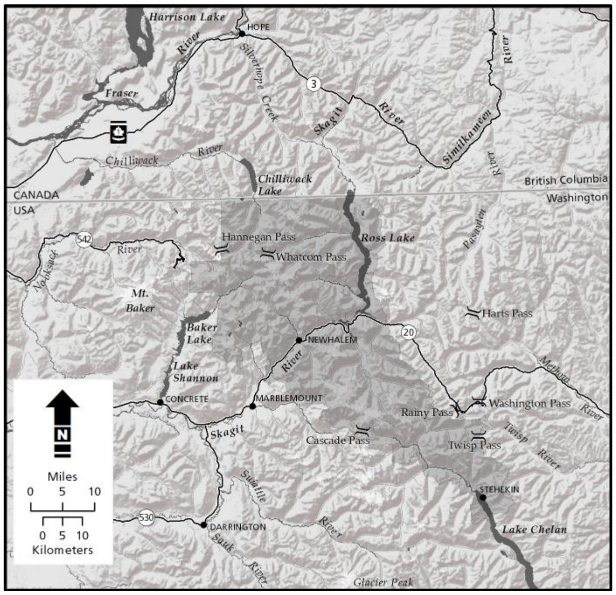

Figure 6-1. North Cascades National Park Service Complex shaded gray, showing place names mentioned in the text.

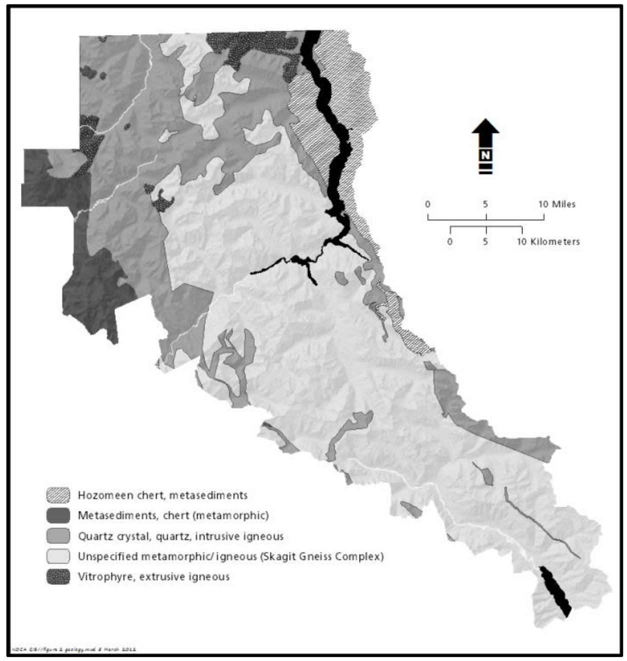

Figure 6-2. Toolstone categories found within major bedrock mapping units, based on site inventory records and archaeological research referenced in the text of this study; mapping units simplified from detailed maps in Haugerud and Tabor (2009).

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.

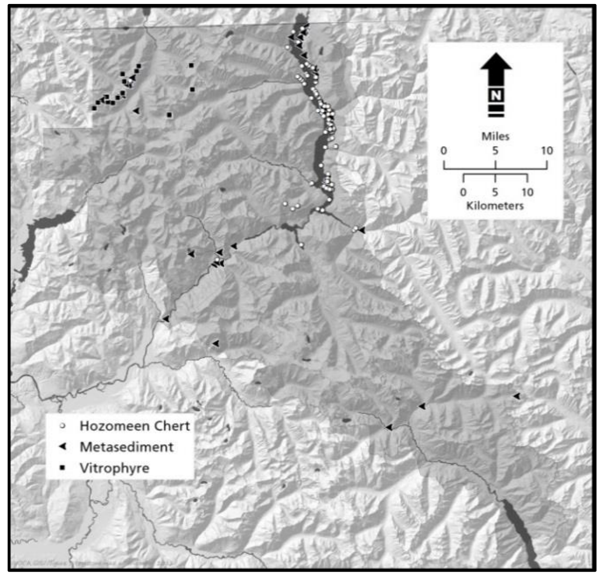

Figure 6-3. Archaeological assemblages where Hozomeen chert is dominant shown by circle, metasediment dominant by a triangle, and vitrophyre dominant by a square.

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

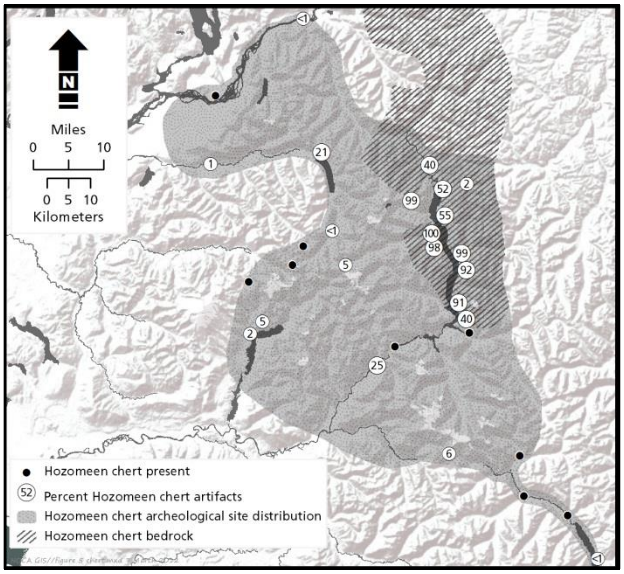

Figure 6-5. Map of archaeological assemblages in the North Cascades containing Hozomeen chert.

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

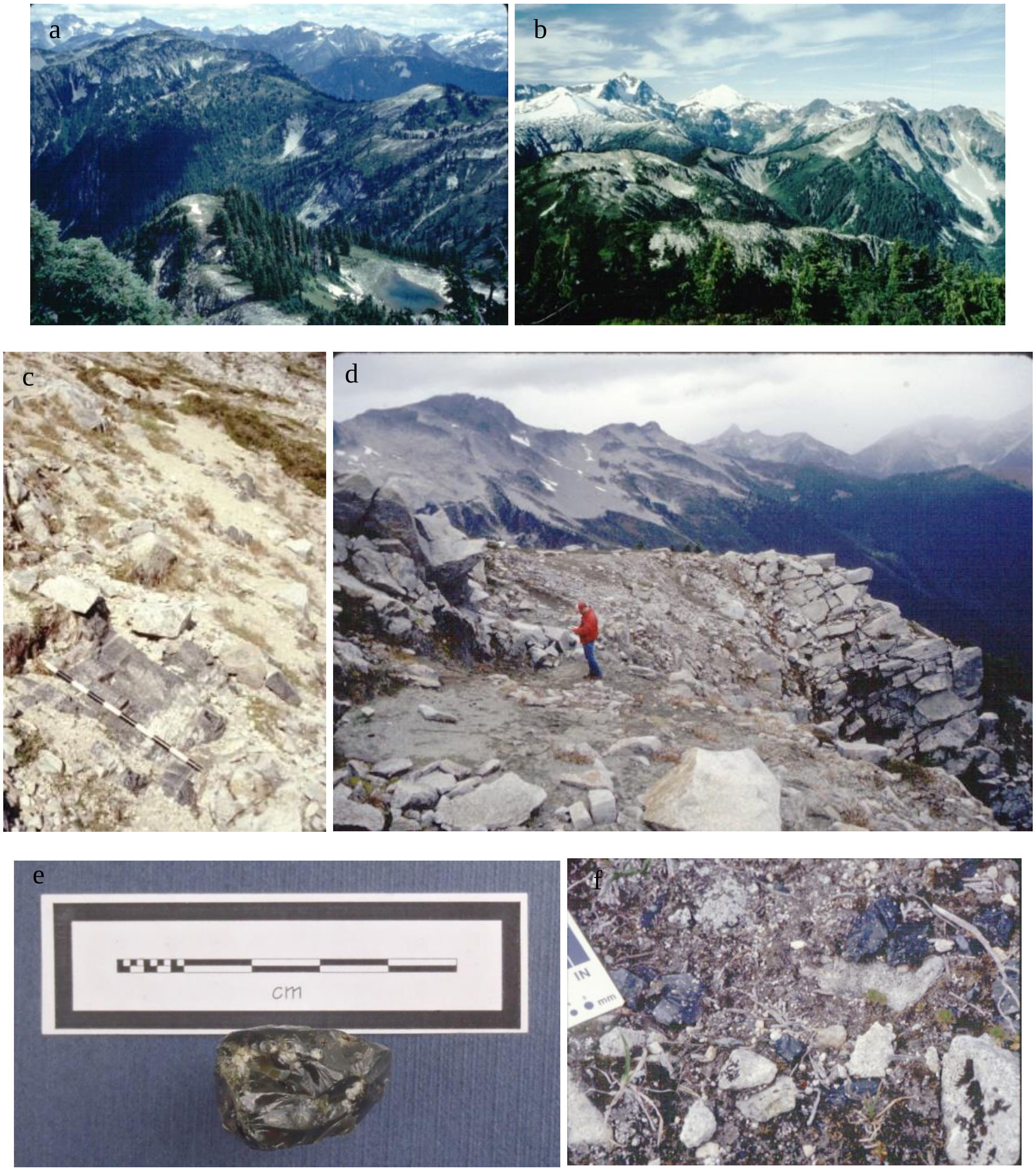

Figure 6-6. Photographs of Hannegan volcanics quarry complex outcrops, artifacts, and macroscopic appearance. (a) Hannegan volcanics quarry complex, upper Chilliwack River watershed, taken from northern end of Hannegan caldera, outcrops iv and vii of Hannegan volcanics vitrophyre and headwaters of Silesia 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

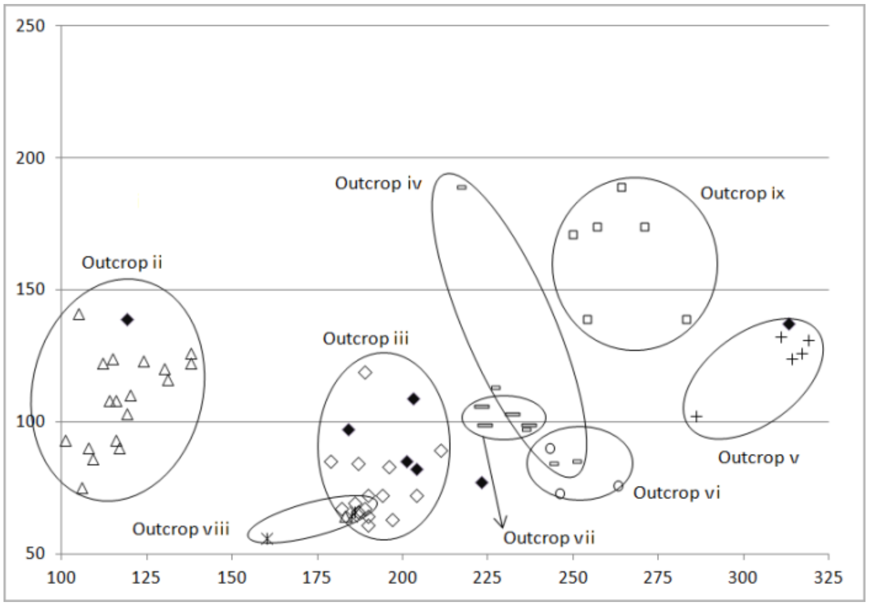

Figure 6-7. Scatterplot shows the amount of the trace elements Zirconium (Zr) on the x-axis and Strontium (Sr) on the y-axis, in parts per million, for all geologic samples collected from vitrophyre outcrops on Copper Ridge (Skinner 1998b, Skinner and Davis 1996). Eight symbols and ellipses designate 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

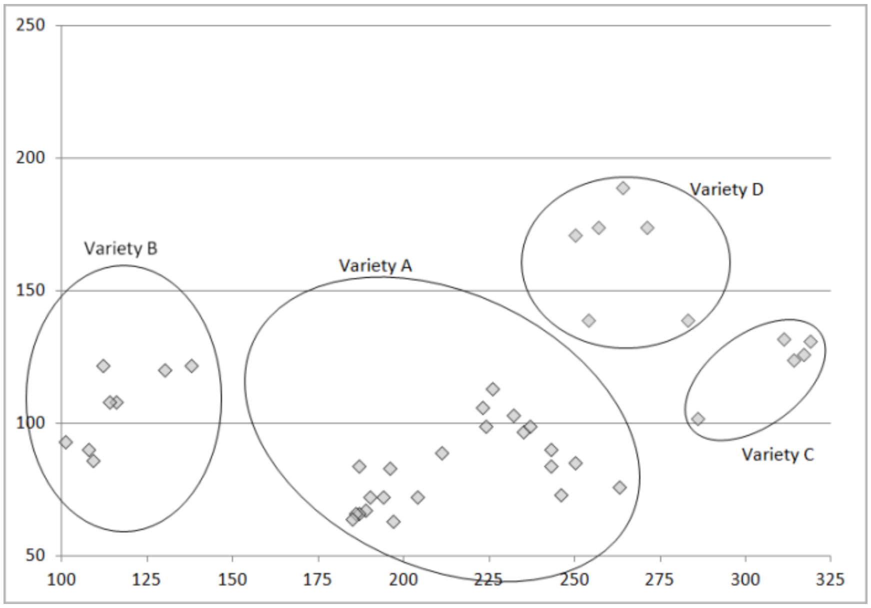

Figure 6-8. Scatterplot showing amount of the trace elements Zirconium (Zr) on the x-axis and Strontium (Sr) on the y-axis, in parts per million, for geologic samples collected from vitrophyre outcrops on Copper Ridge (Skinner 1998b). Only those samples that could be XRF-tested with reasonable accuracy 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

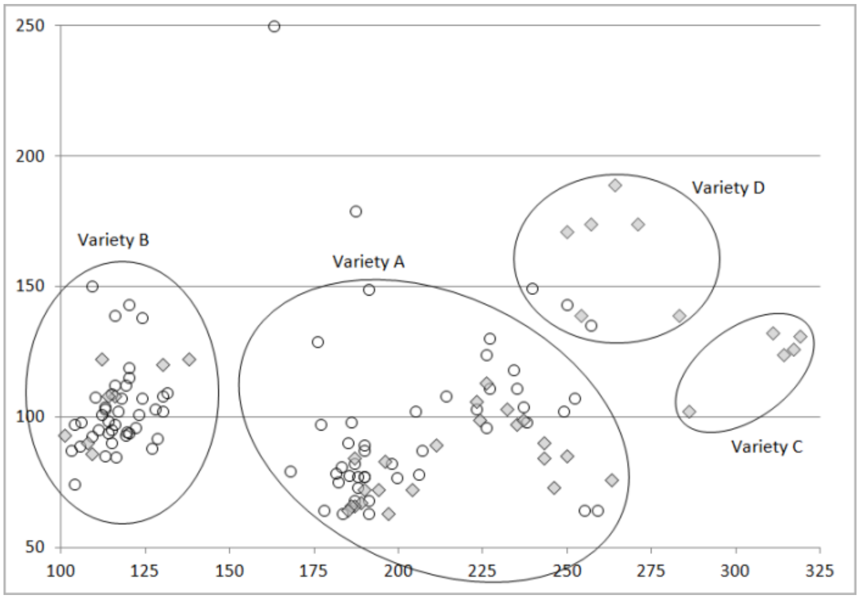

Figure 6-9. Scatterplot showing the amount of the trace elements Zirconium (Zr) on the x-axis and Strontium (Sr) on the y-axis, in parts per million, for geologic and artifact samples. Only those samples that could be XRF-tested with reasonable accuracy are shown. Geologic outliers, unknowns, and unassigned 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.

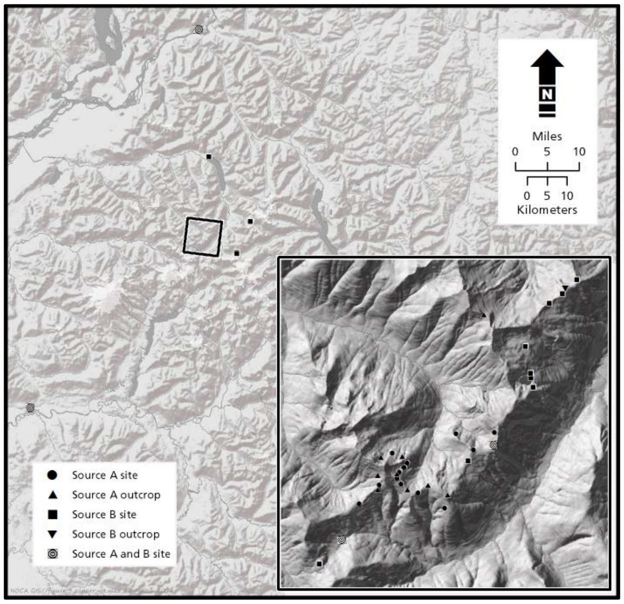

Figure 6-10. Map of Hannegan volcanics quarry complex outcrop and site locations plotted by geochemical source.

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.

Acknowledgements. Copper Ridge vitrophyre XRF data was acquired only through Craig Skinner's considerable support and efforts, despite too many phenocrysts, and this work has benefited immeasurably from his expertise. Numerous colleagues, subject matter experts, and keen observers contributed information about Hozomeen chert or Copper Ridge vitrophyre, or in other ways assisted our research, including Kelly R. Bush, Eric Bergland, Ned Brown, Greg Burtchard, Kent Bush, Larry Campbell, Tessa Campbell, Gerry Cook, Dave Conca, Russ Dalton, Ian Franck, Dave Harry, Ralph Haugerud, Richard Hughes, M. Dale Kinkade, Bob Kopperl, Brooke Larrabee, Michael Lenert, Phil LeTourneau, Rick McClure, John Mattson, Chris Miss, Dan Mulligan, Larry Nelson, Laura Phillips, Rudy Reimer, Jon Riedel, Mike Rousseau, Dave Schaepe, Randall Schalk, Craig Skinner, Doug Stephens, Gregg Sullivan, Roland Tabor, Jim Thomson, Dave Tucker, Andrea Weiser, and Richard Young. Analysis of the DgRi2 artifacts was through a temporary loan made possible by Dave Schaepe. Chris Miss shared unpublished results of XRF data from 45SK258. Throughout the project members of U. S. tribes and Canadian first nations shared their knowledge about traditional uses of the project area. The NPS' System-wide Archeological Inventory Program, Seattle City Light/City of Seattle, and the Skagit Environmental Endowment Commission have all contributed funding that supported field and laboratory studies. Monika Nill, Anne Braaten, and Sonya Pope assisted in design and preparation of maps and diagrams. The Burke Museum of Natural History and Culture, University of Washington, and the Tulalip Tribes Hibulb Cultural Center and Natural History Preserve graciously provided access to their lithic collections.

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