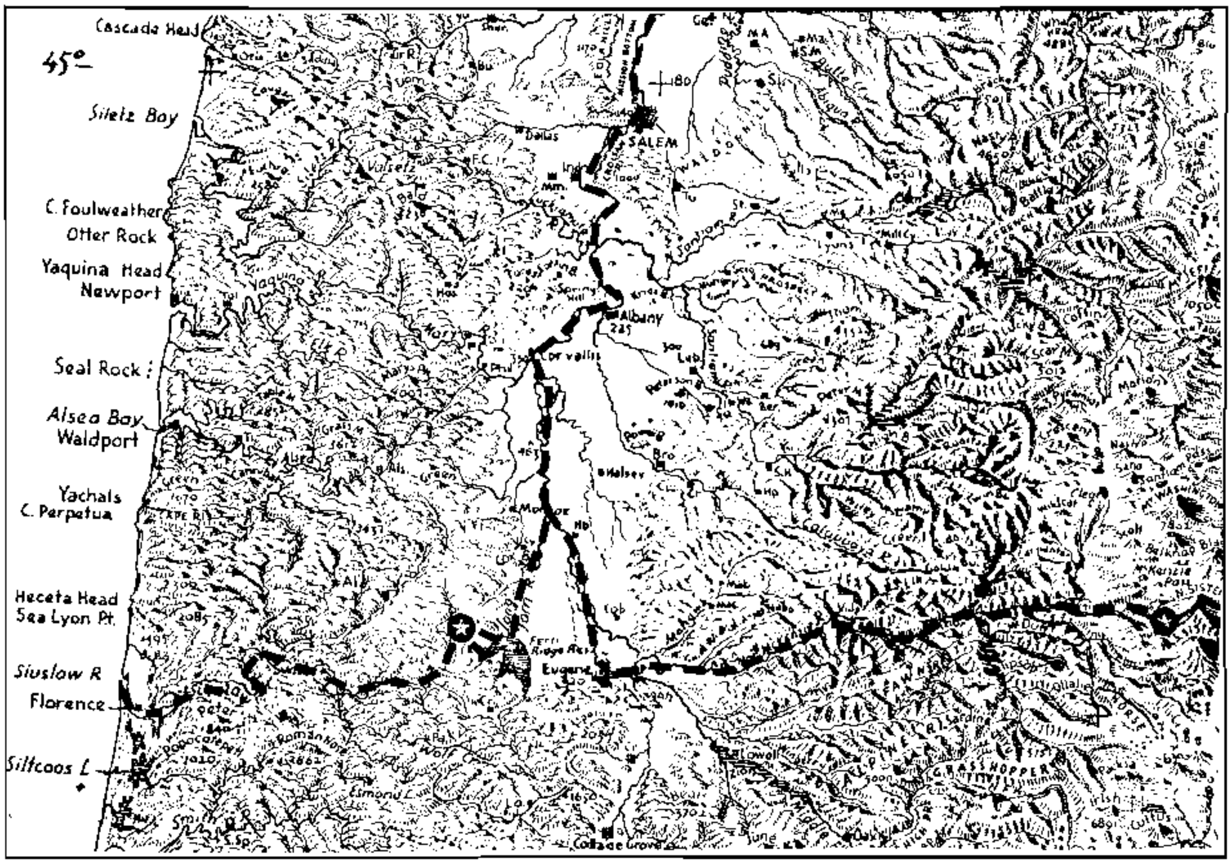
The Occurrence, Characterization, and Prehistoric Utilization of Geologic Sources of Obsidian in Central Western Oregon: Preliminary Research Results



Craig Skinner
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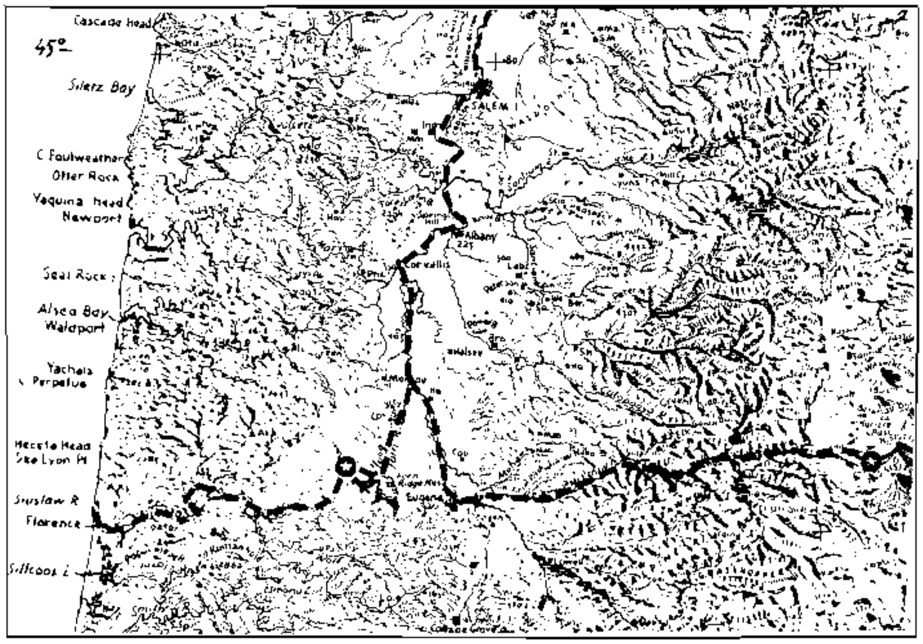

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NOTES AND ACKNOWLEDGEMENTS

The research that is reported in this paper was scattered over a number of years ranging from 1981 when I first began slogging around the Fern Ridge Reservoir mudflats looking for signs of an unlikely local source of obsidian to 1986 when I finished the last of the petrographic analyses of the many samples that ended up in my garage. The research described here about the geology, characterization and prehistoric utilization of Western Oregon obsidian sources, while still in its early stages, did seem to call for some sort of preliminary summing up at this point in time. The last minute discovery (by me, at least) of possible obsidian sources on the Middle Fork of the Willamette River (the Staley Creek source) and the Mt. Jefferson area (the Devil Point source) in the Western Cascades threatened to reduce this report to an even more preliminary state than I'd anticipated. To make things even worse, an initial look at a debitage collection from the coastal Umpqua-Eden Site suggested (numerous obsidian pebbles) that at least one, and perhaps two, secondary sources of obsidian may be present in the gravels of the Umpqua River. The Devil Point and Umpqua River possibilities surfaced after the following report was completed, however, and are not discussed in the text.

My thanks go to a number of different people who were helpful, either knowingly or unknowingly, in this research project: Linda Audrain, for help in crawling around gravel bars in search of the surprisingly elusive obsidian pebbles and for support in general; William Ayres and C. Melvin Aikens, for allowing me the academic room to pull the research together; Ewart Baldwin, for a helpful discussion on why obsidian should not found in the Oregon Coast Range: Pam Endzweig and Don Dumond, for access to the Oregon State Museum of Anthropology library; Elena Nilsson, for early XRF data from the Curt Day Acorn Site; Lance Peterson, for a great deal of tutoring in the pragmatics of X-ray fluorescence analysis; Rick Pettigrew, for details on the Long Tom River obsidian; Jon Silvermoon, for a bag full of much-needed obsidian samples from Obsidian Cliffs; Edward Taylor, for information on the Condon Butte area dome, and John Woodward, for details on the volcanic glass of the Clackamas River area. My special thanks to Rick Minor, who first told me of the Inman Creek and Siuslaw River sources of obsidian and who provided some of the samples.

The text of this report was produced on Leading Edge and Commodore 64 microcomputers using, respectively, the Leading Edge Word Processor and Write Now! word processing software. Text printing was done with a Comrex ComRiter CR-IIE letter-quality printer. The tables were composed using Practicalc and Sideways, electronic spreadsheet software for the Commodore 64. The spreadsheets were printed with a Star SG-10 dot-matrix printer. Figure 17 was created with an Apple Macintosh and the Data Desk statistical software package and was printed on an Apple Laserwriter. The ternary diagram in figure 6 was constructed using an IBM-PC version of the Geochemical Program Package. It's all enough to make you wonder if computers have made this kind of research simpler or not.

While the conclusions that I've drawn here are strictly my own, my thanks to all of you who may have helped along the way.

Craig Skinner
March, 1987

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Front cover: Map of central western Oregon showing known and inferred geologic sources of obsidian and proposed secondary distribution routes due to various geomorphic processes. Base map from Raisz (1965).

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1.0 INTRODUCTION

For many years, it was taken for granted by Oregon archaeologists that the only natural indigenous source of obsidian available to the prehistoric inhabitants of the Willamette Valley was in the river gravels of the McKenzie and Willamette rivers. It was also assumed that the small obsidian pebbles occasionally found in these river gravels originated at Obsidian Cliffs, a glaciated Pleistocene obsidian flow located at the western base of the North Sister in the Oregon High Cascades. Large obsidian artifacts and raw material from Western Oregon archaeological sites were thought to have been obtained either by direct procurement from sources in the High Cascades or through trade and exchange with aboriginal groups having more direct access to sources of glass in Central Oregon or Northern California. Along the Oregon central coast, the small quantities of natural glass found at excavated sites were also thought to have made their way west by trade (through the Coast Range) from the Willamette Valley.

Up until only a few years ago, the obsidian artifactual materials that appeared in archaeological assemblages in central Western Oregon were of interest to archaeologists primarily as a raw material for tool manufacture. Obsidian, though not naturally plentiful in the region, was found in most archaeological sites, especially those in the Willamette Valley and Western Cascades. Recently, though, archaeological interest has been piqued by advances in obsidian hydration dating and in obsidian characterization studies. The former promises the potential to directly date obsidian artifacts while the latter offers a means by which to reconstruct prehistoric patterns of contact and exchange. Western Oregon, with obsidian as an almost ubiquitous archaeological component, can be seen as an almost ideal region to apply these new obsidian analysis technologies.

Initial attempts at obsidian hydration dating and obsidian characterization of artifactual materials have proven somewhat less than successful, however. The Obsidian Cliffs flow was positively identified as the source of the McKenzie River gravel obsidian (White, 1974:220 and 1975:171), but after this initial step, research results became considerably less predictable. Toepel and Sappington (1982), in one of the few obsidian characterization studies to date in Western Oregon, identified the geologic sources of artifactual obsidian from the Halverson Site in the southern Willamette Valley as Obsidian Cliffs and Tucker Hill, an obsidian-rhyolite dome located several hundred kilometers to the east in the Great Basin. While this was certainly possible, it was an anomalous and unexpected finding; numerous sources were considerably closer than the one at Tucker Hill. Later work in the Willamette Valley revealed the presence of a second (and equally unexpected) geologic source of obsidian on the southwestern margin of the Valley (Skinner, 1983:304-320). Alluvial deposits exposed by streams near the Fern Ridge Reservoir northwest of Eugene were found to contain nodules of obsidian glass that would have been easily available to the prehistoric inhabitants of the Valley. Recent obsidian characterization studies in Western Oregon (Sappington, 1984, 1985a and 1985b) have suggested that the glass found in this area may be the actual source of the obsidian earlier attributed to Tucker Hill. A third possible obsidian source in Western Oregon has been reported by Woodward (1974:194-195) in the gravels of the Clackamas River near Oregon City. A Western Cascades source near Oakridge has also been proposed by Sappington (1986) on the basis of archaeological and geochemical evidence.

The few hydration dating studies so far carried out in Western Oregon have fared little better. Fagan (1975) and Minor (1980 and 1985) both found serious inconsistencies in their data that they attributed to stratigraphic mixing. With chemical composition playing a major role role in determining rates of hydration, the presence of unexpected multiple obsidian sources (when only one was anticipated) would have an unsettling effect on hydration research that did not take them into account. Recent obsidian hydration measurements from Western Cascade artifacts by Origer (1986), though not interpreted in the report in which they appear by Baxter (1986), also appear to exhibit similar inconsistencies.

It is the main contention of this report that the unspectacular results of obsidian studies to date in Western Oregon are primarily due to a lack of geologic and geomorphic baseline information about potential primary obsidian sources and their secondary areal distribution. Archaeologists, playing without a full deck, have suffered predictably unsatisfying results. As Earle and Ericson (1977) have pointed out, in regard to the development of characterization studies, it is essential that the archaeological study of obsidian be preceded by a thorough survey and sampling of available primary sources and the limits of their secondary distribution. These are research development stages that have been almost universally sidestepped by archaeologists whose interests are, understandably, focused on the data that artifactual characterization can provide. Nevertheless, it is crucial that these initial, non-archaeological research steps be religiously adhered to. The computer programmer's maxim of garbage in = garbage out applies all too well to archaeological interpretations drawn from haphazard obsidian characterization studies.

It is also suggested here that obsidian studies in Western Oregon could prove to be a very useful adjunct to current routine archaeological analysis strategies in the region. The very paucity of regional obsidian sources simplifies the juggling of the competing variables involved in obsidian studies. Obsidian hydration and characterization research can proceed in a somewhat simplified context in Western Oregon. The possibility of successful and routine characterization research should be considerably enhanced, for example, over the central and eastern portions of the state, where over a hundred discrete obsidian sources are known to exist.

The purpose, then, of this paper and of the research that is reported here is to provide some preliminary data that will enhance archaeological obsidian studies in the central western part of Oregon - the Western Cascades, the Willamette Valley, and the Oregon Coast.

1.1

Obsidian and the Distribution of Geologic Sources in Oregon

Before I move to the major theme of the paper, let me digress for a moment and answer two basic questions germane to the study of obsidian in Oregon - Just what is obsidian? Where is it found in Oregon?

Obsidian is a naturally occurring volcanic glass and is easily recognized by its glassy texture and classic conchoidal fracture. Though the term obsidian is a textural one, the chemical composition of the glass is usually rhyolitic, typically ranging in silica content from between 68 and 78 percent. It is this unusually high silica content that is largely responsible for the formation of the glass. The lavas are extremely viscous when extruded (the high viscosity largely being a function of the large silica content) and the constituent ions are unable to form a crystalline structure prior to cooling. The resulting glass, actually a supercooled liquid, is metastable and over long periods of time will absorb environmental water to form the crystalline perlite. This process of hydration and alteration to perlite proceeds at a regular, if somewhat hard to determine, rate and provides the theoretical basis underlying the obsidian hydration dating method. Oregon is blessed (or perhaps cursed, in the case of obsidian characterization research) by a considerable overabundance of obsidian sources. With well over 100 separate obsidian sources so far identified in the state, it seems likely that nowhere else in the world are so many discrete sources found in so limited a geographic area. In archaeological characterization studies where it is necessary to identify the geologic source of artifactual materials, this preponderance of sources is a notable complicating factor. Not only does the reliable correlation of artifactual obsidian and geologic sources become more difficult, but the archaeologist is faced with the monumental task of adequately identifying and characterizing over 100 geologic sources before the results of archaeological obsidian studies can be considered at least approximations of the truth.

These numerous Oregon sources are found almost exclusively in the portion of the state located to the east of the Cascade Range and are most commonly found as obsidian flows or as domes of comingled obsidian and rhyolite. The majority of the obsidian domes and flows are found associated with three large-scale tectonic features:

1. The north-south trending High Cascade Range - Obsidian sources are particularly common in the Three Sisters and Crater Lake areas, two regions dominated by late Pleistocene to Holocene bimodal (basalt-rhyolite) volcanic activity (Williams, 1944; Bacon, 1983; Clark, 1983).

2. Two broad belts of obsidian-rhyolite domes in south-central and southern Oregon - These zones, trending about N. 75 deg. to 80 deg. W., roughly parallel the Brothers Fault Zone in the north and the Oregon-Nevada (Orevada) lineament in the south (Allen and Bealieu, 1976; Berri, 1982; Hughes, 1983; MacLeod et al., 1975; Skinner, 1983:227-302); Stewart et al., 1975; Walker, 1974).

Caldera structures are also associated with several major obsidian source areas in Oregon. Most notably, these include the Newberry, Crater Lake, and McDermitt calderas, though further investigation will likely confirm the importance of other Oregon calderas as well (Allen, 1979 and 1982).

In addition to these major source areas of natural glass, obsidian is also found in a number of other locations in the state, though these tend to be concentrated in the Great Basin. Only two sources are definitely known to exist west of the High Cascades, both of these in the Coast Range. The rhyolitic volcanic activity associated with obsidian has been widespread in Oregon from the Miocene through the Holocene and this volcanism has left behind a plentiful legacy to be utilized by prehistoric peoples and to be studied by modern-day archaeologists.

2.0 RESEARCH OBJECTIVES

The main overall objective of the research reported in this paper is the geologic and geomorphic investigation of indigenous sources of obsidian glass in central Western Oregon, including the central coast, the Coast Range, the Willamette Valley, and the Western and High Cascades. There were, however, a number of explicit research objectives that were considered during the course of the study. These were:

1. The identification of primary and secondary sources of obsidian in central Western Oregon - It has long been taken for granted that the only natural sources of obsidian in west central Oregon were small nodules of glass fluvially transported from a single source in the High Cascades, the Obsidian Cliffs flow. Additional sources in the Willamette Valley, in the Western Cascades and at the Oregon coast have recently been identified and described, however (Woodward, 1974:194-195; Skinner, 1983:304-320; Sappington, 1986). A thorough literature search was conducted to locate extant references to possible Western Oregon obsidian sources. Field investigations and sampling were then carried out at the possible sources of natural glass that were identified. Care was taken to distinguish both the primary and secondary depositional contexts of the glass, an often overlooked aspect in obsidian studies, so as to determine the actual boundaries of the sources. Geomorphic processes responsible for the transport of the obsidian to secondary contexts were also identified.

2. The geochemical characterization of the identified obsidian sources - The trace element abundances (Sr, Zr, and Rb) of several samples collected during early stages of the research was determined so as to "fingerprint" or characterize the obsidian sources. These data were used to determine the number of geochemically-discrete obsidian source populations that were distinguishable among the Western Oregon sources. The viability of petrographic methods of characterization for Western Oregon obsidians was also tested using this baseline geochemical data.

3. The testing of the usefulness of petrographic characterization methods in the "fingerprinting" of Western Oregon obsidian sources - The presence of microscopic petrographic structures has been suspected to be useful in the identification of obsidian sources or in the delineation of subgroups of obsidian populations. Based on encouraging preliminary research results (Skinner, 1983:142-151,334-335,355 and 1984), it was decided to test the usefulness of petrographic characterization techniques in the identification of Western Oregon glass. This was done using the rather small population of geochemically characterized obsidians collected early in the research. Results of this test were then used to tentatively identify the primary sources of obsidian collected (from secondary contexts) during later stages of the investigation.

4. The examination of patterns of prehistoric obsidian procurement and utilization in central Western Oregon - The results of archaeological research conducted in Western Oregon were carefully examined to determine the extent of indigenous obsidian use by prehistoric populations and to approach several questions: Was procurement of the obsidian from Western Oregon sources

accomplished by direct access or through exchange? Was there differential utilization of obsidian and obsidian sources in Western Oregon? How would differential utilization, if found, be expressed in synchronic and diachronic dimensions? What kind of natural and cultural processes could reasonably be used to explain the patterns or changing patterns of obsidian utilization that are found in the archaeological record of Western Oregon?

5. The examination of the archaeological implications of the geological and geomorphic results of this investigation - What are the archaeological implications resulting from the identification of multiple native obsidian sources in Western Oregon? How would this affect obsidian characterization studies in Western Oregon? Will petrographic characterization methods be useful in future archaeological obsidian studies? How about the implications for the reconstruction of prehistoric patterns of contact and exchange? Obsidian hydration studies? These are all questions that have to be addressed by archaeologists dealing with the systematic study of natural glass found in archaeological settings in Western central Oregon.

3.0 PRIMARY AND SECONDARY CONTEXTS OF OBSIDIAN SOURCES

3.1
Introduction

As archaeologists become increasingly interested in the reconstruction of extinct trade and exchange networks through the investigation of characterized lithic artifacts, an understanding of the role of the natural processes that are involved in the distribution of artifactual raw materials will also become increasingly important. The human transport of obsidian, as reflected in the spatial patterning of artifactual obsidian, is only one of many different ways in which obsidian may find its way from an original, primary source to a secondary location spatially removed from the original source.

The natural, geomorphic processes that may account for the spatial distribution of natural glass have been largely disregarded by archaeologists engaged in the study of prehistoric exchange or procurement systems. As I will emphasize here, however, it is essential in archaeological obsidian characterization studies, both in Western Oregon and elsewhere, that the geomorphic processes that affect the movement of obsidian from primary to secondary localities be understood.

3.2
Primary and Secondary Sources of Obsidian

Primary sources of obsidian are those that occur at or near the volcanic vent from which the obsidian was extruded. Typically, these primary sources are obsidian flows, obsidian-rhyolite domes, or the chilled selvage of rhyolitic bodies. Vents from which volcanic ash-flows or tephra containing obsidian were erupted are considered to be primary sources; their resulting deposits are considered to be secondary sources.

As is the case for most Western Oregon obsidian sources, obsidian can also be recovered from secondary contexts or sources. Secondary sources are spatially removed from their parent primary sources, sometimes as much as several hundred kilometers. These secondary sources of obsidian can be found as stream gravels, as surface float, as fragmental glass, as glacial till, as volcanic bombs, in laharic deposits, in ash-flow deposits, in near-to-vent tephra deposits, as landslide debris, as glacial erratics, or in archaeological sites (see figure 2)(Skinner, 1983:52-56; Torrence, 1984).

For the purpose of archaeological characterization studies, an obsidian source is definable as an aggregate of its primary and secondary occurrences. This source must also be distinguishable from other sources on the basis of some geochemical or physical property such as trace element composition, index of refraction, or presence of some petrographic structure. Aboriginal inhabitants of the Willamette Valley who used obsidian from Obsidian Cliffs, for example, would be drawing from a single geochemically-distinguishable source whether they gathered the glass directly at Obsidian Cliffs or from river gravels 150 kilometers from the flow. Both would be considered as widely-separated outcrops of one source, though each could be classified as a separate quarry site on the basis of archaeological evidence. The nature of the characterization technique may also influence what may be considered a source. Trace element abundances, for instance, might be used to identify an individual obsidian flow in a region crowded with sources. On the other hand, a less powerful attribute such as major element composition may only be able to distinguish to a regional level; the "source" considered would actually consist of several discete units resulting from different eruptive events.

Little archaeological attention has been focused on the problems of primary and secondary deposits of lithic raw materials. Hurtado de Mendoza (1977:59-60) and Hurtado de Mendoza and Jester (1978) recognized that not all obsidian sources are primary. They attributed the presence of obsidian in secondary contexts to "drift" processes, which they classified as natural and cultural (human). Specific modes of obsidian transport were later described, in somewhat more detail, by Skinner (1983:52-56). Most recently, Meltzer (1984-85), in a study of supposed "exotic" (made from materials not available locally) chert artifacts from the Great Lakes region of the United States, identified secondary transport factors that accounted for their local availability. Previous researchers had used the presence of this so-called "exotic" chert in their attempts to demonstrate wide-range patterns of prehistoric mobility.

The source area, then, that must be considered in archaeological obsidian characterization studies, is a combination of both the primary and secondary sources. The size and boundaries of this resultant source area can only be determined (when the existence of secondary sources is suspected) through careful geologic field investigation during which the aerial extent and primary source(s) of the glass are determined. While this is a methodological step almost universally passed over in archaeological obsidian studies, it is one that must be taken so that these studies reflect cultural movement and not the existence of unrecognized natural processes. These principles hold true, of course, for any lithic artifactual material that can be characterized when the subsequent reults are used to make inferences about prehistoric behavioral systems. The identification of the true boundaries of obsidian sources is particularly important in the archaeological investigation of Western Oregon natural glass, most of which has been transported to widely dispersed secondary sources by a variety of geomorphic processes.

3.3

Modes of Obsidian Transport in Western Oregon

In general, the major types of processes involved in the natural movement of materials on the earth's surface are mass-wasting, fluvial, aeolian, tectonic, glacial, and volcanic (Butzer, 1976). In addition to these, human or biological agents are also responsible for the movement of relatively small quantities of material, though these may be significant in their effect on human populations.

The most significant transport processes that may affect the spatial distribution of obsidian are illustrated in figure 2. Aeolian and large-scale tectonic processes are not considered here as important. Though examples of almost all these processes can be found in Oregon (Skinner, 1983:54-56), only three are of importance in considering the spatial patterns of the obsidian found in Western Oregon:

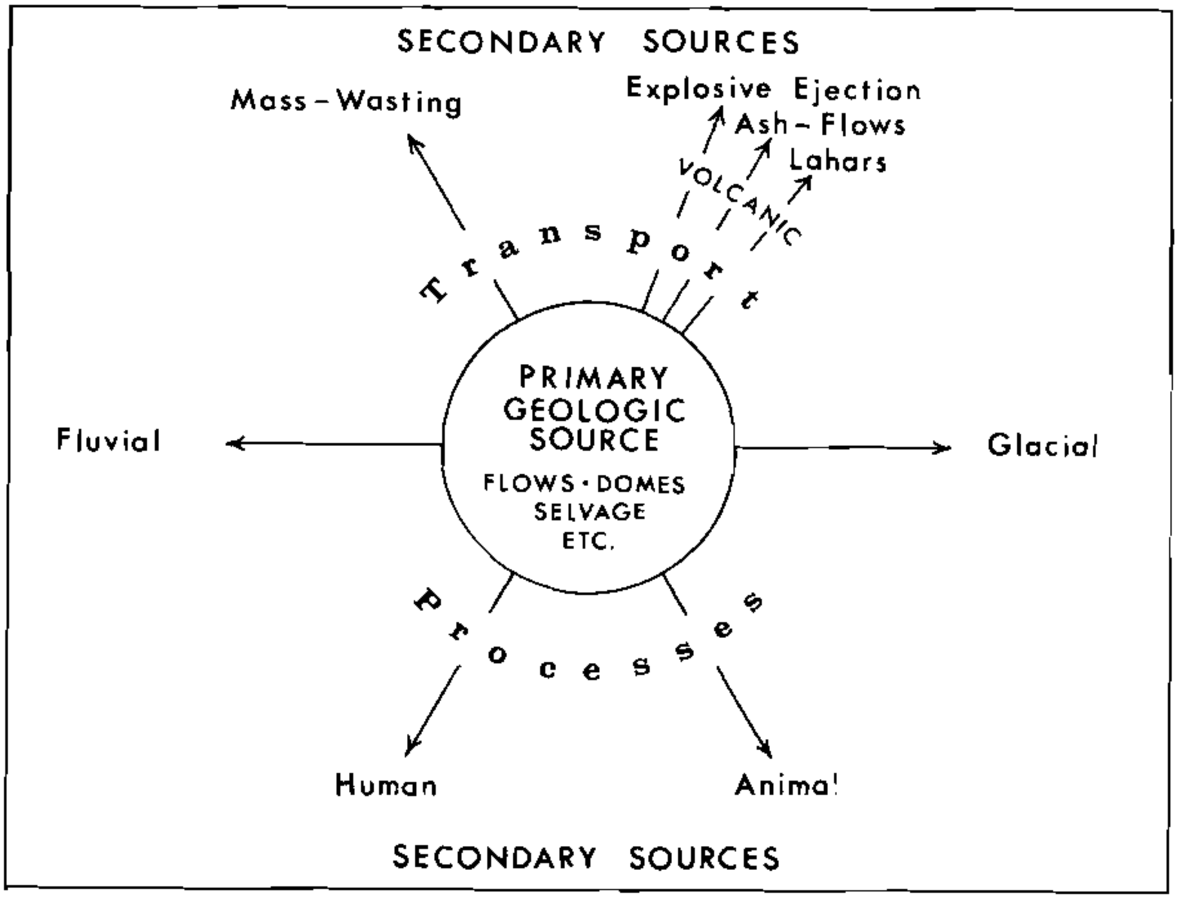


Figure 2: Geomorphic processes involved in transport of obsidian from primary to secondary depositional contexts (from Skinner, 1983, with additional inspiration from Torrence, 1984).

1. Glacial Transport. Glaciers overriding primary obsidian sources can undermine or pluck obsidian from the source, later depositing the glass "downstream" in morainal deposits of glacial till. This process took place in Oregon's central Cascade Range when Pleistocene mountain glaciers moved High Cascade debris, including obsidian, into the river valleys of the Western Cascades (Taylor, 1968; Skinner, 1983: 54,102).

2. Fluvial Transport. The movement of obsidian from its primary source by rivers and streams is the most important geomorphic transport mode in evidence in Western Oregon. Obsidian finding its way into the bed-load of a river can be carried long distances downstream, though the potential transport distance for glass of large enough size for prehistoric use was probably limited because of mechanical abrasion (Pettijohn, 1975:45-46). O'Keefe (1976:29) describes a study concerning the weight loss of artificial glass as a function of its distance downstream from its source. 99 percent of the mass of the glass was lost in a distance of 40 kilometers. Studies with other lithic materials have

shown, though, that weight loss plotted versus distance displays a lognormal relationship with a higher rate of loss taking place near the source (Schlee, 1957; Pelletier, 1958; Pettijohn, 1975:47). Small nodules of obsidian could therefore be expected to survive intact for relatively long distances; in practice, obsidian of archaeologically-usable size (at least 4 cm in diameter) has been recovered from Willamette River gravels several hundred kilometers downstream from its primary source in the High Cascades (Minor, 1977; also, this study).

3. Human Transport. The last important agent of transport is the human one and it is this process that most archaeologists involved in the characterization of archaeological obsidian are interested in documenting. When artifactual obsidian from these human-introduced secondary sources (archaeological sites) is correlated with their primary sources, it becomes possible to infer extinct patterns of procurement, movement, contact, and trade. This end can only be reliably achieved, though, when the primary and secondary sources are both well-documented. Humans provide only one of several means of removal and transport of obsidian from its parent source and the failure to take other (natural) processes into account can lead to fallacious and unreliable archaeological models of prehistoric behavior.

4.0 PRIMARY AND SECONDARY SOURCES OF OBSIDIAN IN WESTERN OREGON

Primary and secondary sources of obsidian are found in numerous locations in central Western Oregon. In this section, the geologic and geomorphic contexts of these sources are described.

4.1

The High Cascades Sources

Primary obsidian sources in the Central High Cascades are focused exclusively in the Three Sisters area, a region of unusually abundant silicic volcanic activity. Obsidian flows and domes, ranging in age from the Pleistocene to the late Holocene, are found in two areas in this region. The most significant of these sources for Western Oregon obsidian studies are found near the North Sister, most notably at Obsidian Cliffs. The majority of the Three Sisters sources, though, lie on the flanks of the South Sister. These flows and domes are not located in drainages leading to the western side of the Cascades and were only sampled on a reconnaissances basis for this current investigation. Because of the proximity of the South Sister obsidian sources to significant Western Oregon sources and to probable prehistoric travel routes into the Willamette Valley, though, these sources are briefly described here.

4.11 Obsidian Cliffs Obsidian Flow

The Obsidian Cliffs source is a large glaciated flow of obsidian and rhyolite that is located near the northern end of the Three Sisters Wilderness Area (figure 4). Spectacular 70 to 90 m-high cliffs of rhyolite and obsidian mark the northwest end of the 2.4 km-long flow, giving the source its name (plate 2). Above the cliffs is a sloping, glacially-scoured plateau (plate 1) that reaches an elevation of about 2,130 m (7,000 ft) at the vent area.

Much of the Obsidian Cliffs source consists of pale gray rhyolite intermixed with glassy, gray-black and occasionally red obsidian. Spherulites and lithophysal bands are common, though they were most frequently encountered during sample collection near the borders and vent area of the flow. The top of the flow, a plateau sloping upwards towards the Middle Sister, is covered in many areas by obsidian nodules with diameters commonly exceeding 20 cm. The entire area is blanketed by a layer of volcanic tephra, most likely originating from Mount Mazama (the ancestral Crater Lake) or perhaps from a nearby vent now covered by the Rock Mesa Obsidian Flow.

The geology of the Obsidian Cliffs flow has been described by a number of researchers, most notably Hodges (1925:103-108) and Williams (1944:48). The major and trace element composition of the glass has appeared in Anttonen (1972:92), S. Hughes (1983:133), and Skinner (1983:155,161).

The glacier that swept over the Obsidian Cliffs flow extended westward down the Lost Creek Valley to the McKenzie River. Taylor reports (1968:15) that during

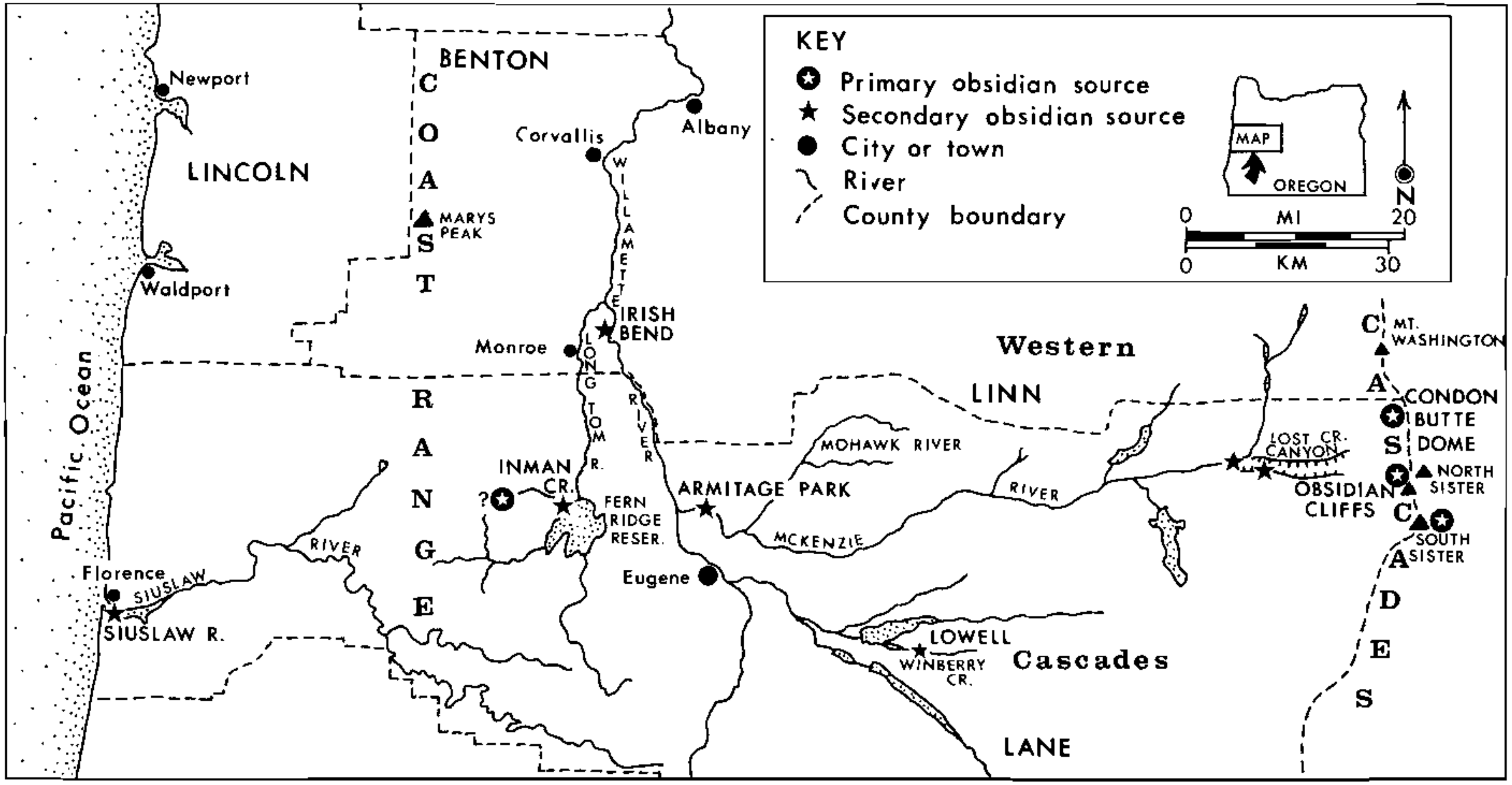


Figure 3: Location of the primary and secondary sources of obsidian and obsidian-like vitrophyre that were sampled for this investigation.

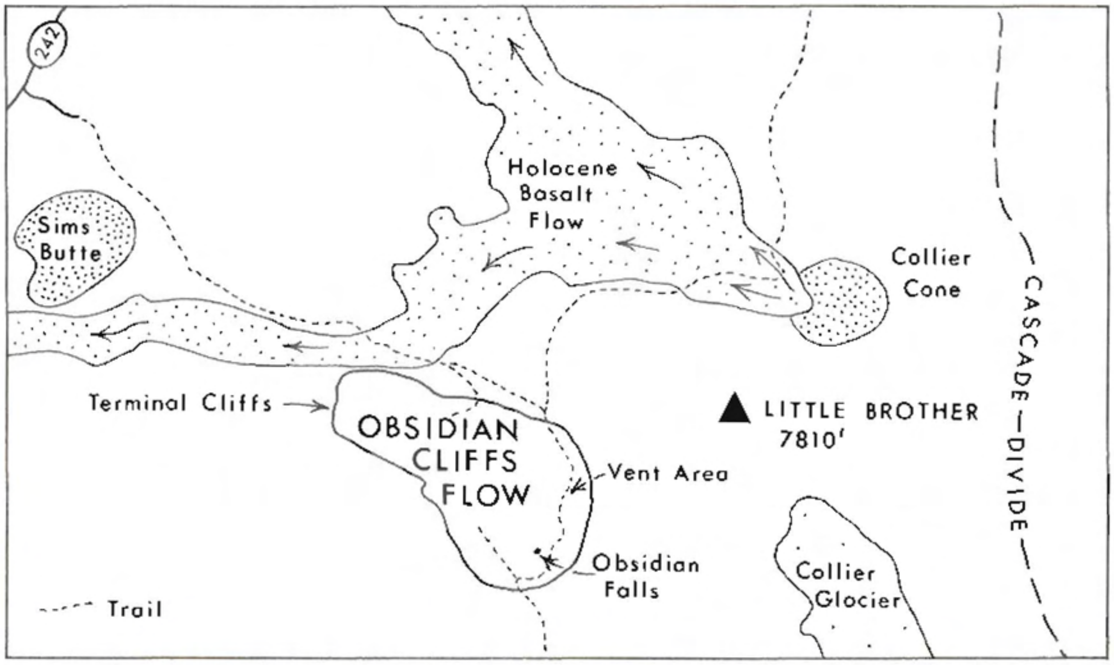
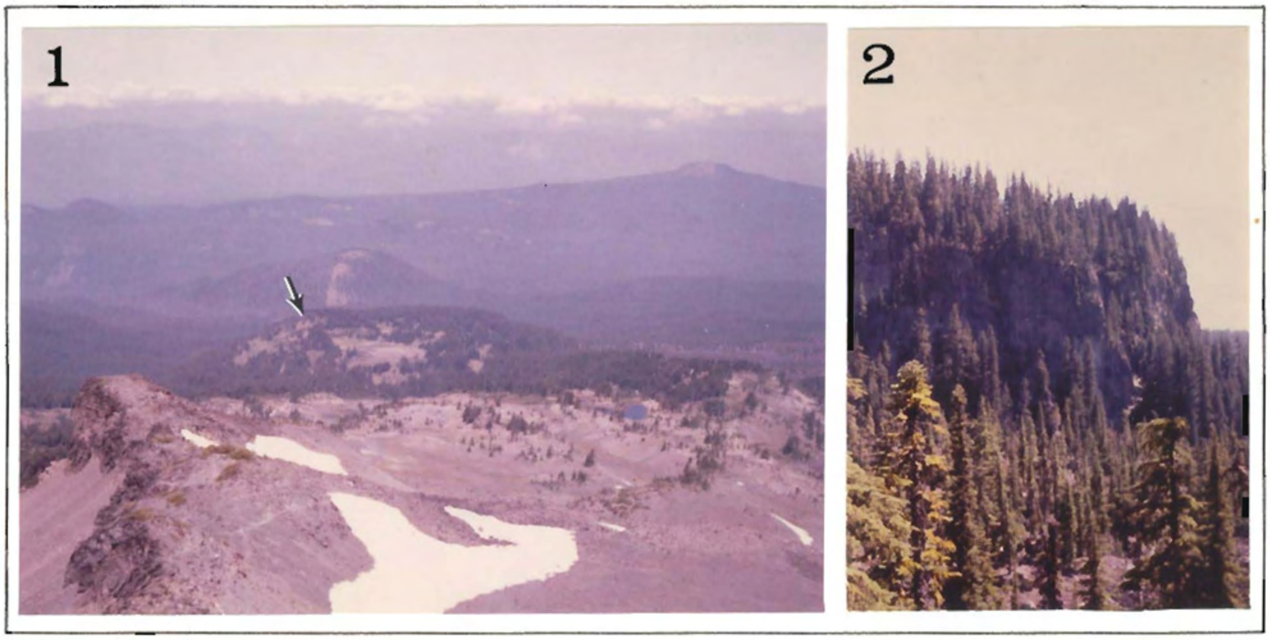


Figure 4: Sketch map of Obsidian Cliffs area, High Cascades. Scale: 1.5 cm = 1 km. North is to the top.



Plates 1-2. Obsidian Cliffs obsidian flow, Oregon High Cascades. Plate 1: The Obsidian Cliffs flow appears in the center of the photograph as a lobe projecting westward from near the foot of the Middle Sister. The plateau on top of the flow is littered with nodules and outcrops of obsidian as well as with many prehistoric quarry sites. Taken facing west from the summit of the Middle Sister. Plate 2: The 90 m-high terminal cliffs at the western end of the flow. Taken facing southwest.

the latest Wisconsin glaciation this canyon was completely filled with ice that overflowed the north rim, depositing morainal obsidian in at least one adjacent valley. Obsidian nodules can be found today in deposits of glacial till on the floor of the Lost Creek Valley and in road cut exposures near the junction of Highways 126 and 242 (Taylor, 1968:14). The glacially-transported obsidian also found its way into the McKenzie River where the river intersected deposits of till left near the terminus of the Lost Creek Valley glacier. This obsidian has been carried west down the McKenzie drainage into the Willamette River, creating a widespread secondary source of glass in Willamette Valley River gravels. Glacial outwash from the central Cascade Range was also widely distributed throughout the southern Willamette Valley during the late Pleistocene (Lawrence et al., 1977), though obsidian from Obsidian Cliffs has been reported only from the gravels of the present-day McKenzie and Willamette rivers (White, 1974:220 and 1975:171; Toepel and Sappington, 1982). Waterworn obsidian pebbles have also been found, however, in late Quaternary gravels from modern quarry locations near Corvallis in the central Willamette Valley.

Eighteen samples of glass from scattered localities at the Obsidian Cliffs flow were examined as part of this investigation

4.12 Condon Butte Area Rhyodacite Dome

Located 1 km southwest of Condon Butte and 3.3 km south of Highway 242, this unnamed rhyodacite dome lies only 5 km west of the Cascade Divide. The dome is clearly visible from the Dee Wright Observatory at McKenzie Pass as a knob to the left of Condon Butte (Skinner,1983:16).

This landform is briefly described by Taylor (1968:21 and 1981:66) as a glaciated dome of rhodacitic obsidian. Taylor feels that the obsidian formed as selvage at the outer part of the dome, this outer layer being later completely removed by Pleistocene glaciation. He attributes very small fragments of obsidian found to the east in airfall deposits as originating from this source (E. Taylor, personal communication, 1982). Fragments of gray obsidian from the dome are also found in surficial glacial deposits a few kilometers to the west in the Hand Lake area (Taylor, 1968:18). A search by the author in 1981 and 1985 revealed no obsidian at the dome, though several samples of a very fine-grained, glassy, gray rhyodacite (perhaps interpreted as obsidian?) were collected in 1985. The aerial distribution of obsidian from this source is presently unknown. It is conceivable, though, that the same mountain glaciers that carried Obsidian Cliffs glass west to the McKenzie River could have also carried obsidian from the Condon Butte area dome.

4.13 South Sister Area Obsidian Sources

Numerous Quaternary obsidian domes and flows are located on the eastern and southern flanks of the South Sister Volcano (figure 5). Over a dozen unglaciated (Holocene) and glaciated (Pleistocene) obsidian occurrences have been identified in geologic studies of the South Sister area (Hodges, 1925:55-58; Williams, 1944; Anttonen, 1972:90-93; Taylor, 1978:25-26,33-35; Clark, 1982:15,29,32-33; S. Hughes, 1983:128; Wozniak, 1982:24-26,37; Skinner, 1983:246,269-270,272-273). Major and trace element composition of several of these obsidian sources has been reported by Anttonen (1972:90-93), Taylor (1978:37-38,41,43), Clark (1982:204-205), S. Hughes (1983:133), and Wozniak (1982:87,96). A reconnaissance survey of the southern slopes of the South Sister in 1986 revealed that many of the reported obsidian sources in this area are not of artifactual quality. Obsidian at the Rock Mesa flow, a small dome immediately to the northeast of Rock Mesa, the chain of obsidian domes roughly paralleling Goose Creek, Kaleetan Butte and Devil's Hill all proved to be very porphyritic and were not of tool-making quality.

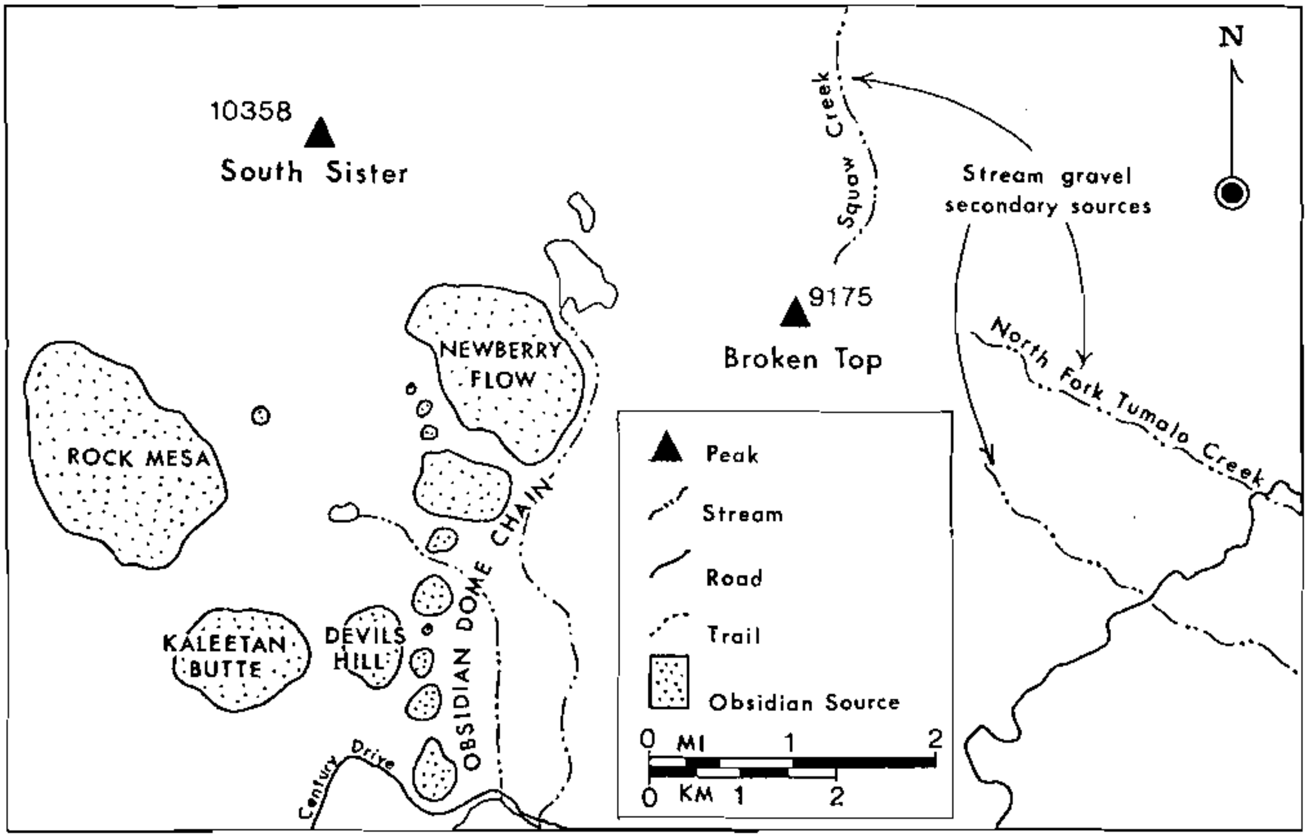


Figure 5: Sketch map of the South Sister vicinity showing obsidian sources.

A single secondary source of artifact-quality obsidian was found, however, on the eastern upper slopes of Broken Top Volcano. Nodules of obsidian up to 10 cm in diameter were found in the gravels of the Upper North Fork of Tumalo Creek up to an elevation of at least 2,130 m (7,000 ft). Similar glass nodules were also located in an intermittent unnamed stream less than 1 km south of Tumalo Creek. Based on the presence of the glass and the similar suite of rocks found in the fluvial gravels of both streams, it seems almost certain that a source of obsidian is being intersected locally by these streams at an elevation greater than 2,130 m (7,000 ft). Another unnamed intermittent stream bed located approximately 3 km south of Tumalo Creek contained no obsidian. The source of the Tumalo Creek glass may be the same source described by Taylor (1978:34-35) as a glaciated rhyodacite tuff cone composed of devitrified pumice and welded tuff containing obsidian and rock fragments. Explosive vent activity could have easily spread obsidian fragments over a relatively wide area where they are now being eroded out by stream activity. The Upper North Fork of Tumalo Creek is a tributary to the Deschutes River and it is likely that obsidian from this source is being contributed to the gravels of the Deschutes River.

Swift (1986) has also reported the presence of obsidian nodules in the gravels of Squaw Creek, the headwaters of which are located only a few kilometers northwest of the source of Tumalo Creek. It may well be that the same primary obsidian source is being intersected by both streams. Obsidian is also found in deposits of glacial till in the Squaw Creek area (Swift, 1986) and it is likely that glacial activity has widely distributed obsidian glass on the flanks of Broken Top Volcano.

4.2
The Western Cascades Sources

While no true primary obsidian sources are definitely known to exist in the Western Cascades, secondary deposits of glass as well as an unusual deposit of obsidian-like vitrophyre can be found there.

4.21 Lost Creek Canyon Morainal Obsidian

Obsidian nodules originating from the previously-described Obsidian Cliffs source are plentiful in morainal deposits on the floor of the Lost Creek Valley. The diameter of the obsidian till commonly exceeds 5 cm. Several samples were collected from the valley floor and from a roadcut where the glacier flowed into the Upper McKenzie River Valley near the present-day community of McKenzie Bridge.

4.22 McKenzie River Gravels

Several samples of glass from secondary river gravel deposits were also obtained from the McKenzie River near Armitage Park in Eugene. McKenzie River gravel bars near the towns of McKenzie Bridge and Blue Ridge were also unsuccessfully searched for obsidian.

4.23 Obsidian-Like Vitrophyre Near Lowell

An unusual outcrop of obsidian-like vitrophyre was located at an elevation of about 300 m (1000 ft) in the Willamette National Forest about 14 km east of the town of Lowell. This outcrop, actually the densely-welded portion of a volcanic ash-flow tuff, is exposed in a road cut adjacent to Winberry Creek, a perennial stream now feeding the Fall Creek Reservoir. The obsidian-like vitrophyre, while not considered a true obsidian, bears a megascopic resemblance to obsidian and could be easily confused with it by a non-geologist.

The ash-flow deposit consists of a black, glassy zone about 3 m thick located at the base of the main ash-flow unit. The densely-welded zone overlies thin-bedded pond or lake sediments and was likely formed when the original hot pyroclastic flow was emplaced over the water. When this occurred, water vapor was absorbed, lowering the melting point of the ash-flow and allowing refusion into a dense black glass (McBirney, 1968). The areal extent of the obsidian-like component of the ash-flow is not known, though it is probably limited. Ashwill (1951:18) mentions that small lake and pond deposits are found in upper Miocene to Oligocene ash-flow tuffs only a few kilometers north of the Winberry Creek exposure and that they were limited in size. These tuffs may be approximately contemporaneous in age with the Winberry Creek vitrophyre.

This locality was geochemically-characterized and briefly described by Skinner (1983:103-105), who speculated that the ash-flow tuff may have been used as a limited local source of archaeological lithic material.

4.21 Staley Creek Source

The high percentage of obsidian debitage, the presence of larger than expected quantities of unworked obsidian pebbles at several archaeological sites, and the trace element analyses of obsidian from four sites in the Oakridge area of the Upper Middle Fork of the Willamette River have recently led archaeologists to suggest the presence of a new obsidian source in this area (Baxter, 1986b; Sappington, 1986). Sappington (1986) has named this suspected source the Staley Creek source after a local tributary to the Willamette River.

While there is no reason to doubt the existence of new sources (to archaeologists) of natural glass in the Western and High Cascades, trace element data concerning the Staley Creek source and the geologic sources of archaeological obsidian from the Staley Creek area present some problems. Sappington (1986:110), in discussing trace element analyses of obsidian pebbles from sites in the Staley Creek area, writes:

> "As a group, these pebbles were distinct from all sources with the exception of Fern Ridge, located 15 km west of Eugene, based on F-statistics at the .01 level. Individually, most items in this group were also classified as belonging to the Fern Ridge source. While it is possible that the Staley Creek material simply represents material brought into the Oakridge area by the aboriginal inhabitants of these sites, the preferred explanation is that these two groups represent different exposures of chemically similar material."

Sappington concludes, after statistically comparing the Oakridge area glass with 13 previously characterized Oregon sources (the Fern Ridge source was not included because of its known similarity in composition to the Oakridge samples) that 98.2% of the 282 characterized artifacts originated from the Staley Creek source. Notwithstanding the reliability problems associated with statistical correlation methods and incomplete source universes (see Chapter 1 of this paper and Hughes, 1984), there is simply no basis for this conclusion. The removal of the Fern Ridge source because its presence creates disagreement with the expected results flies in the face of good science - in this case, data are being manipulated so that a hypothesis (the proximity of a local obsidian source) is supported. There is no reasonable geologic or petrologic basis to support the belief that the Fern Ridge and "Staley Creek" sources are "different exposures of chemically similar material". Many years of obsidian characterization studies have shown that obsidian sources are remarkably distinct in their trace element composition (Skinner, 1983:19-20). Even though other lines of evidence, particularly the anomalously high relative frequency of obsidian debitage at the Oakridge area sites, suggest the possible existence of a local geologic source of obsidian, a more plausible research methodology must be utilized to verify that fact.

Trace element analyses by Hughes (1986) of 20 obsidian artifacts from two of the same four archaeological sites (35 LA 529 and 35 LA 599) that Sappington examined does little to clear up the confusion. It is, unfortunately, not possible to directly compare the data of Sappington with others as his data are presented only as intensity counts for each detected trace element. Hughes, however, concludes that the artifactual obsidian from the two sites originated from at least seven different geologic sources (see figure 6). The Fern Ridge area source was represented by 28% of the collection, Obsidian Cliffs by 13%, and 28% by two unknown sources; the remaining artifacts appear to have originated from central Oregon. Whether the "unknowns" of Hughes results are from a local source or from other as yet unidentified sources in his database will require further research to clarify. The contradictory results of the work of Sappington and Hughes, though, are striking and once again, only further research will reveal whether one or several sources were utilized by the inhabitants of the Western Cascades. If a Staley Creek source does exist, though, it would be another potential contributor of natural glass to the alluvial gravels of the Willamette Valley. A clear understanding of obsidian utilization patterns in western Oregon will require that further characterization work be directed towards clearing up the status of this possible source. Is there a Staley Creek source or is it only a figment of the archaeological imagination?

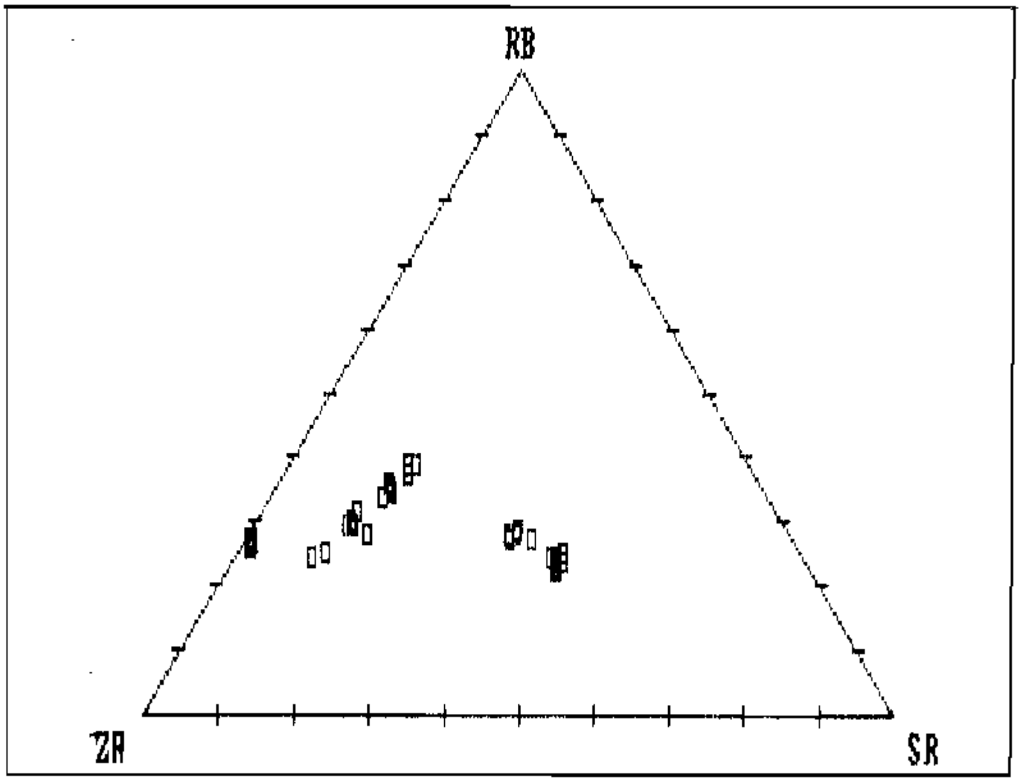


Figure 6: Ternary diagram illustrating the relative abundances of Rubidium, Strontium, and Zirconium found in artifactual obsidian from sites 35 LA 529 and 35 LA 599 in the Oakridge area of the Western Cascades. Trace element data for the diagram are from Hughes (1986). At least seven different geologic sources appear to be represented.

4.3
The Willamette Valley Sources

While small fluvially-transported obsidian pebbles from the High Cascades Obsidian Cliffs source are widespread in McKenzie and Willamette River gravel deposits, two geologically-unexpected secondary sources have also been located in the southwestern part of the Valley.

4.31 McKenzie River Gravel Obsidian

As previously mentioned, obsidian from Obsidian Cliffs can be found in the gravels of the McKenzie River. Pebbles of unworked glass recovered from the Hurd archaeological site near the McKenzie River were reported as large as 6.7 cm in diameter (White, 1975). Samples collected from river gravels near Eugene for the present study were up to 5 cm in diameter.

4.32 Willamette River Gravel Obsidian

The McKenzie River has also contributed obsidian pebbles to gravels intersected by the Willamette River. Most reported occurrences of obsidian in Willamette River gravels come indirectly from archaeological sites adjacent or near to the River. Waterworn obsidian nodules that were probably collected from Willamette River gravels have been found at archaeological sites near Eugene (Follansbee, 1975; Toepel and Minor, 1980:21; Toepel and Sappington, 1982; Pettigrew, 1975), near Salem (Pettigrew, 1980:43,56,65-66; Sanders et al., 1983:221) and near McMinnville (Laughlin, 1943). Sanford (1975) and Minor (1977) also mention the Willamette River as a source of obsidian pebbles.

Ten obsidian pebbles were recovered for this study from Willamette River gravels at Irish Bend, a prominent river meander located about 20 km south of Corvallis. The maximum diameter of obsidian from this location was 4 cm, and it is likely that this is close to the maximum pebble size available in the middle and lower Willamette River. It is also probable that there was a negligible decrease in obsidian pebble size downstream from this location (see the previous discussion in section 3.2 on the relationship of pebble size to distance from source). A single 2.5 cm-diameter glass pebble was also recovered from Willamette River gravels about 20 km north of Salem at Wheatland Ferry.

4.33 The Inman Creek Area Sources

Inman Creek is a short perennial stream located on the western margin of the southern Willamette Valley near Eugene. Though the creek is now a tributary to the Fern Ridge Reservoir, before construction of the Fern Ridge Dam in 1941 the stream fed the Long Tom River. Inman Creek would be of little interest to geologists or archaeologists were it not for the somewhat enigmatic presence of obsidian nodules in the gravels of this and several other small streams in the reservoir area. When broken open, these waterworn nodules are revealed to be a fine, artifact-grade of black and sometimes red and black volcanic glass.

Inman Creek and other local streams in the area cut as much as 2 m into the Ingram or Dolph geomorphic surface, a former high flood plain of the Willamette River (Balster and Parsons, 1968:6,9 and 1969). At least 60 m of alluvial sand, gravel, and mudstone were deposited in the area during the late Pleistocene and Holocene (Baldwin and Howell, 1949; Frank, 1973). These deposits originated in the Western Cascades and the east-central Coast Range and were fluvially transported to the Fern Ridge area. Some of the alluvial fill in this area may have also been deposited during the multiple Pleistocene floods of the Willamette Valley that were caused by the repeated failure of ice dams that contained Glacial Lake Missoula (Allison, 1978; Baker and Bunker, 1985). Evidence of these catastrophic floods, dated at between 12,000 and

16,000 years B.P. (Baker and Bunker, 1985), have been found in the southern Willamette Valley as ice-rafted boulders of exotic, non-local materials.

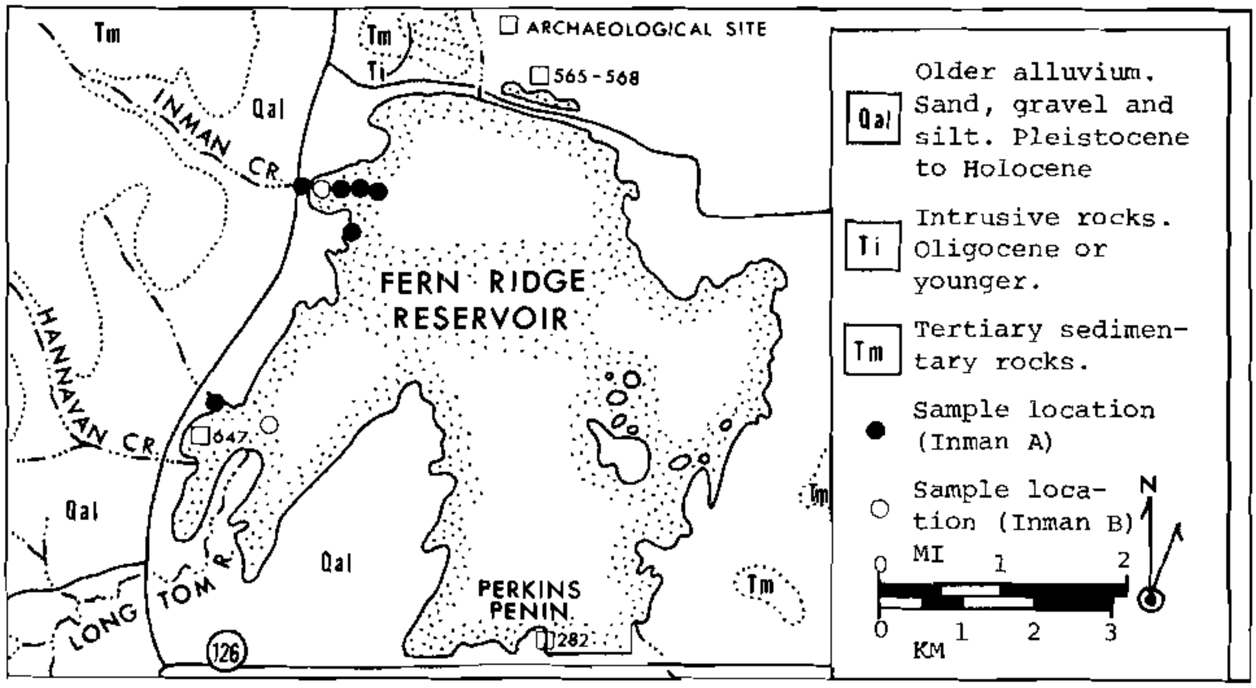
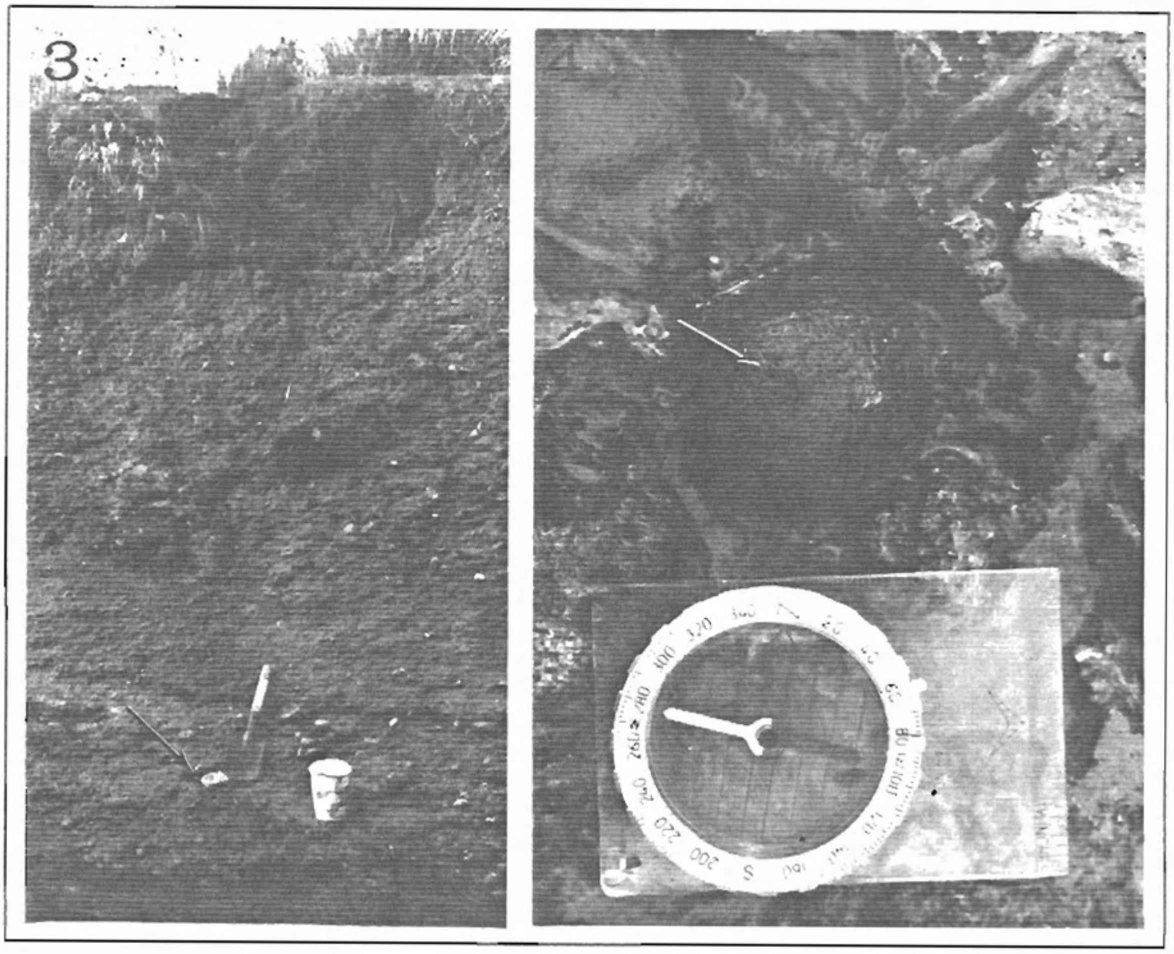


Figure 7: Sketch map of the Fern Ridge Reservoir and Inman Creek area.

Nodules of rounded obsidian ranging in size from less than 1 cm to occasionally more than 10 cm in diameter are common in the stream gravels of Inman Creek and the other creeks entering the Fern Ridge Reservoir on the west and southwest sides. The obsidian appears to be originating from a locally widespread bed of clay and water-rounded gravel that dips gently towards the northeast (the floor of the Willamette Valley). This stratum, best exposed about 2 m below the ground surface in the banks of Inman Creek, contains abundant nodules of obsidian located in situ (plates 3 and 4). The thickness of the obsidian-bearing stratum is not known. Obsidian from other creek and river beds in the area appears after the water has intersected a bed of resistant clay and gravel identical to the one at Inman Creek. These outcrops of obsidian are now normally covered by the Fern Ridge Reservoir Lake and are only accessible in the winter months during the annual reservoir drawdown.

The grain-size of the vertical section of sediments exposed in the banks of Inman Creek appears to increase significantly as the obsidian-bearing stratum is reached. This suggests the presence of a higher-energy depositional regime than is now present in the area, one perhaps related to the wetter climate in Western Oregon during the late Pleistocene and early Holocene epochs (Hansen, 1941 and 1942). The age of deposition of the obsidian-bearing sediments is not known. A radiocarbon date of >39,900 years B.P. (I-4068; Buckley and Willis, 1970) from wood recovered at a depth of 4.1 m in a comparable geomorphic surface in the area does suggest, however, a late Pleistocene maximum to the terminal phase of the depositional period.



Plates 3-4. Obsidian at Inman Creek. Plate 3: Obsidian-bearing sediments exposed in the north bank of Inman Creek. The major obsidian-bearing bed of clay and gravel lies at the base of the shovel. The bed is somewhat more resistant than the overlying sediments, creating a small shelf at the edge of this and other streams in the area. The shovel is 45 cm long. Plate 4: A 5 cm-diameter nodule of obsidian shown *in situ* at the location marked by the arrows in both photographs.

The obsidian was originally thought to have originated in the High Cascades, as rhyolitic volcanic rocks are unknown in the more proximate Coast Range. (Major element analysis of the Inman Creek area glass is not yet complete, however, and it is assumed here that the glass, like most obsidians, has a rhyolitic composition). Volcanic rocks in the central Coast Range are dominated by the presence of early Cenezoic gabbroic to dioritic sills and extensive flows of submarine basalts (Snavely and Wagner, 1961; Snavely et al., 1968 and 1980). Local geologic studies also fail to mention rhyolitic rocks in the Coast Range adjacent to the Fern Ridge Reservoir area (Zimmerman, 1927; Frank, 1973; Gandera, 1977). In addition, no post-Pliocene volcanism has been reported from anywhere in the Coast Range and it would be expected that early Cenezoic obsidian glass would be devitirified by now (E. Baldwin, personal communication, 1982). Geochemical and petrographic studies of the Inman Creek area obsidian by Skinner (1983:304-320), however, indicate that the obsidian does indeed appear to have originated in the Oregon Coast Range. Alternative scenarios to explain the presence of exotic obsidian such as ice-rafting and prehistoric human introduction were considered but eliminated as highly unlikely. Evidence presented to indicate the Coast Range as the probable primary source of the glass was:

1. The discovery of small (rarely larger than 2 cm in diameter) obsidian pebbles in gravel bars near the mouth of the Siuslaw River at the Oregon Coast (R. Minor, personal communication, 1981). The trace element composition of the Siuslaw and Inman Creek area obsidian was subsequently found to be identical (discussed later in this investigation), indicating that they originated from the same primary geologic source.

2. The recovery of a single piece of obsidian at a depth of no more than 2 m from alluvial deposits near Noti on a former Long Tom River terrace (R. Pettigrew, personal communication, 1982).

3. The Long Tom River, now a westward-flowing tributary of the Willamette River, was found by Baldwin and Howell (1949) to be a former tributary of the eastward-draining Siuslaw River. It is probable that a primary obsidian source in the upper Long Tom River drainage contributed volcanic glass both to the east and the west of the Coast Range.

4. The relatively large size of the obsidian nodules suggests that the primary source of the glass in the Inman Creek area secondary deposits is not far removed from the primary source.

A tributary of the Long Tom River and the streams of the Fern Ridge Reservoir area were all found to originate in the same area, a large, unnamed hill located immediately west of the Reservoir. It is felt that this hill is very likely the primary source area for the obsidians found in the Willamette Valley margins and at the coast. A search of the area in 1984 also suggests that the precise location of the primary source is well-camouflaged by a thick mantle of soil, brush, and trees and will remain unknown,. It should also be noted that Toepel (1985:27-29), relying on much the same evidence as was cited above, concluded that the Fern Ridge area obsidian probably originated in the Cascades. Though this still remains a possibility, the large nodule size of the glass and its presence in the Siuslaw River gravels argues strongly against it.

Obsidian nodules were probably also locally available for prehistoric procurement in the Long Tom River drainage. A search was made in the Long Tom channel between Fern Ridge Reservoir and the river's confluence with the Willamette River, but no glass was found. The entire length of the river from the reservoir to the Willamette River has been channelized and lined with rip-rap to prevent flooding. Sappington (1985a) reports that nodules of obsidian from the Fern Ridge area are found as far north as Corvallis, though no mention is made of the geologic context. Petrographic data from the current study also indicates that Fern Ridge area glass is found in Willamette River gravels above where the Long Tom River joins it. It appears that obsidian-bearing sediments made their way east at least as far as the current Willamette River channel, probably during the initial period of secondary deposition.

Preliminary work by Skinner (1983:304-320) also suggests that not one, but two geochemically-distinct sources of obsidian are found in the Fern Ridge Reservoir area. The results of this current investigation also bear this out.

4.34
Clackamas River Gravels

Woodward (1974:194-195) mentions that a dull gray obsidian can be found in the gravels of the Clackamas River near Oregon City. This material was recovered by Woodward from archaeological sites along the lower Clackmas River and was utilized for the manufacture of flaked stone artifacts. Woodward later describes the material as a volcanic glass, more opaque and less glassy than obsidian, but still of a good tool-making quality (J. Woodward, personal communication, 1986). He also reports that artifacts and split nodules of this volcanic glass occur mainly in early (8000 to 3000 B.P.) archaeological sites and that debitage is rare. Small hard-to recognize nodules of the glassy rock are also found in the gravels of the Sandy River. The primary source of this glassy rock is unknown, though it is likely that it lies in the Cascades to the east. A 1986 search of the Clackamas River gravels for samples of this material was unsuccessful and this source of lithic material still remains largely undocumented.

4.4
The Oregon Coast Sources

4.41 The Siuslaw River Mouth Sources

The same primary source that provided obsidian for the Fern Ridge Reservoir area also introduced natural glass into the former upper drainage of the Siuslaw River (Baldwin and Howell, 1949). Obsidian pebbles a few centimeters in diameter can currently be found in gravel bars located near the mouth of the Siuslaw River at the town of Florence. Like the obsidians at Inman Creek, two different geochemical populations are represented. It is also likely that obsidian can be found in the gravels of the upper reaches of the Siuslaw River, though none has yet been reported.

4.5
Conclusions

Recent work has presented information contrary to the long-held assumption that a single natural source of obsidian was represented in the river gravels of the Willamette Valley. Instead, at least three distinct secondary source groups, one from Obsidian Cliffs in the High Cascades and two others from an unidentified primary source in the Oregon Coast Range, are present. Another potential High Cascade source, an unnamed rhyodacite dome near Obsidian Cliffs, has not been identified in obsidian recovered from secondary deposits in the Willamette Valley. Obsidian has also been reported from the gravels of the Clackamas River, though this material is more fittingly classified as a glassy volcanic rock than as a true obsidian. Finally, a possible obsidian source in the Western Cascades near Oakridge has been proposed from indirect evidence, though its existence remains to be confirmed through valid research methods.

5.0 THE CHARACTERIZATION AND PRIMARY SOURCE ASSIGNMENT OF OBSIDIAN FROM SECONDARY GEOLOGIC SOURCES OF OBSIDIAN IN WESTERN CENTRAL OREGON

> Just as flint or chert can only be derived from particular strata, and must have been carried by trade if found at any distance from these centres, so the presence of obsidian objects in a non-volcanic country is proof of trade with some centre of volcanic activity. Unhappily the scientific identification of any given piece of obsidian with specimens from any one deposit is beset with difficulties, so that it is at present impossible to say categorically that the given piece did, or did not, come from a certain locality.
>
> G.A. Wainwright (1927:77)

5.1

Principles of Obsidian Characterization

Scientific methods of obsidian characterization and source identification have advanced a long way since Wainwright wrote the above statement in his study of obsidian artifacts and sources in the Near East. Techniques now exist that can identify the geologic sources of archaeological obsidian with a degree of sophistication undreamed of in Wainwright's day. The analytical techniques for identifying sources have advanced, in fact, far ahead of the methods used to interpret the resultant data. With the exception of a few isolated efforts, these techniques of obsidian characterization have been largely developed over the past 25 years. The benchmark paper by Cann and Renfrew in 1964 marks the beginning of this modern period of obsidian characterization study. That paper, followed by several other related ones (see Cann et al., 1970), touched off a still continuing period of research in which artifactual obsidian has been characterized, its geologic source identified, and this information used to generate hypotheses about possible patterns of prehistoric contact and trade.

Though trace element abundances have most often been used to characterize natural glass, a variety of other less powerful, but more accessible techniques have also been developed or suggested. In this section of the project, I discuss the results of the application of two different methods that were used to characterize obsidian from Western Oregon sources. Trace element abundances (determined by X-ray fluorescence spectrometry) were initially used to characterize the glass because of the acknowledged high degree of reliability. Petrographic methods of characterization, while lacking the reliability of the geochemical methods, were added because of their technological accessibility and low cost (always a factor in a chronically underfunded discipline such as archaeology).

Properties of obsidian, whether geochemical, petrographic, or otherwise, must share two key qualities to be effective as characterization attributes. These are:

1. Intrasource homogeneity - the attribute must have a low degree of intraunit variability.

2. Intersource heterogeneity - the attribute must show a recognizable degree of intraunit variation, i.e. it must be clearly distinguishable from other obsidian sources that lie within the source universe being considered.

While trace element characterization is the method of choice when funds and equipment are available, any attribute which has some degree of intrasource homogeneity and intersource heterogeneity can be used (see Skinner, 1983:76-84, for a review). These methods, however, are dependent on and reflect the chemical composition of the glass, though in petrographic characterization the cooling history (which affects crystallization processes) may also be an important factor.

5.2

Trace Element Characterization

Abundances of selected trace elements (Rb, Sr, Zr) were initially used to characterize the glass. These elements have been found to exhibit a remarkably consistent degree of intrasource homogeneity as well as a marked tendency (especially in genetically unrelated sources) to intersource heterogeneity (Cann and Renfrew, 1964; Cann et al., 1970; Ericson, 1977 and 1981; Skinner, 1983:152-166; also see Appendix 5).

The 18 obsidian samples prepared for trace element analysis in this study were collected from the Inman Creek area, the Siuslaw River mouth, the McKenzie River gravels near Eugene, morainal deposits in the Lost Creek Canyon of the Western Cascades, and the Obsidian Cliffs obsidian flow (see Appendix I for detailed provenance information). All of the samples, with the exception of those from Obsidian Cliffs, were from secondary contexts in Western Oregon. The four samples from Obsidian Cliffs were collected from widely dispersed areas at this source so as to provide a measure of control over any geochemical intraunit variability that might be present. While obsidian sources are almost always geochemically homogeneous, Bowman et al. (1973a and 1973b) warn that this cannot be automatically assumed.

5.21 Preparation and Analytical Methods

The trace element composition of the 18 samples was extablished by X-ray fluorescence spectrographic methods using a GE XRD-7 Vacuum Spectrometer located at the University of Oregon X-Ray Fluorescence Laboratory. During XRF analysis, excitation of elements is by means of a primary X-ray beam. These elements are made to emit in the X-ray wavelength region and these emissions are detected and used to identify the elements and their abundances in a sample. An X-ray spectograph such as the one used in this study is simply an instrument that disperses X-rays and then measures their intensity as a way of making quantitative or qualitative analyses (Norrish and Chappell, 1967). Quantitative XRF analysis, the technique used here, is a comparative method and requires standards of known composition to obtain quantitative results. U.S. Geological Survey standards AGV-1, BCR-1, DTS-1, G-2, GSP-1, PCC-1, and W-1 were used as standards in this investigation (Abbey, 1973).

Each sample of obsidian was then prepared for XRF analysis. The larger samples from Obsidian Cliffs and the Lost Creek Valley were broken into small pieces and a minimum of 100 gm of cortex-free fragments collected. These chips were placed in a tungsten carbide Spex shatterbox for six minutes and reduced to a fine powder. The smaller samples from secondary sources were cleaned with acetone, and powdered in a ball mill. Pressed powder pellets were then prepared. 5 gm of powdered glass was placed in a mold that uses boric acid as a backing agent, and then pressed at 10,000 pounds pressure to create a cohesive disk that can be used for analysis in the XRF spectrometer (Norrish and Chappell, 1967). Samples were counted for 300 seconds in an air pathway.

5.22 Results and Discussion

The quantitative results of the trace element analysis are shown in table 1. When plotted on a ternary graph (figure 8), the samples cluster into four distinct populations, indicating that four possible obsidian sources may be represented by the data.

Both group A and group B include samples collected in the Inman Creek area and at the Siuslaw River mouth. This indicates that:

1. Not one, but two different geochemically discrete sources are found in the Fern Ridge area. This strongly suggests that two separate geologic sources of obsidian contributed volcanic glass to the Fern Ridge Reservoir area. Further trace and major element analyses will be required to ascertain if any genetic relationship exists between these two sources.

2. The same two geologic sources of obsidian were supplying glass to both the central Oregon Coast and the southwestern Willamette Valley. Current river drainage patterns do not account for this, corroborating the findings of Baldwin and Howell (1949) that the upper reaches of the Long Tom River once drained to the west.

The group C population includes, as was expected, obsidian from Obsidian Cliffs, the Lost Creek Valley, and the McKenzie River gravels. This further establishes the Obsidian Cliffs flow as a primary contributor of obsidian to secondary sources in the Western Cascades and the Willamette Valley.

A single sample collected from fluvial gravels near Eugene forms the D population. It was initially hypothesized that this could represent either an unidentified High or Western Cascades source or that it could be evidence of glass originating from the Condon Butte area dome. A reeximination of the original sample (only partially destroyed for analysis) also suggests a third, and perhaps more likely possibility. This sample (MCK-3) is composed not only of obsidian glass, but also contains spherulites, petrographic structures common at the Obsidian Cliffs source. It is likely that the portion of the sample that was analyzed also contined spherulites. While these features coexist with the glassy phase of rhyolitic obsidian, they have been noted by Ewart (1971) to differ in major element composition from the glass. Though not verified, the compositional differences of this sample from the others collected near Eugene is considered to probably be due to contamination of the analyzed portion by a spherulite.

SAMPLE	TRACE ELEMENTS			PRIMARY	ANALYTICAL ERROR (+-)		
NO.	RB	SR	ZR	SOURCE	RB	SR	ZR
INM-1	88.8	116.5	76.5	INMAN B	2.7	2.4	2.4
INM-2	82.8	156.9	106.2	INMAN A	2.6	2.6	2.5
INM-3	85.1	150.6	107.4	INMAN A	3.0	2.8	2.6
INM-5	80.1	151.8	109.0	INMAN A	2.6	2.6	2.5
INM-7	81.8	154.0	104.1	INMAN A	2.6	2.6	2.5
INM-9	82.3	153.8	104.2	INMAN A	2.7	2.7	2.6
INM-11	89.1	111.8	76.7	INMAN B	2.7	2.4	2.4
INM-12	84.8	154.2	106.0	INMAN A	2.7	2.6	2.5
MCK-1	76.7	121.2	112.1	OCLIFFS	2.6	2.4	2.5
MCK-2	78.5	105.8	95.9	OCLIFFS	2.6	2.4	2.4
MCK-3	70.8	179.7	200.8	OCLIFFS	2.6	2.8	3.0
MCK-4	80.6	104.1	92.8	OCLIFFS	2.6	2.4	2.4
OBC-1	83.6	110.0	101.6	OCLIFFS	3.0	2.6	2.5
OBC-2	79.4	103.4	92.9	OCLIFFS	2.9	2.5	2.5
OBC-3	85.1	103.6	98.0	OCLIFFS	3.0	2.5	2.5
OBC-4	83.9	102.7	95.6	OCLIFFS	2.9	2.5	2.5
SIU-1	83.8	144.3	100.7	INMAN A	2.6	2.6	2.5
SIU-2	92.4	115.9	76.7	INMAN B	2.7	2.4	2.4

INM: OBSIDIAN SAMPLES FROM FERN RIDGE RESERVOIR AREA
MCK: OBSIDIAN SAMPLES FROM MCKENZIE RIVER AND LOST CREEK VALLEYS
OBC: OBSIDIAN SAMPLES FROM THE OBSIDIAN CLIFFS OBSIDIAN FLOW
SIU: OBSIDIAN SAMPLES FROM THE SIUSLAW RIVER MOUTH

(A): SPHERULITE IN SAMPLE; PROBABLY ORIGINATED AT OBSIDIAN CLIFFS
OCLIFFS: OBSIDIAN CLIFFS

(FILE:TRACE)

Table 1: Trace element abundances of obsidian samples from geologic sources in Western Oregon. All samples except those from Obsidian Cliffs are from secondary sources. The probable primary sources of each sample, based on the geochemical data, are also designated.

The trace element abundances were also plotted on scatterplots to see how well different trace element pairs could differentiate among the obsidian source populations (figure 9). Only when Sr is plotted versus Zr can all four of the different geochemical populations be easily visually distinguished.

5.23 Conclusions

The trace element composition (Sr, Rb, Zr) of 18 different samples of obsidian, primarily originating from secondary contexts in the Willamette Valley, the Oregon Coast,and the Western Cascades, were determined by XRF analysis. Assuming geochemical homogeneity at the primary sources, it appears that three discrete primary geologic sources are contributing obsidian to secondary sources in central western Oregon. Two of these are located in the Coast Range at unknown localities; the third is the Obsidian Cliffs obsidian flow in the High Cascades. A single compositionally anomalous sample could have originated from another High or Western Cascades source, but is interpreted here to be the result of the inclusion of a spherulite in the analyzed sample.

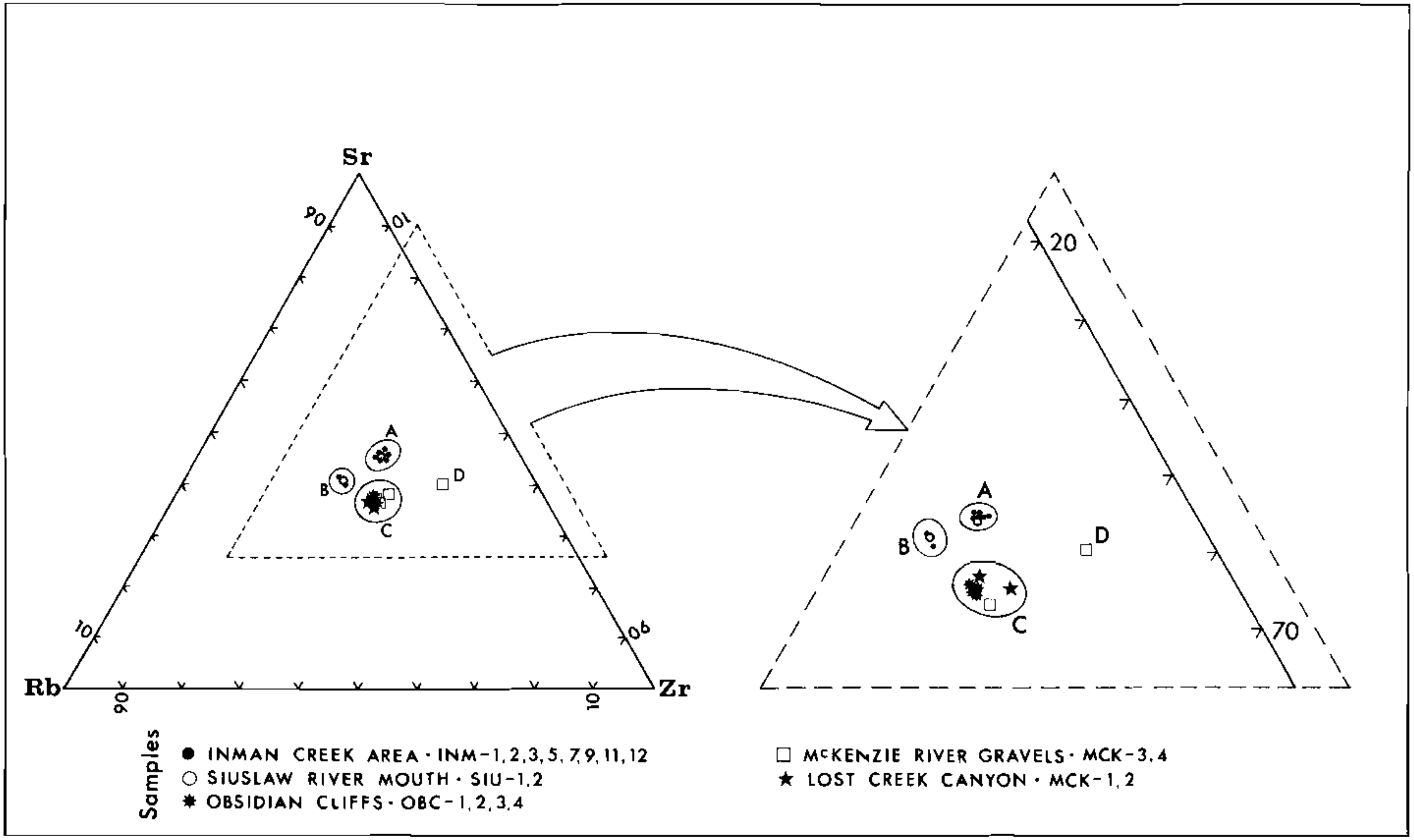


Figure 8: Ternary diagram illustrating the relative abundances of Rubidium, Strontium, and Zirconium found in obsidian from geologic sources in the High Cascades, the Western Cascades, the Willamette Valley, and the Oregon Coast.

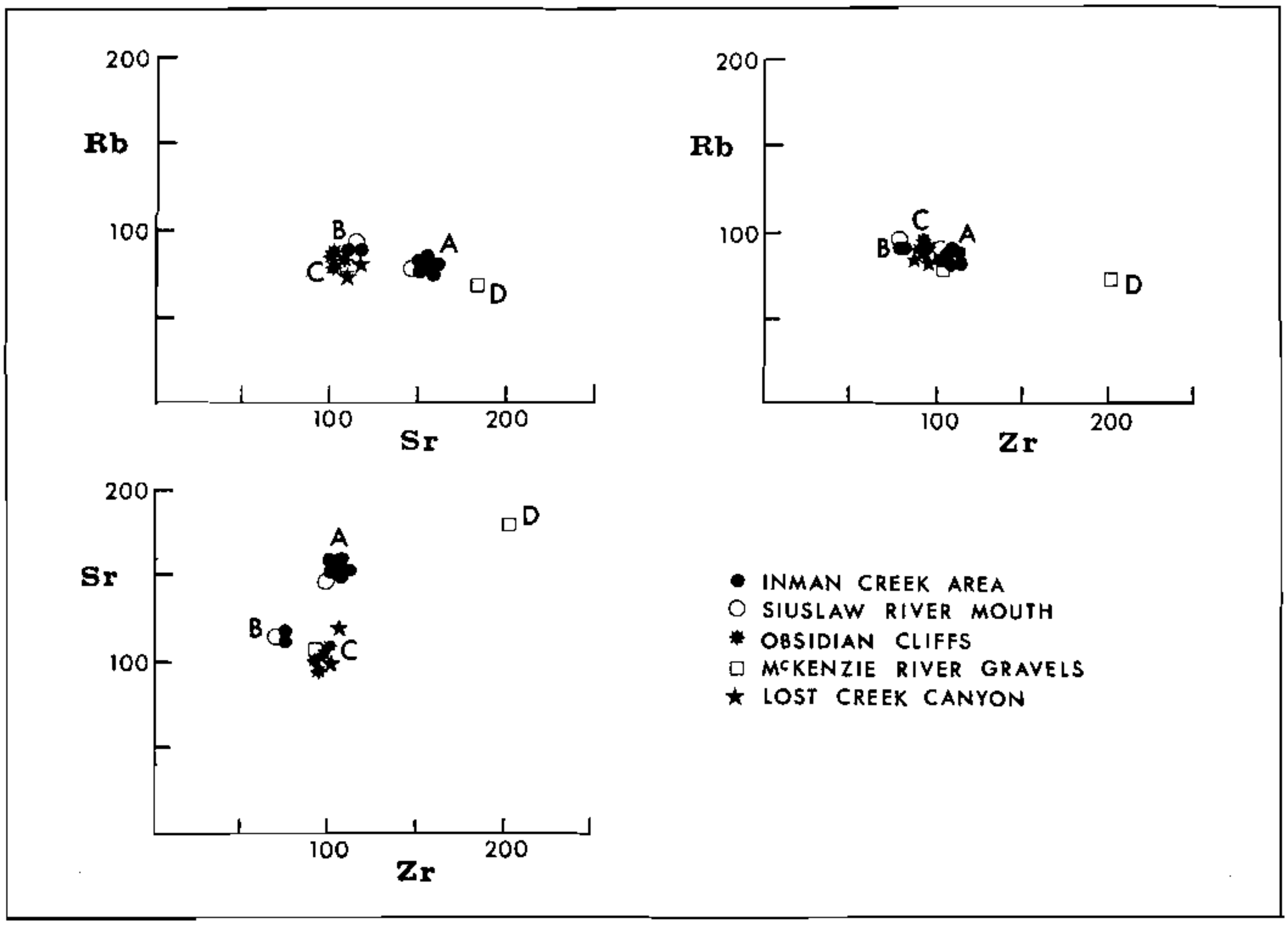


Figure 9: Different trace element pairs plotted versus one another from sources in central Western Oregon. Of these three scatterplots, Sr plotted versus Zr provides the best visual discrimination of the different geochemical populations represented by Western Oregon obsidian sources.

5.3
Petrographic Characterization

5.31 Introduction

Although obsidian is often thought of as an aphyric glass, when examined in thin section with a microscope almost all obsidians can be found to contain at least a few crystalline or subcrystalline structures. Microscopic phenocrysts, commonly plagioclase feldspars, are often found in small quantities. Tiny opaque specks of magnetite, usually only a few microns in diameter, are virtually ubiquitous in rhyolitic obsidians. It is the presence of this magnetite that gives obsidian glass its most common color, black. In addition to these petrographic features, natural glasses almost invariably contain a variety of microscopic structures known as microlites and crystallites (collectively referred to in this paper as microlitic structures - see figure 10).

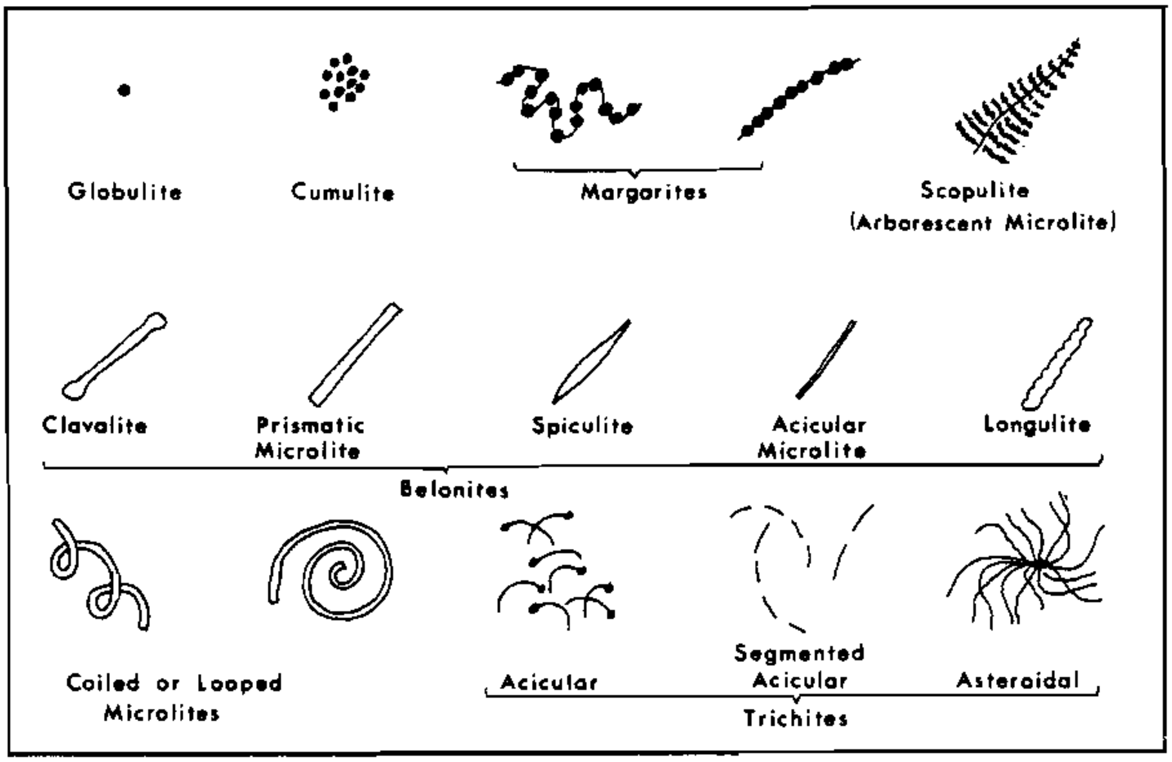


Figure 10: Microlitic structures (microlites and crystallites) that are commonly found in obsidian glass. Compiled from several sources (Rutley, 1890; Johannsen, 1931:11-15; Williams et al., 1954:13-14; Clark, 1961:99-114; Ross, 1962; Suzuki, 1973:303-304; Skinner, 1983:142-151).

Though microlite and crystallite terminology is somewhat vague, microlites are usually defined as microscopic crystals that polarize light and that have some determinable optical properties (anisotropic). The term crystallite is a more general one and refers to microscopic bodies of unknown mineralologic composition which do not polarize light (isotropic). Crystallites and microlites are considered to represent early stages of crystallization in a magma, though the petrologic processes involved in their formation are not well understood (Johanssen, 1931:11-15; Marshall, 1961). Microlites and crystallites may be virtually nonexistent in obsidian or they may occasionally take up nearly all of the volume of the glass (Ericson, 1977:100-103,115-119; 1981:60-62,68-72). The common microlitic structures are illustrated in figure 10 and are described in additional detail in Appendix 3. Preliminary research results also indicate that these microlitic structures may have some usefulness in the characterization of obsidian (Skinner,1983:142-151; 1984). This possibility, particularly as it applies to the geological and archaeological obsidian of Western Oregon, will be examined in more detail later in this section of the paper.

5.32 Previous Research in the Petrographic Characterization of Obsidian

The history of the utilization of petrographic features in the characterization of archaeological obsidian research is a brief one. Microlitic forms were first superficially considered as a method of characterizing Egyptian obsidian by Frankfort (1927:191-192) who, nevertheless, dismissed the method as being too unreliable to be of any use. In a study of a small sample of archaeological and geological obsidian samples from Kenya, Game (1945) reported some success in separating the samples into groups on the basis of their microlitic features. Heizer et al. (1965), citing the work of Ordonez (1892), suggested that the characterization of obsidian using the crystallite and microlite structures present in the glass might be worth pursuing. Clark (1961) also suggested the use of microlitic structures for obsidian characterization but did not pursue the subject in his research. Sukuki (1973:303-304) mentions three Japanese studies in which artifactual obsidian was assigned a geologic source based on microcrystalline characteristics. In his own research, though, Suzuki (1973:304) found that the identification of the sources based on microlitic structures present was awkward due to considerable overlap among geologic sources. He does mention, however, that some microlitic features were unique, specifically the presence of asteroidal trichites at one source and the high density of prismatic microlites at two other sources. Bettinger (1978) and Bettinger et al. (1984) report some success in identifying the source of obsidians from California and Nevada based on criteria that included the presence or absence of petrograhic features. The petrographic data from this study are, though, rather vague. Preliminary work by Skinner (1983:142-151,352,334-335; 1984) indicates that the presence or absence of specific microlitic structures appears to have some promise as a characterization technique. This was particularly true when the source universe was limited or the identification of source sub-groups was adequate.

5.33 Preparation and Analytical Methods

All obsidian samples that were collected for this investigation (with the exception of two) were prepared as standard petrographic thin sections. SIU-1 and SIU-2 were completely destroyed during XRF analysis preparation and could not be prepared as thin sections. A total of 53 thin sections representing obsidian from the Obsidian Cliffs source (OBC sample number prefix), the Lost Creek Valley glacial till (some MCK samples), the McKenzie River gravels (some MCK samples), the Willamette River gravels (IRB and WHF prefixes), the Siuslaw River gravels (SIU prefix), the Lowell area obsidian-like vitrophyre deposit (LOW prefix), the Condon Butte area dome (CNB prefix), and the Fern Ridge Reservoir area deposits (INM prefix) were prepared.

Each slide was examined with a petrographic microscope and the presence or absence of various microlitic structures and significant petrographic features was noted (tables 2 and 3). The specific provenance for each sample is recorded in Appendix 1.

Do sources of obsidian (and obsidian-like vitrophyre) in Western Oregon possess petrographic characteristics that will allow them to be characterized on that basis alone? Three different petrographic characteristics were examined to see if they exhibited sufficient intrasource homogeneity and intrasource heterogeneity to be useful as characterization attributes. These three petrographic properties (in order of importance) are:

1. Microlitic structures present. The presence or absence of specific microlitic structures is the major criterion that was examined in this investigation. A specific microlite or crystallite type was considered to be present if it made up 5 percent or greater of the total microlites observed in the microscopic field of view at any point on the sample slide. The percentage

was estimated using standard geologic comparison charts for estimating percentage composition (Terry and Chilingar, 1955). In the case of borderline instances, the microlite was considered to be present. The 5 percent lower limit was adopted to minimize the influence of occasional anomalous microlite and crystallite types that were sometimes noted in samples. While microlitic structures are often found distributed relatively homogeneously at obsidian sources, the degree of homogeneity is rarely as great as with some other attributes such as chemical composition.

Normal prismatic microlites were considered those with a diameter equal to or greater than one micron; acicular prismatic microlites were considered as those with a diameter of less than one micron. In borderline examples, prismatic microlites were judged as normal.

2. Degree of crystallization. This criterion was adopted when it was observed that different obsidian sources often exhibited quite different quantities of microscopic and occasionally megascopic phenocrysts in the glassy groundmass. The degree of crystallization refers, then, to whether the percentage of phenocrysts in the obsidian (usually plagioclase) was found to be greater than or less than 5 percent. The percentage was determined to be greater than 5 percent if phenocrysts were found to occupy greater than 5 percent of the field of view at any point in the sample slide. Percentages were estimated using the same estimation charts as were the microlitic structures (Terry and Chilingar, 1955). The slides were observed under crossed nichols and the percentage of microphenocrysts estimated using their birefringence properties. Please note that this percentage measurement is based on different parameters than that of the microlitic structures. The phenocryst percentage is a measure of the phenocrysts present in the total field of view; the microlitic structure percentages represent ratios of the total microlitic structures found, not the area density.

3. The presence of welded glass shards. This was taken to be an absolute indicator that the sample was not a true obsidian but that it was an obsidian-like vitrophyre originating in a volcanic ash-flow deposit. An active volcanic ash-flow is a turbulent combination of high-temperature pyroclastic materials and gases erupted explosively from a volcanic vent. Pumice blocks and siliceous, glass-rich portions of the ash-flow may collapse and weld during emplacement, creating an obsidian-like vitrophyre sometimes called fiamme (Williams and McBirney, 1979:134). Though the obsidian-like vitrophyre of welded ash-flows may megascopically resemble obsidian, microscopic examination in thin section shows that there are striking differences. True obsidian consists of a glassy, isotropic groundmass filled with varied quantities of microlitic structures, phenocrysts, and magnetite grains. Obsidian-like vitrophyre, however, is made up of distinctive glass shards (see plate 8), leaving little chance of confusion between the two.

The presence or absence of these petrographic features is recorded in tables 2 and 3. Table 2 does not include samples that were also geochemically characterized; petrographic characteristics of these samples are shown in table 3.

5.34 Petrographic Characteristics of Western Oregon Obsidian Sources

5.341 Obsidian Cliffs: Seventeen of the eighteen samples from Obsidian Cliffs exhibited a high degree of similarity. The single exception to this is discussed at the end of this section and is not considered until then. Prismatic microlites were, by far, the dominant microlitic structure in the glass, occurring in very high densities. Needle-like, acicular prismatic microlites, those with a diameter of less than 1 micron, were the prevalent microlite types, though in some samples many of the microlites were considered as normal or nearly so. In a few samples, crystallization appears to have progressed to the point where the microlites had evolved into skeletal crystals (see plate 17 for a probable example). The dense swarms of microlites typically exhibited a strong alignment, though this might best be described as occurring in a somewhat chaotic manner in many examples. Tiny magnetite particles, most of which were less than 5 microns in diameter, were present in large quantities throughout the glass. The degree of crystallization of the glass was quite high, with small phenocrysts of plagioclase always present in a concentration of at least 5% (and often >10%) in the field of view in all samples. Very small megascopic phenocrysts of plagioclase were also common in the glass. Spherulitic structures varying in size from a few microns to greater than a centimeter were often encountered. These spherulites were noted in many locations during field work at the Obsidian Cliffs source and were found at no other Western Oregon Obsidian Sources. In a single specimen (OBC-13) a few asteroidal trichites were found, but at no time did they exceed 5 percent of the total microlitic structures present in the field of view. The high percentage of phenocrysts and high density of prismatic microlites found in the glass, in addition to the presence of skeletal prismatic microlites, suggest that the Obsidian Cliffs flow was very close to the eutectic when it was extruded.

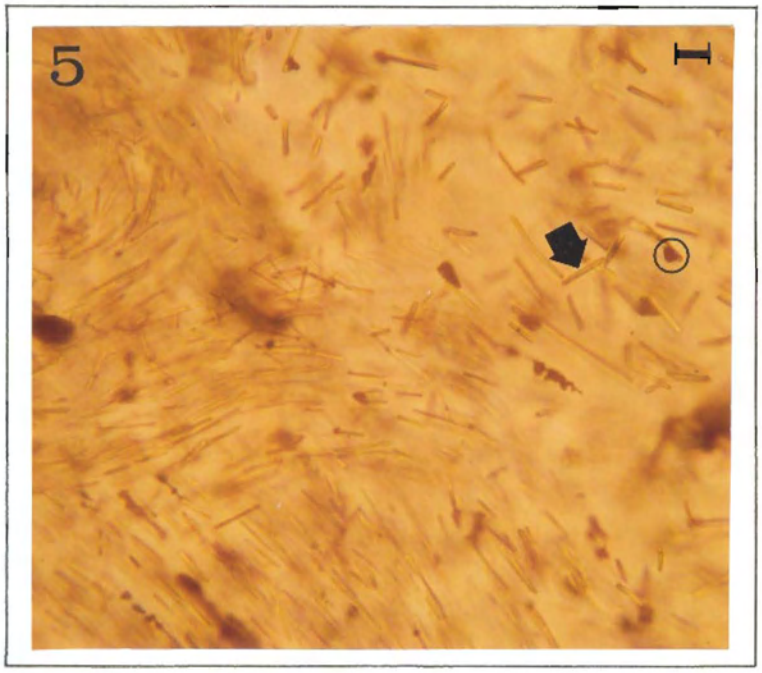
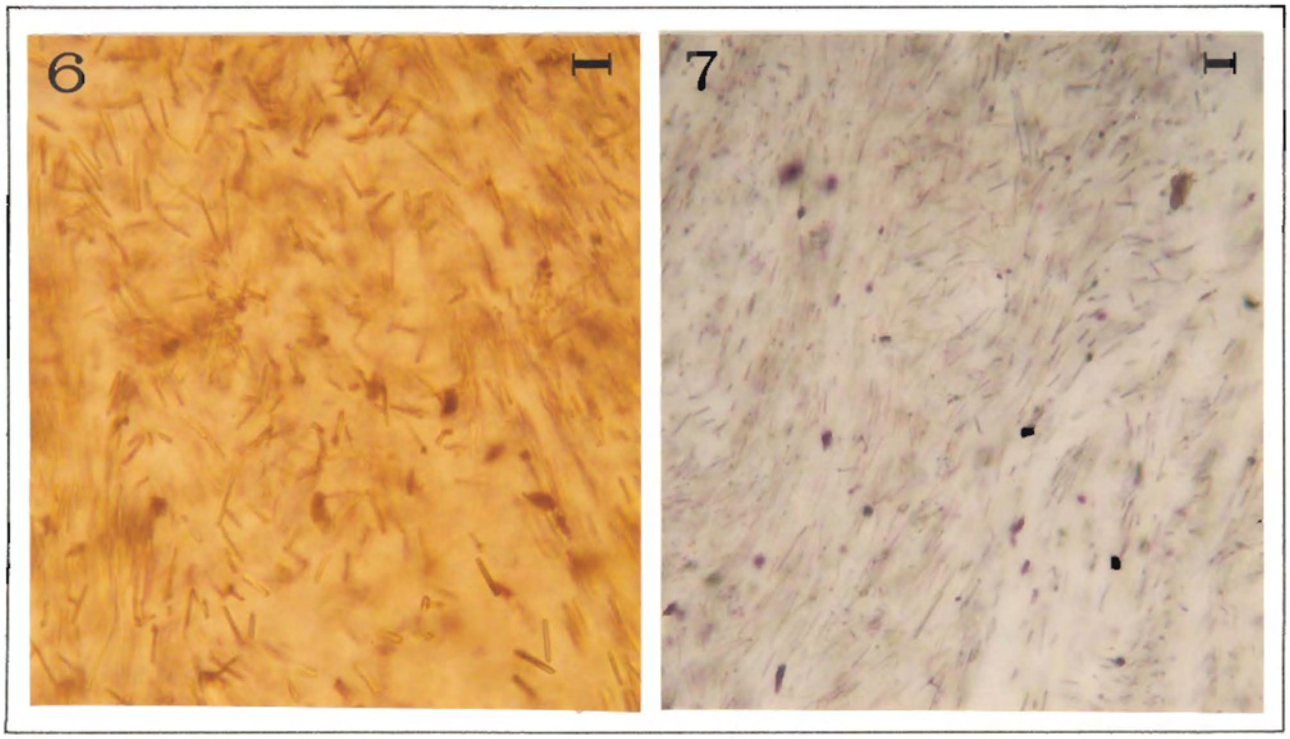


Plate 5: Photomicrograph of obsidian from Obsidian Cliffs (OBC-1). This sample is typical of the majority of the specimens examined from this source. The arrow points to an acicular prismatic microlite. The black particles (an example is circled) in this picture, as well as in the following photomicrographs, are magnetite. The bar in upper right corner is 10 microns long. Nicols not crossed, x100.

The single anomalous sample, OBC-8, was red and black in color and exhibited a quite different petrographic signature. A few areas of acicular prismatic microlites were found on the slide, but the sample could be best characterized by areas of relatively clear glass filled with red, scopulitic microlites. The red color is probably the result of the oxidation of magnetite to hematite, and is often accompanied by striking, fern-like scopulitic structures (Skinner, 1983:43).



Plates 6-7: Photomicrographs of obsidian from the Lost Creek Canyon of the Upper McKenzie River Valley and the gravels of the McKenzie River near Eugene. Both appear to have originated from the Obsidian Cliffs source. Plate 6: This sample (MCK-5) is from ground moraine deposits only a few kilometers from where the McKenzie River intersects glacial till containing obsidian. The glass is petrographically identical to all other obsidian specimens found in morainal deposits in this area as well as with glass from Obsidian Cliffs. The high density of acicular prismatic microlites is characteristic of the Obsidian Cliffs source. Nicols not crossed, x100. Plate 7: This sample is from the McKenzie River gravels near Armitage Park in Eugene. Once again, acicular prismatic microlites are the dominant petrographic feature and identify the probable primary source as Obsidian Cliffs. The apparent difference in microlite size between the two photographs is due largely to differences in magnification. Scales in the upper right corners are 10 microns in length. Nicols not crossed, x93.

5.342 Obsidian from the Lost Creek Canyon and McKenzie River gravels: Eight samples were examined from these two source areas, four from glacial deposits at the Lost Creek Canyon and four from McKenzie River gravels near Eugene. Seven of the eight samples (the exception being MCK-3) were petrographically similar. High densities of acicular prismatic microlites and a high percentage of phenocrysts were found in all samples (except MCK-3)(plates 6 and 7). A petrographic description of the seven similar samples would be identical to many of the Obsidian Cliffs specimens. The anomalous sample (MCK-3), discussed briefly in section 5.21, contains spherulitic structures and shows a higher degree of crystallization than other samples. It is interpreted as originating, like the other samples in this group, from the Obsidian Cliffs source.

5.343 Lowell area obsidian-like vitrophyre: The obsidian-like glass from this site was easily characterized in thin section by the presence of remnants of glass shards (bubbles) visible in the section (plate 8). The shards are molded against each other and only the outlines remain visible. All pore space has been eliminated by the very complete welding.

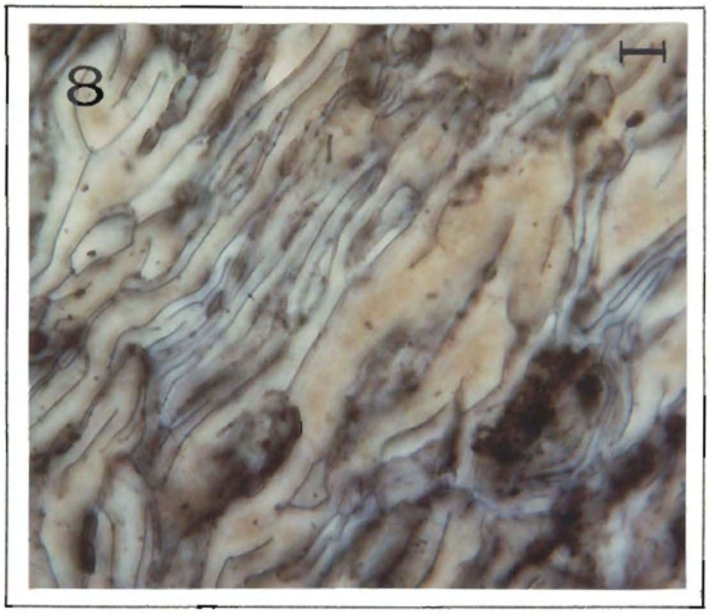


Plate 8: Photomicrograph of obsidian-like vitrophyre from the densely-welded zone of the Lowell area welded ash flow. This sample (LOW-1) is typical of several others examined from this source. The bar in the right corner is 10 microns long. Nicols not crossed, x150.

5.344 Fern Ridge Reservoir area obsidian: Thirteen samples were examined from specimens collected at Inman Creek, Hannavan Creek, and other localities in the Fern Ridge area. Though it was known that two different geochemical populations could be found in the area, these two groups appear to be petrographically indistinguishable. If there was any characteristic that the two geochemical groups shared, it was an apparent lack of a homogeneous occurrence of microlitic structures. A wide variety of structures were found in both populations. Asteroidal and acicular trichites were common in most samples; all contained acicular varieties, while most shared the asteroidal type. Globulites were frequently encountered in both groups as were acicular and normal prismatic microlites. Margarites and longulites were observed in only a few separate specimens. Phenocryst density was low, less than 5 percent in the samples examined, though small megascopic plagioclase crystals were often found. Plates 9 through 14 on the next page illustrate the wide range of microlitic structures that were noted in samples from the Fern Ridge Reservoir area. There is considerable intrasource as well as intersource heterogeneity in the obsidian from the Fern Ridge area. In several samples, the varieties of microlitic structures found varied considerably over the scale of a single slide; though one or two types would be most ofen found in close association at a single point on the slide, they would often rapidly grade into an area where another microlite or crystallite structure dominated the microlitic structures in the field of view. In summary, the degree of heterogeneity found in the Fern Ridge area glass was very high. No characteristics were found that would distinguish between the two geochemically-distinct populations.

5.345 Willamette River obsidian: Ten samples were collected from a gravel bar on the inside of a large river meander at Irish Bend. The petrographic analysis of the obsidian revealed that two distinct petrographic populations appear to be found at this location. One of these groups, represented by eight of the ten samples collected, shared similar petrographic characteristics with the Obsidian Cliffs source. Acicular prismatic microlites were the most commonly shared petrographic attribute in these samples (see plates 15 and 16). The presence of phenocrysts in excess of 5 percent of the field of view was also a shared trait. These eight samples are all considered to have originated from the Obsidian Cliffs source.

Plates 9-14 (overleaf) : Photomicrographs of obsidian from several locations in the Fern Ridge Reservoir area. These serve to illustrate the considerable range of petrographic variation that is found in glasses from the two discrete geochemical populations represented at this source area. Though there is suffucuent variation in microlitic structures among these two source groups to prevent their definite source assignment, the two populations are petrographically distinguishable from obsidian from the Obsidian Cliffs source. Plate 9: This sample (INM-5) is dominated by the presence of acicular and asteroidal trichites. This specimen was geochemically characterized and found to originate from the Inman A source. The scale bar in this and the other photomicrographs is 10 microns long. Nicols not crossed, x93. Plate 10: Margarites are the predominant structures seen in this sample (INM-11). This specimen was geochemically characterized and found to originate from the Inman B source. Nicols not crossed, x93. Plate 11: Strongly aligned margarites and acicular to normal prismatic microlites wrap around a small phenocryst in this sample (INM-9). The Inman B source was geochemically determined to be the source of this sample. Nicols not crossed, x93. Plate 12: In this specimen (INM-2), margarites, isolated and in clusters, are the primary microlitic structures. A single large microlite can be seen in the upper central portion of the picture. This sample was geochemically characterized and found to originate from the Inman A source. Nicols not crossed, x150. Plate 13: Abundant aligned groups of longulites, coalesced chains of globulites, dominate the microlitic forms in this sample (INM-12). The Inman A group was geochemically determined to be the parent source of this specimen. Nicols not crossed, x93. Plate 14: Acicular and asteroidal microlitic structures (INM-8). The arrow points to a bubble in the glass that apparently acted as a nucleus for the growth of a trichite. Nicols not crossed, x63.

Plates 9-14

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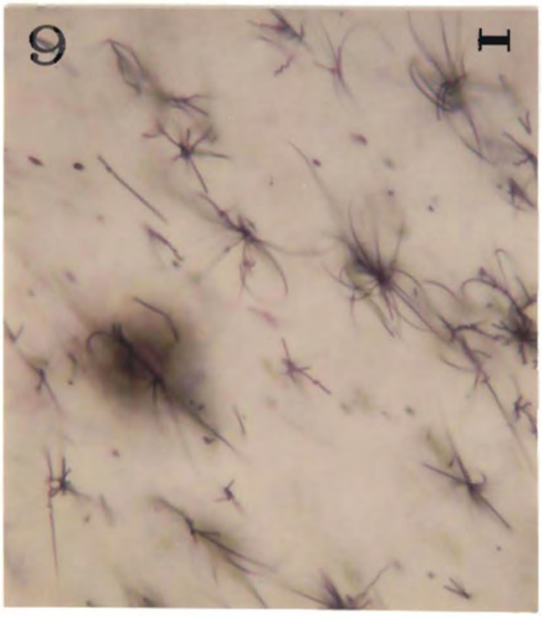

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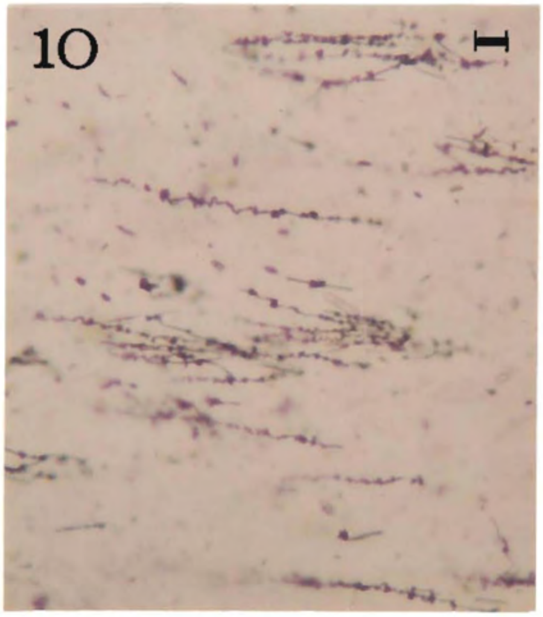

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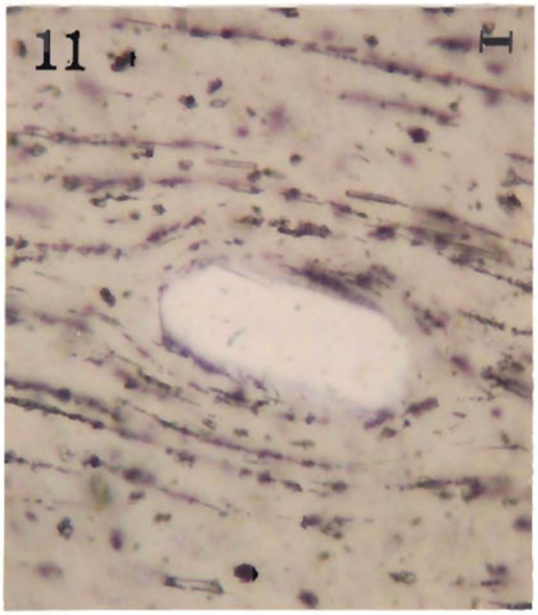

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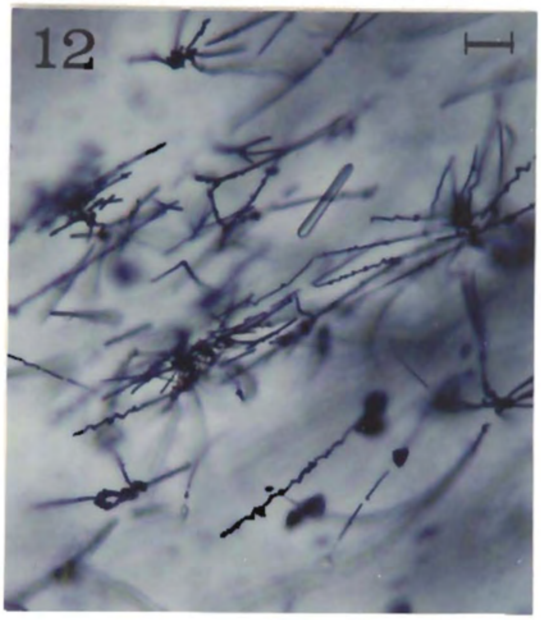

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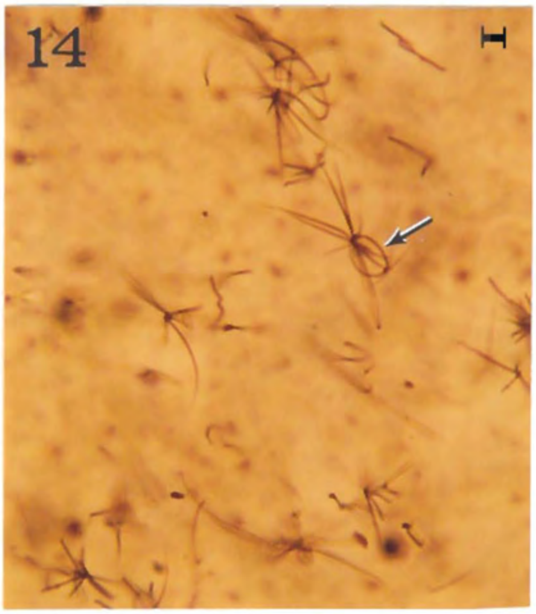

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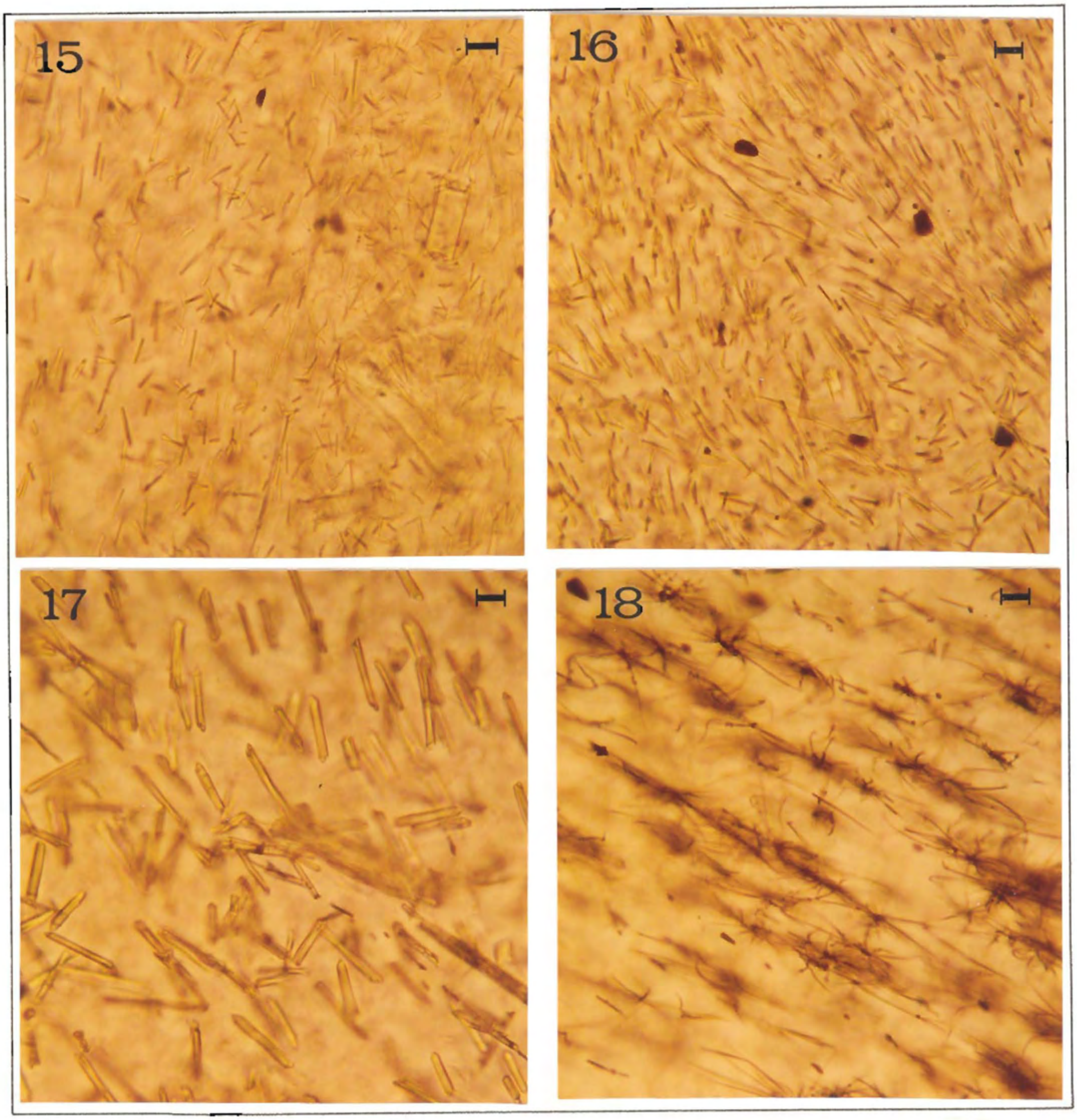
SAMPLE NO.	GLOBU-LITES?	LONGU-LITES?	NORMAL PRSMTIC?	ACICULAR PRSMTIC?	ACICULAR TRCHITE?	ASTROIDL TRCHITE?	PCRYSTS > 5%?	SHARDS? (ASHFLOW)	SOURCE TYPE (PRIMARY OR SECONDRY)	PRIMARY SOURCE	* COMMENTS *
INM-1	YES	NO	NO	YES	YES	YES	NO	NO	SECNDRY	INMAN B	-
INM-2	YES	NO	YES	NO	YES	YES	NO	NO	SECNDRY	INMAN A	-
INM-3	YES	NO	YES	YES	YES	NO	NO	NO	SECNDRY	INMAN A	-
INM-5	NO	NO	NO	NO	YES	YES	NO	NO	SECNDRY	INMAN A	ALMOST EXCLUSIVELY TRICHITES
INM-7	YES	NO	NO	YES	YES	YES	NO	NO	SECNDRY	INMAN A	NUMEROUS ASTEROIDAL TRICHITES
INM-9	YES	NO	NO	NO	YES	NO	NO	NO	SECNDRY	INMAN A	
INM-11	YES	NO	YES	NO	YES	NO	NO	NO	SECNDRY	INMAN B	FEW ASTEROIDAL TRICHITES
INM-12	YES	YES	NO	NO	NO	NO	NO	NO	SECNDRY	INMAN A	MANY LONGULITES; LONG MICROLITES
LOW-1	NO	NO	NO	NO	NO	NO	YES	YES	PRIMARY	--	OBSIDIAN-LIKE ASH-FLOW TUFF
MCK-1	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	TYPICAL OBSIDIAN CLIFFS
MCK-2	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	TYPICAL OBSIDIAN CLIFFS
MCK-3	YES	YES	YES	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	(A)
MCK-4	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	TYPICAL OBSIDIAN CLIFFS
OBC-1	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	ACICULAR PRISMATIC MICROLITES ARE
OBC-2	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	THE MAJOR TYPE PRESENT AT THIS
OBC-3	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	SOURCE AND OCCUR IN A VERY HIGH
OBC-4	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	DENSITY IN THE GLASS

TABLE 2: PETROGRAPHIC CHARACTERISTICS OF OBSIDIAN FROM GEOCHEMICALLY-CHARACTERIZED PRIMARY AND SECONDARY SOURCES IN WEST CENTRAL OREGON. THE MICROLITIC STRUCTURES WERE CONSIDERED TO BE PRESENT (YES RESPONSE) IF >5% OF THE TOTAL MICROLITIC STRUCTURES IN THE MICROSCOPE FIELD OF VIEW AT ANY ONE LOCATION ON THE SLIDE.

(A) ANOMALOUS SAMPLE; MARKED SMALL-SCALE VARIABILITY IN MICROLITE TYPES PRESENT. LESS GLASSY THAN OTHER MCK SAMPLES. SPHERULITES PRESENT; LARGER PLAGIOCLASE PHENOCRYSTS PRESENT THAN IN OTHER MCK SAMPLES

PCRYSTS = PHENOCRYST



Plates 15-18: Photomicrographs of obsidian from the gravels of the Willamette River. The scale bars in the upper right corners are 10 microns long. Plates 15 and 16 (IRB-1 and IRB-5, respectively): These two samples contain the typical acicular prismatic microlites of the Obsidian Cliffs source. Nicols not crossed, x100. Plate 17: This sample (IRB-3) exhibits large microlites that are still subcrystalline (skeletal), though more petrographically evolved than normal prismatic microlites. The primary source of this sample is thought to be Obsidian Cliffs. Nicols not crossed, x100. Plate 18: This sample (IRB-7) is characterized by the presence of easily-recognizable asteroidal and acicular trichites, a petrographic trait shared by a number of specimens from the Fern Ridge Reservoir area. Nicols not crossed, x100.

The remaining two Irish Bend samples are easily distinguished from the other specimens by the presence of acicular trichites (plate 18). They also share several other attributes (see table 3) with obsidian from the Inman A and Inman B sources and are considered to have originated from one of those two sources.

A single obsidian nodule from a gravel bar at Wheatland Ferry was found to contain normal prismatic microlites and longulites in quantities greater than 5 percent and was assigned to the source population attributed here to the Inman A and Inman B sources.

5.346 Siuslaw River gravel obsidian: The single slide that was prepared from obsidian at this source was found to share petrographic attributes with the Fern Ridge Reservoir area sources. Acicular and asteroidal trichites were common; acicular and normal prismatic microlites were also found (see plate 19). This sample is thought to have originated from one of the two Inman sources.

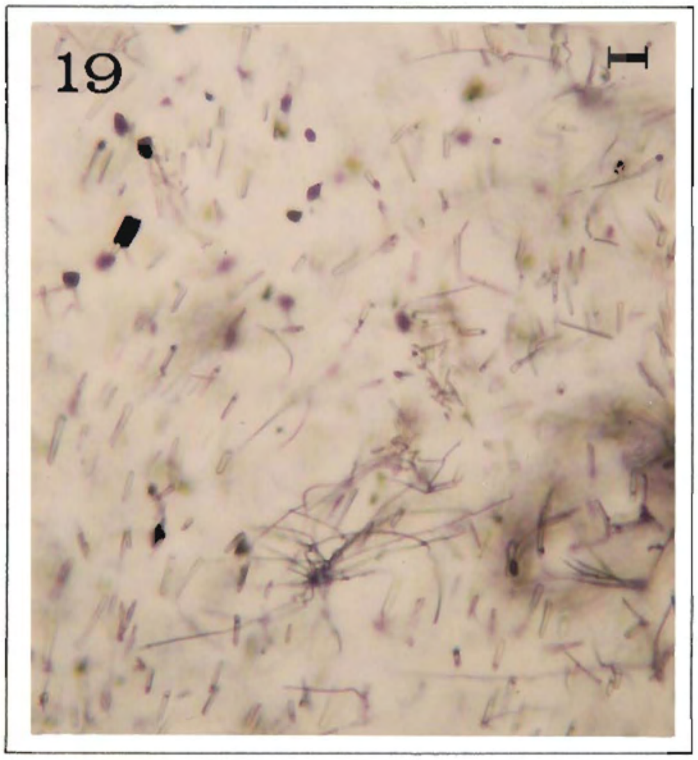


Plate 19: Photomicrograph of obsidian (SIU-3) from a gravel bar near the mouth of the Siuslaw River, Oregon Coast. Slightly acicular to normal prismatic microlites are common in the glass as are asteroidal and acicular trichites. This sample appears to have originated from one of the two Oregon Coast Range source groups, through from which population is petrographically undeterminable. Scale bar in the right corner is 10 microns in length. Nicols not crossed, x93.

The obsidian samples recovered from secondary sources in the Willamette Valley and Oregon Coast were all petrographically separable into two different groups - those that originated from Obsidian Cliffs and those that apparently originated from the Coast Range sources (Inman A and B). It is not possible to distinguish between the two Coast Range sources on the basis of petrographic attributes alone. The most useful attributes that were found to distinguish between the Coast Range and High Cascades sources were the presence of asteroidal and acicular trichites, the high density of acicular prismatic microlites, and phenocrysts in excess of 5 percent of total field of view. Obsidian-like vitrophyre from the Lowell area ash flow was not found in any secondary contexts though it would have been easily distinguishable.

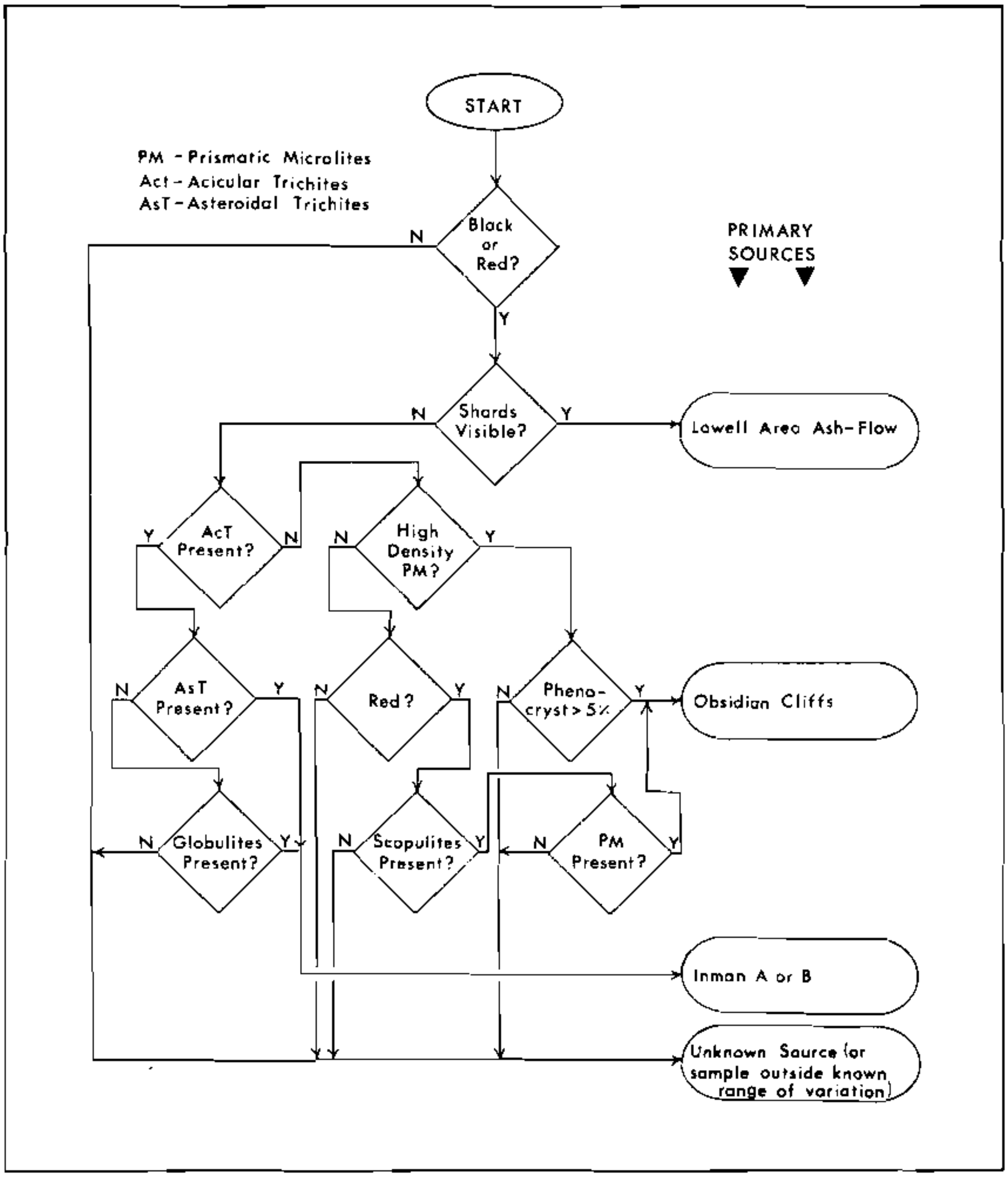


Figure 11: Preliminary flowchart for identifying the primary sources of obsidian recovered from secondary contexts in Western Oregon. The presence or absence of selected petrographic attributes provide the decision criteria (y=yes; n=no). The presence of absence of weathered cortex and/or stream-rolled surfaces could also be added as additional criteria for differentiating between primary and secondary sources.

Based on these initial findings, a flowchart was constructed that would allow the identification of primary sources of obsidian utilizing the criteria of presence or absence of selected petrographic attributes (see figure 11). Using the attributes recorded in tables 2 and 3, the primary sources (as concluded through the petrographic analysis) of obsidian from all secondary Western Oregon contexts are all determinable by following the decision pathways through the flowchart.

Though this decision network does yield the speculated primary sources, the question remains - Is it accurate? The primary sources of obsidian samples from secondary deposits were determined through petrographic analysis, a relatively untested characterization technique. A potential source may also exist in the Staley Creek area of the Western Cascades; its presence in Willamette Valley alluvial gravels would force a reexamination of the criteria used to construct the flow chart. The validity of a petrographic characterization method in Western Oregon can only be ascertained by comparing the results of petrographically-characterized obsidian with the results of a more proven and reliable obsidian characterization method. The method of choice would be the trace element characterization of the glass. In the next section, these two methods are compared in an attempt to provide an independent, though still preliminary test of petrographic characterization methods in Western Oregon.

The other major flaw in this source identification flowchart is its low reliability in distinguishing geologic sources of obsidian that do not lie in Western Oregon. The source universe was purposefully delimited at this stage of the research to include only those sources so far identified in Western Oregon. This was considered justifiable, though not methodologically rigorous, because of the relative geographic isolation of central Western Oregon, the ease of procurement from the sources located there, and the overall lack of petrographic data from other sources. A few independent checks, however, were included in the flowchart to flag down samples that were obviously from outside the regional or known source universe. In an informal test of these checks, obsidian source petrographic data from Skinner (1983:142-151), which included the Obsidian Cliffs flow and Lowell ash-flow, were introduced into the decision network. From a total group of ten, eight sources from Central Oregon were correctly identified as "unknown sources"; the remaining two Western Oregon sources (Obsidian Cliffs and the Lowell ash-flow) were also correctly identified. While these checks are not particularly crucial when determining the geologic source of glass from natural deposits in Western Oregon, they are important when considering the sources of archaeological obsidian. There has probably long been varied degrees of prehistoric contact between Western Oregon and other neighboring regions. The likelihood that obsidian from Central Oregon or Northern California was introduced by trade or other means into Western Oregon is almost certain. Henn (1975) and Rarick (1962:36), for example, both cite ethnographic accounts of Central Oregon Indians whose seasonal subsistence rounds included travel into the Upper McKenzie River Valley of Western Oregon. The presence of a 25.5 cm long obsidian blade from a mound in the Willamette Valley (Laughlin, 1941) also argues for the importation of obsidian. The only Western Oregon sources that could have provided the size of raw material necessary for this artifact was Obsidian Cliffs. While this source does provide artifact-quality glass, it is not always of the high quality that is usually utilized in the production of very large points.

What the flowchart is intended to provide, then, despite these acknowledged weaknesses, is a starting point for the routine petrographic characterization of geological and archaeological obsidian from Western Oregon.

5.35 A Test of the Method

How valid a method is the petrographic characterization of Western Oregon obsidian? Can this technique of identifying geologic sources of artifactual and geologic materials be used with confidence? Would the simple flowchart pictured in figure 11 be adequate to identify primary sources? To provide a preliminary test for this method, primary sources were determined, using both petrographic and trace element attributes, for samples that had been previously geochemically characterized (see tables 1 and 3 for data). The results of the two independent source identification methods were then compared. Since trace element characterization methods have long been proven reliable, particularly in a simplified context such as in Western Oregon, the sources identified by this technique were considered as the correct ones. The use of petrographic attributes to assign primary sources yielded the same results as those determined by trace element abundances. Petrographic characterization, however, does lack the resolution of trace element methods - it was impossible to determine, on the basis of petrographic attributes alone, which of the two Inman source groups a sample originated from.

It is concluded that the valid petrographic characterization of Western Oregon obsidian sources is possible. Results to date are still based on a relatively small and possibly incomplete sample of obsidian, though. More extensive sampling of Western Oregon sources and those of adjoining regions will still be needed to establish the long-term reliability of this technique.

5.4
Conclusions

Obsidian characterization studies of volcanic glass from several different primary and secondary sources in Western Oregon indicate the existence of three geochemically-distinct source populations of natural glass. The secondary distribution of this obsidian throughout Western Oregon is fairly extensive, particularly in the Willamette Valley. Three primary sources of obsidian are presumed to exist, though the location of only one, the Obsidian Cliffs obsidian flow, is presently known. The remaining two primary sources are represented only by obsidian found in secondary deposits of clay and gravel in the south-central Willamette Valley and in the gravels of the Siuslaw River at the Oregon Coast. The location of these two sources, while not known, almost certainly lies in the Coast Range to the west of the Fern Ridge Reservoir. A cover of soil and vegetation has apparently erased any signs of the original primary sources. The presence of obsidian from the Coast Range sources in the Willamette River gravels upstream from its confluence with the Long Tom also indicates that the Willamette River has intersected obsidian-bearing stratum. Whether this is the same one that is exposed in the Fern Ridge Reservoir stream banks is not known. It does point out the fairly widespread fluvial distribution of the Inman obsidian groups prior to the establishment of the present-day Long Tom River drainage. A primary source of obsidian-like vitrophyre was also examined, but was not encountered during the sampling of secondary depositional contexts.

SAMPLE NO.	BACIL-LITES? 	GLOBU-LITES? 	LONGU-LITES? 	MARGA-RITES? 	NORMAL PRSMTIC? 	ACICULAR PRSMTIC? 	ACICULAR TRCHITE? 	ASTROIDL TRCHITE? 	PCRYSTS > 5%? 	SHARDS? (ASHFLOW) 	SOURCE TYPE (PRIMARY OR SECNDRY?)	PROBABLE SOURCE	* COMMENTS *
CNB-1	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	PRIMARY	--	MICROCRYSTALLINE RHYODACITE
INM-4	NO	YES	NO	NO	NO	NO	YES	YES	NO	NO	SECNDRY	INMAN	UNUSUALLY SMALL TRICHITES
INM-6	NO	YES	NO	NO	NO	YES	YES	NO	YES	NO	SECNDRY	INMAN	-
INM-8	NO	NO	NO	NO	YES	NO	YES	YES	NO	NO	SECNDRY	INMAN	-
INM-10	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO	SECNDRY	INMAN	-
INM-13	NO	NO	NO	YES	YES	YES	YES	YES	NO	NO	SECNDRY	INMAN	-
IRB-1	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	(A)
IRB-2	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	(A)
IRB-3	NO	NO	NO	NO	YES	NO	YES	NO	YES	NO	SECNDRY	INMAN?	W/MEGASCOPIC PLAG. PCRYSTS (A)
IRB-4	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	(A)
IRB-5	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	(A)
IRB-6	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	W/MEGASCOPIC PLAG. PCRYSTS (A)
IRB-7	NO	NO	NO	NO	NO	NO	YES	YES	YES	NO	SECNDRY	INMAN	-
IRB-8	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	HIGH % CRYSTALLIZATION (>10%)
IRB-9	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	HIGH % CRYSTALLIZATION (>10%)
IRB-10	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	PERLITIC TEXTURE TO GLASS
MCK-5	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	(A)
MCK-6	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	HIGH % CRYSTALLIZATION (>10%)
MCK-7	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	HIGH % CRYSTALLIZATION (>10%)
MCK-8	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	SECNDRY	OCLIFFS	HIGH % CRYSTALLIZATION (>10%)
OBC-5	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	SOME MICROLITES APPROACH NORMAL
OBC-6	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	MORE PCRYSTS THAN USUAL
OBC-7	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	(A)
OBC-8	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	PRIMARY	--	ANOMALOUS; RED & BLACK (B)
OBC-9	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	PRIMARY	--	(C)
OBC-10	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	PRIMARY	--	SPHERULITES (C)
OBC-11	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	PRIMARY	--	(C)
OBC-12	NO	NO	NO	NO	YES	YES	NO	NO	YES	NO	PRIMARY	--	A FEW ISOLATED ASTEROIDAL TRICHITES
OBC-13	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	RARE ASTEROIDAL TRICHITES (C)
OBC-14	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	(A)
OBC-15	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	(A)
OBC-16	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	(A)
OBC-17	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	(A)
OBC-18	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	PRIMARY	--	SOME MICROLITES APPROACH NORMAL
SIU-3	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	SECNDRY	INMAN	-
WWF-1	NO	NO	YES	NO	YES	NO	NO	NO	YES	NO	SECNDRY	INMAN	-

TABLE 3: PETROGRAPHIC CHARACTERISTICS AND PROBABLE PRIMARY SOURCES OF OBSIDIAN FROM SECONDARY DEPOSITS IN WESTERN OREGON. THESE SAMPLES WERE CHARACTERIZED STRICTLY ON THE BASIS OF THEIR PETROGRAPHIC FEATURES, I.E. MICROLITE TYPES PRESENT, PERCENTAGE OF MICROPHENOCRYSTS PRESENT, AND PRESENCE OR ABSENCE OF DIAGNOSTIC COLLAPSED SHARDS.

(A) TYPICAL OBSIDIAN CLIFFS SAMPLE; HIGH DENSITY (>50% OF ACICULAR PRISMATIC MICROLITES
(B) RED & BLACK GLASS; SMALL AREAS OF ACICULAR PRISMATIC MICROLITES (BETWEEN RED ZONES); POORLY-DEVELOPED SCOPULITIC STRUCTURES
(C) ZONES OF WELL-DEVELOPED NORMAL PRISMATIC MICROLITES

PCRYST=PHENOCRYST   PLAG.=PLAGIOCLASE

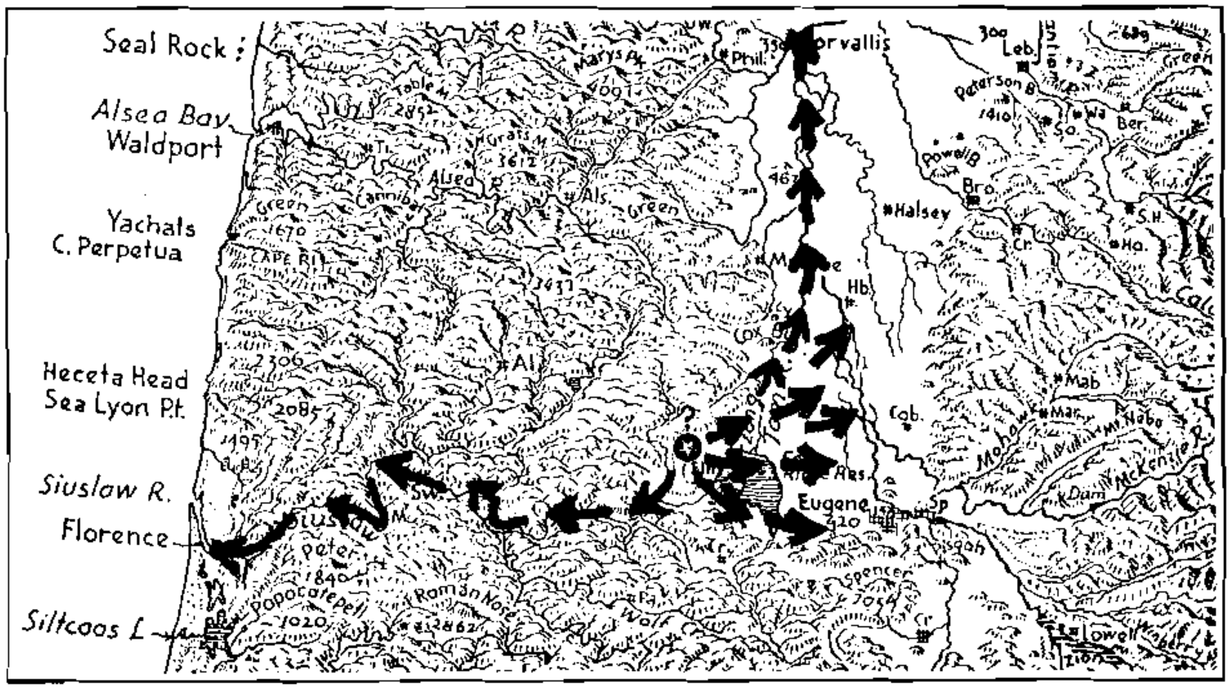


Figure 12: Known and inferred primary and secondary distribution of obsidian from unknown sources in the Coast Range. The primary sources of the secondary deposits of obsidian found in the southwestern Willamette Valley and the Central Oregon Coast, though they have not yet been found, are thought to be located near the Fern Ridge Reservoir.

The preliminary petrographic analysis of obsidian from primary and secondary sources in Western Oregon also indicates that these sources exhibit an observable degree of intrasource homogeneity and intersource heterogeneity. This suggests that obsidian from Western Oregon may be petrographically, as well as geochemically characterized. Based on the presence or absence of specific petrographic attributes, a source identification flowchart was constructed that would allow the determination of primary sources. When tested against geochemically characterized glass, the petrographic method was found to be a valid one, though not as powerful in its discrimination qualities as the trace element method.

Based on the results of this characterization investigation, it becomes possible to chart the probable primary and secondary distribution of obsidian in Western Oregon (figures 12 and 13). The importance and consequences of the identification and delineation of these sources and their secondary boundaries for archaeological obsidian studies is the subject of the remainder of this study.

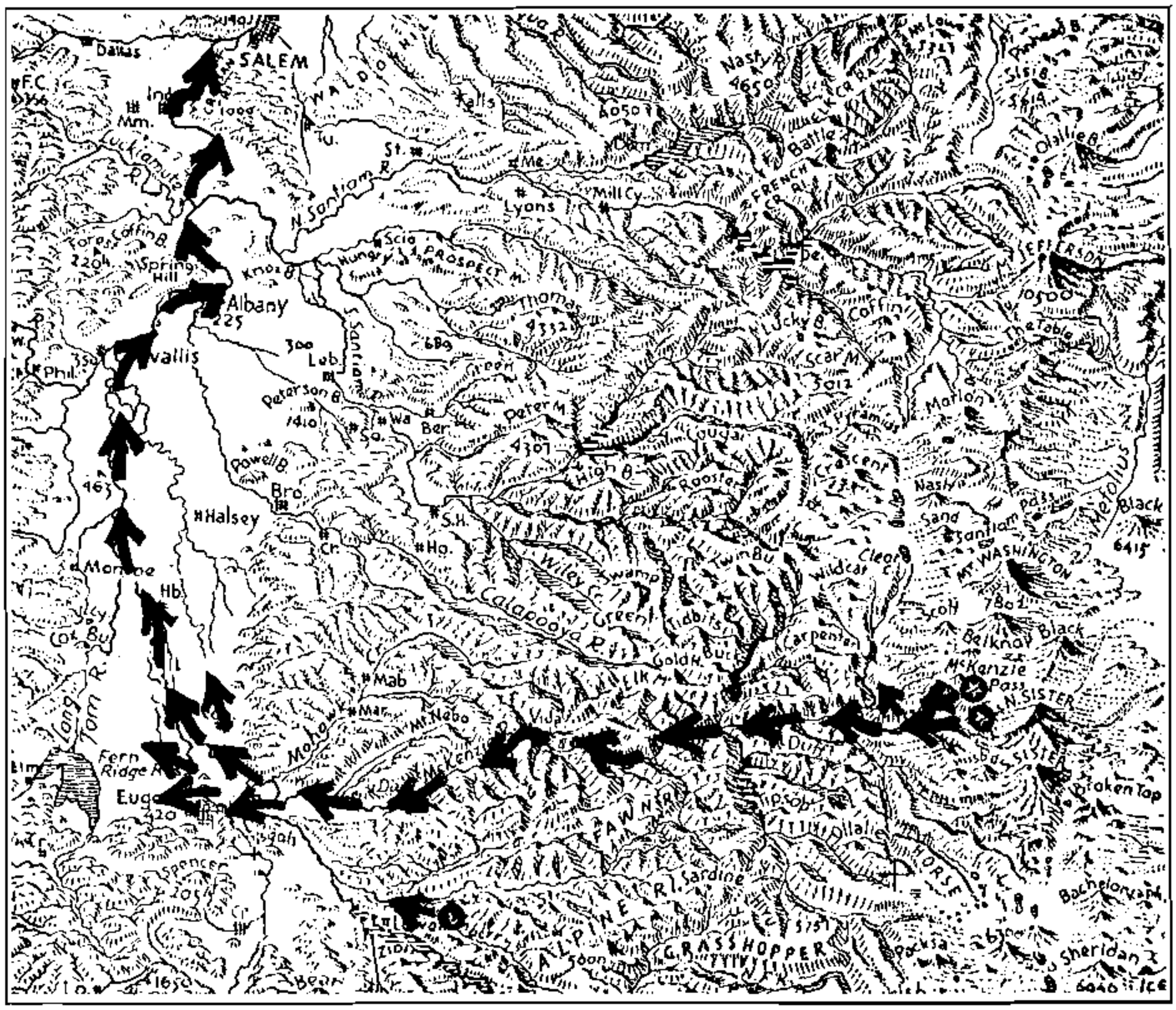


Figure 13: Primary and secondary distribution and of obsidian from the Western and High Cascades. Obsidian in late Pleistocene deposits of glacial outwash is probably widely spread in alluvial deposits of the southern Willamette Valley. Deposits of gravels containing obsidian pebbles that originated at Obsidian Cliffs are currently accessible in existing (and probably recently abandoned) river channels. Though the Condon Butte area dome and Lowell area sources are shown on the map, their secondary distribution is not known. It is likely that neither of these last two sources will prove to be archaeologically significant.

6.0 PREHISTORIC UTILIZATION OF CENTRAL WESTERN OREGON OBSIDIAN SOURCES: EVIDENCE FROM ARCHAEOLOGICAL RESEARCH

6.1

Introduction

It is clear from the descriptions of Western Oregon obsidian in Chapter 4 that sources of natural glass were widely distributed throughout the Willamette Valley. Along the Oregon central coast, obsidian was available in small amounts in at least one location, the mouth of the Siuslaw River. Natural glass was also present in the Western and High Cascades in an east-west linear belt stretching from the Obsidian Cliffs flow down through most of the length of the lower McKenzie River Valley. In all of these regions, the glass was available in secondary geologic contexts throughout the Holocene, a 10 to 12,000-year time span which appears (based on current archaeological evidence) to comfortably encompass the range of prehistoric human occupation in Western Oregon.

Given, then, that obsidian was widely available in Western Oregon, what was the extent of prehistoric exploitation of this raw material? Were all available sources being utilized? Does the archaeological record provide us, either syncronically or diachronically, with any visible patterning of obsidian utilization? What kind of evidence do the limited numbers of obsidian characterization studies provide? These issues will be briefly explored in the remainder of this chapter.

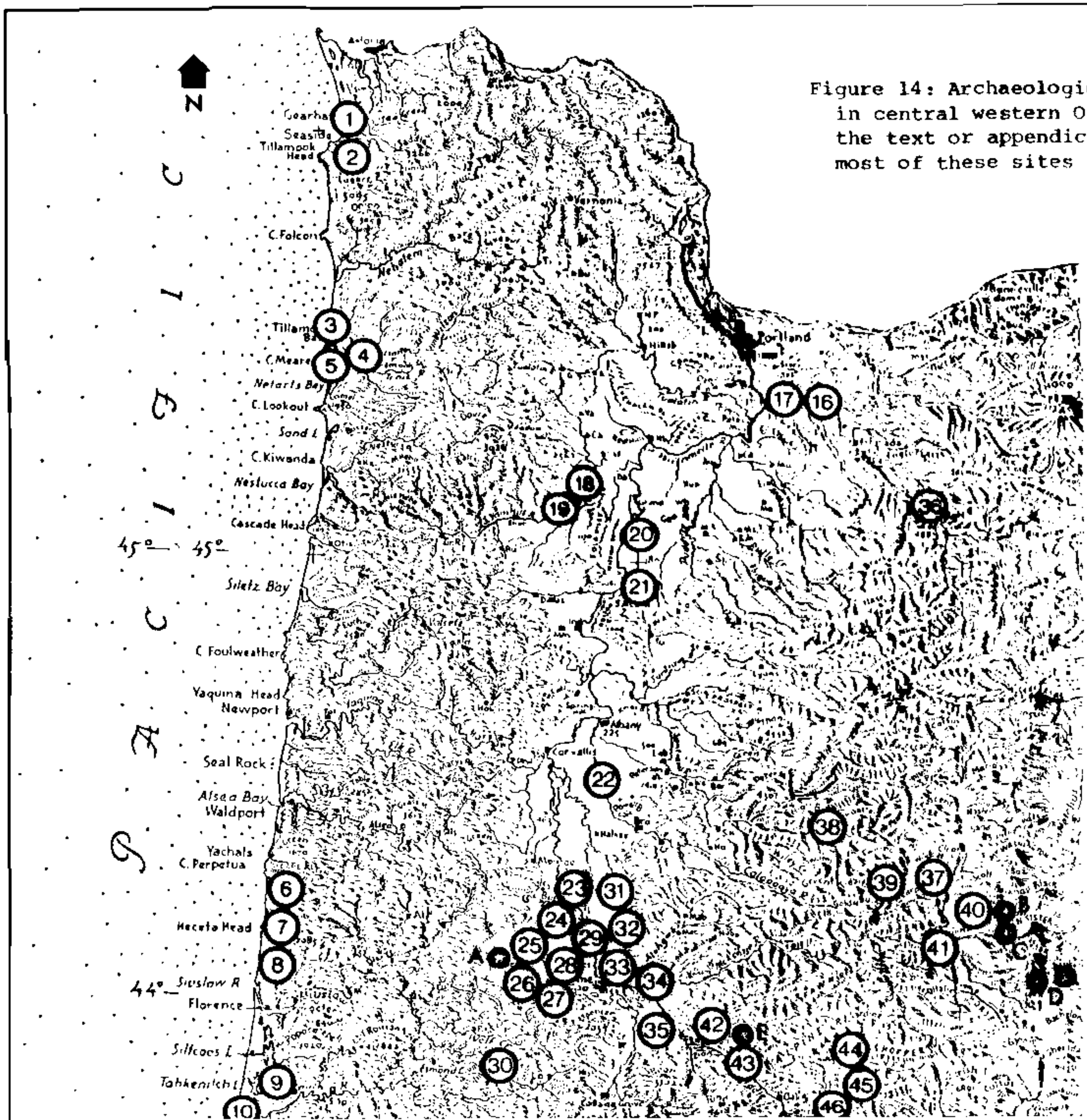
The raw data for this analysis of prehistoric obsidian procurement and utilization in Western Oregon were drawn from reports of archaeological site investigations throughout the western portion of the State (see figure 14). Classes of data that might provide clues about obsidian utilization patterns (such as the presence of absence of obsidian artifacts or the percentage of obsidian debitage at a site) were tabulated and examined (see Appendix 4 for this data). The most telling of these classes of information appeared to be:

1. The presence or absence of artifactual obsidian at a site (debitage or tool-manufacturing waste is considered to be artifactual material).

2. The maximum length of any artifactual obsidian object at the site. This figure was often tentatively arrived at by measuring photographs of obsidian artifacts. It was assumed that most archaeologists, even when writing the briefest of reports, cannot resist including in their site report a picture of the largest obsidian tool that was recovered. Data compiled under this assumption, however, must be considered provisional.

3. The percentage of obsidian debitage that was recovered from the site. This number was computed, when possible, using the total number of debitage items recovered, i.e. if 100 pieces of debitage were found and 50 of these were obsidian, the obsidian debitage percentage would be 50%. The relatively large numbers of debitage recovered compared to other artifactual classes makes this a particularly valuable indicator of obsidian utilization in an archaeological context. Statistical sampling error should be considerably reduced due to these large quantities.

Figure 14: Archaeological sites and obsidian sources in central western Oregon that are discussed in the text or appendices. Obsidian-related data for most of these sites are found in Appendix 4.

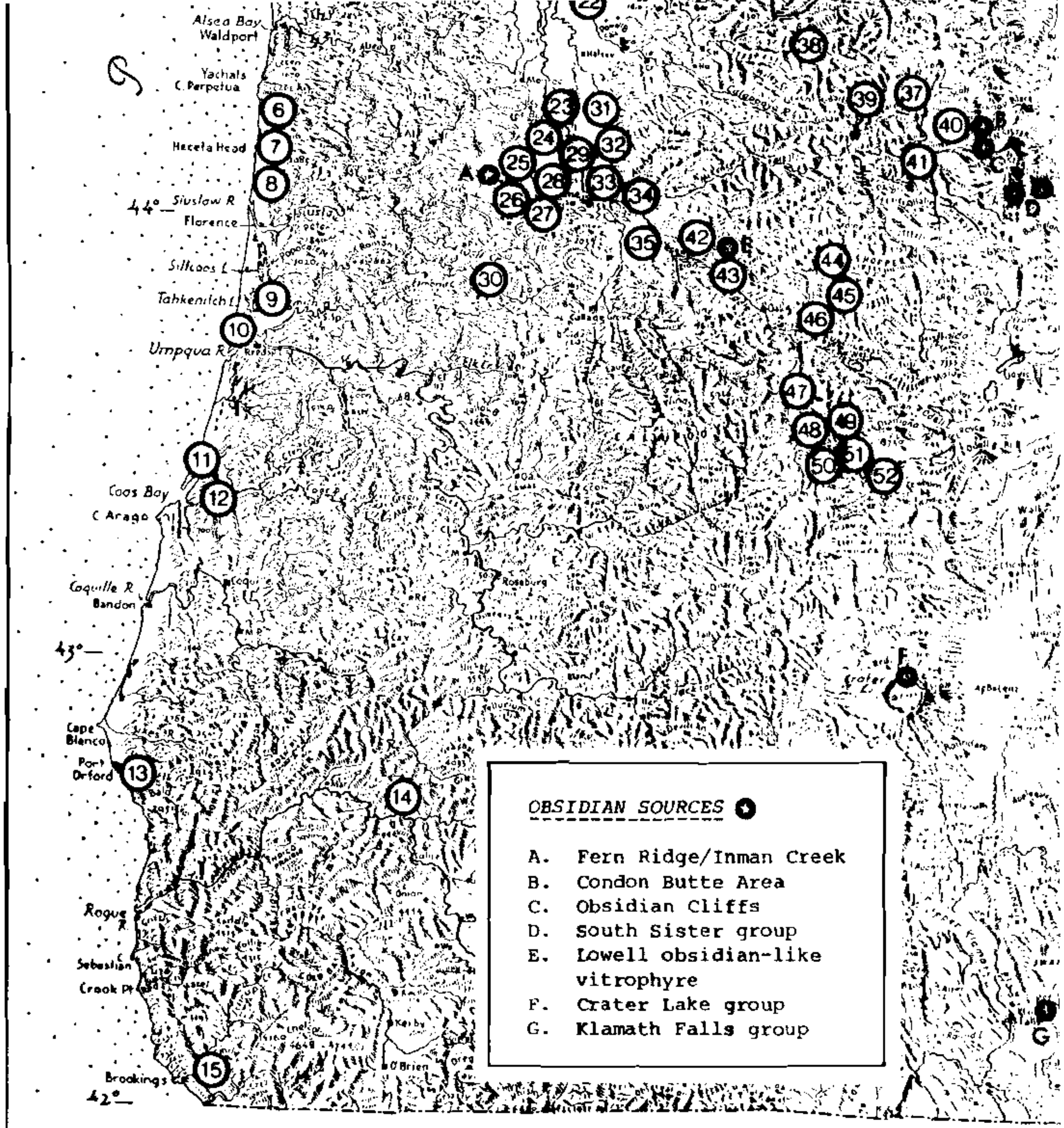


COASTAL SITES

1. Palmrose
2. Partee
3. Netart's Spit
4. Kilchis Point
5. Oceanside Beach Wayside
6. Neptune
7. Good Fortune Cove
8. Good Fortune Point
9. Tahkenitch Lake
10. Umpqua/Eden
11. Bullard's Beach
12. Philpott
13. Pistol River
14. Curt Day Acorn
15. Lone Ranch

WILLAMETTE VALLEY SITES

16. Geertz
17. Mostul Village
18. Fuller Mound
19. Fanning Mound
20. Willamette Mission
21. Hager's Grove
22. Lynch
23. Lingo
24. Benjamin
25. Kirk Park
26. Hannavan Creek
27. Perkins Peninsula



OBSIDIAN SOURCES ●

A. Fern Ridge/Inman Creek
B. Condon Butte Area
C. Obsidian Cliffs
D. South Sister group
E. Lowell obsidian-like vitrophyre
F. Crater Lake group
G. Klamath Falls group

WILLAMETTE VALLEY SITES

16. Geertz
17. Mostul Village
18. Fuller Mound
19. Fanning Mound
20. Willamette Mission
21. Hager's Grove
22. Lynch
23. Lingo
24. Benjamin
25. Kirk Park
26. Hannavan Creek
27. Perkins Peninsula
28. Flanagan
29. Eugene Vicinity
30. Siuslaw Falls
31. Beebe
32. Hurd
33. Armitage Bridge
34. Halverson
35. Simons

WESTERN CASCADES SITES

36. Ripple
37. Blitz
38. Cascadia Cave
39. Tidbits
40. Condon Butte
41. Indian Ridge
42. Fall Creek
43. Armet Rockshelter
44. Sardine Confluence
45. White Cliffs Rockshelter
46. Baby Rock Shelter
47. Buck Creek
48. Colt Timber Sale
49. Colt
50. Saddle
51. Vine Rockshelter
52. Horse Pasture

4. The ratio of obsidian cores to the total debitage number. This was considered as a possible indicator of quarry distance. Ethnographic observations of behavior at obsidian sites (Gould et al., 1971; Clark, 1978 and 1979; Gallagher, 1977) suggest that the raw material is generally reduced in some respect (to cores, blanks, bifaces, or flakes) prior to transport from the source. It was thought, then, that the number of obsidian cores, normalized for site size by their ratio with the total debitage count, could provide an index of quarry proximity. This ratio proved to be of only limited value, though, for four reasons. First, there are often very few obsidian cores recovered at any given site, leaving their number highly vulnerable to sampling error. Secondly, the definition of just what constitutes a core is often tacitly determined among different workers. The intersite comparison of any inadequately defined artifact class should be considered as methodologically suspect - after the classic polyhedral core types have been eliminated, the identification criteria of what constitutes a core can become somewhat amorphous. Thirdly, small differences in core frequencies among sites, when compared to high debitage numbers, can lead to large variations in core to debitage ratios. Errors introduced by sampling or identification problems can quickly become very significant. Lastly, as suggested by Pettigrew (1980:67), small pebbles of obsidian (such as those available throughout much of Western Oregon) may be completely reduced during tool manufacture, leaving no trace in the archaeological record.

5. The presence of unworked nodules of obsidian at the site. Small, stream-rolled nodules or pebbles of glass are frequently recovered from Willamette Valley sites. Their presence was interpreted to provide evidence of utilization of fluvially-transported obsidian that is commonly found in the river gravels of the Willamette and McKenzie Rivers.

6. The results of obsidian characterization studies that have identified the geologic sources of artifactual obsidian from Western Oregon sites. Though there are methodological problems with some of these studies, particularly concerning the incomplete source universes and the statistical methods of correlation that were used (see Skinner, 1983:85-86, and Hughes, 1984, for discussions of these problem areas), they still provide useful information when cautiously used. Particularly important to note in these studies is the identification of artifacts from the Eastern Oregon Tucker Hill source in archaeological assemblages in the Willamette Valley and Western Cascades (Toepel and Sappington, 1982; Sappington, 1984b and 1984c). These artifacts almost certainly originated from one of the two geochemically-distinct obsidian sources in the Fern Ridge area of the southwestern Willamette Valley, sources that were not adequately characterized or identified at the time of the research. Studies performed after one of the Fern Ridge sources (named the Inman Creek source) had been included in the source universe also failed to recognize that there were two intermixed sources available in this one area, though their existence was by this time strongly suspected (Sappington, 1984a).

Obsidian-related information drawn from these many site reports, while not always completely comparable, provides at least a preliminary glimpse at the prehistoric patterns of obsidian utilization that have existed in Western Oregon. These data are summarized in figure 16.

6.2
Utilization of Western and High Cascades Sources

Glass from the Obsidian Cliffs source, besides appearing in Willamette Valley gravel deposits, also was utilized in the Western and High Cascades, though archaeological data is rather sparse. A brief trace element and petrographic characterization study of obsidian from a small surface scatter in the Condon Butte area suggested that most, if not all of the glass at this site originated at the nearby Obsidian Cliffs flow (Skinner, 1983:353-355). Forty-Three percent (43%) of the characterized obsidian from the Blitz Site was also found to originate from Obsidian Cliffs (Sappington, 1984c). The obsidian debitage percentages at the Condon Butte area site and the nearby Indian Ridge and Blitz sites also suggest the utilization of a locally-available source, most likely the nearby Obsidian Cliffs source - 100% of the Condon Butte debitage and 93% of the Indian Ridge site debitage was composed of obsidian (figure 15). Obsidian debitage ratios from several sites on the Upper Middle Fork of the Willamette River are also large, suggesting procurement from Obsidian Cliffs or perhaps a more local, still unidentified, source (Baxter, 1983, 1984, 1986b; Connolly and Baxter, 1983; Sappington, 1986). Obsidian used at these sites could easily have come from multiple sources, as characterization studies by Hughes (1986) suggest. Glass from more distant archaeological sites in the southwestern Willamette Valley may also have originated at Obsidian Cliffs (Toepel and Sappington, 1982; Sappington, 1985b). The geographic distribution and frequency of characterized artifactual obsidian from this source is graphically illustrated in figure 16. Whether the relatively low percentage of Obsidian Cliffs glass present in characterized artifactual assemblages from Western Cascade sites reflects procurement styles, geographic barriers, or sampling limitations is still hard to tell. This is a trend worth watching in future work, though.

The distribution of relatively large obsidian artifacts in the Obsidian Cliffs area also argues for its use as a quarry source (see figure 17). Artifacts up to 9.5 cm in length have been reported from Western Cascades sites and there is a tendency for maximum length to decrease as a function of distance from the Obsidian Cliffs source.

The Obsidian Cliffs flow lies near the McKenzie Pass, one of the few natural passes over the Central High Cascades; its use by prehistoric hunting parties has been suggested by previous researchers (Newman, 1966:2). The Scott Trail, an early pioneer path that crossed the Cascade Divide near Obsidian Cliffs was reputed to follow an Indian trail (Rarick, 1962:32; Minor and Pecor, 1977:155). Rarick (1962:36), Henn (1975), and Griffin (1986:100) report that as late as the 1920's Indians from east of the Cascades made annual treks over the mountains to the upper McKenzie area to use local hot springs and to hunt for fish, deer, and berries.

The Obsidian Cliffs source has also been identified as a quarry site (Hopson, 1946:327; Minor and Pecor, 1977:138), though archaeological details are lacking in the literature. More than two dozen archaeological quarry sites have been recently identified at this source (Jon Silvermoon, personal communication, 1986), though the ultimate destination of the glass quarried here is still poorly-known. Some of the glass from this source, though, has made its way to the east into Central Oregon. Obsidian Cliffs was identified as a likely source for three of 103 obsidian artifacts that were recovered 30 km to the southeast at the Lava Island Rockshelter (Sappington, 1982).

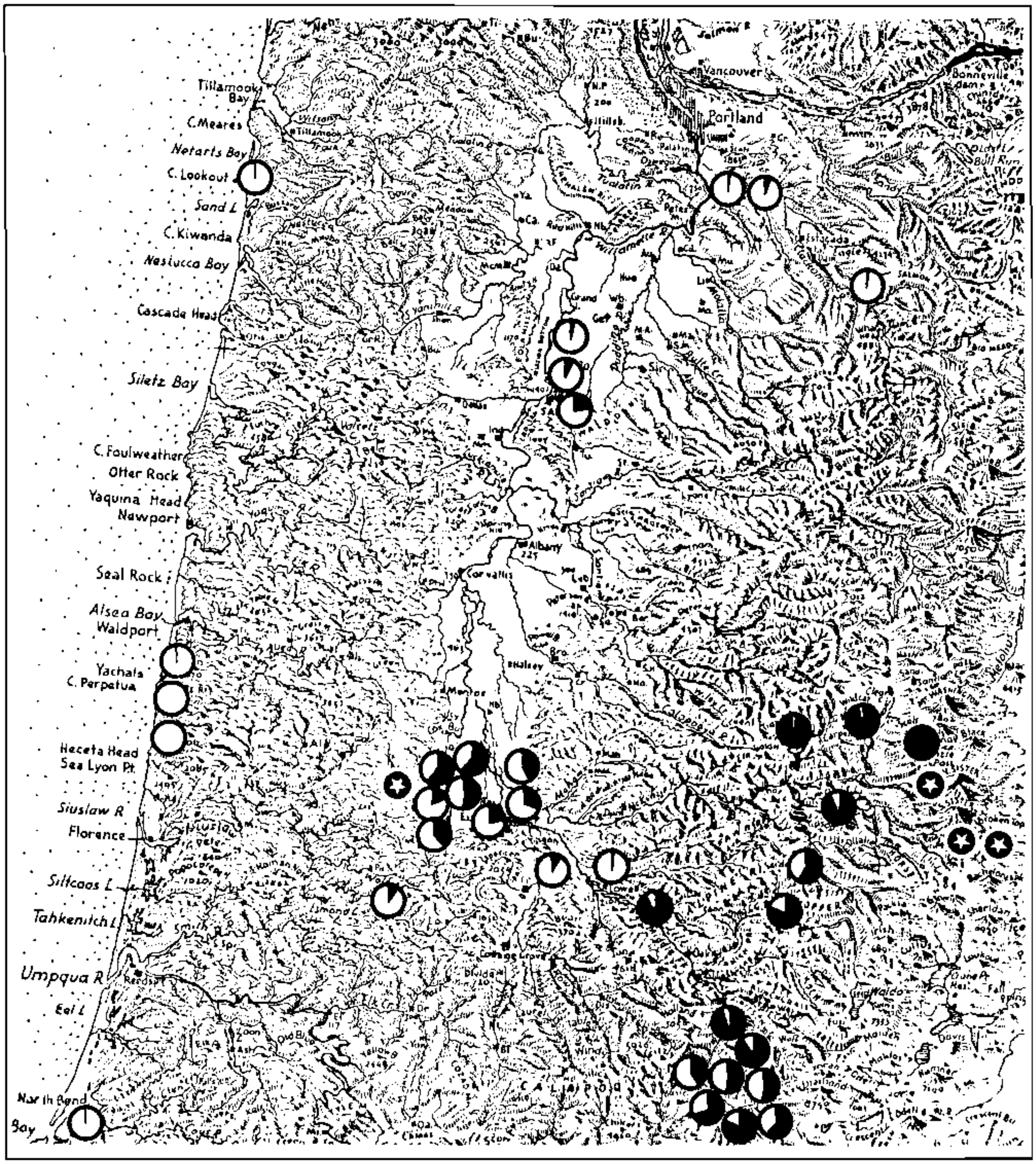


Figure 15: The percentage of obsidian debitage recovered at selected sites in Western Oregon. Completely filled circles indicate that 100% of the recovered debitage was obsidian; completely empty circles show that no obsidian debitage was found.

6.3
Utilization of Willamette Valley Sources

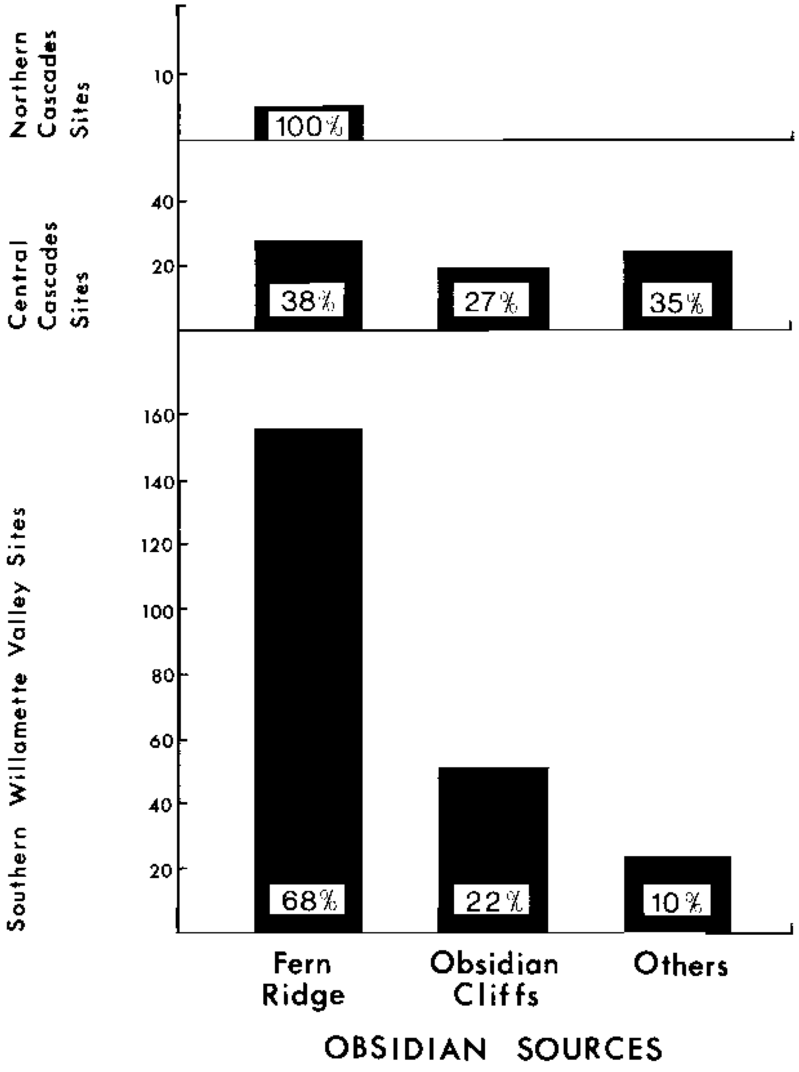
The most complete information about Western Oregon obsidian utilization comes from sites in the Willamette Valley, an area where archaeological research has been carried out for over forty years. One of the conspicuous and long-recognized features of lithic assemblages in the Willamette Valley has been the universal presence of obsidian as a raw material. Until recently, it was assumed that this glass was found locally only in the gravels of the McKenzie and Willamette rivers - any obsidian artifacts over about 4 cm in diameter were thought to have made their way into the Valley through direct procurement at High Cascades sources or what must have been imagined to have been rather active exchange networks with groups to the east and south who had direct access to sources. The recent discovery of obsidian sources in the southwestern Willamette Valley and the preliminary obsidian characterization of obsidian from Valley sites will do much to alter this formerly held picture of Willamette Valley obsidian use.

6.31 Utilization of Obsidian from the Fern Ridge Area Sources

Were the two Fern Ridge area obsidian sources utilized by the prehistoric inhabitants of Central Western Oregon? Two independent lines of evidence, the characterization of archaeological obsidian and the overall areal distribution of obsidian in archaeological sites, suggest that this was indeed the case.

Though obsidian characterization data for the Fern Ridge sources are still sparse, they do indicate that these sources were being exploited for their lithic materials. The characterization of small samples at the Ripple Site in the Northwestern Cascades (Sappington, 1985a), the Colt, Saddle, Blitz, and Condon Butte sites in the central Western Cascades (Hughes, 1986; Sappington, 1984c; Skinner, 1983:347-356), the Halverson Site in the southeastern Willamette Valley (Toepel and Sappington, 1982), and the Hannavan, Perkins Point, Kirk Park and Flanagan sites in the southwestern Willamette Valley (Cheatham, 1984; Sappington, 1984b and 1985b) all demonstrate utilization of the sources. One of the two Fern Ridge sources was clearly being used while the second source (probably misidentified as originating from Tucker Hill) was almost certainly also being utilized. Reports describing excavations at these sites unfortunately do not document the provenience of the characterized samples. No temporal dimension can therefore be assigned to either the artifacts or the periods during which specific sources were being utilized. Sample sizes are also rather small and may not be statistically representative of the range of variation of source utilization at any one site. The summary of obsidian characterization research results in figure 16 clearly illustrates the popularity of the Fern Ridge sources, particularly in the Willamette Valley. One hundred percent (100%) of the characterized obsidian artifacts from Fern Ridge vicinity archaeological sites were found to have come from the local source (Cheatham, 1984; Sappington, 1984b). The Fern Ridge sources were also represented by a surprisingly large number of Western Cascade artifacts (Sappington, 1984c; Hughes, 1986). It appears that the Fern area obsidian sources are not only significant in the archaeolocal record, but that they may be the most heavily utilized of the Western Oregon sources.

The second line of evidence supporting the prehistoric use of the Fern Ridge sources lies in the areal distribution of the percentage of obsidian debitage appearing in Western Oregon sites. The frequency of obsidian debitage in the



		GEOLOGIC SOURCES OF OBSIDIAN ARTIFACTS			
SITE REGION	ARCHAEOLOGICAL SITE	FERN RIDGE SOURCE	OBSIDIAN CLIFFS SOURCE	OTHER SOURCES	TOTAL
NORTH CASCADES	RIPPLE (35CL55)	10 (100%)	0	0	10
CENTRAL CASCADES	BLITZ (35LIN147)	16 (53%)	13 (43%)	1 (3%)	30
	SADDLE (35LA529)	7 (35%)	3 (15%)	10 (50%)	20
	COLT (35LA599)	4	2	14	20
	CONDON BUTTE	0	1 (100%)	0	1
	SUBTOTAL	27 (38%)	19 (27%)	25 (35%)	71
SOUTH WILLAMETTE VALLEY	KIRK PARK 1 (35LA565)	15 (100%)	0	0	15
	KIRK PARK 2 (35LA568)	15 (100%)	0	0	15
	KIRK PARK 3 (35LA567)	12 (100%)	0	0	12
	KIRK PARK 4 (35LA566)	15 (100%)	0	0	15
	PERKINS PENINSULA (35LA282)	15 (100%)	0	0	15
	FLANAGAN (35LA218)	33 (55%)	15 (25%)	12 (20%)	60
	HALVERSON (35LA261)	51 (52%)	36 (37%)	12 (12%)	98
	SUBTOTAL	156 (68%)	51 (22%)	24 (10%)	232
	TOTAL	193 (62%)	70 (22%)	49 (16%)	312

Figure 16: Prehistoric utilization of Western Oregon obsidian sources as reflected by characterized obsidian artifacts from sites in the Western Cascades and the Willamette Valley. Data are from Cheatham (1984), Hughes (1986), Sappington (1984b, 1984c, 1985a, 1985b), Skinner (1983), and Toepel and Sappington (1982). Data from Sappington (1986) are omitted because of methodological problems.

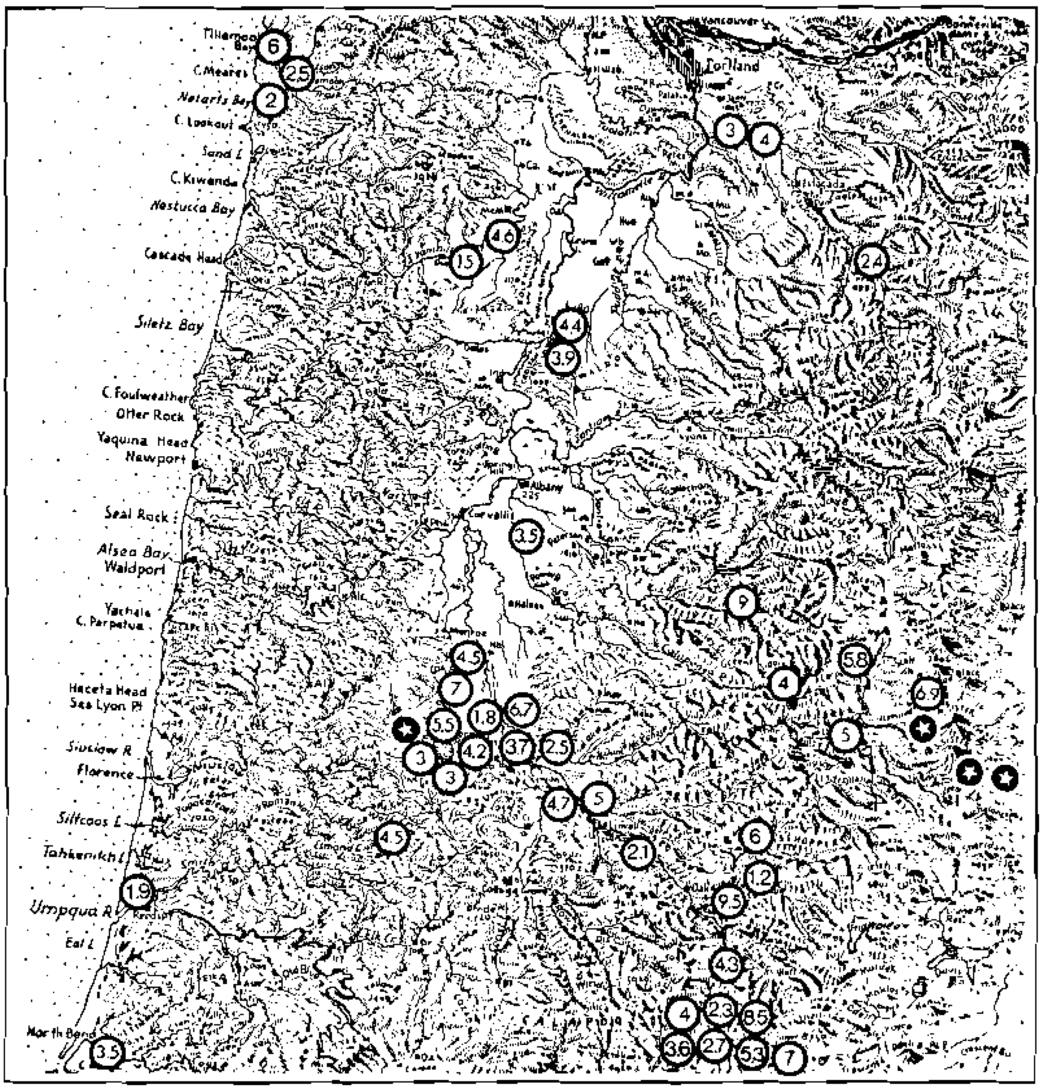


Figure 17: Maximum size of obsidian artifacts from sites in Western Oregon. The number within the circle refers to the largest dimension in centimeters.

Willamette Valley appears to focus on the Fern Ridge area with higher percentages indicated nearer the sources (see figure 15). This is precisely the pattern expected and recorded at numerous other sites throughout the world (Ericson, 1977 and 1981; Renfrew, 1977; Findlow and Bolognese, 1980 and 1982) - that the fall-off of obsidian in archaeological sites is largely a function of the distance of a site from the source. When plotted on a scattergram, as in figure 18, the relationship of obsidian debitage percentage as a function of distance from the Fern Ridge sources becomes even more evident. It must be kept in mind, though, that the distance-decay curve displayed is a rather optimistically crude one based on few data points in which only a minimum of independent variables are taken into account (see Skinner, 1983:87-90, for discussion of these variables). Nevertheless, the decay curve does display the predictable initial low slope that is characteristic of the direct-access

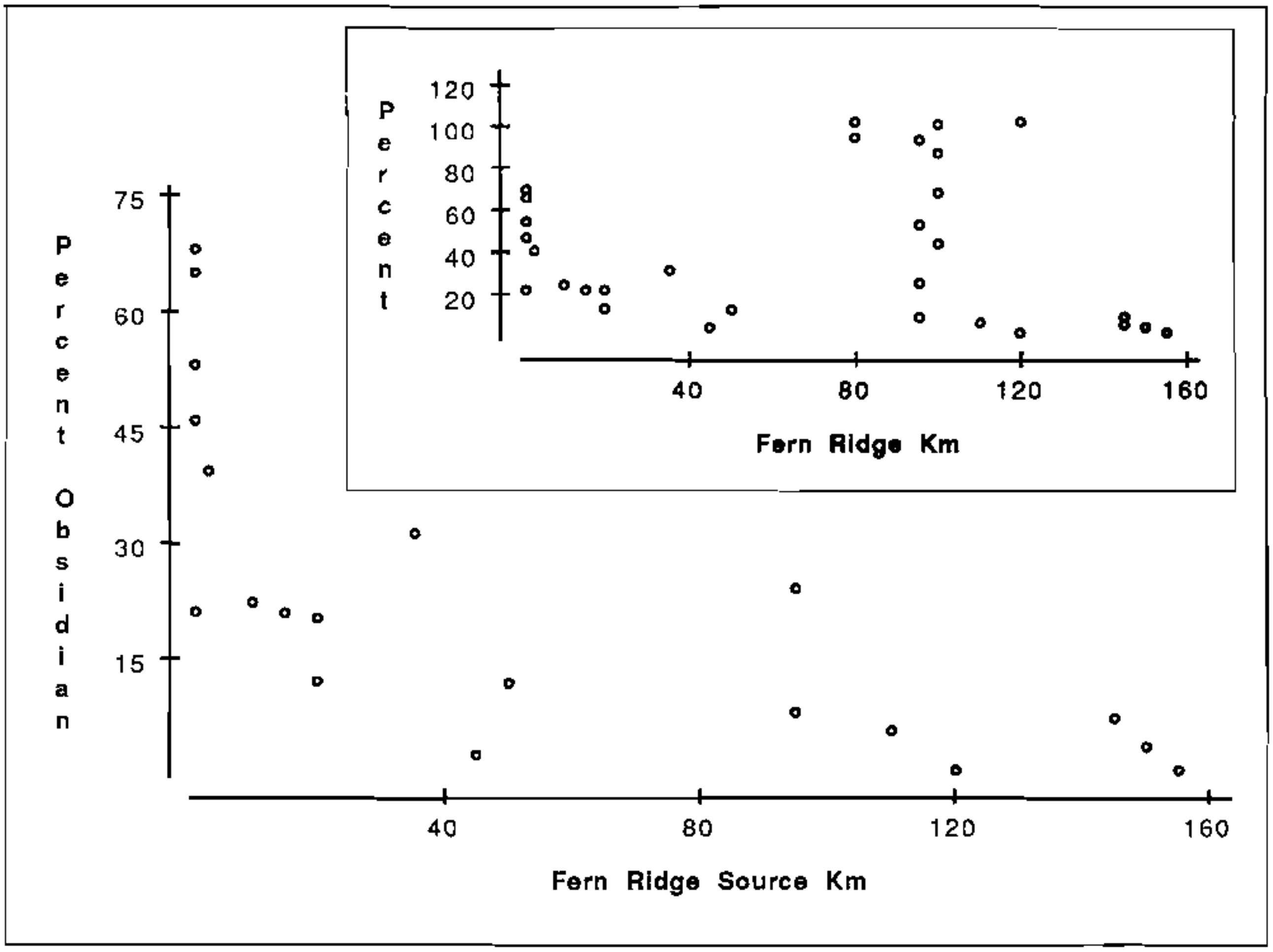


Figure 18: Distance-decay curve generated when the percent of obsidian debitage from Willamette Valley and coastal sites is plotted versus their distance from the Fern Ridge sources. In the inset scatterplot, data from Western Cascades sites have been introduced.

supply zone. This is immediately followed by a rapid initial increase in slope and the gradual fall-off curve typical of an economically valued raw material (Renfrew, 1977). The anomalous data points in the upper right-hand corner of the inset graph almost certainly indicate the utilization of another closer source of glass, probably the Obsidian Cliffs flow. As more characterization studies for Western Oregon sites appear, it will also become possible to examine the relationship of the percentage of characterized artifacts originating at the Fern Ridge sources (or other sources) with the site distance from the sources. Data from figure 16 suggest that a decay curve similar to the one in figure 18 would be the result.

It is also interesting to note the areal pattern of maximum obsidian artifact size that is exhibited near the Fern Ridge sources. While the pattern is only weakly suggested in figure 17, there appears to be a trend towards decreasing size as the Fern Ridge sources are approached. This seemingly enigmatic relationship, if it is a real one, could result from an increasing dependence on the often small nodules of obsidian from the Fern Ridge sources as these sources are approached. All things equal, the energy cost of the raw material would seem to be the major variable - the nearest obsidian source is almost always the one that is most heavily used.

In summary, several different lines of archaeological evidence suggest that the Fern Ridge area sources were being heavily utilized by the prehistoric inhabitants of the Willamette Valley. Additional research is likely to indicate that these sources provided natural glass for much of the Willamette Valley, casting a new light on the role and importance of archaeological sites in the southwestern Willamette Valley.

6.32 Utilization of Obsidian from the Willamette Valley River Gravels

Obsidian is widely distributed in the Willamette Valley as small stream-rolled nodules in the gravels of the McKenzie and Willamette Rivers. The obsidian pebbles in the Willamette River north of Eugene represent a contribution by both the the Obsidian Cliffs and Fern Ridge sources, though in the small sample collected for this study, Obsidian Cliffs glass was more frequently found. Was this river gravel source of obsidian utilized?

Figure 19: Western Oregon archaeological sites where nodules and pebbles of stream-rolled obsidian have been found.

This can be best illustrated through a map of the distribution of obsidian pebbles recovered from archaeological contexts in the Willamette Valley. In figure 19, these pebbles are seen to be largely distributed in a narrow linear zone parallelling the McKenzie and Willamette rivers. It is evident that obsidian was being collected from the river gravels, at least in areas close to the river channels.

6.4
Utilization of Obsidian at the Central Oregon Coast

With the unexpected discovery of an indigenous obsidian source at the Central Oregon Coast, there was considerable interest during this project as to whether the source had been exploited. Research results to date suggest that, in all likelihood, locally-available obsidian was not being utilized or that, if it was, use was very minimal.

Evidence for this conclusion comes primarily from the low frequency of obsidian debitage and tools found at coastal sites. Though published materials are sparse, extremely little obsidian debitage and few tools have been reported from archaeological sites along the Central Oregon Coast. Excavations at the Neptune Site yielded only two obsidian flakes out of the small lithic assemblage recovered (Barner, 1982:64). Work at two small middens, the Good Fortune Cove and Good Fortune Point sites, were even less productive - no obsidian flakes or tools were found (Minor et al., 1985). Farther south at the Philpott Site, 0.1% of the lithic debris found was composed of obsidian (Draper, 1980 and 1982). Whether this paucity of obsidian debitage at central coastal archaeological sites completely reflects obsidian utilization in this area is not known - most of the sites excavated are midden sites whose lithic assemblage may not be representative of all coastal occupation areas.

A single ethnographic account by Drucker (1943) also mentions that obsidian was known to the Alsea Indians near the mouth of the Siuslaw River. Nothing was known by informants, though, of flintworking.

Obsidian usually appears in collections from permament occupation sites, though once again, information is incomplete. The maximum size of obsidian tools from coastal sites (figure 17) exceeds the size of obsidian pebbles available in the Siuslaw River, indicating an exotic origin.

This pattern of small obsidian tools changes dramatically, though, at sites on the far southern coast. Berreman (1944:Plate VII) reported an obsidian point with a length of 12.7 cm from the Lone Ranch village site near the California border. Similarly, Chase (1873) describes artifacts of black and bluish obsidian from an unidentified site on the southern coast. The largest of these tools was a biface 37.5 cm long! The source of this obsidian is not known, though Heflin (1966) suggests that the large obsidian tools from the southern coastal sites originated in Northern California. The nearest obsidian sources, though, are located in the Klamath Falls area (Hughes, 1983:328-331). Draper (1980) comments that the artifacts from the Philpott Site are similar to those found in late prehistoric sites in Southwestern Oregon and Northern Oregon. This all cumulatively suggests cultural affiliations with either interior Southwestern Oregon or Northern California.

The maximum length of obsidian artifactual material also increases along the Northern Oregon coastline. Only along the central coast is obsidian virtually absent.

It appears, then, from the limited evidence available, that the Siuslaw River secondary obsidian source was probably not being used by prehistoric coastal inhabitants. The marked size differential in maximum obsidian artifact size from the northern and southern portions of the Oregon coast also suggests that two different sources, or groups of sources, were being used. It is suggested that obsidian from the central and northern Oregon Coast was obtained, possibly through exchange, from the Willamette Valley sources. Natural glass from the southern part of the coast appears to have originated in either Southern Oregon or Northern California. Only further archaeological research will resolve and clarify these questions, however.

6.5

Diachronic Dimensions: Changing Patterns of Obsidian Utilization in Western Oregon

Until this point, the presence of obsidian in Western Oregon archaeological contexts has been treated as a synchronic feature with entire sites considered as a single analytical unit. Only in the last decade have improved chronological controls and an increased awareness of the importance of lithic debitage made diachronic studies of obsidian distribution and utilization possible. Obsidian debitage and characterization data, though, are still spread very thinly throughout the archaeological literature of Western Oregon. The tentative nature of the conclusions in this section reflects both this sparsity of regional data and the newness of characterization and debitage analysis methods in archaeology. The spatial patterns of archaeological debitage must be accepted as reflecting something about the behavior of the prehistoric populations and cultural systems that created them. Just what that something is or might be is an area only just beginning to be explored.

One diachronic dimension of culture that is available for study in the archaeological record is the relative use of lithic materials through time. Stability of lithic utilization patterns through time implies, at the very least, a certain degree of cultural stability. Changing patterns of utilization as reflected in the changing spatial patterning of recovered lithic materials can likewise be seen as the result of changes in culture. The cultural (and environmental) processes that have the potential to initiate these changing patterns of utilization are many - improved technologies, depletion of lithic resource, creation of lithic sources (such as the eruption of obsidian flows), population increase and changes in sociopolitical structures or relationships are only a few possibilities (see Skinner, 1983:87-90, for a discussion of these and other variables).

The most noticeable diachronic pattern shift concerning lithic utilization in the Willamette Valley is the increasing frequency of obsidian debitage that appears in more recent components of archaeological sites. Pettigrew (1980:65) noted that at the Hager's Grove sites near Salem there was a marked increase in the percentage of obsidian debitage that was found in the later components of the sites (see figure 20). These later components are associated with radiocarbon dates ranging from 1190+-120 yrs. B.P. (Gak-7598) to 2870+-130 yrs. B.P. (Gak-7600). He speculated that some unknown cultural or natural mechanism related to increased availability of obsidian, or more generally, to the reduced cost of the material, was responsible for this phenomenon. He writes: "A tempting notion is

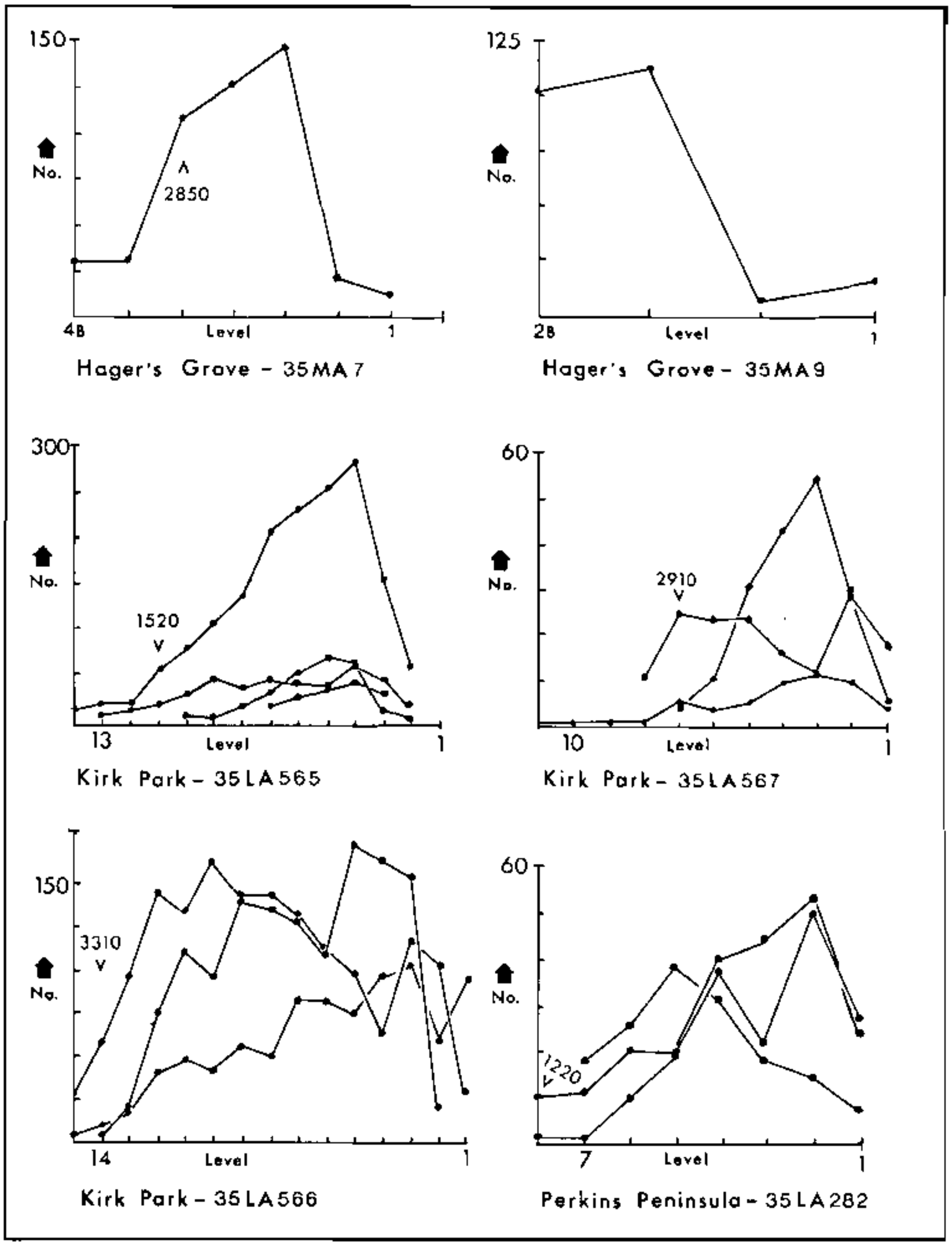


Figure 20: Scattergrams illustrating the change in obsidian debitage frequency over time at selected Willamette Valley archaeological sites. The vertical dimension refers to the number of obsidian waste flakes recovered; the horizontal axis refers to the excavation level (smaller numbered levels overlie larger numbered ones). Multiple plots are from different excavation units at the same site. The figures within the scattergram refer to radiocarbon dates that are associated with the designated excavation level.

that fairly recent (within the last several thousand years) volcanic activity in the Cascade Mountains (perhaps in the Three Sisters area where obsidian is known to exist) created a sudden abundance in the gravels of the streams draining the area." A much more compelling hypothesis (and more geologically-feasible; recent obsidian flows in the Cascades are virtually uneroded and in east-draining locations) is that the secondary sources of obsidian in the Fern Ridge area were either discovered or made available (through direct procurement or exchange) to Willamette Valley inhabitants in the neighborhood of three millennia ago. This intriguing hypothesis (admittedly only one of several that could be formulated) could be easily tested through characterization studies of archaeological obsidian within a temporal framework. The shift to a new (and closer) obsidian source would be reflected by the appearance (in characterized artifactual materials) of obsidian from the Fern Ridge area sources. This shift would also be reflected in archaeological assemblages as a relatively abrupt change towards greater quantities of obsidian tools and debitage and a tendency for larger obsidian tools to appear. Other possible diagnostic tendencies that would support this hypothesis might include the increase in frequency of obsidian cores and other quarry-related artifacts or perhaps a change in settlement patterns in the southwestern Willamette valley of the type suggested by Custer et al. (1983).

When other Willamette Valley sites are examined, a shift in the obsidian frequency of later components similar to the one observed at Hager's Grove also becomes apparent. At the Flanagan Site near Eugene, the frequency of obsidian debitage (both in weight and in number) and obsidian projectile points rises significantly between excavation levels 5 and 8 (Toepel and Minor,1980:32-33; Toepel, 1985:58,120). This increase of obsidian appears to have occurred at the Flanagan Site during a similar time period as at the Hager's Grove sites; radiocarbon dates of 1760+-100 yrs. B.P. (Gak-8363) and 3300 +- 220 yrs B.P. (Gak-8369) are associated, respectively, with levels 5 and 6. Data from the Flanagan Site suggests, as at Hager's Grove, that some changes in obsidian procurement patterns were taking place in the Willamette Valley about 3,000 years ago. The discovery and utilization of the Fern Ridge sources at this time, while not the only possible explanation for these shifting patterns, provides a simple and testable answer.

Additional evidence also comes from several sites in the immediate vicinity of the Fern Ridge area obsidian sources, the Kirk Park and Perkins Peninsula sites (Cheatham, 1984). Obsidian debitage quantities in all of these sites exhibits a marked rise in more recent excavation levels (see figure 20). This rise is approximately bracketed by radiocarbon dates of 1170+-100 yrs. B.P. (UCR-1636) and 3310+-150 yrs. B.P. (UCR-1735). Once again, it appears some kind of change in procurement behavior was taking place in this area as early as 3,000 years ago. The frequency of obsidian projectile points also shows a concomitant rise roughly parallelling that of obsidian debitage frequencies. Seventy-five obsidian artifacts (temporal provenience not reported) from sites in the Fern Ridge vicinity were also geochemically-characterized; all appear to have originated from the local Fern Ridge area sources (Sappington, 1984b).

Whether or not the increasing numbers of obsidian waste flakes and tools appearing in later Willamette Valley archaeological sites were due to the emerging importance of the Fern Ridge area sources or to some other factor such as population increase will have to wait for further research. Equally as interesting as this increase in obsidian in the archaeological record, however, is the sharp decrease in natural glass in the recent components of most sites where data are available. Just what recent changes in the prehistoric cultural system of the Willamette Valley could have led to this decrease are not known, though the dramatic population decrease caused by the early appearance of European-introduced diseases provides one plausible explanation (Taylor and Hoaglin, 1962; Boyd, 1975). The causes for this marked decline pose yet another research question that bears investigation.

7.0 ARCHAEOLOGICAL IMPLICATIONS OF OBSIDIAN CHARACTERIZATION STUDIES IN CENTRAL WESTERN OREGON

What does this multiplicity of obsidian sources and geologic contexts mean to the archaeologist interested in investigating Western Oregon prehistory? Can any good come of this? What is there to know beyond the obvious fact that there was more than one geologic source of obsidian available to the prehistoric occupants of the western portion of the state?

7.1

Implications for the Study of Contact and Exchange Systems

Prior to the recognition of the Fern Ridge area obsidian sources, it could be reasonably assumed that any obsidian artifact longer than three or four centimeters probably came from either the High Cascades or from some point farther to the east. Considered less likely as a source area was Northern California (the existence of several closer obsidian sources in the Klamath Lake Basin region has only been recently documented by Hughes, 1983:328-330). This assumption, of course, can no longer be made, for nodules occasionally exceeding 10 centimeters in diameter are found in the Fern Ridge area. Rarely does archaeological obsidian recovered in the Willamette Valley or Oregon Coast exceed that limit.

Along the Oregon Coast, it was also assumed that any obsidian artifact automatically pointed to contact with the interior. With the presence of obsidian in the gravels of the Siuslaw River, this too can no longer be taken for granted. It can still safely be hypothesized, however, that any glass artifact with a dimension greater than about four centimeters must have originated somewhere other than the Siuslaw River.

Artifact size, then, is no longer as definitive a criterion for an exotic origin as it was once assumed to be. A far better indicator of exchange or long-distance procurement is to be found in the characterization of archaeological obsidian.

Researchers have long argued that the environmentally segmented nature of the Oregon Coast made contact or trade with interior groups a more likely scenario than exchange with other coastal populations (Cressman, 1953 and 1977:206-207; Beckham et al., 1982:182). The presence of items such as Olivella shells, dentalium, and whalebone tools in Willamette Valley archaeological sites certainly argues for some contact between coastal and Valley groups. That these coastally-related artifacts are not distributed uniformly throughout the Willamette Valley, but rather are concentrated in the Fern Ridge area (Perkins Peninsula), Yamhill River sites (Fanning and Fuller mounds) and Oregon City area (Mostul Village) suggests that their distribution may be coincident with travel routes. The existence of obsidian resources in the Fern Ridge area would certainly make it a potential focus for interaction between the Central Coast and the Valley. Similarly, contact between the Northern Coast and the interior may have been directed through the Oregon City-Willamette Falls area, a major center of activity in prehistoric times. That Willamette Falls was a hub of the obsidian economy is suggested by the discovery of thousands of arrow points and obsidian fragments in the 1800's (U.S. Geological Survey, 1893). On the other hand, the extent of interaction between the Central Coast and Willamette Valley, if it did exist, seems to have been rather limited. Very few obsidian artifacts are found along the Central Coast, indicating that the Coast Range may have been an effective barrier in isolating the coastal groups. The maximum length of obsidian artifacts, as well as the frequency of appearance of natural glass in archaeological contexts, appears to be greater (relative to Central coast sites) along the southern and northern portions of the coast. This pattern could have been produced by the introduction of obsidian at points along the Southern and Northern coast, perhaps from sources in the Willamette Valley and the Klamath Falls area. The central segment of the coast, geographically closest to a source of obsidian (Fern Ridge), exhibits the smallest frequency of glass - the little obsidian used may have been imported from the north or south or gathered from the Siuslaw River. Alternatively, this pattern could be the result of sampling problems. A greater number of permanent habitation sites have been examined along the South and North coast and this type of site would be expected to yield a greater variety of chipped stone artifacts that midden sites. Pettigrew's (1975) comparison of similarities between a Coast Range and Willamette Valley site suggests that coastal people may not have traveled very far into the interior (Beckham et al, 1981:182). To these and other similar questions about contact and exchange systems, the use of characterized artifactual obsidian may provide some fairly definitive answers.

Does the presence of an exotic material such as obsidian indicate exchange and trade or does it reflect direct procurement behavior (direct access)? This point is mentioned because it is often casually assumed that exotic materials are acquired through exchange networks. In fact, groups may travel long distances in order to procure prized lithic materials. There is no evidence that access to material sources are necessarily controlled by the groups in whose territory the source falls (a number of examples are cited by Ericson, 1984). Access to the Fern Ridge area sources, for example,was likely not restricted by the Kalapuyan peoples who inhabited the area. At this point, though, little can be said about the procurement strategies that were in operation in Western Oregon. Distance-decay curves may provide some clues (though I do not consider the one pictured in figure 18 in this report to be accurate enough to do this) - in direct access systems, the falloff curve tends to be more rapid and the procurement systems smaller in size than for exchange systems (Bettinger, 1982; Findlow and Bolognese, 1982). Archaeological criteria, however, are far from clearly defined regarding this point. There is not even any assurance that evidence of any kind of procurement strategies has been preserved in the vicinity of utilized sources of raw material (Sappington, 1984a); the only clues to procurement behavior may come through obsidian characterization studies.

7.2

Implications for Obsidian Hydration Studies

The presence of large quantities of archaeological obsidian in Western Oregon also raises the possibility of the utility of obsidian hydration dating methods (I refer the reader not familiar with this method to Friedman and Trembour, 1978, or Manche and Lakatos, 1986).

One of the major variables influencing the rate of hydration, a variable that must be known if the method is to effectively used, is the chemical composition of the glass (Ericson, 1977 amd 1981; Friedman and Long, 1976; Friedman and

Obradovich, 1981). To control for this variable, the geologic sources of obsidian that are to be dated must be differentiated (each source will yield a difference chemical composition and a different rate of hydration). This method has been termed source-specific obsidian hydration analysis (Eriscon, 1975). If the analyst determining hydration ages were expecting only one source (one hydration rate) when there were actually several sources present, hydration dating results could be inexplicably erratic.

To date, only two obsidian hydration studies have been published in regard to Western Oregon obsidian. Fagan (1975) examined artifacts from the Hurd, Lynch, and Baby Rock Shelter sites while Minor (1980, 1985) analyzed material from the Flanagan site. Both authors were expecting only one geologic source of obsidian to be represented in the archaeological assemblages. They both (Minor at the Flanagan Site and Fagan at the Hurd Site) also found inconsistencies in their hydration readings that they concluded were due to stratigraphic mixing at the sites. Both the Fern Ridge area and Willamette and McKenzie River gravel sources of glass would have been easily available at these two sites. These same patterns could have also resulted from the mixing of obsidian specimens from different sources. Fagan, however, found that hydration readings were more consistent at the Lynch and Baby Rock Shelter sites. At Baby Rock Shelter, Obsidian Cliffs was the nearest source and probably provided the bulk of the glass at this site, leading to a single source-single hydration rate phenomenon. Data from the Lynch site appear to be less consistent than for the Baby Rock Shelter Site, though more so than the Hurd Site. The utilization of different sources at the Lynch Site could have easily been masked by the relatively young age of the site.

It should be clear than any further obsidian hydration studies in Western Oregon will have to take into account the presence of multiple obsidian sources and multiple rates of hydration.

7.3

Implications for the Characterization of Western Oregon Obsidian

Obsidian characterization studies have proven themselves to be, when carefully used, a valuable tool for archaeological research in many areas throughout the world. I have argued here that characterization methods could be particularly valuable in their applications to Western Oregon archaeological studies. While few researchers would deny that this analytical technology would be the useful in their work, the techniques available are still only rarely employed. Why?

The answer lies in both the cost of the most widely employed obsidian characterization method, the use of trace element abundances, and in the difficulty in finding someone who will characterize a sample or samples with a reasonable turnaround time. Not many researchers are willing to send off their artifacts when there is little assurance that analytical results will appear within any predictable length of time. This is, of course, particularly true in contract archaeology situations where deadlines must be met. The availability of a relatively simple and inexpensive method of obsidian characterization that would allow for many, instead of only a few samples, to be characterized (with a rapid turnaround) would certainly be a welcome addition.

The petrographic characterization technique that is outlined in Chapter 5 of this report offers some potential of providing such a method for Western Oregon archaeologists. Further studies of greater numbers of samples from additional obsidian sources are needed , but in this preliminary developmental stage, the potential of the method appears promising. Sample preparation requires only that a petrographic thin section of the obsidian be produced (this can be done with very small waste flakes), a procedure that takes about 15 to 30 minutes for a practiced analyst. Source assignment can be made by a trained observer in only a few minutes by using a decision network such as the one pictured in figure 11. Material cost for thin section preparation is minimal and takes only a few days to carry out (minimum time). There is no free lunch, though - the disadvantages of the method that have been encountered so far are:

1. It is destructive - a small slice of artifactual obsidian is needed for thin section preparation.

2. It is not as powerful in its source discriminating ability as trace element characterization methods - petrographic features typically exhibit far less intersource and far more intrasource variation than do trace element abundances. For example, in Western Oregon it appears that the Obsidian Cliffs source can be reliably discriminated from the Fern Ridge area sources but that these latter two sources cannot be petrographically distinguished from each other.

The advantages of the method, though, low cost and rapid analysis, would seem to argue for its adoption, particularly when funding and time are not available for trace element characterization. Further investigation of petrographic and other characterization methods, currently underway, will provide a clearer picture for their future use.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1
Conclusions

1. Contrary to a long-held archaeological assumption, there are a minimum of at least three geochemically-distinct sources of obsidian to be found widely distributed in secondary contexts throughout Western Oregon. The primary sources for this obsidian are Obsidian Cliffs in the High Cascades and two as yet unknown sources that are likely located in the Central Western Coast Range.

2. Obsidian from the Obsidian Cliffs source is found in glacial deposits in the High and Western Cascades and in the gravels of the McKenzie and Willamette Rivers in the Willamette Valley. This was verified through geochemical studies of trace element abundances in the glass.

3. Obsidian from the Coast Range (Fern Ridge area) sources is found in the gravels of the Willamette River north of Eugene and in a stratum of clay and gravel that is exposed in the Fern Ridge area near Eugene. Initial geochemical studies of the Fern Ridge area glass indicate that two geochemically-distinct sources (termed the Inman A and Inman B sources in this study) are present in a mixed context at the Fern Ridge area.

4. Obsidian pebbles from Obsidian Cliffs and the Fern Ridge area are both represented in the Willamette River gravels north of Eugene. Natural glass was probably distributed by fluvial action throughout most of the Willamette Valley; pebbles of obsidian have been recovered from archaeological contexts bordering the river at least 15 kilometers north of Salem.

5. Obsidian pebbles have also been recovered from the gravels of the Siuslaw River at the Oregon Coast, once again challenging an assumption that coastal archaeological obsidian must have originated from inland sources. Geochemical studies indicate that two geochemical populations are present at the Siuslaw River source and that their primary source is identical to that of the two Fern Ridge area sources.

6. Geochemical studies (X-ray fluorescence) of obsidian recovered from geologic contexts in Western Oregon indicate that determinations of abundances of the trace elements Strontium, Rubidium, and Zirconium are adequate to characterize each of the sources. The chemical composition of each source, with regard to these three trace elements, was found to be very homogeneous.

7. A fourth source of obsidian in the gravels of the Clackamas River has additionally been reported in the archaeological literature but is most likely a glassy rhyolite. Obsidian has also been reported from the High Cascades in the Condon Butte area but none was located during two reconnaissance trips. An obsidian-like vitrophyre of rather low artifactual quality from an ash-flow deposit in the Western Cascades near Lowell was also examined but no evidence exists that this source was ever utilized or even available to prehistoric occupants of the Valley.

8. The existence of a Western Cascades obsidian source in the vicinity of Staley Creek, a tributary to the Upper Middle Fork of the Willamette River, has been recently suggested. Initial geochemical studies of glass from nearby archaeological sites, however, were methodologically flawed and the reality of this possible source has yet to be verified.

9. Petrographic analyses of thin sections of obsidian samples from primary and secondary geologic contexts were undertaken to identify any distinctive characteristics that might be useful in their characterization. Preliminary results indicate that the presence or absence of selected petrographic features can be reliably used to differentiate between the Obsidian Cliffs and Fern Ridge area sources. It was not possible to distinguish between the Inman A and Inman B geochemical groups on the basis of petrographic characteristics alone. The petrographic analysis of geochemically-characterized obsidian samples was used to support this conclusion.

10. Limited obsidian characterization studies indicate that glass from the Fern Ridge area sources and Obsidian Cliffs were being utilized by the aboriginal population of Western Oregon. The Fern Ridge sources were probably extensively used by Valley inhabitants. Dependence on Obsidian Cliffs glass appears to increase in the Western Cascades, though limited data from Cascades sites points to procurement from multiple sources. Earlier studies that identified obsidian from the Eastern Oregon source at Tucker Hill in Willamette Valley archaeological assemblages are almost certainly in error. The Tucker Hill source is thought here to have been confused, possibly because of geochemical similarities, with one of the two geochemical groups from the Fern Ridge area.

11. Prehistoric utilization of Western Oregon obsidian sources is also reflected in the percentage of obsidian debitage that has been recovered from archaeological sites. Obsidian debitage frequences appear to vary in relation to their distance from quarry sources; preliminary data from Western Oregon sites indicate probable foci in the Fern Ridge and Obsidian Cliffs areas, further corroborating their role as quarry source areas. Stream-rolled obsidian pebbles have been found in several sites bordering the McKenzie and Willamette rivers, also suggesting that river gravel sources of glass were being utilized.

12. Regional patterns of raw material usage, reflected by indices such as the obsidian debitage ratio (illustrated in figure 15), can be used to predict the existence of unrecognized natural sources.

13. The closest source of a lithic material, all things being equal, is the one that tends to get the most use.

14. Obsidian debitage and projectile point frequencies appear to rise in the Willamette Valley archaeological record beginning approximately 3,000 years ago. While the reason for this is not apparent (many are possible), it is hypothesized here that the increase might be due to the discovery of the easily-accessible Fern Ridge area obsidian sources. This hypothesis could be easily tested using chronologically controlled and characterized archaeological collections.

15. Only at the Central Oregon Coast does obsidian appear in very low quantities in archaeological sites. Though no obsidian characterization

studies exist for coastal sites, it is suggested here that obsidian available near the Siuslaw River mouth was only minimally uitilized, if at all, by the early coastal inhabitants. The lack of obsidian at the Central Coast indicates that there was probably little direct contact between that area and the interior. Apparent rises in projectile point size at sites along the northern and southern coast suggest procurement ties, respectively, with the Willamette Valley and with Northern California or the Klamath Lake Basin.

16. The recognition of multiple sources of obsidian in Western Oregon is crucial for future obsidian hydration dating investigations. Source-specific hydration dating will have to be practiced as it can no longer be assumed that only one source has been dominantly used. The multiplicity of sources is also suggested as the probable cause for the generally unsatisfying results of hydration studies to date.

17. Obsidian characterization studies should prove to be a particularly valuable research tool in the further investigation of Western Oregon prehistory. The low number of obsidian sources in this region greatly reduces the methodological difficulties of characterization research. The use of reliable petrographic characterization techniques in the region, as is suggested by this research, also offers a relatively simple and fast addition to the geochemical methods now available.

8.2
Recommendations for Further Research

From the still preliminary research that is reported in this project can be gleaned several suggestions for further research directions regarding obsidian research in Western Oregon archaeological studies. Briefly, these are:

1. Further study is still needed about the geologic contexts and areal distribution of obsidian in Western Oregon. While secondary sources are now known in the Fern Ridge area, do other geochemically-related ones exist in other locations in the Willamette Valley or Coast Range? Are the two Fern Ridge sources petrologically-related or are they the result of two distinctive, but proximate, eruptive episodes? In what relative abundances are the obsidian sources represented when found in mixed contexts, such as in the Fern Ridge area or in the Willamette River gravels? Is there a Staley Creek source in the Western Cascades? Could obsidian nodules also be found in coastal rivers other than the Siuslaw River. Additional fieldwork is still needed before serious archaeological characterization studies can begin in earnest.

2. Further geochemical characterization of the geologic sources of obsidian must be carried out to identify the maximum range of variation for all existing sources.

3. The source universe considered for any Western Oregon obsidian studies should be expanded to include bordering regions. Many obsidian sources have been identified in the High Cascades, the Western High Lava Plains, the Far Northwestern Great Basin, and the Medicine Lake Highlands of Northern California. These should all be characterized, described, and included in the possible obsidian source catchment zone for Western Oregon.

4. Further research into the potential of petrographic methods of obsidian characterization should be pursued. With the low number of sources in Western Oregon, this method could prove to be a valuable one.

5. Further research into other low-cost, easy-to-use obsidian characterization methods is also encouraged. Trace element characterization, while very reliable, is slow and expensive, characteristics which have inhibited its use by many archaeologists. Numerous other techniques have been tentatively explored or suggested (see Skinner, 1983:74-84) and may prove to be important for future reseach.

6. Further characterization of archaeological obsidian from Western Oregon sites is needed. Obsidian characterization data cannot be used if it does not exist. More research is called for. As more characterization methods and/or data become available, patterns of utilization, procurement, and exchange can be much more clearly documented. The analysis of the spatial patterning of characterized lithic materials, though still a very new research area, offers the potential to provide information about cultural processes not often accessible to archaeologists.

7. Characterized obsidian materials should be placed, whenever possible, within a chronologic framework. Only then are diachronic studies of any changes in spatial patterning possible. Research designs incorporating obsidian characterization studies should be constructed so as to reflect both the synchronic and diachronic dimensions of obsidian utilization at a site. Needless to say, the exact provenience of any characterized obsidian should be presented in site reports.

8. Careful records of lithic debitage distribution should be made during archaeological excavations. Though this is rapidly becoming standard practice as the importance of lithic debitage is recognized, it is not yet universal. Comparative statistical studies of debitage also require that screen size remain consistent throughout an excavation project. The occasional mixing of 1/4 inch and 1/8 inch screen during excavations makes intersite comparisons of debitage difficult while the use of only 1/8 inch screen makes comparison with older excavation data difficult. A useful method of screening might be to use nested 1/4 inch and 1/8 inch screens, yielding artifactual materials that could be easily compared with earlier studies.

9. The use of quantitative measures or indices such as those used in the construction of the distance-decay curve in figure 18 deserve some attention in the study of Western Oregon prehistory. Measures such as the exchange index, the debitage index, the cortex index, the core index, or the obsidian density index can be represented quantitatively or graphically and may hold potential in interpreting and reconstructing prehistoric cultural behavior (Sidyrs, 1977; Renfrew, 1977; Ericson, 1984).

Western Oregon possesses a distinctive geographic character with its well-defined physiographic barriers and boundaries. If this is combined with a thorough understanding of the lithic resources that were available for its prehistoric inhabitants, this region could hold the potential to contribute significantly to both obsidian characterization and lithic debitage research. It may be possible to use this region as a natural archaeological laboratory for creating and testing methods and hypotheses concerning the patterns and principles of lithic utilization and procurement systems. Obsidian, with its economic value and unique physical properties that allow for reliable characterization, will occupy a central part in any research of this nature. The presence of only a few competing sources of glass within this geographically-delineated area presents a situation in which patterns of obsidian procurement and utilization are not hopelessly complicated by scores of interacting variables. Generalized principles coaxed from studies in this region could perhaps be then applied to other areas of the world where more complex patterns of lithic resource utilization exist. Those complex areas are not the places to begin research, though - more productive research strategies in this still poorly-understood field will move most effectively from simple to complex applications. Only time will tell whether this information will come from Western Oregon studies.

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APPENDICES

APPENDIX I: SAMPLE PROVENIENCE

All samples are listed in alphabetical order by sample number. See table I-1 for additional provenience data.

CNB-1: Condon Butte Area Dome - Glassy gray rhyodacite from the southwest margin of the dome. Microcrystalline texture when observed in thin section. This sample was considered representative of several collected. Though this dome is reported as a glaciated obsidian dome, no true obsidian was found at the site.

INM-1 through INM-5: Inman Creek - Obsidian nodules from the gravels of Inman Creek between the paved highway and the reservoir low-water line.

INM-6: Fern Ridge Reservoir - Obsidian from point beach immediately south of Inman Creek.

INM-7: Fern Ridge Reservoir - Obsidian from reservoir beach immediately south of Inman Creek

INM-8: Fern Ridge Reservoir - Obsidian from reservoir beach immediately northeast of the first unnamed creek north of Hannavan Creek.

INM-9: Fern Ridge Reservoir - Obsidian found _in situ_ in clay stratum exposed in bank of first unnamed creek north of Hannavan Creek.

INM-10 and INM-11: Hannavan Creek - Obsidian from gravels of Hannavan Creek below the reservoir high-water line.

INM-12 and INM-13: Inman Creek - _In situ_ obsidian nodule from the bank of Inman Creek immediately west of paved highway.

IRB-1 through IRB-9: Irish Bend - Obsidian pebbles found in gravel bar adjacent to Willamette River. Diameters of pebbles, respectively, from INM-1 to INM-9 were 2 cm, 2 cm, 2 cm, 2.5 cm, 1.5 cm, 3 cm, 3 cm, 2.5 cm, and 4 cm. INM-9 is mixed rhyolite and obsidian.

MCK-1: Lost Creek Canyon - Obsidian from deposit of glacial till exposed in roadcut at intersection of Highways 242 and 126; west end of Lost Creek Canyon.

MCK-2: Lost Creek Canyon - Obsidian from ground moraine deposit on floor of Lost Creek Canyon approximately 3 km east of the intersection of Highways 242 and 126.

MCK-3 and MCK-4: Armitage Park - Obsidian pebbles from McKenzie River beach gravels immediately west of Armitage Park on the north bank of the river.

MCK-5: Lost Creek Canyon - Obsidian from ground moraine deposits on the floor of the Lost Creek Canyon. Same sample location as MCK-2.

MCK-6: Lost Creek Canyon - Obsidian nodule from glacial till exposed in roadcut at same location as MCK-1.

MCK-7 and MCK-8: Armitage Park - Obsidian pebbles from McKenzie River beach gravels near Armitage Park; same sample location as MCK-3 and MCK-4.

OBC-1: Obsidian Cliffs Obsidian Flow - Obsidian from the base of the Obsidian Cliffs near where the trail from Frog Camp crosses Holocene lava from from Collier Cone.

OBC-2 through 18: Obsidian Cliffs Obsidian Flow - Obsidian from widely scattered localities on the Obsidian Cliffs plateau. Samples 5-18 were collected by J. Silvermoon, U.S. Forest Service archaeologist, and are associated with archaeological obsidian quarry sites at this source.

SIU-1 through 3: Siuslaw River Mouth - Obsidian pebbles from a gravel bar near the mouth of the Siuslaw River. Collected by R. Minor.

TABLE I-1: OBSIDIAN SAMPLE PROVENANCE DATA

SAMPLE NAME	SAMPLE NO.	COUNTY	SECT.	TOWN.	RNGE.	SOURCE TYPE	SOURCE IF SECONDARY	CHARACT. METHOD
CONDON BUTTE DOME	CNB-1	LANE	31	15S	7-1/2E	PRIMARY	--	PETRO
INMAN CREEK	INM-1	LANE	8	15S	5W	SCNDARY	INMAN B	TRACE
INMAN CREEK	INM-2	LANE	8	15S	5W	SCNDARY	INMAN A	TRACE
INMAN CREEK	INM-3	LANE	8	15S	5W	SCNDARY	INMAN A	TRACE
INMAN CREEK	INM-4	LANE	8	15S	5W	SCNDARY	INMAN(1)	PETRO
INMAN CREEK	INM-5	LANE	8	15S	5W	SCNDARY	INMAN A	TRACE
FERN RIDGE RESERVOIR	INM-6	LANE	8	15S	5W	SCNDARY	INMAN(1)	PETRO
FERN RIDGE RESERVOIR	INM-7	LANE	8	15S	5W	SCNDARY	INMAN A	TRACE
FERN RIDGE RESERVOIR	INM-8	LANE	19	15S	5W	SCNDARY	INMAN(1)	PETRO
FERN RIDGE RESERVOIR	INM-9	LANE	19	15S	5W	SCNDARY	INMAN A	TRACE
HANNAVAN CREEK	INM-10	LANE	19	15S	5W	SCNDARY	INMAN(1)	PETRO
HANNAVAN CREEK	INM-11	LANE	19	15S	5W	SCNDARY	INMAN B	TRACE
INMAN CREEK	INM-12	LANE	8	15S	5W	SCNDARY	INMAN A	TRACE
INMAN CREEK	INM-13	LANE	8	15S	5W	SCNDARY	INMAN(1)	PETRO
IRISH BEND	IRB-1	BENTON	7	14S	4W	SCNDARY	OCLIFFS	PETRO
IRISH BEND	IRB-2	BENTON	7	14S	4W	SCNDARY	INMAN?	PETRO
IRISH BEND	IRB-3	BENTON	7	14S	4W	SCNDARY	OCLIFFS	PETRO
IRISH BEND	IRB-4	BENTON	7	14S	4W	SCNDARY	OCLIFFS	PETRO
IRISH BEND	IRB-5	BENTON	7	14S	4W	SCNDARY	OCLIFFS	PETRO
IRISH BEND	IRB-6	BENTON	7	14S	4W	SCNDARY	OCLIFFS	PETRO
IRISH BEND	IRB-7	BENTON	7	14S	4W	SCNDARY	INMAN(1)	PETRO
IRISH BEND	IRB-8	BENTON	7	14S	4W	SCNDARY	OCLIFFS	PETRO
IRISH BEND	IRB-9	BENTON	7	14S	4W	SCNDARY	OCLIFFS	PETRO
IRISH BEND	IRB-10	BENTON	7	14S	4W	SCNDARY	OCLIFFS	PETRO
LOWELL ASH-FLOW	LOW-1	LANE	20	19S	2E	PRIMARY	--	PETRO
LOST CREEK CANYON	MCK-1	LANE	10	16S	6E	SCNDARY	OCLIFFS	TRACE
LOST CREEK CANYON	MCK-2	LANE	24	16S	6E	SCNDARY	OCLIFFS	TRACE
ARMITAGE PARK	MCK-3	LANE	4	17S	3W	SCNDARY	OCLIFFS	TRACE
ARMITAGE PARK	MCK-4	LANE	4	17S	3W	SCNDARY	OCLIFFS	TRACE
LOST CREEK CANYON	MCK-5	LANE	24	16S	6E	SCNDARY	OCLIFFS	TRACE
LOST CREEK CANYON	MCK-6	LANE	10	16S	6E	SCNDARY	OCLIFFS	TRACE
ARMITAGE PARK	MCK-7	LANE	4	17S	3W	SCNDARY	OCLIFFS	TRACE
ARMITAGE PARK	MCK-8	LANE	4	17S	3W	SCNDARY	OCLIFFS	TRACE
OBSIDIAN CLIFFS	OBC-1	LANE	10	16S	8E	PRIMARY	--	TRACE
OBSIDIAN CLIFFS	OBC-2	LANE	15	16S	8E	PRIMARY	--	TRACE
OBSIDIAN CLIFFS	OBC-3	LANE	19	16S	8-1/2E	PRIMARY	--	TRACE
OBSIDIAN CLIFFS	OBC-4	LANE	19	16S	8-1/2E	PRIMARY	--	TRACE
OBSIDIAN CLIFFS	OBC-5	LANE	19?	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-6	LANE	19?	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-7	LANE	19?	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-8	LANE	19?	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-9	LANE	19	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-10	LANE	19	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-11	LANE	19	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-12	LANE	19	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-13	LANE	19	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-14	LANE	19	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-15	LANE	19?	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-16	LANE	19?	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-17	LANE	19?	16S	8-1/2E	PRIMARY	--	PETRO
OBSIDIAN CLIFFS	OBC-18	LANE	19?	16S	8-1/2E	PRIMARY	--	PETRO
SIUSLAW RIVER	SIU-1	LANE	?	18S	12W	SCNDARY	INMAN A	TRACE
SIUSLAW RIVER	SIU-2	LANE	?	18S	12W	SCNDARY	INMAN B	TRACE
SIUSLAW RIVER	SIU-3	LANE	?	18S	12W	SCNDARY	INMAN(1)	PETRO
WHEATLAND FERRY	WHF-1	MARION	6?	6S	3W	SCNDARY	INMAN(1)	PETRO

(1) INDIVIDUAL INMAN OBSIDIAN POPULATIONS (INMAN A OR INMAN B GEOCHEMICAL GROUPS) NOT DISTINGUISHABLE

CHARACT=CHARACTERIZATION

OCLIFFS=OBSIDIAN CLIFFS

PETRO=PETROGRAPHIC

TRACE=TRACE ELEMENT

(FILE:PROVENANCE)

APPENDIX II: GLOSSARY OF TERMS

Acicular: Needle-like in form.

Acicular Prismatic Microlite: A prismatic microlite with a diameter of less than 1 micron.

Acicular Trichite: A hairlike trichite.

Anisotropic: Having a physical structure that varies with direction; this usually refers to optical properties of crystalline materials.

Artifactual: Referring to an object used, moved, modified, or manufactured by humans.

Ash-Flow: Avalanche of very hot gas-rich pyroclastic material erupted explosively from a volcanic vent.

Ash-Flow Tuff: Ash-flow deposit indurated by compaction and heat.

Basalt/Basaltic: Dark-colored extrusive igneous rock with a silica content of between 48 and 53 percent.

Characterization: A distinguishing attribute or characteristic.

Conchoidal Fracture: Smoothly-curved fracture surface; typical of the glassy rocks such as obsidian or quartz.

Core: An objective piece whose function is to produce flakes suitable for tool manufacture.

Crystallites: A broad term applied to a minute crystal form or body of unknown mineralologic composition which does not polarize light.

Debitage: Non-tool artifactual materials considered as waste.

Diachronic: Changes or patterns considered over time.

Diorite/Dioritic: Intrusive volcanic rocks approximately equal in composition to andesite; higher in silica than gabbros and basalts but lower than rhyolites.

Direct Access: Procurement style in which the users of a lithic material obtain it directly from its primary or secondary geologic source.

Direct Procurement: Direct access procurement of resource material; no exchange is involved in procurement.

Erratic: Ice-transported rocks.

Exchange System: Procurement style in which needed materials are obtained through trade.

Eutectic Point: The lowest melting temperature obtainable with mixtures of given components (as in magmas) where the components remain in a liquid state.

Fiamme: Obsidian-like lumps of collapsed pumice occasionally found in ash-flow deposits

Fingerprint: To characterize a material using physical or geochemical attributes that serve to distinguish a particular source or source group from all others; for example, trace element abundances of lithic materials are often used to characterize both geologic sources and artifactual materials.

Float: Loose surface rocks found separated from parent veins or strata due to weathering processes.

Gabbro/Gabbroic: Intrusive volcanic rocks approximately equivalent in composition to basalt.

Glacial Lake Missoula: Large, Pleistocene, glacially-dammed lake in Montana that periodically failed to produce massive floods that washed over southeastern Washington and into the Willamette Valley.

Globulite: A small, spherical crystallite commonly found in glassy rhyolitic rocks.

Holocene: The post-glacial epoch spanning the last 10-12,000 years.

Holohyaline: An igneous rock that is composed entirely of glass.

Isotropic: Exhibiting the same optical properties (when viewed under polarized light) in all directions; characteristic of glassy rocks such as obsidian

Lahar: Landslide or mudflow of pyroclastic material associated with volcanic activity.

Lithophysae: Hollow, bubble-like structures composed of concentric shells of finely crystalline materials; often found in rhyolites and obsidians.

Longulite: Cylindrical crystallite thought to be formed by the coalescence of globulites.

Major Element: Elements occurring in abundances greater than about 0.1 percent.

Margarite: Bead-like string of globulites found in glassy igneous rocks.

Microlite: A microscopic crystal with determinable optical properties.

Microlitic Structure: A microlite or crystallite.

Micron: One-millionth of a meter.

Moraine: Unstratified glacial drift deposited by the direct action of glacial ice.

Normal Prismatic Microlite: Prismatic microlite with a diameter equal to or greater than one micron.

Obsidian Hydration Dating: Dating method based on the assumption that a freshly-fractured surface of obsidian absorbs water as a predictable rate over time; the hydrated obsidian is present as a visible and measurable hydration rim.

Perlite: A crystalline rhyolitic rock that can result from the devitrification of obsidian.

Petrographic: Referring to the systematic description and classification of rocks.

Phenocryst: A relatively large crystal set in a finer-grained groundmass.

Pleistocene: Epoch preceding the Holocene that spans the time period of about two million to ten thousand years ago.

Polyhedral Core: The "classical" core; cylindrical core bearing multiple flake removal scars.

Post-Mazama: Referring to event or time period postdating the Mazama (Crater Lake) ashfall of about 7,000 radiocarbon years ago.

Primary Source: The primary, initial context of a lithic material i.e. an obsidian flow or dome, ash-flow eruptive vent, etc.

Prismatic microlite: Rod-shaped microlite.

Procurement Systems: Systems through which prehistoric peoples obtained raw materials; see direct access and exchange systems.

Pyroclastic: General term applied to volcanic material that has been explosively or aerially ejected from a volcanic vent.

Quarry Site: An archaeological site centered around a natural source of a raw material.

Quaternary: The geologic period comprising the Holocene and Pleistocene epochs.

Rhyodacite: A rather vague classificatory term often used synonomously with rhyolite.

Rhyolite: Extrusive volcanic rocks with a silica content greater than 70 about percent.

Scopulites: Stemlike crstallite that terminates in branches or plumes.

Secondary Obsidian Source: A source of obsidian occurring in a context removed from its original, primary location.

Selvage: The marginal zone of a rock mass having some distinctive textural or compositional characteristic; chilled margins often exhibit a glassy or fine-grained texture.

Shard: A curved fragment of volcanic glass; a bubble remnant.

Sourcing: Bad grammar for characterization.

Spherulite: Small, radiating, and usually concentrically arranged aggredation of minerals of a spheroidal shape formed by the rapid growth of crystals in a rigid glass; differs in chemical composition from the surrounding glass.

Synchronic: With no reference to time.

Tephra: Ejecta blown through the air by explosive volcanic eruptions.

Thin Section: A very thin slice (30 to 50 microns thick) of rock mounted on a slide for the purpose of microscopic petrographic examination.

Till: Unstratified glacial deposits; see moraine.

Trace Element: Element occurring in quantities of less than about 1000 parts per million.

Vitrophyre: Any porphyritic igneous rock having a glassy groundmass.

X-Ray Fluorescence Spectrometry: An analytical method used for determining the chemical composition of rocks.

XRF: X-ray fluorescence.

APPENDIX III: MICROLITIC STRUCTURES IN VOLCANIC GLASSES

A substantial collection of different microlitic structures have been identified in the volcanic glasses and the more common of these are illustrated in Figure 10. Microlite and crystallite nomenclature is based entirely on the morphology of the structures, a clue to the lack of information concerning these forms. It should also be noted that the terms defined here reflect a majority and not concensus opinion in the literature. Because of this lack of information in geologic and archaeological literature, the terminology and genesis of microlitic structures are discussed in some detail in this appendix.

Crystallites

Globulites are small spherical or oval structures reaching a diameter of no more than about 5 microns. Some of the earlier studies also appear to refer to the optically anisotropic grains of magnetite as globulites, creating some confusion. In this investigation, the term globulite refers to isotropic structures. When globulites are found in structures, they are known as cumulites; if the aggregrates are approximately round, they are termed globospherites (Rutley, 1892; Johannsen, 1931:13-14).

When the globulites form chainlike structures, they are known as margarites. In this form, the globulites appear to be strung as if on a necklace with the individual adjacent globulites sometimes coalescent. Longulites appear to be rows of coalesced globulites, with only traces of their original globulite structure remaining. Club-ended longulites are known as clavalites. Masses of longulites oriented with their longest axes parallel have been termed bacillites and may appear, at first glance, as a microscopic banding of the glass (Rutley, 1892; Johannsen, 1931:14).

Thin, hair-like bodies, trichites, also occur in some obsidians and may appear as straight, segmented, or curved. When observed in groups radiating from a central point, they are known as asteroidal trichites; when seen singly, they are termed acicular trichites. This latter trichite usually radiates from a nucleus of magnetite and Clark (1961:105) speculates that trichites are not primary structures in the glass, but are microscopic cracks that have been altered. Diller (1898) and Johannsen (1931:14) consider them to be some form of iron-rich silicate. Ross (1962) also concludes, from the examination of trichites in welded ash-flow tuffs, that these microlitic structures form after deposition of the parent rock, at least in some instances. A structure similar to the asteroidal trichites, termed here the pseudo-asteroidal trichite, is occasionally seen radiating from tiny bubbles in the glass (see plate 14 for an example). Whether these two structures are related is not known, though they will be considered separately here (Johannsen, 1931:14; Ross, 1962).

Scopulites are brush-like or plume-like bodies, often red in color, that may caused by the oxidation of other iron-rich microlitic structures in the glass. They may appear as fern-like fronds or as rods terminated by brushes or plumes. Scopulites are occasionally termed arborescent microlites (Rutley, 1892; Williams et al., 1954; Skinner, 1983:41).

When the ends of a longulite or prismatic microlite are pointed, the form is known as a spiculite. The term belonite is also used to describe any rod-like microlitic structure (crystallite or microlite) but appears to be an outdated term (Ross, 1962).

Microlites

These rod-shaped structures (sometimes called lath crystals or microliths) are minute, incipient crystals that polarize light. The prismatic microlites are found as normal and acicular. Normal varieties (the most common) vary in diameter from about one to two microns and are typically five to 20 microns in length. Acicular varieties exhibit a diamter averaging about 0.5 microns and are visibly more acicular than the normal varieties when compared to them (Ross, 1962; Skinner, 1983). Prismatic microlites are sometimes found in loops or coils. Ross (1962) found that prismatic microlites were characteristically pyroxene, occasionally sanidine, and rarely amphibole or biotite. The prismatic microlites are often found oriented in the same direction and this was taken by Ross (1962) to be due to flow movement during emplacement. Clark (1970), though, has found that microlites are mobile under static stresses at temperatures far below the melting point of obsidian and that the alignment of microlites in flow bands may take place during cooling in situ. The differential concentration of microlites in obsidian glass is megascopically visible as flow-banding.

Petrogenesis of Microlitic Structures

The genesis of the many types of crystallites and microlites is poorly known but is probably related primarily to the cooling history, chemical composition and volatile content of the parent rhyolitic magma.

Ross (1964) notes that obsidians with a small volatile content (0.10 to 0.12% in his examples) usually do not contain microlites while obsidians with a large volatile content (0.32 to 0.34% in his examples) usually do contain microlites. The low volatile content would lead, he concluded, to a higher obsidian viscosity that would inhibit microlite. He also found exceptions to this relationship, though, suggesting that volatile content is only one of the variables controlling the presence or absence of microlitic structures. Tektites have also been noted to contain essentially no microlites (O'Keefe, 1976:7). Their low water content (less than 0.05 %) would suggest an inverse relationship between microlite presence and volatile content. The role of trace or major element concentrations in microlite and crystallite genesis is not known.

The cooling history of the melt also plays a part in the formation of microlites and crystallites. Lofgren (1974), in experimental studies of plagioclase crystallization, found that the rate of cooling played a key role in the determination of the morphology of the resultant crystals. Marshall (1961) also noted the importance of the cooling history on the morphology of microlitic forms - the more rapid the rate of cooling, the smaller the microlitic structure. An understanding of these poorly-understood petrogenetic processes can be the key to determining whether the presence or absence of certain crystallite and microlite types will have any eventual archaeological utility in obsidian characterization research. To be useful in an archaeological context, the glass must exhibit intrasource homogeneity and intersource heterogeneity in the morphology of the microlitic structures. If the process of formation of these petrographic features can be determined, it may be possible to predict, on the basis of the behavior of erupting rhyolitic lavas, whether obsidian can be "fingerprinted" using the microlitic structures that are present. Lacking a solid theoretical base, a more pragmatic approach to determining the usefullness of the petrographic characterization method should suffice - the extensive sampling and petrographic analysis of different obsidian sources.

APPENDIX IV: OBSIDIAN DATA FROM WESTERN OREGON ARCHAEOLOGICAL SITES

Tables 4, 5, and 6 contain tabulated information relating to archaeological obsidian found at sites along the Oregon coast, the Willamette Valley, and the High and Western Cascades. This collected data was used in the construction of the graph and figures of Chapter 6.

Site name: Popular name of the designated archaeological site.

Site no.: State of Oregon archaeological site number, if known.

Obsidian artifacts present? Were any obsidian artifacts found at the site? Yes or no.

Maximum length (Cm): The maximum length or dimension of any obsidian artifact found at the site. When the maximum length of the artifact exceeds the maximum diameter of locally available raw materials, an exotic origin is suggested. The length is measured in centimeters.

Percent obsidian (Weight): Of the lithic debitage recovered at a site, this figure refers to the weight percentage of obsidian debitage (relative to other materials such as CCS or basalt) that is recovered. Weight is measured in grams.

Percent obsidian (Number): Of the lithic debitage recovered at a site, this figure refers to the percentage of obsidian relative to the total debitage count. If 1000 pieces of debitage are recovered and 500 of these are obsidian, the obsidian percentage is 50. This figure is sometimes referred to as the debitage index.

Debitage number (N=): N = the total count of debitage items recovered from an archaeological site including obsidian, chert, CCS, basalt, or any other lithic material. This is the figure that the obsidian percentage and core to debitage ratios are computed from. The typically large quantities of debitage relative to lithic tool types that are found in archaeological sites makes this a particularly statistically valuable figure.

Number of cores: The total number of obsidian cores identified at a site.

Core to debitage ratio: The ratio of obsidian cores to total debitage count. This ratio was initially thought to provide some index of the proximity of obsidian quarry sites - the lower the ratio, the closer the quarry. It is likely, though, that several factors render this a not altogether reliable concept (see section 6.1). The ratio does, however, appear to have some utility in spite its problems - archaeological sites near Western Oregon obsidian sources tended to exhibit a lower ratio of cores to debitage near the quarry source. An indicator of quarrying activity less prone to error than the obsidian core count (such as a debitage with cortex index) could likely provide a more reliable index of quarry proximity.

Unworked nodules present? Were any unworked obsidian nodules found at the site? The presence of nodules was taken to suggest the likelihood of local obsidian sources and direct procurement. The discovery of stream-rolled pebbles at many Willamette Valley archaeological sites, for instance, strongly suggests that local river gravels were being exploited for the material.

Maximum nodule diameter (Cm): The longest dimension of the largest size obsidian nodule or pebble that was found associated with th site. This was intended to give some indication of the largest size of artifactual items that could be manufactured from local raw materials.

Maximum size non-local? Was the largest obsidian artifact recovered larger than the obsidian material available at the closest natural obsidian source? This was thought to provide an indication of exchange activity or long-distance direct procurement.

Obsidian projectile points (%): The percentage of obsidian projectile points found in the total projectile point assemblage. This was also thought to provide some indication of the proximity of a quarry source. In all instances, the percentage of obsidian projectile points was higher than the percentage of obsidian debitage, indicating the preferred usage of obsidian in projectile point manufacture (certainly no surprise). Projectile points were chosen over other artifact classes because of the known preoccupation of archaeologists with this artifactual category and the high likelihood that any projectile point information will make its way into a site report.

Characterization studies? Have any obsidian characterization studies been undertaken at the site? Yes or no.

If yes, primary source: If obsidian characterization studies were performed, what primary sources of obsidian were identified? It is important to keep in mind, when considering these results, that the sample size is typically very low and may well not be representative of the site in general. It is also important to remember that a representative sample of characterized obsidian projectile points only yields reliable information about the artifact class of projectile points. Differential raw material use has been reported for different artifactual classes (Hughes and Bettinger, 1984). Abbreviations for obsidian sources used are:

1. CL - Crater Lake area obsidian sources (see Williams, 1942).
2. FR - Fern Ridge area secondary sources (also designated the Inman A and Inman B geochemical source groups).
3. KF - Klamath Falls area obsidian sources (see Hughes, 1983).
4. MR - McKenzie River gravel secondary source (obsidian originating from Obsidian Cliffs).
5. OC - Obsidian Cliffs primary source.
6. SR - Siuslaw River gravel secondary source (obsidian originating from one of the two Inman geochemical groups).
7. TH - Tucker Hill obsidian-rhyolite dome in eastern Oregon. Obsidian initially identified as originating from this source almost certainly came from an apparently geochemically-similar source in the Fern Ridge area (probably the Inman B geochemical group).
8. WR - Willamette River gravels secondary source (obsidian originating from both the Obsidian Cliffs and Fern Ridge area sources.

Nearest source: The closest source of obsidian raw material to the site. If this source was not being exploited, it raises certain interesting questions about why this was the case.

Source distance: The distance from the archaeological site to the nearest obsidian source.

References: Numbers refer to authors listed at the bottom of the table.

Comments: Anything unusual or distinguishing about the site not covered elsewhere. Several of these were independent indicators of exchange or long-distance contact:

M - The site was a shell midden.
N - No obsidian artifacts or debitage were found.
O - Olivella or other marine origin shells found at site.
R - Red or mahogany-colored obsidian was found.
W - Whalebone artifacts were recovered.

APPENDIX V: INTRASOURCE TRACE ELEMENT HOMOGENEITY OF OBSIDIAN SOURCES

To be of use as an attribute of characterization, a particular geochemical or physical characteristic must exhibit a sufficient degree of intersource heterogeneity so that each source (or source group) possesses a distinct identifying "fingerprint". In addition to this, a high degree of intrasource homogeneity is also desirable so that the range of variation of any source characterization attribute is small (see section 5.1). Large variation ranges do not automatically disqualify an attribute as useful but do make it more likely that overlapping values among sources will exist, particularly when the number of sources within the universe considered is large. Ideal characterization attributes, then, are those which combine low intrasource variation with high intersource variation. In practice, these attributes are often pragmatically determined - when applied to a collection of obsidian sources and/or artifacts an attribute either works, or it doesn't. There is, however, a simple statistical measure that can be applied to distributions of quantitative data that will provide a useful measure of variation. This measure is the coefficient of variation (CV%) or the relative standard deviation, defined as the ratio of the standard deviation to the mean or average (Anderson and Sclove, 1986:136). The resultant figure is usually expressed as a percentage and can provide a quantitative aid in determining the usefulness of an attribute for characterizing a source.

The coefficient of variation has been shown to be a useful means for quantifying the degree of intrasource trace element variation. A trace element data set (from a single source or source group) which yields a small coefficient of variation can be considered to possess a large degree of intrasource homogeneity, one of the necessary qualities of a characterization attribute. Hughes (1986a and 1986b) has successfully applied this measure to sources of obsidian though he cautions that care must be taken when interpreting trace element abundances which approach their instumental limits of detection. Chase (1974), in a study of bronze artifacts, found the coefficient of variation a useful measure in comparing interlaboratory analytical results.

Though there is no absolute numerical value of the coefficient of variation that indicates whether a particular trace element will be useful in characterizing a source of obsidian, this measure can still be of use. As a rough guideline, any trace element set with a CV% of less than 5 percent could be considered to exhibit a very high degree of intrasource homogeneity. There is no hard and fast rule, though, about the useful upper limit of the coefficient of variation; values of 50% or larger may be useful in some instances. Good judgement is the deciding factor. The coefficient of variation may be of particularl value when comparing different data sets. When several different trace elements, for example, are being considered as characterization attributes, those with the lowest coefficients of variation would be judged to be the most effective in characterizing the source (though they must still also show intersource variation to be of use).

Trace element abundances of samples from the present investigation were compared and the average, standard deviation, and coefficient of variation computed (table V-1). Though the sample sizes for each source population are small (particularly for the Inman B group), the degree of intrasource variability for Rb, Sr, and Zr in all three sources is very low - less than 5% in most instances. The Inman A and Inman B sources both exhibit very low CV% values with all three trace elements, attesting to a low amount of intrasource variation; the Obsidian Cliffs flow, while demonstrating a greater range of variation, still reflects a small degree of intrasource variability. The small CV% values of Rb, Sr, and Zr abundances for all three sources suggests that they are all excellent candidates as characterization attributes.

TABLE V-1: MEASURES OF VARIANCE FOR OBSIDIAN TRACE ELEMENT ABUNDANCES

SOURCE GROUP	SAMPLE NO.	RB*	SR*	ZR*
INMAN A	INM-2	82.8	156.9	106.2
	INM-3	85.1	150.6	107.4
	INM-5	80.1	151.8	109.0
	INM-7	81.8	154.0	104.1
	INM-9	82.3	153.8	104.2
	INM-12	84.8	154.2	106.2
	AVERAGE	82.8	153.6	106.2
	ST.DEV.	1.9	2.2	1.9
	CO.VAR.	2.2%	1.4%	1.7%
INMAN B	INM-1	88.8	116.5	76.5
	INM-11	89.1	111.8	76.7
	AVERAGE	89.0	114.2	76.6
	ST.DEV.	0.2	3.3	0.1
	CO.VAR.	0.2%	2.8%	0.1%
OBSIDIAN CLIFFS	OBC-1	83.6	110.0	101.6
	OBC-2	79.4	103.4	92.9
	OBC-3	85.1	103.6	98.0
	OBC-4	83.9	102.7	95.6
	MCK-1	76.7	121.2	112.1
	MCK-2	78.5	105.8	95.9
	MCK-4	80.6	104.1	92.8
	AVERAGE	81.1	107.3	98.41
	ST.DEV.	3.1	6.6	6.8
	CO.VAR.	3.8%	6.1%	6.9%

ST.DEV.=STANDARD DEVIATION

CO.VAR.=COEFFICIENT OF VARIATION
=ST.DEV. / AVERAGE X 100

* TRACE ELEMENT ABUNDANCES REPORTED IN PARTS PER MILLION

(FILE:VARIATION)

TABLE IV-1: OBSIDIAN FROM ARCHAEOLOGICAL SITES IN THE WESTERN CASCADES

SITE NAME	SITE NO.	OBSIDIAN ARTIFCTS PRESENT?	MAXIMUM LENGTH (CM)	PERCENT OBSIDIAN (WEIGHT)	PERCENT OBSIDIAN (NUMBER)	DEBITGE NUMBER (N=)	NUMBER OF CORES	CORE TO DEBITGE RATIO	UNWORKED NODULES PRESENT?
AMMET ROCKSHELTER NO.1	--	YES	2.12	N/A	94.6	446(C)	0	N/A	NO
BABY ROCK SHELTER	35LA3	YES	9.5(A)	N/A	N/A	N/A	N/A	N/A	N/A
BLITZ	35LIN147	YES	5.8(A)	N/A	99.2	1745(D)	5	1:349	NO
BUCK CREEK	35LA297	YES	4.34	N/A	91.0	4101(C)	0	N/A	NO
CASCADIA CAVE	35LIN11	YES	9.0(A)	N/A	N/A	N/A	N/A	N/A	N/A
COLT	35LA599	YES	8.5	N/A	51.0	10504(C)	0	N/A	YES
COLT TIMBER SALE LA674	35LA674	YES	2.75	17.0	53.9	89(C)	0	N/A	NO
COLT TIMBER SALE LA573	35LA573	YES	2.35	25.1	71.3	164(C)	0	N/A	NO
COLT TIMBER SALE LA572	35LA572	YES	0.37	68.9	87.9	58(C)	0	N/A	NO
CONDON BUTTE	--	YES	6.9	100	100.0	64	0	N/A	NO
FALL CREEK	35LA33	YES	5.0(A)	N/A	2.2	4781	0	N/A	N/A
HORSE PASTURE CAVE	35LA39	YES	7.0	N/A	66.2	10296(C)	7	1:2017	N/A
INDIAN RIDGE	--	YES	5.0(A)	N/A	93.0	4150(D)	0	N/A	N/A
RIPPLE	35CL86	YES	2.4(A)	N/A	3.4	36166	0	N/A	NO
SADDLE	35LA829	YES	3.59	N/A	43.0	14468(C)	0	N/A	YES
SARDINE CONFLUENCE	35LA539	YES	6.07	N/A	60.9	253(D)	0	N/A	NO
TIDBITS	35LIN100	YES	4.0	N/A	99.8	656(E)	0	N/A	NO
VINE ROCKSHELTER	35LA304	YES	5.3	N/A	85.3	8911(C)	22	1:405	YES
WHITE CLIFFS RS NO.1	--	YES	1.21	N/A	80.5	334(C)	0	N/A	NO

(A) FROM INCOMPLETE DATA
(B) NEARLY HALF OF ARTIFACTS RECOVERED WERE OBSIDIAN
(C) BOTH 1/4 AND 1/8 IN. SCREEN USED IN EXCAVATION
(D) 1/4 IN. SCREEN USED IN EXCAVATION
(E) 1/8 IN. SCREEN USED IN EXCAVATION
(F) CONFLICTING RESULTS; SEE DISCUSSION IN TEXT
(G) NEAREST CONFIRMED SOURCE IS THE MCKENZIE RIVER GRAVELS; THE HIGH PERCENTAGE OF OBSIDIAN DEBITAGE SUGGESTS, THE PRESENCE OF A LOCAL SOURCE; SEE DISCUSSION IN THE TEXT

SOURCES: MR-MCKENZIE RIVER GRAVELS; OC-OBSIDIAN CLIFFS; WR-WILLAMETTE RIVER GRAVELS

REFERENCES

1. WILLIG
2. OLSEN,
3. MINOR
4. [illegible]
5. BAXTER,
6. NEWMAN,
7. BAXTER,
8. BAXTER,
9. BAXTER,

(FILE:CASCADESITE)

BITGE MBER N=)	NUMBER OF CORES	CORE TO DEBITGE RATIO	UNWORKED NODULES PRESENT?	MAXIMUM NODULE DIAM(CM)	MAXIMUM SIZE NON-LOCAL?	OBSIDIAN PRJCTILE PNTS(%)	CHARACT. STUDIES?	IF YES, PRIMARY SOURCES	NEAREST SOURCE	SOURCE DISTANCE (KM)	REFER-ENCES	COMMENTS
446(C)	0	N/A	NO	N/A	NO	100	NO	--	MR	35	1	-
/A	N/A	N/A	N/A	N/A	YES	N/A	NO	--	MR	40	2	0
745(D)	5	1:349	NO	N/A	NO	N/A	YES	OC,FR	MR	13	3,4	-
1101(C)	0	N/A	NO	N/A	NO	100	NO	--	MR	55	5	-
N/A	N/A	N/A	N/A	N/A	YES	N/A(B)	NO	--	MR	30	6	-
504(C)	0	N/A	YES	3.47	YES	66	YES	(F)	MR(G)	70	7,8,9,10,11	-
89(C)	0	N/A	NO	N/A	NO	N/A	NO	--	MR	70	7	-
164(C)	0	N/A	NO	N/A	NO	100	NO	--	MR	70	7	-
58(C)	0	N/A	NO	N/A	NO	N/A	NO	--	MR	70	7	-
64	0	N/A	NO	N/A	NO	N/A	YES	OC	OC	5	12,13	-
781	0	N/A	N/A	N/A	YES	20	NO	--	MR	15	14	-
296(C)	7	1:2017	N/A	N/A	YES	N/A	YES	(F)	MR	75	15,16	-
1150(D)	0	N/A	N/A	N/A	YES	82	NO	--	MR	15	16	-
166	0	N/A	NO	N/A	YES	14	YES	OC	WR	60	17,18	-
465(C)	0	N/A	YES	5.63	YES	70	YES	(F)	MR(G)	70	7,8,9,10,11	-
253(D)	0	N/A	NO	N/A	NO	100	NO	--	MR	30	19	-
656(E)	0	N/A	NO	N/A	NO	100	NO	--	MR	14	20	-
911(C)	22	1:405	YES	4.57	NO	70	YES	(F)	MR(G)	75	10,21	-
334(C)	0	N/A	NO	N/A	NO	100	NO	--	MR	35	1	-

CENTAGE OF
USSION IN THE TEXT

IVER GRAVELS

REFERENCES:

1. WILLIS & MUSIL, 1986
2. OLSEN, 1975
3. MINOR & TOEPEL, 1984
4. SAPPINGTON, 1984C
5. BAXTER, 1984
6. NEWMAN, 1966
7. BAXTER, 1983
8. BAXTER, 1986A
9. BAXTER, 1986B
10. SAPPINGTON, 1986
11. HUGHES, 1986
12. SKINNER, 1983
13. SKINNER, 1986
14. COLE, 1966
15. BAXTER ET AL., 1983
16. HEAN, 1975
17. LEBOW, 1985
18. SAPPINGTON, 1985A
19. CONNOLLY & BAXTER, 1983
20. MINOR & TOEPEL, 1982
21. BAXTER & CONNOLLY, 1986

TABLE IV-2: OBSIDIAN FROM ARCHAEOLOGICAL SITES IN THE WILLAMETTE VALLEY REGION

SITE NAME	SITE NO.	OBSIDIAN ARTIFCTS PRESENT?	MAXIMUM LENGTH (CM)	PERCENT OBSIDIAN (WEIGHT)	PERCENT OBSIDIAN (NUMBER)	DEBITGE NUMBER (N=)	NUMBER OF CORES	CORE TO DEBITGE RATIO	UNWORKE NODULE PRESEN
ARMITAGE BRIDGE	35LA354	YES	3.71	N/A	30.6	776(B)	N/A	N/A	N/A
BEEBE	35LA216	YES	N/A	N/A	N/A	1691(A)	N/A	N/A	YES
BENJAMIN	35LA41-2	YES	7.0(B)	N/A	N/A	N/A	N/A	N/A	N/A
EUGENE VICINITY	35LA243	YES	1.8	0.5	5	10	1	1:10	NO
FANNING MOUND	--	YES	4.6(B)	N/A	N/A	N/A	N/A	N/A	N/A
FLANAGAN	35LA218	YES	4.2(B)	6.0	22	1187(A)	37	1:32	N/A
FULLER MOUND	--	YES	15.25(B)	N/A	N/A	N/A	N/A	N/A	YES
GEERTZ	--	YES	4.0(B)	N/A	7	704	N/A	N/A	N/A
HAGER'S GROVE MA7	35MA7	YES	4.4(B)	N/A	23.5	547(A)	1	1:547	YES
HAGER'S GROVE MA9	35MA9	YES	3.9(B)	N/A	7.5	293(A)	0	N/A	YES
HALVERSON	35LA261	YES	2.5(B)	5.5	20	262(A)	N/A	N/A	N/A
HANNAVAN CREEK	35LA647	YES	3.0(B)	N/A	20.4	N/A	23	N/A	YES
HURD	35LA44	YES	6.7(B)	9.0(E)	41.0(E)	9634(E)	N/A	N/A	YES
KIRK PARK LA565	35LA565	YES	5.5(B)	N/A	64.4	2658(D)	27	1:98	N/A
KIRK PARK LA566	35LA566	YES	4.5(B)	N/A	45.3	13383(D)	22	1:608	N/A
KIRK PARK LA567	35LA567	YES	3.5(B)	N/A	67.6	829(D)	8	1:104	N/A
KIRK PARK LA568	35LA568	YES	3.5(B)	N/A	52.5	4137(D)	19	1:218	N/A
LINGO	35LA29	YES	4.5(B)	N/A	N/A	N/A	N/A	N/A	N/A
LYNCH	35LIN36	YES	3.5(B)	N/A	N/A	N/A	N/A	N/A	N/A
MOSTUL VILLAGE	--	YES	3.0(C)	N/A	3.0	4370	2	1:2185	YES
PERKINS PENINSULA (L)	35LA282	YES	3.0(C)	N/A	38.9	1969(D)	1	1:1969	N/A
SIMONS	35LA116	YES	4.7(C)	N/A	11.5	206	4	1:547	YES
SIUSLAW FALLS	35LA173	YES	4.5(C)	N/A	11.2	52	0	N/A	N/A
WILLAMETTE MISSION	35MA5001	YES	1.9	N/A	5.2	58(A)	N/A	N/A	YES

(A) 1/4 IN. SCREEN USED FOR EXCAVATION
(B) 1/8 IN. SCREEN USED FOR EXCAVATION
(C) FROM POTENTIALLY INCOMPLETE DATA
(D) 1/4 AND 1/8 IN. SCREEN WERE USED FOR EXCAVATION
(E) OBSIDIAN AND FINE-GRAINED DACITE FROM RIVER GRAVELS WERE APPARENTLY PLACED IN SAME CLASS
(F) 13 PROJECTILE POINTS ORIGINATED FROM THE FERN RIDGE SOURCE (PROBABLY THE INMAN A GEOCHEMICAL GROUP)
POINTS ORIGINATED FROM THE TUCKER HILL SOURCE (PROBABLY THE INMAN B GEOCHEMICAL SOURCE)
(G) 11 ARTIFACTS RECOVERED ORIGINATED FROM THE FERN RIDGE (INMAN A) SOURCE; 1 PROJECTILE POINT ORIGINAT
HILL (INMAN B)
(H) PARK AREA ONLY (DOES NOT INCLUDE DRAWDOWN ZONE)
(I) 78.9% OF OBSIDIAN IDENTIFIED AS ORIGINATING FROM THESE TWO SOURCES

SOURCES: FR-FERN RIDGE SOURCES; MR-MCKENZIE RIVER GRAVELS; OC-OBSIDIAN CLIFFS; TH-TUCKER HILL (FERN RI
WR-WILLAMETTE RIVER GRAVELS

LEY REGION (FILE:VALLEYSITE1)

DEBITGE NUMBER (N=)	NUMBER OF CORES	CORE TO DEBITGE RATIO	UNWORKED NODULES PRESENT?	MAXIMUM NODULE DIAM(CM)	MAXIMUM SIZE NON-LOCAL?	OBSIDIAN PRJCTILE PNTS(%)	CHARACT. STUDIES?	IF YES, PRIMARY SOURCES	NEAREST SOURCE	SOURCE DISTANCE (KM)	REFER-ENCES	COMMENTS
776(B)	N/A	N/A	N/A	N/A	NO	64	NO	--	MR	<1	1	-
1691(A)	N/A	N/A	YES	--	N/A	N/A	NO	--	MR	10	2	-
N/A	N/A	N/A	N/A	N/A	NO	N/A	NO	--	FR	<1	3,4	-
10	1	1:10	NO	--	NO	N/A	NO	--	WR	<5	5	-
N/A	N/A	N/A	N/A	N/A	YES	N/A	NO	--	WR	32	6,7	0
1187(A)	37	1:32	N/A	N/A	YES	N/A	YES	FR-OC(I)	WR	6	8,9,10	-
N/A	N/A	N/A	YES	N/A	YES	N/A	NO	--	WR	22	7,11	0,W
704	N/A	N/A	N/A	N/A	YES	11	NO	--	WR	20	12	-
547(A)	1	1:547	YES	SMALL	YES	45	NO	--	WR	5	13	-
293(A)	0	N/A	YES	SMALL	YES	39	NO	--	WR	5	13	-
262(A)	N/A	N/A	N/A	N/A	N/A	N/A	YES	OC-TH	MR	<10	14,15	-
N/A	23	N/A	YES	N/A	NO	N/A	NO	--	FR	<1	16	-
) 9634(E)	N/A	N/A	YES	6.7(E)	YES	88	YES	OC	MR	<5	17,18	-
2658(D)	27	1:98	N/A	N/A	NO	N/A	YES(F)	FR-TH	FR	<1	16,19	-
13383(D)	22	1:608	N/A	N/A	NO	N/A	YES(F)	FR-TH	FR	<1	16,19	-
829(D)	8	1:104	N/A	N/A	NO	N/A	YES(F)	FR-TH	FR	<1	16,19	-
4137(D)	19	1:218	N/A	N/A	NO	N/A	YES(F)	FR-TH	FR	<1	16,19	-
N/A	N/A	N/A	N/A	N/A	N/A	N/A	NO	--	FR	<1	20,21	-
N/A	N/A	N/A	N/A	N/A	NO	N/A	NO	--	WR	<5	22,23	-
4370	2	1:2185	YES	3.0(C)	NO	N/A	NO	--	WR	<5	24	-
1969(D)	1	1:1969	N/A	N/A	NO	N/A	NO	--	FR	<5	16,25	0
206	4	1:547	YES	2.9	YES	N/A	NO	--	WR	<10	26	-
52	0	N/A	N/A	N/A	NO	N/A	NO	--	FR	50	26	-
58(A)	N/A	N/A	YES	N/A	NO	60	NO	--	WR	1	27	-

LY PLACED IN SAME CLASS
BLY THE INMAN A GEOCHEMICAL GROUP); 2 PROJECTILE
 B GEOCHEMICAL SOURCE)
OURCE; 1 PROJECTILE POINT ORIGINATED FROM TUCKER

S

AN CLIFFS; TH-TUCKER HILL (FERN RIDGE);

REFERENCES:

1. TOEPEL & MINOR, 1983
2. FOLLANSBEE, 1975
3. MILLER, 1970
4. MILLER, 1975
5. CHEATHAM, 1980
6. MURDY & WENTZ, 1975
7. LAUGHLIN, 1943
8. TOEPEL & MINOR, 1980
9. TOEPEL, 1985
10. SAPPINGTON, 1985
11. WOODWARD ET AL., 1975
12. WOODWARD, 1972
13. PETTIGREW, 1980
14. MINOR & TOEPEL, 1982
15. TOEPEL & SAPPINGTON, 1982
16. CHEATHAM, 1984
17. WHITE, 1974
18. WHITE, 1975
19. SAPPINGTON, 1984A
20. CORDELL, 1967
21. CORDELL, 1975
22. SANFORD, 1975
23. DAVIS ET AL., 1973
24. WOODWARD, 1974
25. COLLINS, 1951
26. PETTIGREW, 1975
27. SANDERS ET AL., 1983

TABLE IV-3: OBSIDIAN FROM ARCHAEOLOGICAL SITES ALONG THE OREGON COAST

SITE NAME	SITE NO.	OBSIDIAN ARTIFCTS PRESENT?	MAXIMUM LENGTH (CM)	PERCENT OBSIDIAN (WEIGHT)	PERCENT OBSIDIAN (NUMBER)	DEBITGE NUMBER (N=)	NUMBER OF CORES	CORE TO DEBITGE RATIO	UNWORKE NODULES PRESENT
BULLARD'S BEACH	35CS3	NO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
GOOD FORTUNE POINT	35LNC55	NO	N/A	N/A	N/A	212(A)	0	N/A	NO
GOOD FORTUNE COVE	35LNC56	NO	N/A	N/A	N/A	35	0	N/A	NO
KILCHIS POINT	--	YES	2.5(B)	N/A	N/A	N/A	N/A	N/A	N/A
LONE RANCH	35CU47	YES	12.7(B)	N/A	N/A	N/A	N/A	N/A	N/A
NEPTUNE	35LA3	NO	N/A	N/A	(C)	N/A	N/A	N/A	N/A
NETART'S SPIT	35TI1	YES	6.0(B)	N/A	N/A	N/A	N/A	N/A	N/A
OCEANSIDE BEACH WAYSIDE	35TI47	YES	1.95(F)	N/A	0.07	1452(F)	N/A	N/A	N/A
PALMROSE	35CT47	YES	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PARTEE	35CT20	YES	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PHILPOTT	35CS1	YES	3.5(D)	N/A	0.10(E)	3765(F)	0	N/A	NO
PISTOL RIVER	35CU61	YES	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TAHKENITCH LAKE	35DO130	YES	N/A	N/A	N/A	N/A	N/A	N/A	N/A
UMPQUA/EDEN	35DO83	YES	1.9(C)	N/A	N/A	N/A	N/A	N/A	N/A

(A) 1/8 IN. SCREEN USED IN EXCAVATION
(B) FROM INCOMPLETE DATA
(C) TOTAL OF ONLY 2 OBSIDIAN FLAKES WERE RECOVERED
(D) THIS WAS THE SINGLE NON-DEBITAGE OBSIDIAN ARTIFACT RECOVERED
(E) 0.08 % BLACK OBSIDIAN; 0,02 % RED OBSIDIAN
(F) 1/4 IN. SCREEN USED IN EXCAVATION

SOURCES: KF-KLAMATH FALLS AREA; SR-SIUSLAW RIVER GRAVELS

REFEREN

1. LEAT
2. MINO
3. COLL
4. BERR
5. BARN
6. NEWM
7. ZONT
8. CRES

(FILE:COASTSITE)

ITGE BER =)	NUMBER OF CORES	CORE TO DEBITGE RATIO	UNWRKED NODULES PRESENT?	MAXIMUM NODULE DIAM(CM)	MAXIMUM SIZE NON-LOCAL?	OBSIDIAN PRJCTILE PNTS(%)	CHARACT. STUDIES?	IF YES, PRIMARY SOURCES	NEAREST SOURCE	SOURCE DISTANCE (KM)	REFER-ENCES	COMMENTS
/A	N/A	N/A	N/A	N/A	N/A	0	NO	--	SR	100	1	N
2(A)	0	N/A	NO	N/A	N/A	0	NO	--	SR	25	2	M,N
5	0	N/A	NO	N/A	N/A	0	NO	--	SR	25	2	M,N
/A	N/A	N/A	N/A	N/A	NO	N/A	NO	--	SR	170	3	-
/A	N/A	N/A	N/A	N/A	YES	N/A	NO	--	SR-KF	220	4	M
/A	N/A	N/A	N/A	N/A	N/A	0	NO	--	SR	30	5	M
/A	N/A	N/A	N/A	N/A	YES	N/A	NO	--	SR	170	6,8	R
2(F)	N/A	N/A	N/A	N/A	NO	N/A	NO	--	SR	160	7	M
/A	N/A	N/A	N/A	N/A	N/A	N/A	NO	--	SR	210	9	M
/A	N/A	N/A	N/A	N/A	N/A	N/A	NO	--	SR	210	9	M
5(F)	0	N/A	NO	N/A	YES	N/A	NO	--	SR	100	10,11	M,R
/A	N/A	N/A	N/A	N/A	YES	N/A	NO	--	SR-KF	220	12	-
/A	N/A	N/A	N/A	N/A	N/A	N/A	NO	--	SR	20	13,14	M
/A	N/A	N/A	N/A	N/A	NO	N/A	NO	--	SR	35	15	M

REFERENCES:

1. LEATHERMAN & KRIEGER, 1940
2. MINOR ET AL., 1985
3. COLLINS, 1952-53
4. BERREMAN, 1944
5. BARNER, 1982
6. NEWMAN, 1959
7. ZONTEK, 1978
8. CRESSMAN, 1952
9. PHEBUS & DRUCKER, 1979
10. DRAPER, 1980
11. DRAPER, 1982
12. HEFLIN, 1966
13. MINOR & TOEPEL, 1982
14. MINOR & TOEPEL, 1985
15. STENHOUSE, 1974