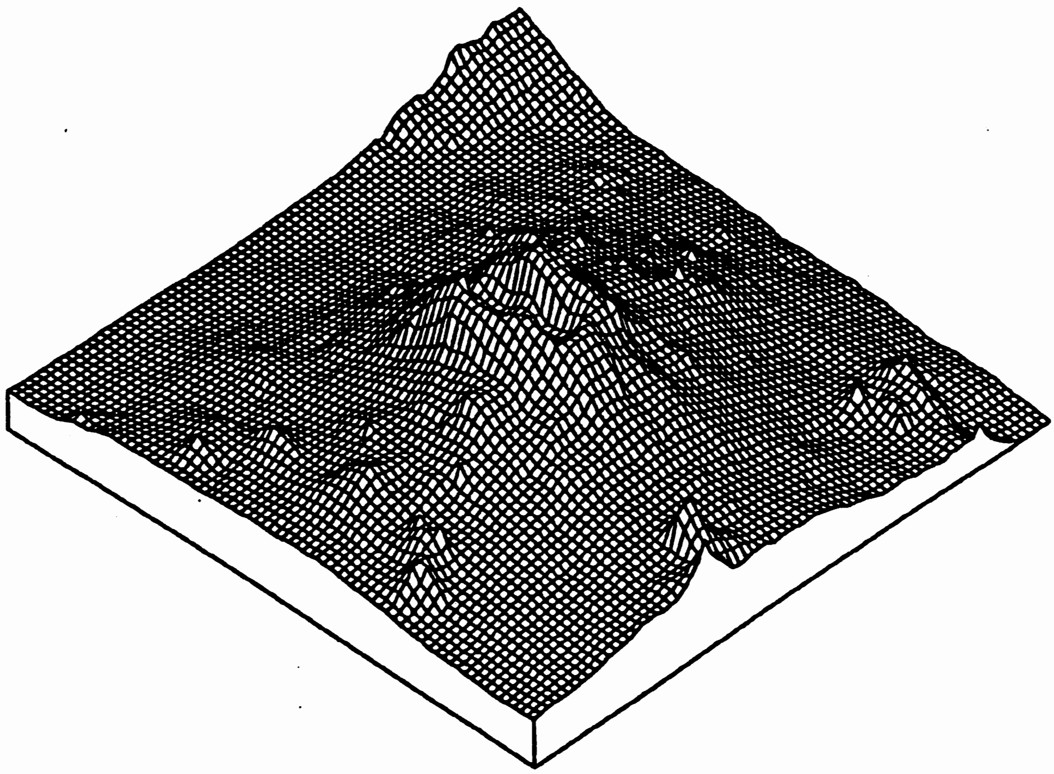
Spatial Patterns of Obsidian Use in Central Oregon: An Early View from the Trenches



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DRAFT VERSION

Spatial Patterns of Obsidian Use in Central Oregon: An Early View from the Trenches

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Abstract

The geologic sources of over 6,500 chemically characterized obsidian artifacts from 83 central Oregon archaeological sites were identified during laboratory studies of material recovered during the PGT-PG&E Pipeline Expansion Project. Many of these artifacts also yielded measurable obsidian hydration rims that added a chronological dimension to the analysis of the archaeological materials. The results of all obsidian analyses have been compiled in an extensive analytical database for the IBM-PC, greatly simplifying the potential data analysis problems that would typically be experienced with a large and complex data set such as the one examined here.

Many different geochemically-discrete sources of obsidian lie within the potential procurement sphere of the Oregon Pipeline-related sites. It is clear, however, that a limited number of sources - Obsidian Cliffs, Newberry Volcano, McKay Butte, Quartz Mountain, Glass Buttes, Whitewater Ridge, Silver Lake/Sycan Marsh, Spodue Mountain, and a few unknown sources - dominate the geologic sources of characterized artifacts. We examine the spatial distribution of obsidian from selected major sources and make a preliminary assessment of the diachronic variability in source patterning that is suggested by obsidian hydration measurements. Obsidian procurement sphere boundaries are tentatively identified as is the geographic variability in source richness (sample size versus number of utilized sources). Long-distance procurement (greater than 100 km from the source) of glass is recorded at several sites, although the procurement processes (direct access or exchange) are not yet determinable. Further investigation of the spatial patterning of these characterized artifacts, particularly when combined with the available extensive obsidian hydration data, are certain to provide information that will be of use in identifying and refining our knowledge of the obsidian procurement processes in play in prehistoric central Oregon.

INTRODUCTION

Over the past three decades, obsidian characterization studies have been incorporated into archaeological research strategies with increasing frequency and source identification investigations have rapidly progressed from the exotic to the commonplace. In the Far Western United States and many other regions of the world, obsidian studies are now considered a routine and essential component of any well-developed archaeological research design. In this paper, we briefly present the initial results of the just-completed extensive Oregon obsidian characterization studies carried out in 1990 through 1993 in conjunction with the PGT-PG&E Pipeline Expansion Project (PEP). We also provide an early view of the synchronic and diachronic prehistoric utilization patterns of four major central Oregon obsidian sources, Obsidian Cliffs, Newberry Volcano, McKay Butte, and the still enigmatic Unknown X source. Lastly, we comment on the probable sources of many characterized obsidian artifacts from north central Oregon sites that were previously unable to be correlated with known geologic sources of glass.

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PEP Sites and Samples Selected for Characterization Studies

During the Project, over 9,500 obsidian artifacts from 133 Oregon, California, and Idaho archaeological sites were selected for obsidian characterization studies (Table 1). The trace element composition of 9,059 of these items was determined by X-ray (XRF) fluorescence spectrometry and the resultant elemental abundances were used to identify the geochemical sources of the samples. The remainder of the artifacts, most from California sites, were visually or petrographically characterized. After geologic source identification, the majority of the obsidian artifacts were also examined for the presence of obsidian hydration rims.

Oregon samples are represented by 6,644 items from 83 archaeological sites in the eight Oregon counties intersected by the Pipeline (Figure 1). Sample sizes ranged by county from four artifacts in Umatilla County to 2,602 items in Deschutes County. Forty eight sites from eight California counties were also selected for characterization studies and a total of 2,864 items were submitted for source identification. Two items of obsidian debitage from Idaho, the only two Idaho artifacts of adequate size for XRF analysis, were also included in the trace element studies. This combined corpus of 9,510 specimens constitutes, to our knowledge, the largest sample of characterized obsidian artifacts associated with any single archaeological project in the world to date.

The sample of Oregon artifacts selected for obsidian studies includes most of the obsidian tools that were suitable for XRF analysis. The selection of debitage samples at individual sites was made on the basis of site specific strategies typically relating to obsidian procurement or chronologic objectives. Due to the previously recognized problematic nature of obsidian studies at north central Oregon sites and the relatively small number of obsidian artifacts recovered during testing and data recovery activities, a 100 percent sample of obsidian debitage suitable for XRF analysis was selected from many of these sites.

Table 1. PEP samples selected for characterization studies.

State	Number of Sites	Obsidian Debitage	Obsidian Tools	Other Obsidian	Basalt Artifacts	Tota l XRF	Total Visua l	Total
Idaho	1	2	0	0	0	2	0	2
Washington	0	0	0	0	0	0	0	0
Oregon	83	5,526	1,113	4	0	6,595	49	6,644
California	49	2,091	771	2	26	2,492	354	2,866
Total	133	7,619	1,884	6	26	9,087	401	9,510

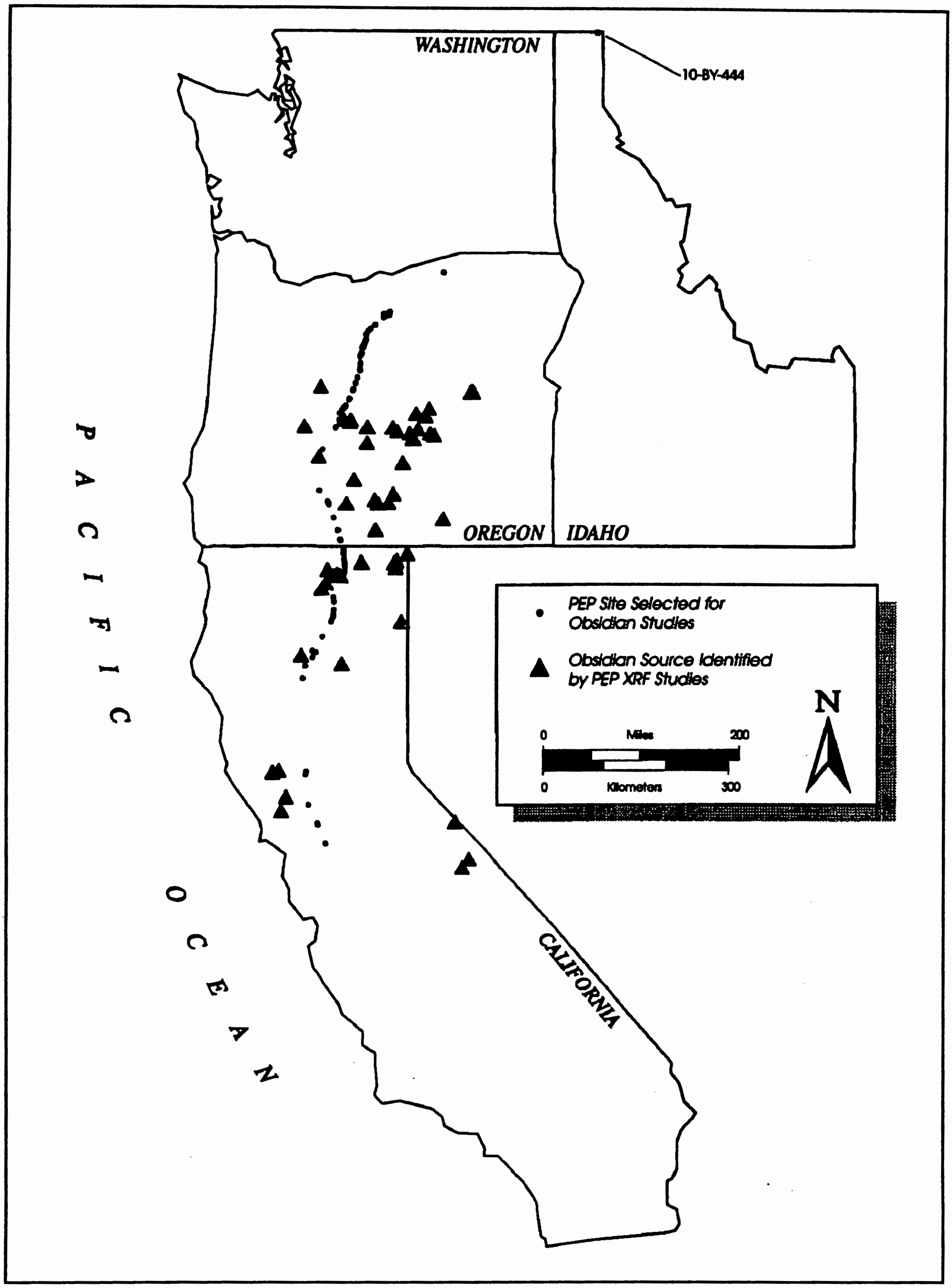

Figure 1. Distribution of PEP sites selected for obsidian characterization studies.

Research Objectives

The Pipeline Expansion Project runs through some of the most obsidian-rich regions of the world. Well over 100 geochemically identifiable sources of rhyolitic volcanic glass have been identified in Oregon; dozens of other sources have been found in California, particularly in the northern part of the state (Ericson et al. 1976; Hughes 1986a; Skinner 1983). Because of the importance of obsidian, both in its role as a prehistoric lithic resource and its value as a source of chronologic and lithic procurement information, considerable emphasis was placed on obsidian studies during the course of the Project.

The chemical composition of obsidian is an important variable influencing the hydration rate of the glass and obsidian source identification studies were used to control for that variable during the Pipeline Project. In addition to providing a chemical control for use with obsidian hydration analyses, obsidian characterization studies were used to explore prehistoric procurement and interactional systems. Patterns of source use can provide crucial information about seasonal subsistence ranges and territoriality and direct and indirect procurement boundaries. Given the previous dearth of knowledge about prehistoric lithic procurement patterns in northern California and Oregon, particularly in central and north-central Oregon, trace element studies of artifact obsidian were expected to provide essential baseline information for both current and future investigations. The PEP characterization data, used in conjunction with obsidian hydration measurements and the presence of well-dated Mazama tephra at several sites, provide information about obsidian use against which Project research objectives and subsequent hypotheses can be tested and provide a foundation upon which further archaeological research will be built.

X-RAY FLUORESCENCE ANALYSIS CHARACTERIZATION OF PEP ARTIFACTS

Analytical Methods

All nondestructive XRF analyses and obsidian source determinations were carried out by Dr. Richard E. Hughes of Geochemical Research (Rancho Cordova, California) and BioSystems Analysis (Santa Cruz, California). Hughes analyzed and assigned sources to a total of 7,083 artifacts, including all items from Oregon sites. In addition, he assigned sources to 106 artifacts that had been analyzed by BioSystems. The remaining 2,009 artifacts, all from California sites, were analyzed by BioSystems Analysis.

Correlation of Artifacts and Geologic Sources

All trace-element values used to characterize the artifacts were compared directly to values for known obsidian sources reported by Hughes (1986a), Jack (1976), and Skinner (1983, 1986). Artifacts were assigned to a parent obsidian source or chemical source group (two or more chemically indistinguishable obsidian occurrences) if diagnostic trace-element abundances (Rb, Sr, Y, and Zr) corresponded at the 2-sigma level, that is, if the diagnostic mean measurements for the artifacts fell within two standard deviations of mean values for the source standards. Diagnostic trace elements, as the term is used here, refer to those trace elements that are measured by XRF with high precision and low analytical uncertainty and whose abundances show low intrasource variability along with marked intersource variability. In short. these diagnostic elements are those whose concentrations allow the clearest geochemical distinctions between sources (Hughes 1990a; Skinner 1983).

When initial diagnostic trace elements (Rb, Sr, Y, Zr) failed to provide adequate resolution to distinguish between sources (as was the case with the Quartz Mountain and McKay Butte sources, for example), additional analyses were often carried out. In these instances, the determination of titanium (Ti), manganese (Mn), barium (Ba), and iron (Fe_2O_3) abundances were usually sufficient to identify specific sources or chemical source groups. In cases where diagnostic elements could not discriminate between different chemical sources, the identified possible sources are designated as a combined chemical group, for example, Quartz Mountain/McKay Butte. It should be noted that, in many cases, indeterminate and ambiguous source assignments currently reported for PEP samples could be resolved with further geochemical studies.

After the geochemical data for all PEP samples had been gathered over a period of several years, the entire data set was reexamined. New chemical data resulting from field work and additional source analyses by Richard Hughes, particularly for sources in north central Oregon, were integrated into the earlier results reported in Moratto et al. (1991). This resulted in the resolution or partial resolution of many of the unknown sources identified in the early stages of the project. Whenever possible, sources that had been previously designated as unknown were reassigned to the preliminary chemical source groups identified by Hughes in later source characterization studies. The presence of many north central Oregon artifacts with uncertain source assignments or undifferentiated chemical groups reflects our still very incomplete knowledge of the distribution and geochemistry of obsidians in that region.

Data Management and Analysis

Due to the size of the obsidian studies project, data management considerations were both crucial and unique. Artifact data were initially recorded and stored in Lotus-compatible worksheets using Quattro Pro (Windows and DOS versions). The results of each year's obsidian studies were compiled on a separate worksheet containing between 1150 (1991) and 2350 items (1992). Obsidian data associated with BioSystems and FWARG investigations were stored on separate in separate spreadsheet files. All trace-element (and obsidian hydration) data collected during the latter part of the Project were recorded or acquired on disk and were incrementally imported into and integrated with the annual artifact spreadsheets. Provenience and classification information were integrated into the worksheets from subsets of site catalogs created with dBASE IV. Other data fields that would be useful during the overall management or analysis of the data were developed as needed.

When analysis of the artifacts was complete, the spreadsheets were exported for curation purposes as dBASE IV databases. Most data analysis was carried out with dBASE IV and FileMaker Pro, a Windows database. This latter database was used because of its ease of operation and ability to produce publication-quality tables. The reassignment of unknown to known obsidian sources at the end of the Project using newly available trace element data was accomplished using trace element value range queries of the completed databases. Although statistical and graphical methods are often used for the correlation of characterized artifacts and geologic sources, we find that database-assisted source assignments can be very effectively used to initially assign sources. This method is particularly useful when examining large numbers of characterized artifacts such as those encountered during this project. Final data analysis was carried out on an 80486 50-Mz IBM-compatible microcomputer with 8MB RAM and a 600MB HDD.

Results of X-Ray Fluorescence Analyses

Fifty-six chemically discrete potential parent geologic sources (chemical types) of obsidian were identified from the 9,089 obsidian artifacts characterized with XRF methods. Thirty-three of the sources are located in Oregon, 22 are found in California, and one, Obsidian Cliff, is located within the boundaries of Yellowstone National Park, Wyoming.

The trace element composition of 6,595 artifacts from 83 Oregon archaeological sites was determined during the course of the Project (Figure 2). In addition to the 33 geochemically distinguishable known obsidian sources that were identified (Figure 3), several unknown chemical source groups were delineated after known source assignments were completed. These unidentified sources were particularly prevalent in the John Day and Lower Deschutes River drainages of north central Oregon and it is a certainty that several obsidian sources in these regions have yet to be identified by modern obsidian researchers.

Based on their chemical composition, 55 of the items were found to be non-obsidian. Of the remaining specimens, geologic sources or tentative sources were assigned to 5,998 items. The composition of the remaining 537 artifacts could not be correlated with any known source at this time. About 350 of these artifacts, however, fall into a single tentative source group designated here as the Unknown X source. Sample sizes at investigated sites ranged from one item for several sites to 964 tools and flakes from 35-DS-33.

Twelve of the 33 identified Oregon geologic obsidian sources or chemical groups accounted for over 95 percent of the analyzed artifacts - Obsidian Cliffs, Newberry Volcano, Big Obsidian Flow, McKay Butte, Unknown X, Quartz Mountain, Cougar Mountain, Glass Buttes, Whitewater Ridge/Little Bear Creek, Silver Lake/Sycan Marsh, and Spodue Mountain. In this paper, we take a closer look at four of these sources - Obsidian Cliffs, Newberry Volcano, McKay Butte, and Unknown X.

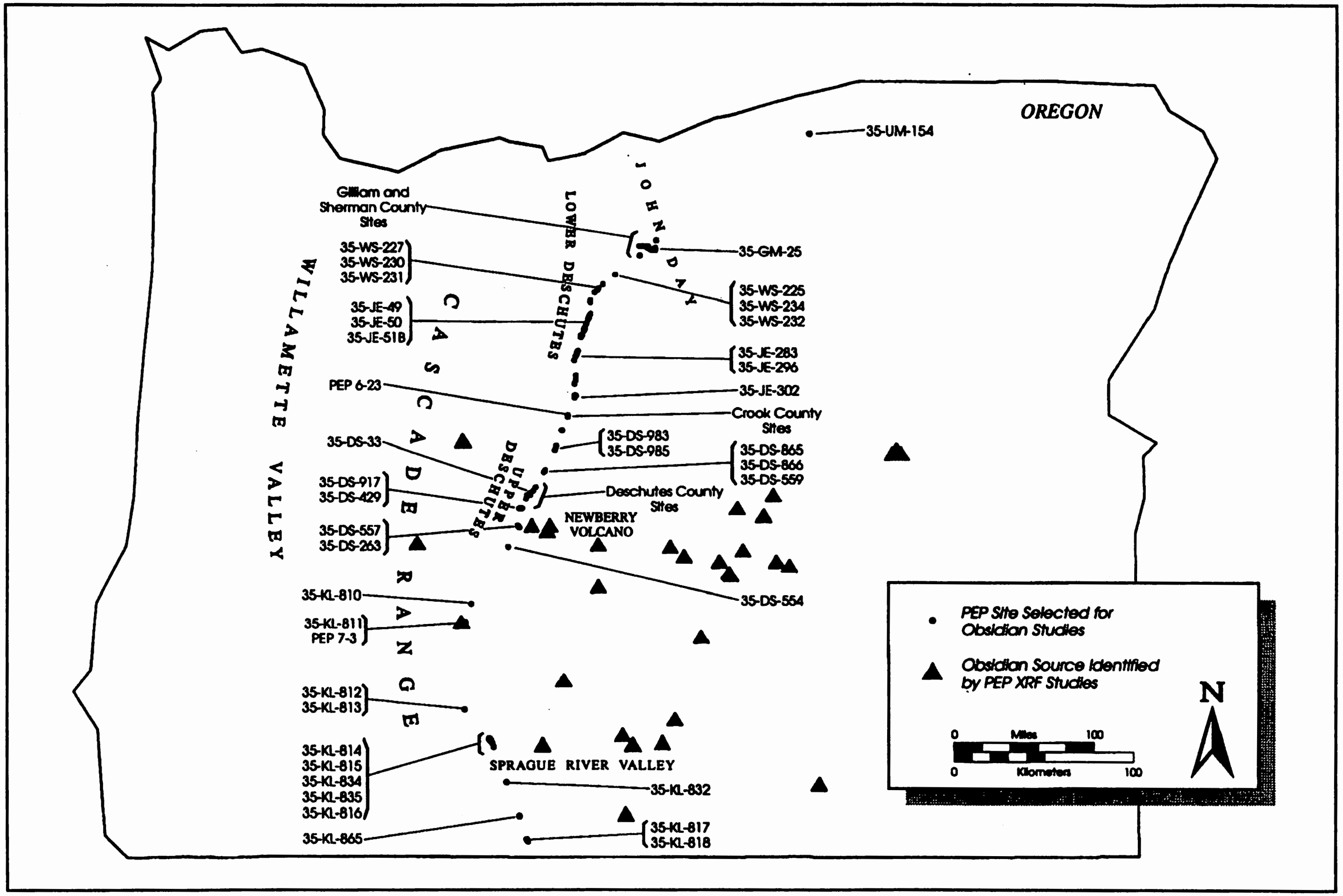

Figure 2. Location of characterized Oregon PEP archaeological sites and obsidian sources identified during characterization studies.

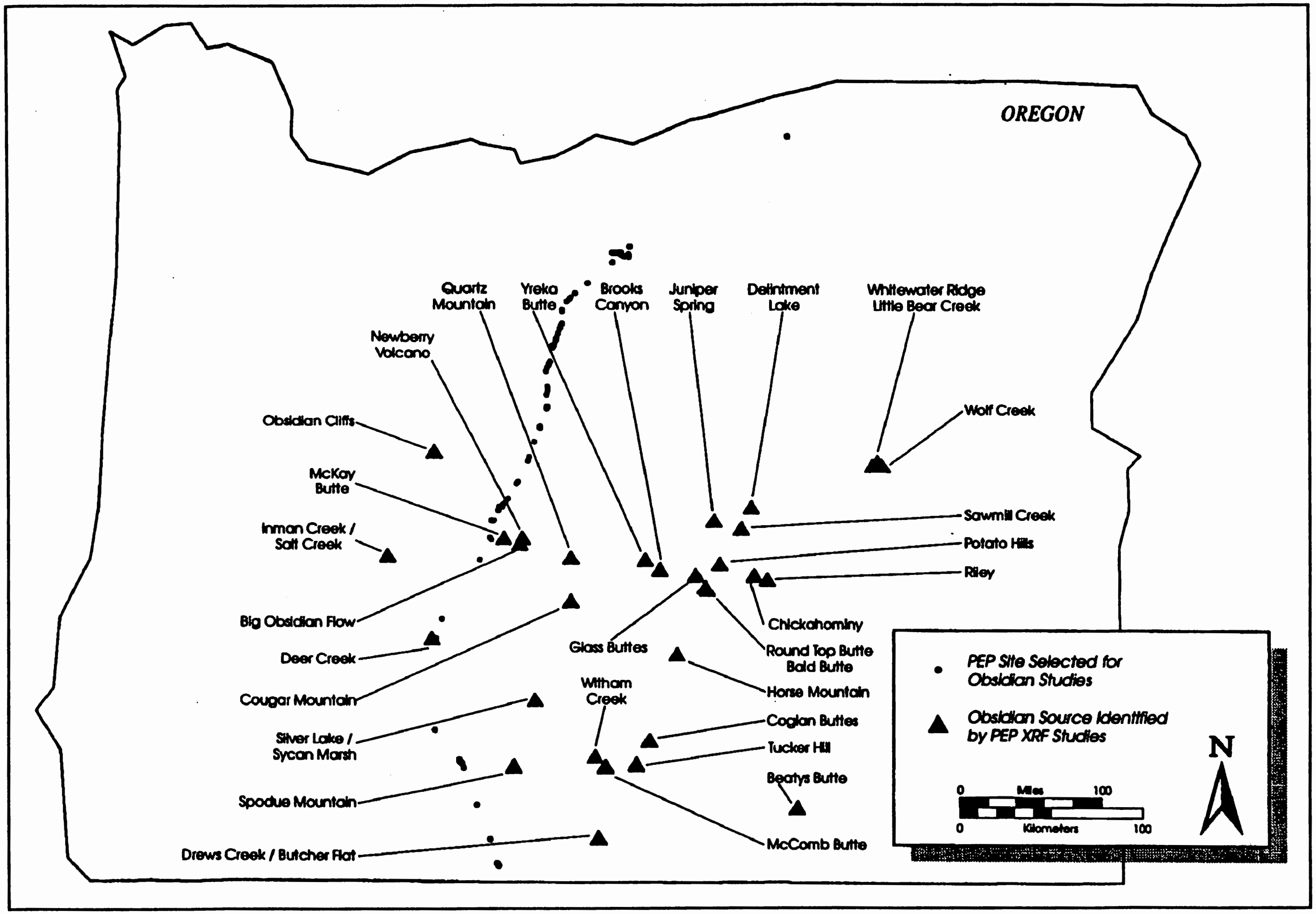

Figure 3. Location of obsidian sources identified during trace element studies of PEP artifacts.

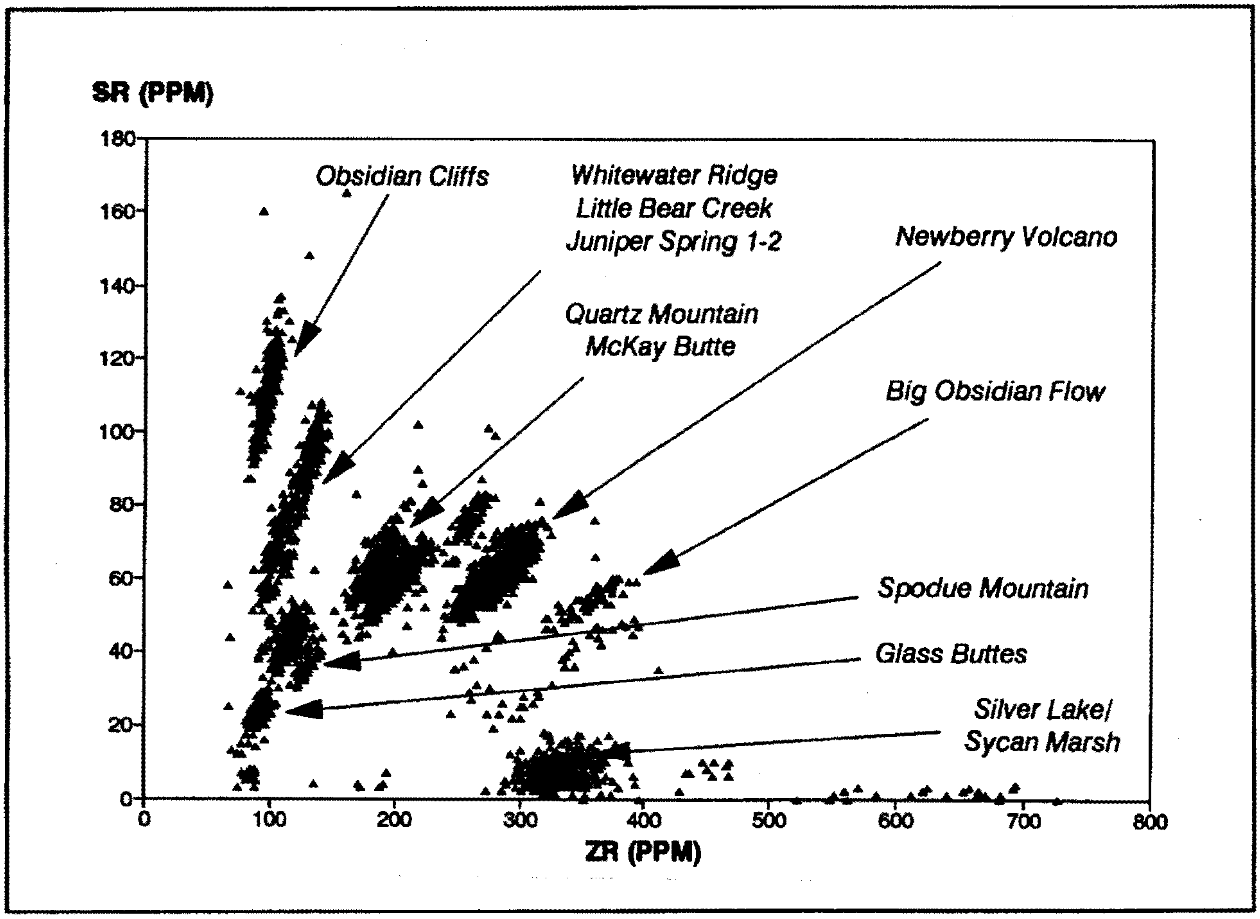

Figure 4. Scatterplot of Sr plotted versus Zr for all Oregon artifacts correlated with known geologic sources.

Obsidian Cliffs, Oregon High Cascades

Obsidian Cliffs is a large glaciated flow of obsidian and rhyolite that is located near the northwestern base of the Middle Sister in the Central High Cascades (Figure 3). Spectacular 70 to 90 m-high cliffs mark the terminus of the 2.4 km-long flow, giving the source its name. Nodules of glacially-transported obsidian are found in valleys leading west from the sources while rounded pebbles of glass can be collected in alluvial deposits and river gravel bars in the Willamette Valley of western Oregon.

The top of the Obsidian Cliffs flow is littered with obsidian nodules and reduction debris; evidence for long-term intensive prehistoric use of this source is abundant. Trace element studies indicate that Obsidian Cliffs glass was widely prehistorically used throughout the Western Cascades and Willamette Valley of northwestern Oregon (Skinner and Winkler 1990). Use of the raw material in central Oregon from this source was greatest in north central Oregon sites, particularly at sites in Jefferson and Wasco counties, where it was used along with glass from Newberry Volcano and other sources to the southeast (Figure 6). The presence of obsidian from the central High Cascades is consistent with a model of stone resources acquired during seasonal resource forays into the High Cascades and Western Cascades. The summer trans-Cascade travel of Lower Deschutes River Basin groups into the Western Cascades for seasonally-available foods is a well-documented ethnographic pattern (Minor 1987:23-35; Murdock 1980). Artifacts from this source have also been identified in sites along the Oregon coast, in southern Washington, and make up a small but consistent percentage of obsidian artifacts recovered from western Deschutes County sites.

The overall obsidian hydration rim width distribution curve for Obsidian Cliffs glass from PEP sites is somewhat skewed and probably results from a bias towards post-Mazama obsidian artifacts (Figure 5). Hydration band values range from 0.9 to 7.6 μm, indicating that Obsidian Cliffs was a major source of glass in central and north central Oregon throughout much of the Holocene.

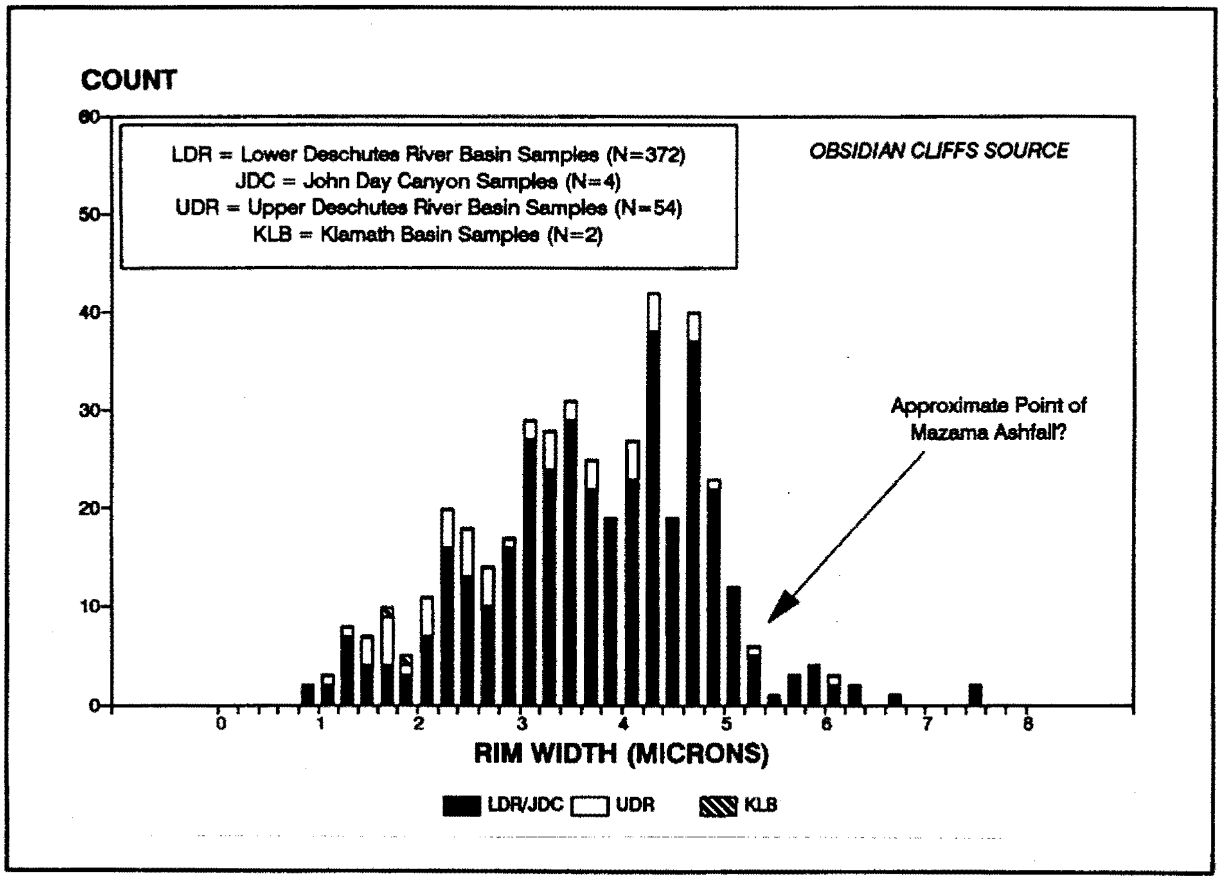

Figure 5. Frequency Distribution of Obsidian Hydration Rim Measurements from Artifacts Correlated With the Obsidian Cliffs Source.

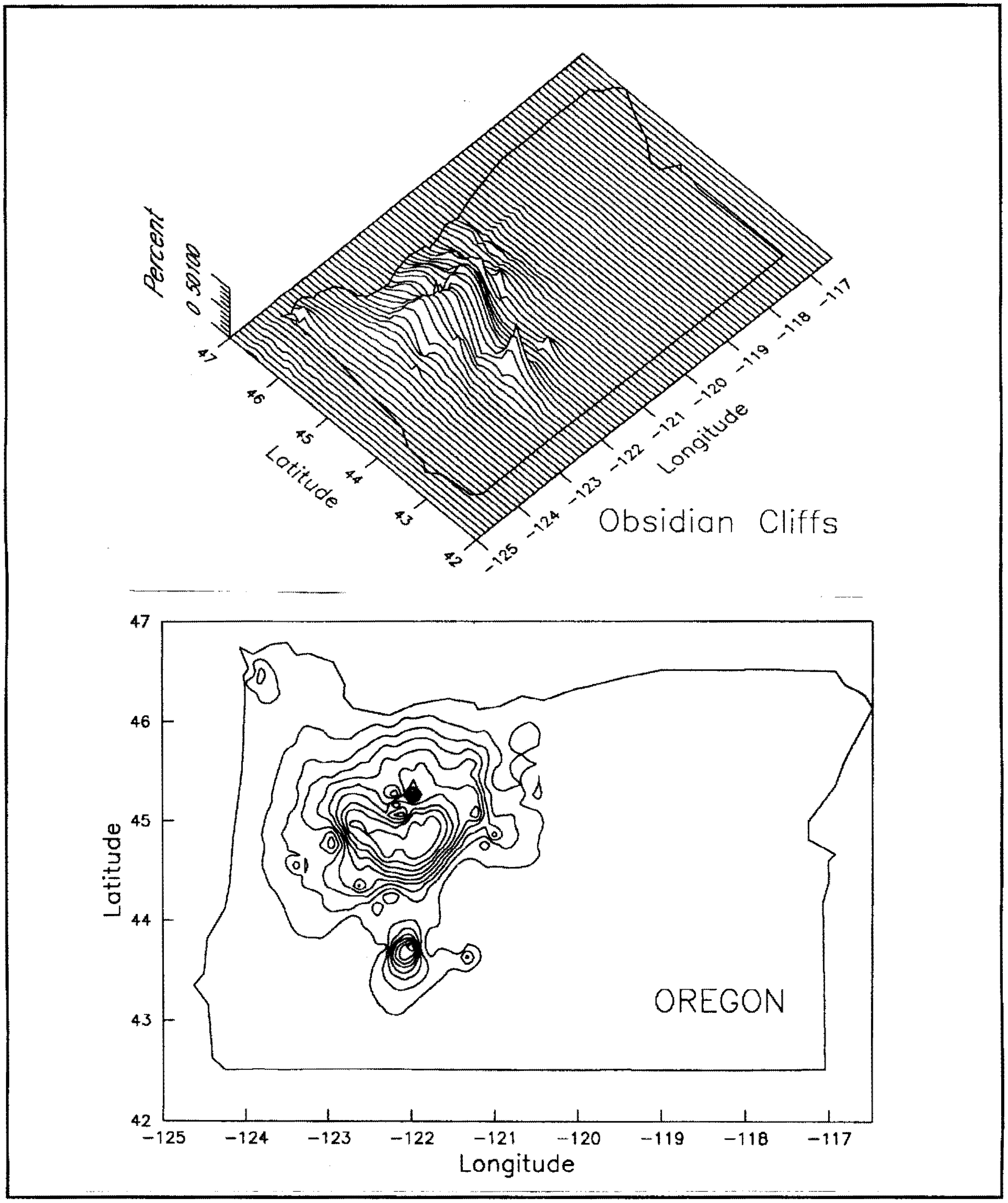

Figure 6. Trend surface and contour maps illustrating the prehistoric spatial distribution of artifacts from the Obsidian Cliffs source. Obsidian source percentage data are from 205 characterized archaeological sites, including all PEP sites; no attempt is made to correct for differences in sample size. Source percentage contours are 10 percent.

Obsidian Cliffs source use boundaries inferred from PEP obsidian studies indicate an almost complete disappearance of central Oregon artifacts originating from this source at about the Klamath Basin-Upper Deschutes River Basin divide (site 35-KL-810). In western Oregon, artifact obsidian from this source in other projects all but vanishes south of the Rogue River drainage basin – source use almost completely shifts at this point to dependence on sources located in the Klamath Basin of Oregon and the Medicine Lake Highlands of northern California (Skinner and Winkler 1990). The use of this source gradually decreases to the north in central Oregon, although a few Obsidian Cliffs artifacts have been reported from sites in south-central Washington (McClure 1992). To the east of the Pipeline transect, a lack of characterization data leaves any determination of eastern source use boundaries as very speculative. A few isolated studies, however, suggest that artifacts from Obsidian Cliffs are found only in very small proportions and disappear entirely in the northwestern Great Basin where many other sources of high-quality glass are available.

Newberry Volcano Caldera Sources

Numerous sources of obsidian were locally available to the prehistoric inhabitants of the examined Newberry Volcano region sites. Many glass sources are found in the caldera and on the lower flanks of Newberry Volcano, a large composite volcano centered about 35 km (20 mi) southeast of Bend. Covering an area of nearly 1300 km^2 (500 mi^2), it is one of the largest volcanoes in the conterminous United States. With several late Pleistocene to late Holocene obsidian flows (Figure 7), the six to eight km (4 to 5 mi) wide summit caldera of Newberry Volcano was a major regional focal point for prehistoric obsidian procurement, initial lithic reduction and biface manufacture, and transportation (Connolly 1991:93-94, 1993; Flenniken and Ozbun 1988:140; Ozbun 1991).

Obsidian from the caldera sources of Newberry Volcano falls are divisible into two chemical groups, the Newberry Volcano group and the Big Obsidian Flow group. Geochemically indistinguishable flows that fall into the Newberry Volcano group include the Interlake flow, The two East Lake flows, the Game Hut flow, and the Central Pumice Cone flow. These sources were all erupted beginning shortly after the Mazama ashfall of about 6,850 radiocarbon years ago.

Obsidian from the Newberry Volcano chemical group is common in post-Mazama archaeological contexts in the Newberry Volcano region and in north-central Oregon. Of the over 5,500 characterized PEP artifacts from north central Oregon and the Newberry Volcano region sites, in excess of 2,400 items originated from this single chemical group. To the east and southeast of the volcano, the frequency of appearance of artifacts from this chemical group decreases rapidly as areas in which other sources of high-quality glass are reached. The southern boundary prehistoric use of Newberry glass is found at approximately the Upper Deschutes and Klamath Basin divide – at this point, obsidian from Klamath Basin sources rapidly dominates the archaeological assemblages (Atwell et al. 1993). Small quantities of Newberry glass are also consistently found in the central Western Cascades, particularly in the Willamette and Umpqua River drainages, and very occasionally as far west as the

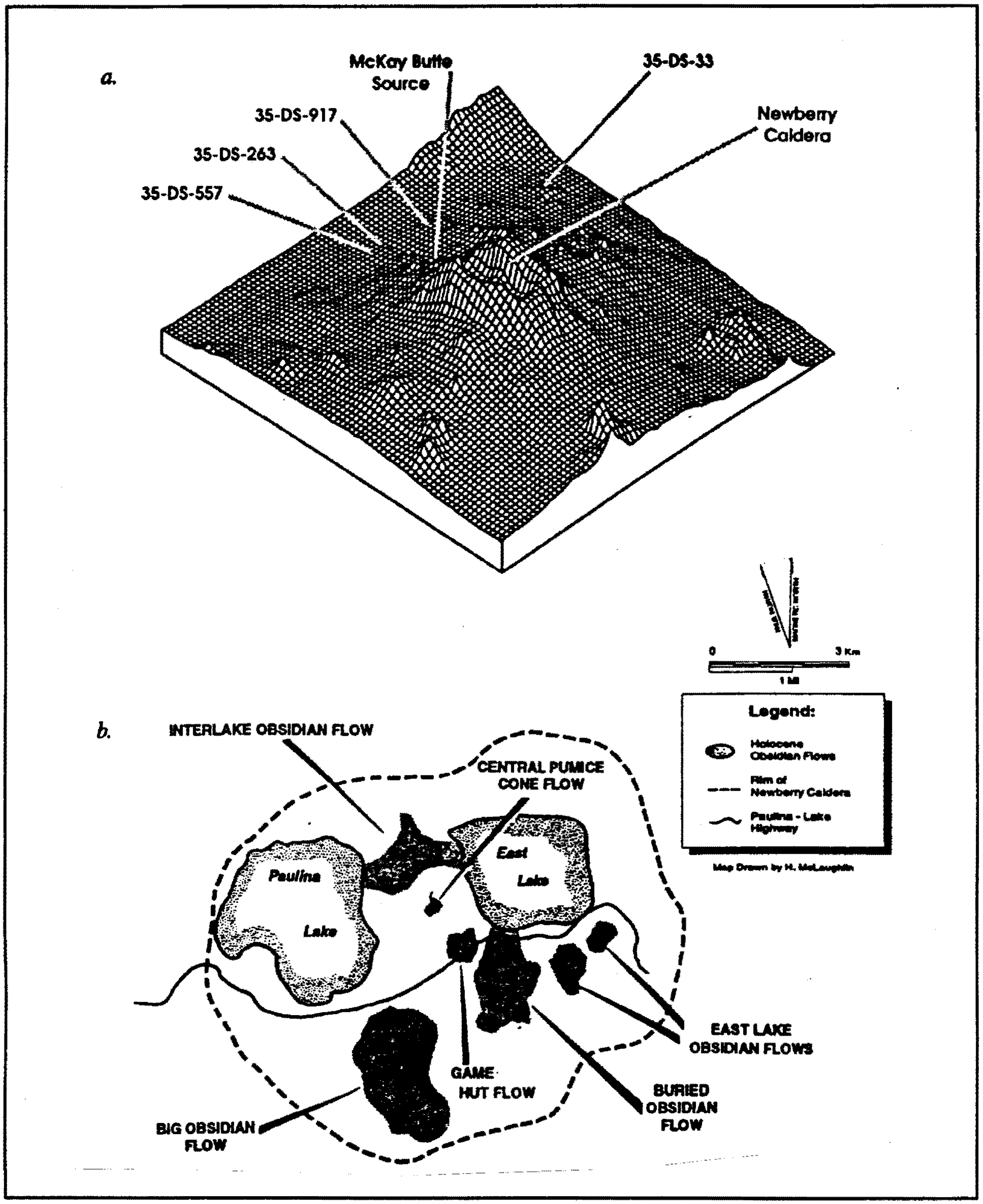

Figure 7. *a*, a digital elevation model of Newberry Volcano, oriented towards the northwest; and *b*, a geologic sketch map of Newberry Caldera region showing the location of major obsidian sources (adapted from McLeod et al. 1982).

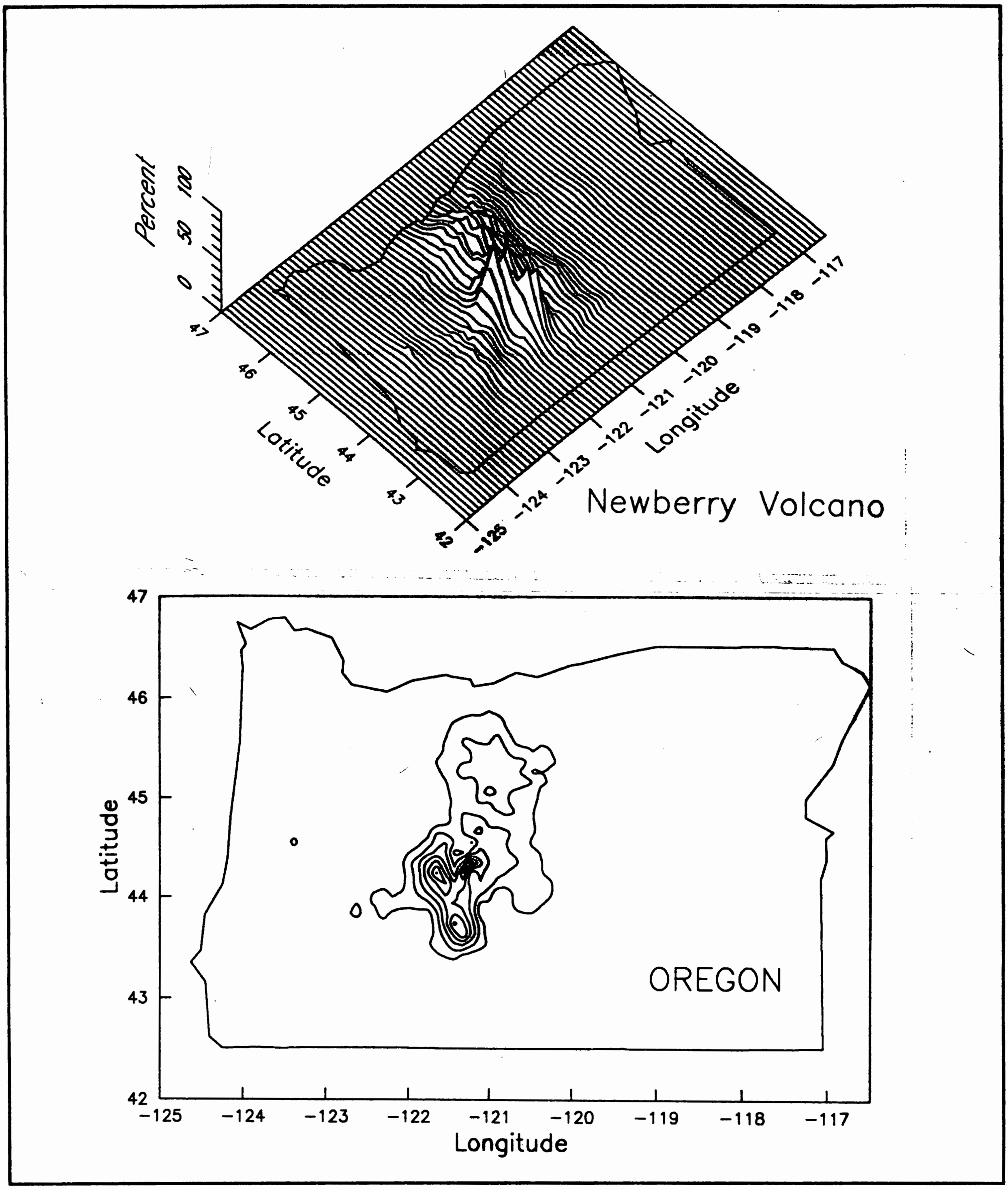

Figure 8. Trend surface and contour maps showing the prehistoric geographic spatial distribution of artifacts from the Newberry Volcano chemical group. Obsidian source percentage data are from 205 characterized archaeological sites, including all PEP sites; no attempt is made to correct for differences in sample size. Source percentage contours are 10 percent.

Willamette Valley and the northern Oregon coast. A few samples have been reported from as far east as central and southeastern Washington State (Draper and Andrefsky 1991; McClure 1992).

The second of the caldera chemical groups is the Big Obsidian Flow. This spectacular flow, the most recent of any of the caldera obsidian sources, erupted about 1,300 radiocarbon years ago (MacLeod et al. 1982). The prominent Big Obsidian Flow is geochemically distinguishable from the geographically proximate Newberry Caldera geochemical group flows on the basis of its relatively large Zr content. Until recently, it appeared that this provided archaeologists with a chemically unique source of known age, one that could provide a maximum procurement age to artifact obsidian correlated with the source. New evidence suggests, however, that another caldera obsidian source, the pre-Mazama Buried Obsidian Flow (Figure 7), is compositionally similar to the Big Obsidian Flow. Limited geochemical analyses by Linneman (1990:277) indicate that the glass of the Buried Obsidian Flow (called the Southeastern Obsidian Flow by Linneman) and Big Obsidian Flow are geochemically comparable. Both flows are similarly enriched in Zr, the element most commonly used to differentiate between the Newberry and Big Obsidian Flow sources; the diagnostic trace elements generally used to differentiate among the caldera sources (Rb, Sr, Zr) would fail to distinguish between the Big Obsidian Flow and Buried Obsidian Flow.

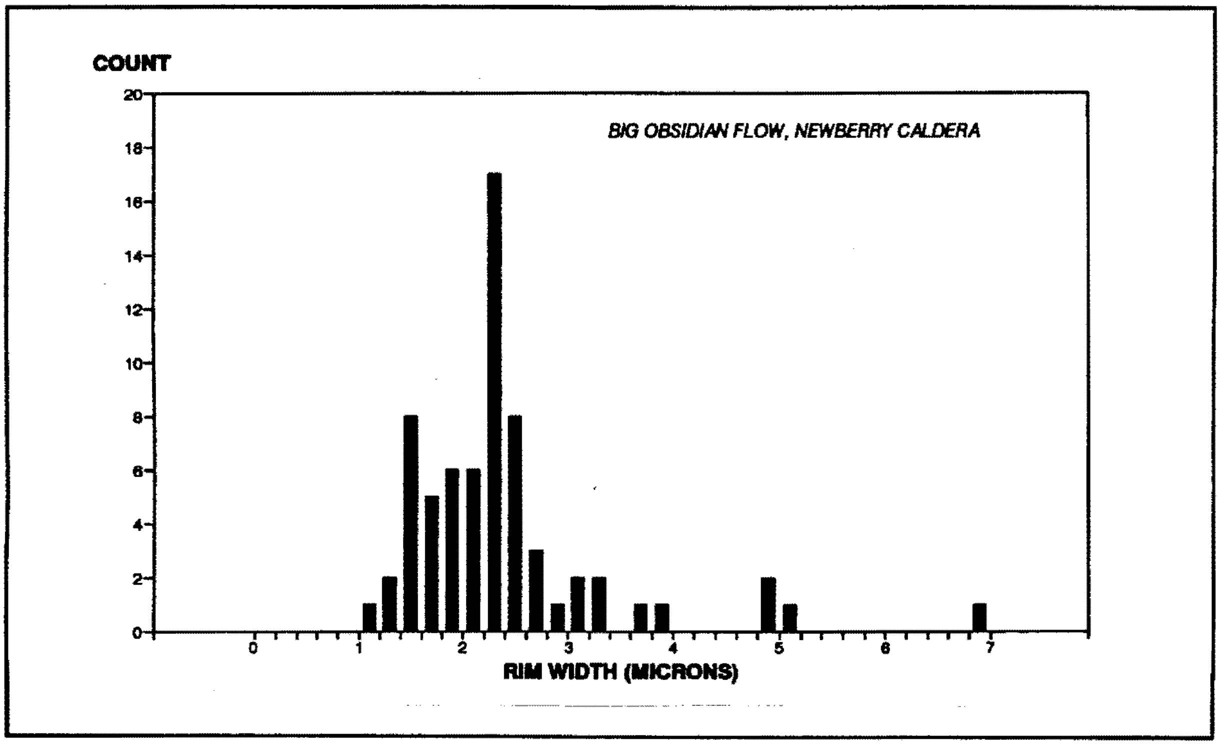

Figure 9. Obsidian hydration rim width frequency distribution for artifacts from the Big Obsidian Flow chemical group.

The age of the pre-Mazama Buried Obsidian Flow is estimated to be at least 10,000 years B.P. (Linneman 1990:87), and any chronological inferences for artifacts previously correlated with the Big Obsidian Flow should be carefully reexamined. The Buried Obsidian Flow was not among the reference samples used for artifact comparison during the present trace-element study — any Big Obsidian Flow source assignments reported here should, therefore, be considered in the context of the Big Obsidian Flow chemical group and may not originate from the 1,300 year-old caldera flow.

A total of 83 artifacts from five PEP sites in the Newberry Volcano region and north central Oregon were firmly or provisionally assigned to the Big Obsidian Flow chemical group. Previous to these obsidian studies, artifacts from this chemical group had been found only within the caldera and at a few scattered sites in the Western Cascades and central Oregon. Obsidian hydration rim values from these artifacts range from 1.1 - 5.1 microns and exhibit a modal value of 2.3 microns (Figure 9). Hydration rims from the Big Obsidian Flow geologic source were measured by Friedman (1977) at about 1.0 ± 0.2 microns and the range of measurements recorded during the PEP studies was initially quite unexpected. This disparity between expected and observed rim values provides corroborating evidence of the utilization of a pre-Big Obsidian Flow source.

McKay Butte, Newberry Volcano

Prominent in the lithic assemblage of the Deschutes County sites is a distinctive medium dark gray (5YR 4/1) to medium bluish gray (5B 5/1) obsidian originating from McKay Butte, the central dome in an alignment of three Pleistocene rhyolite domes located on the lower western flanks of Newberry Volcano (MacLeod et al. 1981; Skinner 1983:261–262). Nodules of grayish glass up to 20 cm in diameter are common on the lower eastern slopes of the central dome; small nodules of black glass up to about 4 cm in diameter also are found. The glass at the source contains abundant spherulites ranging from several centimeters in diameter to sub-millimeter size; small spherulites were also noted in many of the artifacts chemically correlated with McKay Butte. The presence of spherulites is unique among the Newberry sources and may prove to be an attribute valuable in the macroscopic identification of the glass. The bluish-gray color of the McKay Butte glass also appears to be unique among the Newberry sources. Most other glasses from the Newberry Caldera sources that were examined range from black to dark greenish gray, although obsidian tentatively correlated with the Unknown X group ranges from black to gray and is easily visually confused with material from McKay Butte.

Three of the Deschutes County sites (35-DS-263, 35-DS-557, and 35-DS-917) located within 10 km (6 mi) of the McKay Butte source yielded concomitantly large proportions of McKay Butte glass (Table 2). The presence of the gray to bluish-gray glass that is characteristic of McKay Butte obsidian in collections from these sites suggested that McKay Butte should prove to be the primary source for many of the characterized artifacts. Geochemical characterization of the artifacts partially bore this out – many artifacts did originate from

McKay Butte, although a significant proportion of the visually similar Unknown X glass was found among the darker gray samples.

The obsidian hydration rim distribution frequency of McKay Butte artifacts decreases significantly at values of less than about five microns (Figure 12). This rim width corresponds very approximately to the period of the Mazama ashfall – over 1 m of volcanic tephra fell in this region, significantly altering the original landscape. Why the dramatic decrease of McKay Butte glass from the archaeological record at this time? The sudden appearance of competing sources resulting from the eruption of several post-Mazama obsidian flows in nearby Newberry Caldera provides one possible answer. But why, then, do we find the near disappearance in the archaeological record of high-quality obsidian from a considerably closer source than those in the caldera? We suggest here that the drop in McKay source utilization at this time may have been due to the burial of the McKay Butte source by Mazama ash. Glass from this source is currently poorly-exposed and available for collection almost entirely in areas disturbed by recent road-building and logging activities. The appearance of McKay Butte glass in periods following the ashfall may have been due largely to the recycling of existing materials. If this is true, many post-Mazama artifacts should exhibit evidence for re-use, an observation confirmable through technological and obsidian hydration studies of the original and reused surfaces.

Unknown X, Newberry Volcano?

Of considerable interest at several Deschutes County sites was the identification of relatively large quantities of glass from an as yet unidentified geologic source, termed here the Unknown X source. Initially encountered during trace element studies of artifacts recovered during the 1991 testing of Deschutes County sites, this source at first was suspected to reflect only unrecorded chemical variability of the McKay Butte or Newberry Volcano chemical groups. Later characterization studies using larger sample sizes from pre-Mazama contexts showed that the source was almost certainly a real one. That the Unknown X source is not simply an artifact of unrecorded chemical variability is indicated both by its clear trace element grouping (Figure 10) and the very different obsidian hydration distribution characteristics for the two sources.

Much of the identified Unknown X obsidian occurs at two sites located on stream terraces along Paulina Creek, 35-DS-263 and 35-DS-557. The sites are separated by less than a kilometer and are situated only a few kilometers from the McKay Butte source. Prehistoric use of glass from the Unknown X group decreases very rapidly to the north and south of the two sites and almost disappears from the archaeological record a short distance to the north at 35-DS-33.

In a similar fashion to obsidian from McKay Butte, the frequency of Unknown X glass declines significantly during the post-Mazama period. We hypothesize here that, like McKay Butte, the Unknown X source may have been covered by Mazama tephra and that use of new glass from the source was discontinued. This hypothesis can be tested through technological

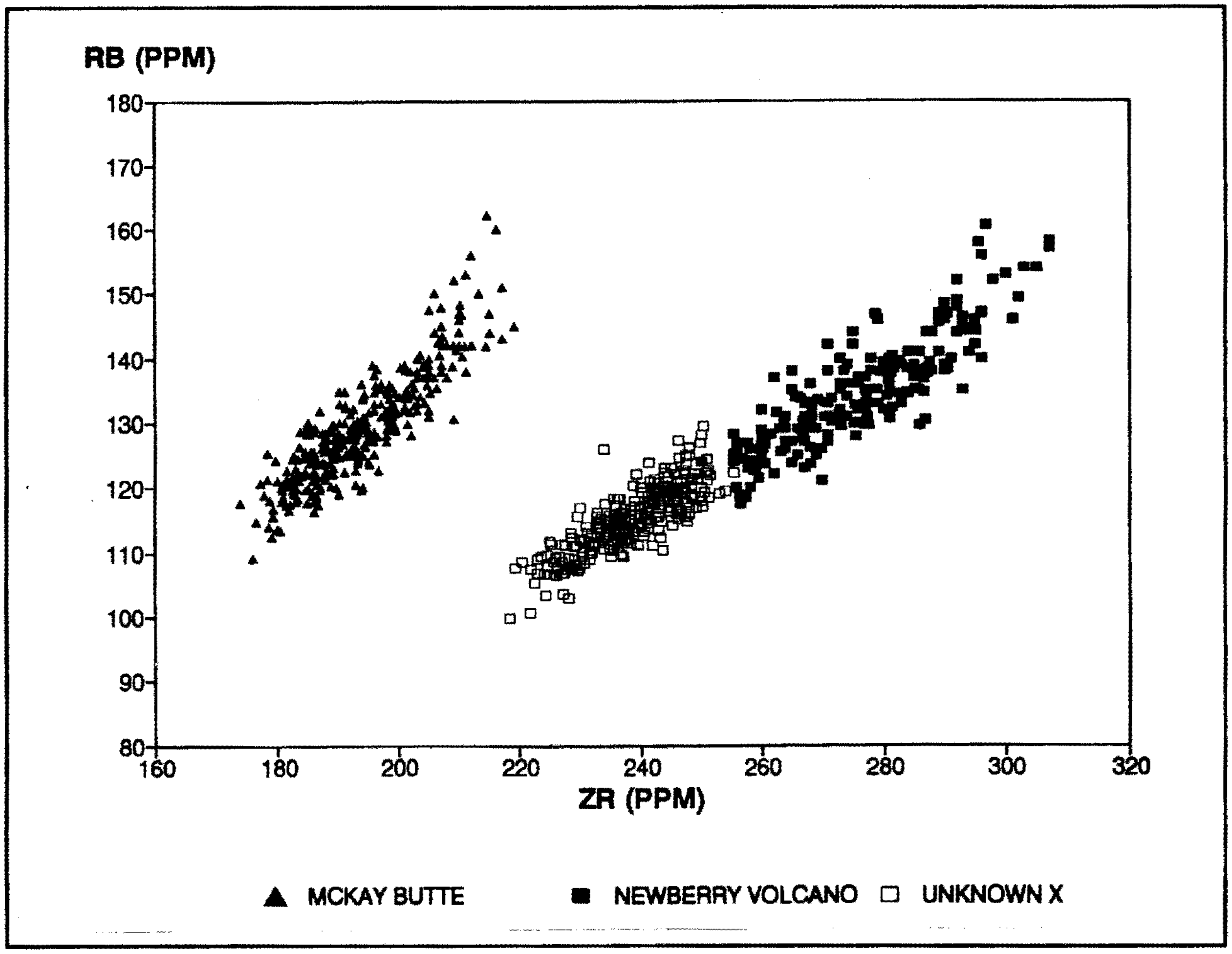

Figure 10. Scatterplot of Rb plotted versus Zr for obsidian artifacts from sites 35-DS-263 and 35-DS-557.

Table 2. Sites with identified Unknown X obsidian.

Site	Unknown X	McKay Butte	Newberry Volcano	Other	Subtotal
35-DS-33	6 (0.6%)	27 (2.8%)	881	50	964
35-DS-263	172 (42.2%)	148 (36.3%)	0	88	408
35-DS-554	1 (4.3%)	1 (4.3%)	16	5	23
35-DS-557	156 (23.9%)	362 (55.5%)	0	134	652
35-DS-865	1 (4.5%)	8 (36.4%)	1	12	22
35-DS-917	14 (13.7%)	24 (23.5%)	3	61	102
35-DS-983	1 (2.6%)	1 (2.6%)	15	21	38
Total	351	571	916	371	2,209

and obsidian hydration analyses of reused surfaces in the same manner that was suggested for the McKay Butte source.

The rapid disappearance of glass from the Unknown X source from artifact collections to the north and south of Paulina Creek, the co-occurence of the material with McKay Butte obsidian, the relative frequencies of glass, and the technological similarities of debitage from the two sources suggests that both sources are located in the same vicinity. Geologic mapping of the area in the vicinity of sites 35-DS-557 and 35-DS-263 indicates the presence of several rhyolite and rhyodacite domes and flows, one of which may prove to be the eventual primary source for the Unknown X material (MacLeod et al. 1982).

Diachronic Characteristics of Obsidian Spatial Patterning: An Early Look

Although we are at a very early stage in the chronologic and spatial analysis of the obsidian characterization data, it is clear that an understanding of the diachronic spatial patterning of prehistoric obsidian use in central Oregon is directly tied to the eruptions of obsidian flows within Newberry Caldera in the period following the Mazama ashfall. The sudden appearance of new sources of glass, perhaps best illustrated by the obsidian hydration distribution frequency curve in Figure 11, had a dramatic effect on the patterns of prehistoric procurement and use of obsidian in central Oregon.

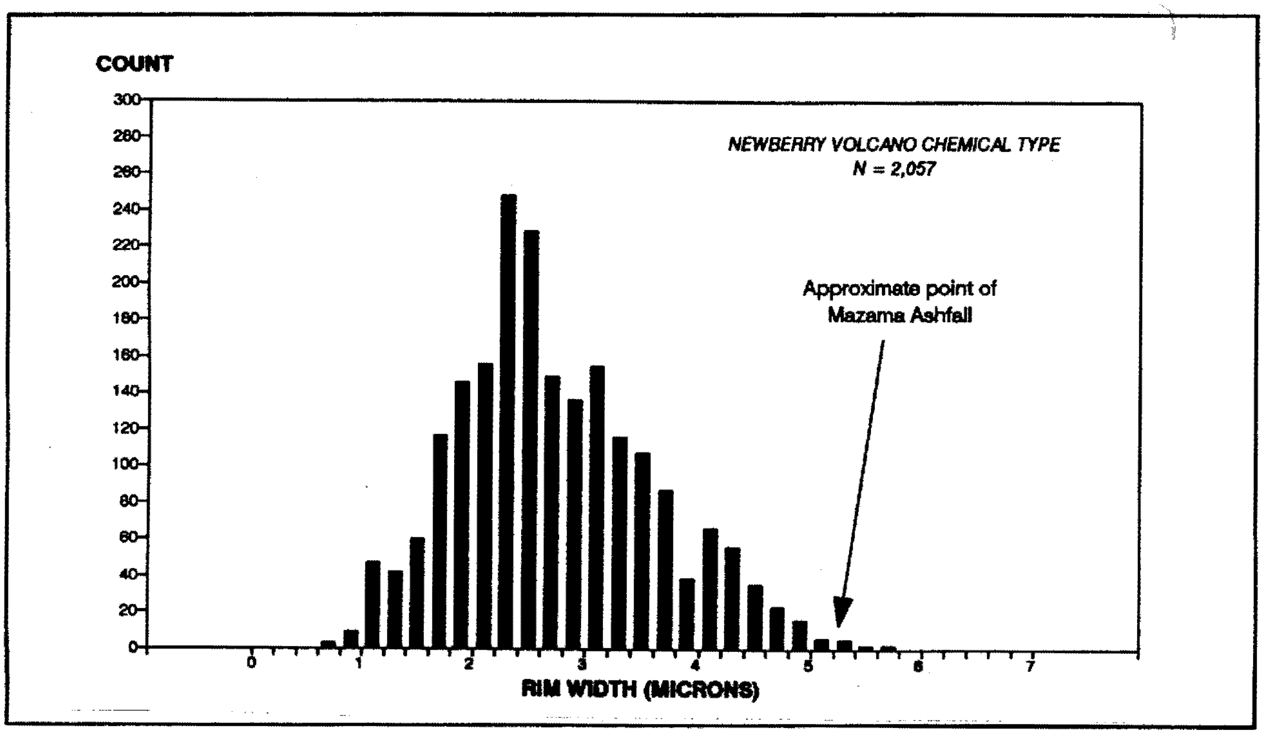

Figure 11. Obsidian hydration rim frequency distribution for all PEP artifacts correlated with the Newberry Volcano chemical group.

Nowhere during the course of PEP obsidian studies was a temporal shift in obsidian source use as striking as at the Deschutes County sites, particularly at 35-DS-263 and 35-DS-557 (Figure 12). Both of these sites contained clearly defined pre- and post-Mazama components and both sites contained large quantities of glass from McKay Butte, Unknown X, and Newberry Volcano.

While the pre-Mazama units were dominated by McKay Butte and Unknown X glass, the use of obsidian in post-Mazama units at the two sites shifts rapidly to obsidian almost exclusively from Newberry Caldera. Obsidian from McKay Butte and Unknown X sources nearly disappears from the archaeological record. The eruption of several obsidian flows within Newberry Caldera closely following the Mazama ashfall combined with the possible burial of

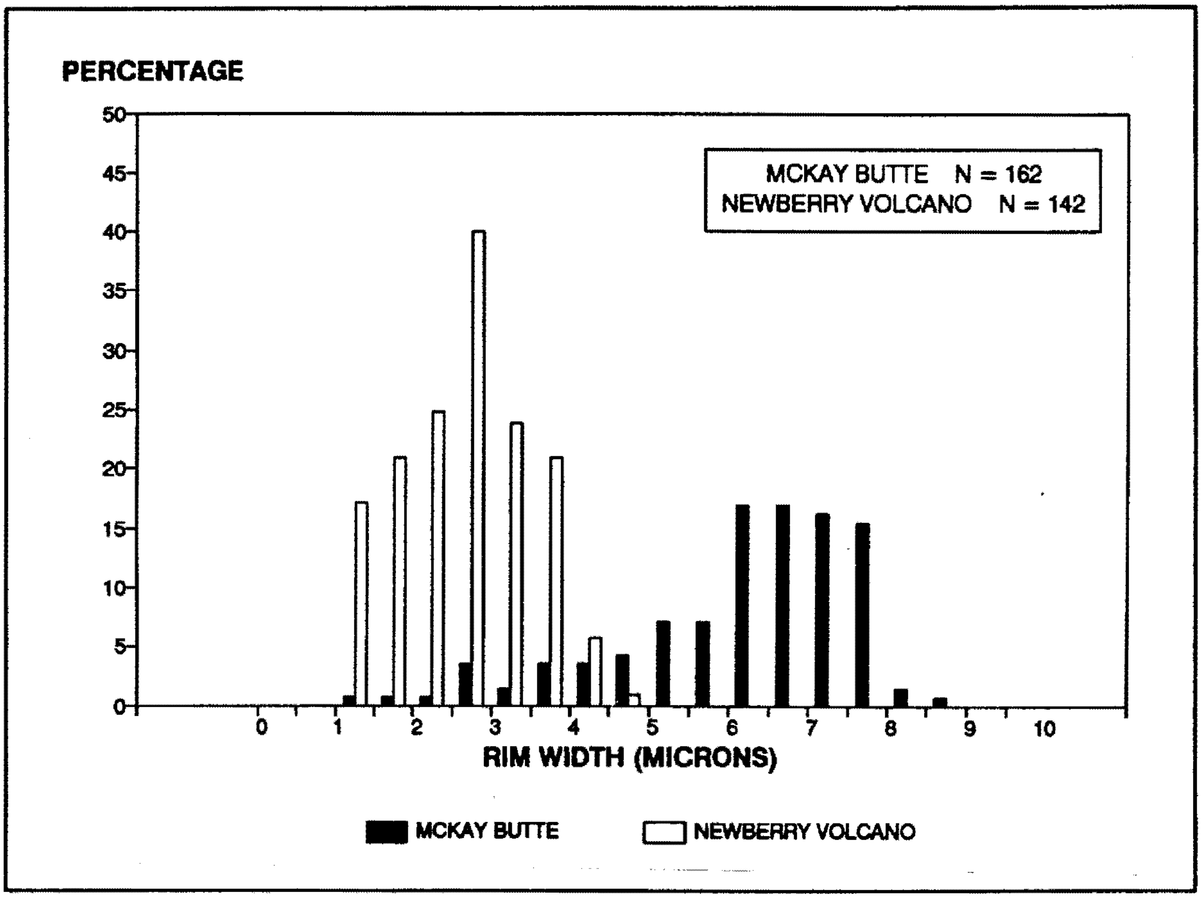

Figure 12. Relative frequency distribution of McKay Butte and Newberry Volcano obsidian at sites 35-DS-263 and 35-DS-429. The shift in use over time from McKay Butte to Newberry Volcano glass is evident.

the McKay Butte and Unknown X sources provides a possible explanation for this dramatic shift in obsidian source utilization in the Newberry Volcano region.

Obsidian Cliffs and the Appearance of Newberry Volcano Obsidian

How did the sudden appearance of Newberry Volcano obsidian affect the prehistoric use of glass from Obsidian Cliffs?

It appears that in the Upper Deschutes River Basin and Newberry Volcano area, the effects of the introduction of new sources of obsidian in the Newberry Caldera on Obsidian Cliffs glass were minimal. The frequency of artifacts manufactured from Obsidian Cliffs material has always been relatively low in this region (Figure 13). In the pre-Mazama period, utilization of glass from McKay Butte and the Unknown X source completely overshadowed that of Obsidian Cliffs material. In the period after the Mazama ashfall and the eruption of the Newberry Caldera sources, glasses from the Newberry Volcano chemical group completely dominate obsidian source use in this region.

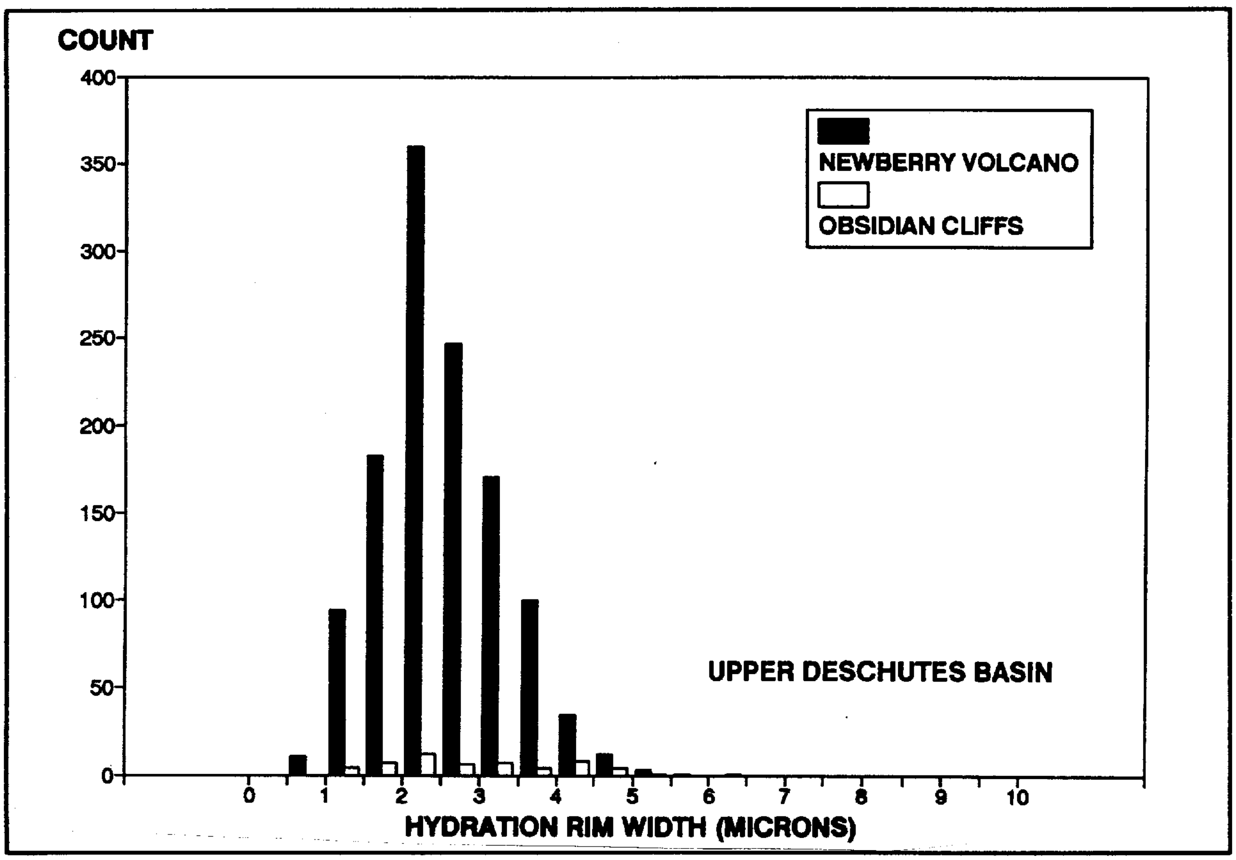

Figure 13. Obsidian hydration rim distribution frequency for Newberry Volcano (Upper Deschutes) region artifacts from Newberry Volcano and Obsidian Cliffs.

In the Lower Deschutes Basin sites of north-central Oregon, however, a different temporal pattern is evident. The eruption of Mount Mazama coincides with hydration rim measurements of approximately five μm for both the Newberry Volcano and Obsidian Cliffs sources. When the hydration rim frequency distribution of the two sources is compared for artifacts recovered from north-central Oregon sites, the relative frequency of clearly co-varies (figure 14). Glass from the Newberry Volcano group appears at a hydration rim width of a little over five μm and rapidly assumes a major role in obsidian utilization patterns in this region. At the same time, the frequency of Obsidian Cliffs artifacts rapidly drops and it appears that this source of obsidian plays an increasingly minor role as the late prehistoric period is reached.

We speculate that the changes in relative frequency of apparent source use over time, as reflected by hydration rim distribution characteristics, is not coincidental and that the availability of glass from the Newberry Caldera sources displaced the importance of Obsidian Cliffs as a regional source of obsidian. Whether this regional shift in obsidian use from Obsidian Cliffs to Newberry Volcano was accompanied by changing seasonal movement patterns is impossible to determine at this point.

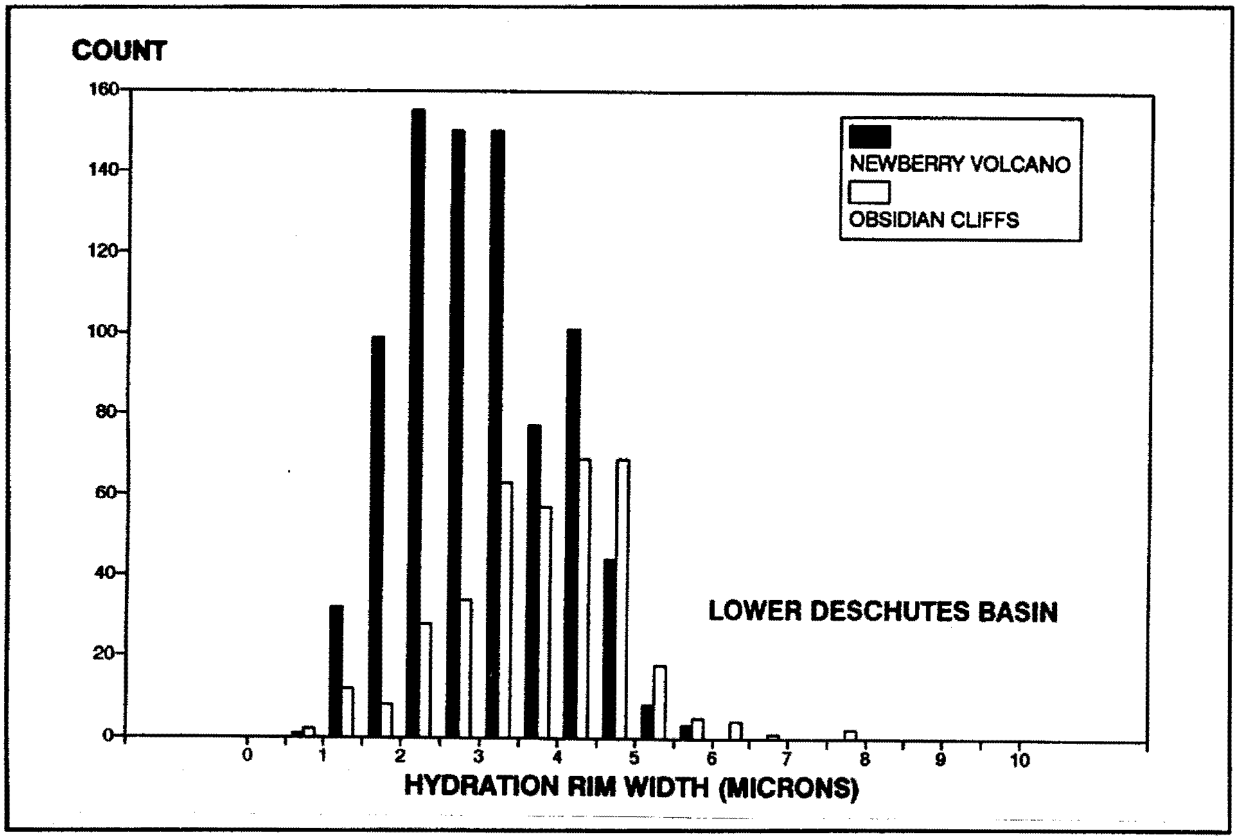

Figure 14. Obsidian hydration rim frequency distribution of north-central Oregon artifacts from Obsidian Cliffs and Newberry Volcano.

Unknown Sources in North Central Oregon

Of the 8,540 artifacts characterized by XRF methods during the Project, 634 were unable to be correlated with known geologic sources of obsidian. After the approximately 350 artifacts assigned to the Unknown X source are removed from this total, north-central Oregon sites are clearly the sources of the largest proportion of the unassigned items.

Unknown source assignments can result from several factors - analytic problems, unrecorded chemical source variability, and unknown sources. While analytical problems likely account for a small number of the unascribed sources, when diagnostic trace element are graphically examined in a scatterplot (Figure 15), the apparent clustering of data strongly suggests that several of the unknown sources are real ones. The visual examination of other trace element pairs also supports the pattern of distinct source clusters. It is clear that researchers looking for new sources of prehistorically-used glass will find rich hunting in Oregon.

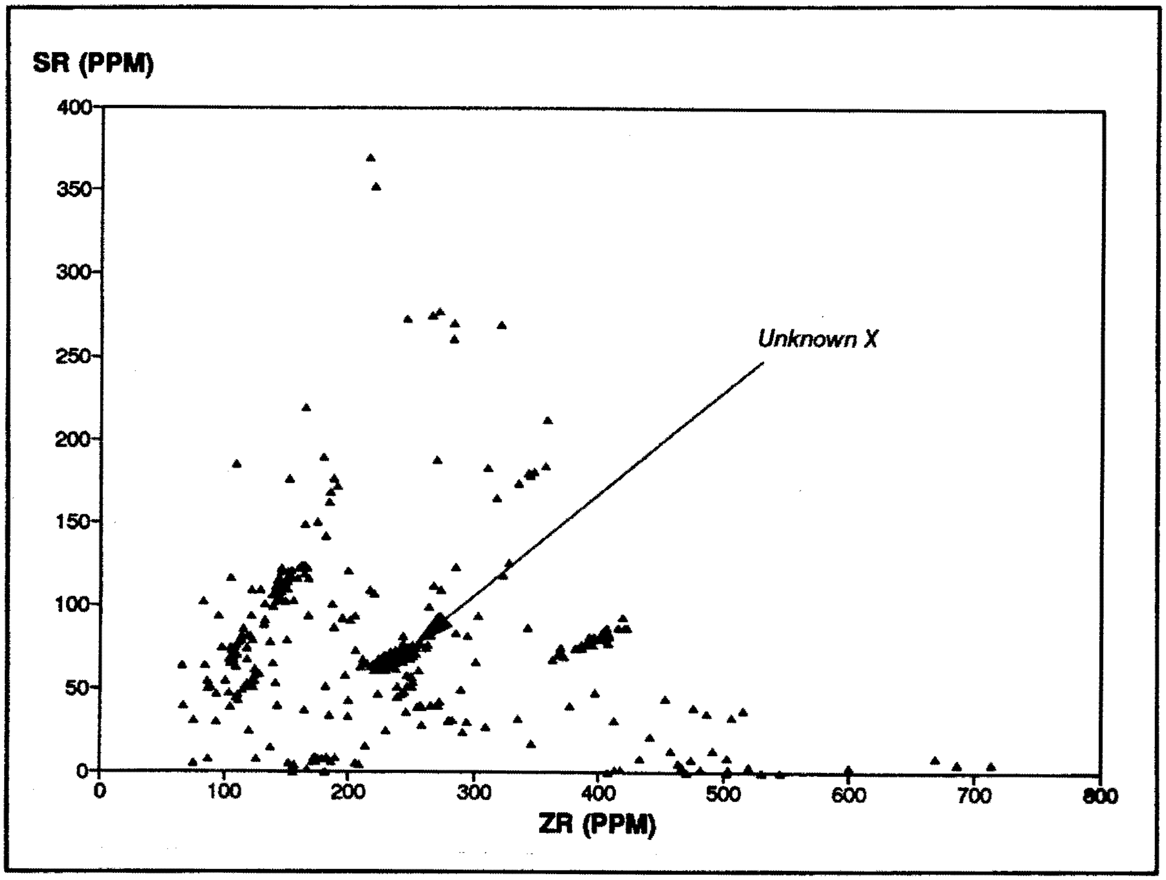

Figure 15. Scatterplot of Sr versus Zr for PEP artifacts from unknown sources.

Designations of samples from unknown sources provisionally classified into discrete chemical source groups must always be considered tentative. Without geochemical source data with which to determine the true range of geochemical variability, it is often difficult to ascertain whether the variation in trace-element data represents the presence of more than one source or simply reflects the chemical range of variation of a single obsidian source.

Obsidian characterization studies of archaeological sites in north-central Oregon, including those sites investigated during the early stages of the Project, have often yielded large proportions of unknown artifact source assignments (Erlandson et al. 1991; Hughes 1987, 1993a, 1993b, 1993c). Archaeological and geological information regarding obsidian in this region is very sparse and low in detail, often limited only to a mention or very brief description of obsidian sources (Bransford and Mead 1975; Brown 1982; Crowley 1960:26; Ericson 1977:316; Hughes 1986b). During the period of the PEP obsidian studies, several new sources of glass in the Ochoco and Malheur National Forests of north-Central Oregon were located, sampled, and analyzed by Richard Hughes. At the current time, however, trace element studies of these sources are still in their very early stages. The number of analyzed samples is low, the geochemical range of variability of the sources is incompletely known, and field studies are still in progress. It is likely that many of the samples assigned here to unknown sources originated from as yet unsampled sources in the Seneca area and the Ochoco-Malheur National Forest region or simply fall outside the chemical range of variability that has so far been determined for known sources.

A significant percentage of the characterized artifacts from the John Day River and Lower Deschutes River PEP sites were initially assigned early in the Pipeline Project to several unknown source groups (Moratto et al. 1990; Speulda et al. 1993). Based on the early results of ongoing trace element studies of obsidian sources from the Seneca and Ochoco/Malheur National Forest regions, it was possible to reassign many of these artifacts to known sources. The Whitewater Ridge and Little Bear Creek chemical group and several other newly-analyzed locales in the northwestern Great Basin and Ochoco and Malheur National Forests proved to be sources of many of these unknowns. Other unknown sources, between 15 and 20 percent of the characterized artifacts in the John Day and Lower Deschutes River drainages, still await positive identification. As trace element studies of obsidian geologic sources in these regions progress, it is probable that many of these artifacts will be found to originate from already known sources whose range of geochemical variability is currently inadequately described. It is a virtual certainty, however, that other new sources of glass that were used by the prehistoric inhabitants of the John Day and Lower Deschutes area sites still remain to be rediscovered by modern archaeologists.

Exchange or Long-Distance Direct-Access Procurement?

Did the prehistoric consumers of central Oregon obsidian go to get it or did it come to them? Was direct access procurement the major process in play or could systems of obsidian exchange have transported the glass to more distant sites in north central Oregon? Evidence for long distance procurement of obsidian is plentiful at north-central Oregon sites. Many, if not most of the sources in north-Central Oregon are found at distances exceeding 100 km (62 mi) from the sites at which they were recovered. Long-distance procurement from the Newberry Volcano region is especially prevalent – over 50 percent of the glass originated from sources located in the caldera or on the flanks of Newberry Volcano.

At this early stage in our investigations, there is little convincing evidence for the existence of indirect obsidian procurement through the operation of exchange systems. The same geographic spatial patterns of prehistoric obsidian source use can result from either long-distance direct procurement or from exchange. Overall, the pattern of obsidian procurement and use at most of the PEP sites is consistent with a model of local direct-access acquisition at nearby sources of glass combined with long distance direct procurement of somewhat more distant obsidian. Most procurement was probably generally embedded within a matrix of normal seasonal subsistence activities (Binford 1979). The distribution of non-local obsidian may also be cautiously used to reconstruct the boundaries of normal seasonal movements and subsistence ranges as well as to explore the possibility of intergroup contact and exchange. Further investigation of the spatial distribution of the characterized obsidian found at PEP sites will focus on the clarification of these procurement patterns and their changes through time.

FUTURE RESEARCH DIRECTIONS

During the last thirty years, trace element studies of obsidian have become a commonplace and invaluable component of archaeological research programs in the Far West. In Oregon and California, in particular, obsidian is frequently an important part of lithic assemblages. The determination of the geologic sources of obsidian artifacts contributes valuable information about the prehistoric procurement patterns that were once in play in these regions. The geographic patterning of characterized obsidian artifacts and sources can provide archaeologists with uniquely convincing evidence for long-distance direct procurement and/or the presence of prehistoric exchange systems. These patterns may also yield clues about seasonal procurement ranges, the location of trade and travel routes, the presence of territorial or ethnic boundaries, differential access to goods, and the changes in these patterns through time. In addition, the determination of the chemical sources of artifacts provides essential information needed for obsidian hydration studies that often accompany artifact source investigations.

Recommendations for Further Research

Although many different obsidian flows, domes, and secondary deposits are known to exist in central Oregon and northern California, prior to this project obsidian characterization studies have been few and far between. Samples sizes have been small and very little was known about the prehistoric distribution and utilization of glass from the many major sources. The mechanisms of prehistoric glass procurement throughout the region transected by the Pipeline were virtually unknown. Until now, theory and speculation about prehistoric obsidian procurement behavior had far outstripped the hard evidence needed to test the substantive hypotheses that will prove of real value to archaeologists. Some future obsidian-related directions and issues in California and Oregon archaeological research might include:

- *Spatial investigations of specific prehistoric obsidian procurement systems or procurement spheres.* From these studies, we can begin to ascertain the significant characteristics of these systems such as magnitude, directionality, and boundaries, and the natural and cultural influences that shaped them. When combined with obsidian hydration data it will also be possible to chart these properties through time as well as through geographic space.

- *Geoarchaeological and geochemical investigations of prehistorically-utilized sources of volcanic glass.* Systematic studies of the primary and secondary distribution boundaries and the range of chemical variability of sources are needed to take full advantage of artifact characterization information. The major sources identified by the Pipeline Project provide a logical starting point for this research.

- *Evaluation of the efficacy of visual characterization methods in identifying sources of obsidian.* The McKay Butte source in central Oregon, as only one example, provides a potentially fertile source of information in exploring the promises and hazards of visual characterization methods. The availability of large numbers of artifacts of known source provenience can provide archaeological researchers with ready-made visual source provenience experiments. Thin sections of these artifacts, already prepared during obsidian hydration studies, also provide researchers with an excellent opportunity to explore the use of microscopic petrographic attributes to identify sources.

- *Identification and geoarchaeological evaluation of unknown sources of obsidian.* The PEP studies presented here indicate that numerous sources sources of glass unknown to archaeologists remain to be found, particularly in north central Oregon. The Unknown X source identified at Newberry Volcano sites is almost certain to lie within a few kilometers of the Pipeline, though it has yet to be located.

- *Exploration of the value of lithic technological data in understanding lithic prehistoric procurement systems.* Technological attributes relating to tool manufacture have been collected for most of the characterized Oregon obsidian artifacts. These data may be used to investigate a variety of technological and procurement issues. What are the relationships of technological attributes to site function or source distance? How can source-specific technological attributes be used investigate prehistoric cultural behavior?

- *Obsidian source diversity issues.* The source diversity – the range of identified geologic sources – may be influenced by several natural and cultural variables. These include the size of the sample, the site function, distance and access to sources, seasonal subsistence activity and territorial boundaries, category and function of artifact, geographic region, and the proximity of competing sources. The database developed here offers a unique opportunity to explore the effects of some of these different variables. For instance, geographically demonstrable differences in diversity may affect sampling strategies in future obsidian research, particularly in the allocation of typically limited obsidian characterization resources. Greater numbers of samples in high-diversity areas will be needed to adequately represent the range of source variability that is expected to be present in these areas.

- *Artifact source diversity issues*. That there is a relationship between formal artifact categories or nonutilitarian and utilitarian artifact groupings and the preferential use of obsidian sources is apparent from recent Far Western obsidian studies. Hughes (1978, 1986, 1990b) and Hughes and Bettinger (1984), in examining the source use of different classes of obsidian tools from southern Oregon and northern California sites, found distinctions in the use of local versus non-local sources. Andrefsky (1994) also points out that the relative availability of different lithic materials also affects their eventual manufacture into formal or informal tools. Given the local availability of a lithic material, ease of procurement tends to outweigh other factors and both formal and informal tools will usually be manufactured from local toolstone. What are the different cultural and non-cultural variables affecting the choice of sources of raw material? The Pipeline Project, with its diverse geographic span, provides an excellent source of data with which to investigate these processes.

- *Relationship between distance to source and intensity of use*. The study of distance-decay or fall-off curves in relation to sources of raw material has been a favorite theoretical topic for many years. PEP obsidian studies can provide investigators with the hard evidence needed to further refine these investigations.

In this paper, we have barely scratched the surface of the potential research value that is contained in the extensive obsidian research database generated during the Pipeline Project obsidian studies. This geochemical artifact and source database holds the promise of providing answers for many of these suggested directions for future research efforts. Prior to the research reported here, very few obsidian characterization studies had been undertaken in the regions bisected by the Pipeline corridor. While this was particularly true in north central and central Oregon, knowledge of obsidian procurement patterns throughout the Project area were very incompletely known. In particular, when these Project data are integrated with already existing obsidian characterization and hydration information, Oregon and California archaeologists will have a body of obsidian-related information currently unprecedented in the world for exploring these different regional research questions and processual issues.

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