AN ABSTRACT OF THE THESIS OF

Jennifer J. Thatcher for the degree of Master of Arts in Interdisciplinary Studies in Anthropology, Anthropology, and Geography presented on December 8, 2000. Title: The Distribution of Geologic and Artifact Obsidian from the Silver Lake/Sycan Marsh Geochemical Source Group, South-Central Oregon.

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Barbara J. Roth

Geochemical characterization methods are commonly used in the reconstruction of prehistoric raw material use and procurement systems. Trace element studies of lithic source material and artifacts, specifically those made of obsidian, can reveal important information about the environmental and cultural factors which influence the prehistoric distribution of raw material. The current investigation uses geochemical characterization methods and data to document and evaluate the distribution of geologic and artifact obsidian that originates from the Silver Lake/Sycan Marsh (SL/SM) obsidian source. This large and prehistorically significant source is located in western Lake County, Oregon.

Few source descriptions or artifact distribution studies exist for SL/SM obsidian. However, over the past decade, a significant increase in the use of geochemical characterization methods has generated a wealth of data for Oregon obsidian sources. This thesis synthesizes the results of the geochemical characterization analysis of 392 geologic obsidian specimens collected from the SL/SM source area and 1,938 SL/SM obsidian artifacts recovered from over 200 archaeological sites in Oregon, Washington and California. The artifact analytical data were derived from previously characterized artifact collections compiled and archived in an extensive database. A subset of artifacts were characterized for the purpose of this study.

Based on the results of geochemical analysis of the geologic material, two distinct source boundaries are defined for the SL/SM geochemical source. The trace element data show that the geologic SL/SM obsidian source material originates from two chemically-related obsidian domes which lie in separate drainage basins. Accordingly, this investigation establishes that the natural distribution of geologic obsidian is highly dependent upon the regional topography.

Spatial analyses of the artifact obsidian demonstrate a widespread distribution of SL/SM obsidian throughout central and western Oregon and parts of northwest California and southwest Washington. Numerous cultural and environmental variables appear to have affected the artifact distribution at local and regional levels. The findings show a predominance of SL/SM artifact obsidian use along the western slopes of the Cascade Range within the southern half of Oregon. Locally, use of the source appears to be less pronounced due to the abundance of competing central and eastern Oregon obsidian sources. The results suggest that SL/SM artifact obsidian was distributed both intentionally and incidentally as a result of prehistoric procurement and exchange systems.

The Distribution of Geologic and Artifact Obsidian from the Silver Lake/Sycan Marsh Geochemical Source Group, South-Central Oregon

by

Jennifer J. Thatcher

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF APPENDICES

LIST OF APPENDIX TABLES

This thesis is dedicated to the memory of Marne Palmateer and my grandparents James S. Gibson and Elizabeth B. Hoffman.

The end is important in all things.
-Yamamoto Tsunetomo

THE DISTRIBUTION OF GEOLOGIC AND ARTIFACT OBSIDIAN FROM THE SILVER LAKE/SYCAN MARSH GEOCHEMICAL SOURCE GROUP, SOUTH-CENTRAL OREGON

1. INTRODUCTION

The research presented in this thesis focuses on the distribution of geologic and artifact obsidian that originates from the Silver Lake/Sycan Marsh (SL/SM) obsidian source located in south-central Oregon. Specific research objectives are:

I. To geochemically characterize geologic obsidian from the SL/SM obsidian source and describe the geographic extent of the geologic source material.

II. To graphically present and evaluate the geographic spatial distribution of over 1,900 prehistoric obsidian artifacts originating from the SL/SM source.

Silver Lake and Sycan Marsh, two physiographic features located in western Lake County, Oregon, are associated with naturally-occurring obsidian deposits. These features have lent their names to what is known as the Silver Lake/Sycan Marsh (SL/SM) geochemical obsidian group (Hughes 1986), one of over 100 documented geochemically distinct Oregon obsidian sources.

Due to an increasing interest over the past 15 years in regional obsidian trace element characterization studies, an extensive collection of geochemically analyzed artifacts and source samples has been compiled by researchers for many Oregon obsidian source locations. However, with the exception of the research reported in the current study, the geographic distribution of geologic and artifact obsidian from the SL/SM source region has been relatively uninvestigated. Previous descriptions of the geographic distribution of raw material from the SL/SM geochemical source have been limited to two primary source locations (Atherton 1966; Hering 1981; Hughes 1986; Sappington 1981b; Skinner 1983). The primary sources are those areas considered to be the points of origin for SL/SM obsidian. Secondary source locations are outcrops that contain geologic material dispersed from the parent source. Although a few secondary SL/SM localities have been documented (Hughes and Mikkelsen 1985), little is known about the secondary boundaries of geologic material from the source. Secondary SL/SM obsidian sources are widely distributed throughout a remote area of Lake and Klamath counties, and as a result, past collection of source samples from this area has been limited.

The research presented in this thesis builds on previous studies of the source region by using obsidian provenance methods and geographic information systems (GIS) to define the geologic source boundaries and plot the spatial distribution of geologic and artifact obsidian from the SL/SM obsidian source. The identified spatial distribution patterns are used to interpret prehistoric use of the SL/SM obsidian source through an analysis of procurement and exchange systems and associated environmental and cultural variables affecting artifact obsidian distribution. Using the results of X-ray fluorescence (XRF) analysis of geologic and artifact obsidian, the research reported here serves to broaden the current understanding of prehistoric raw material use and procurement strategies by groups in south-central Oregon and provides a foundation of spatially referenced data for future research.

1.1 Study Area

The SL/SM geologic source material is restricted to the general area surrounding the two primary obsidian sources located along the extreme northwestern margin of the

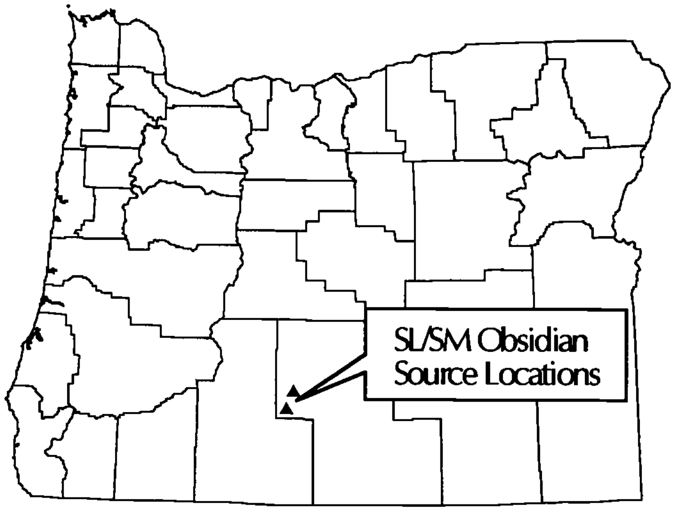


Figure 1.1. Locations of the primary SL/SM obsidian sources, Lake County, Oregon.

northern Great Basin in south-central Oregon. The primary sources consist of two rhyolitic obsidian domes situated approximately 16 and 30 kilometers southwest of the town of Silver Lake, Oregon (Figure 1.1). A variety of geomorphic processes have transported and distributed obsidian nodules and cobbles from the primary sources to numerous geographically-widespread secondary deposits. Deposits and outcrops containing obsidian are found in association with drainages and lacustrine features located along the southern edge of the Fort Rock Basin and within the forested uplands that lie south of this basin and east of the Klamath Basin, predominately within the Fremont National Forest.

1.2 Research Design

The identification and examination of obsidian distribution patterns is made possible through the use of trace element analytical methods such as XRF spectrometry. Although a variety of different analytical methods have been used in obsidian provenance investigations, XRF spectrometry offers a combination of rapid and nondestructive analysis that is often ideally suited for this purpose (Glascock et al. 1998). This analytical tool is used to measure trace element abundances of lithic raw materials (e.g., obsidian) from which geochemical "fingerprints" are determined and upon which chemical source group assignments are based through comparison with existing reference collections. Successful assignment of obsidian artifacts to sources occurs when samples are correlated with known obsidian chemical groups whose chemical compositions have been previously identified. The geographic locations where chemical groups naturally occur are referred to as geochemical or chemical obsidian sources (Hughes 1986; 1998:104). Because geologic obsidian is commonly dispersed by natural processes from primary sources to secondary deposits, the same chemical group will often occur at several obsidian source locations and will frequently be mixed with other chemical groups. For this reason, the definition of geologic obsidian source boundaries for any particular chemical group is critical to the understanding of geologic and artifact obsidian distribution studies.

The geochemical characterization ("sourcing") of geologic and artifact obsidian was used in the current research to identify natural and cultural SL/SM obsidian distribution patterns. The analytical data were compiled in several stages and from several data sources: 1) Field work was conducted for the collection of almost 400 geologic samples from the SL/SM obsidian source area. XRF analysis of these specimens generated the data used to define preliminary SL/SM obsidian source boundaries. 2) A collection of 168 obsidian artifacts was obtained on loan from the University of Oregon Museum of Natural History for trace element analysis. These artifacts originate from field excavations conducted by Stephen Bedwell during the late 1960's at the Connley Caves, a cave site located in the Fort Rock Valley. The Connley Caves artifacts were integrated into this research to provide a general understanding of SL/SM obsidian source use in south-central Oregon and to demonstrate obsidian procurement patterns within the Fort Rock Basin. 3) A project database of more than 1,900 obsidian artifacts correlated with the SL/SM source was compiled from the Northwest Research Obsidian Studies Laboratory reference database. This database contains analytical results of over 40,000 previously geochemically characterized obsidian artifacts from archaeological contexts in the United States. The artifact data used here originated from more than 200 Pacific Northwest archaeological sites.

The geochemical characterization of geologic samples provided the spatial data required to identify the geographic extent of the SL/SM source area. The source boundaries denote the limits of the region from which naturally occurring SL/SM obsidian was available for exploitation by prehistoric Native American populations. Based on the firmly established source area, a synchronic evaluation of SL/SM obsidian artifact distribution in Oregon, northern California, and southern Washington is carried out through a discussion and description of procurement and exchange systems. From this perspective, a reconstruction of prehistoric SL/SM obsidian source use patterns is described for the identified spatial distribution of SL/SM artifact obsidian.

In summary, the main objectives of the research presented in this thesis are the geochemical characterization of geologic and artifact obsidian that correlate with the SL/SM obsidian source area and the presentation, description, and evaluation of spatial distribution patterns of characterized obsidian artifacts for that source. In providing an analysis of SL/SM obsidian distribution, the research presented in this thesis will serve as a foundation for future geoarchaeological investigations of SL/SM obsidian source use.

1.3 Structure of the Thesis

The thesis is presented in seven chapters. Chapter 2 synthesizes the environmental, ethnographic and archaeological context of the study area. The theoretical context and a discussion of procurement and exchange systems is outlined in Chapter 3. Chapter 4 summarizes obsidian provenance studies and explains the field and laboratory methods used in this research. The results of geologic and geochemical source analyses are presented and described in Chapter 5. In this chapter, the geologic source distribution is illustrated with maps created from GIS software applications. Chapter 6 presents the results of artifact analyses and describes potential prehistoric procurement patterns. In the sixth chapter, maps generated with GIS and 3D surface mapping software are used to illustrate the spatial patterning of artifact obsidian. Chapter 7, the final chapter, summarizes the results and discusses future research considerations.

2. ENVIRONMENTAL AND CULTURAL CONTEXT

This chapter provides a synthesis of the environment, ethnographic history, prehistory, and previous archaeological research of the geologic study area. This region encompasses the SL/SM obsidian source area and is described below.

2.1 Environmental Overview

The geologic study area is located on the western edge of Lake County in south-central Oregon along a transition zone between two diverse physiographic regions, the Basin and Range and the High Lava Plains. Among several prominent physiographic features contained within the study area are the Silver Lake sub-basin and Sycan Marsh. These features are associated with geochemically homogenous obsidian deposits originating from two nearby obsidian domes (Figure 2.1). Naturally occurring nodules that have eroded from the obsidian domes are generally found in association with drainages and lacustrine features located along the southern edge of the Fort Rock Basin and within the forested uplands that lie to the south of the basin. The majority of the land within the geologic study area is public property managed by the National Forest Service and the Bureau of Land Management (BLM). Sycan Marsh, located in the southern end of the region, is owned and managed by the Nature Conservancy. The remaining area includes the town of Silver Lake and consists of privately and commercially owned land.

2.1.1 Physiography and Geology

The SL/SM obsidian source area is primarily located in the northwest section of the Basin and Range physiographic province, a region bordered to the west by the High

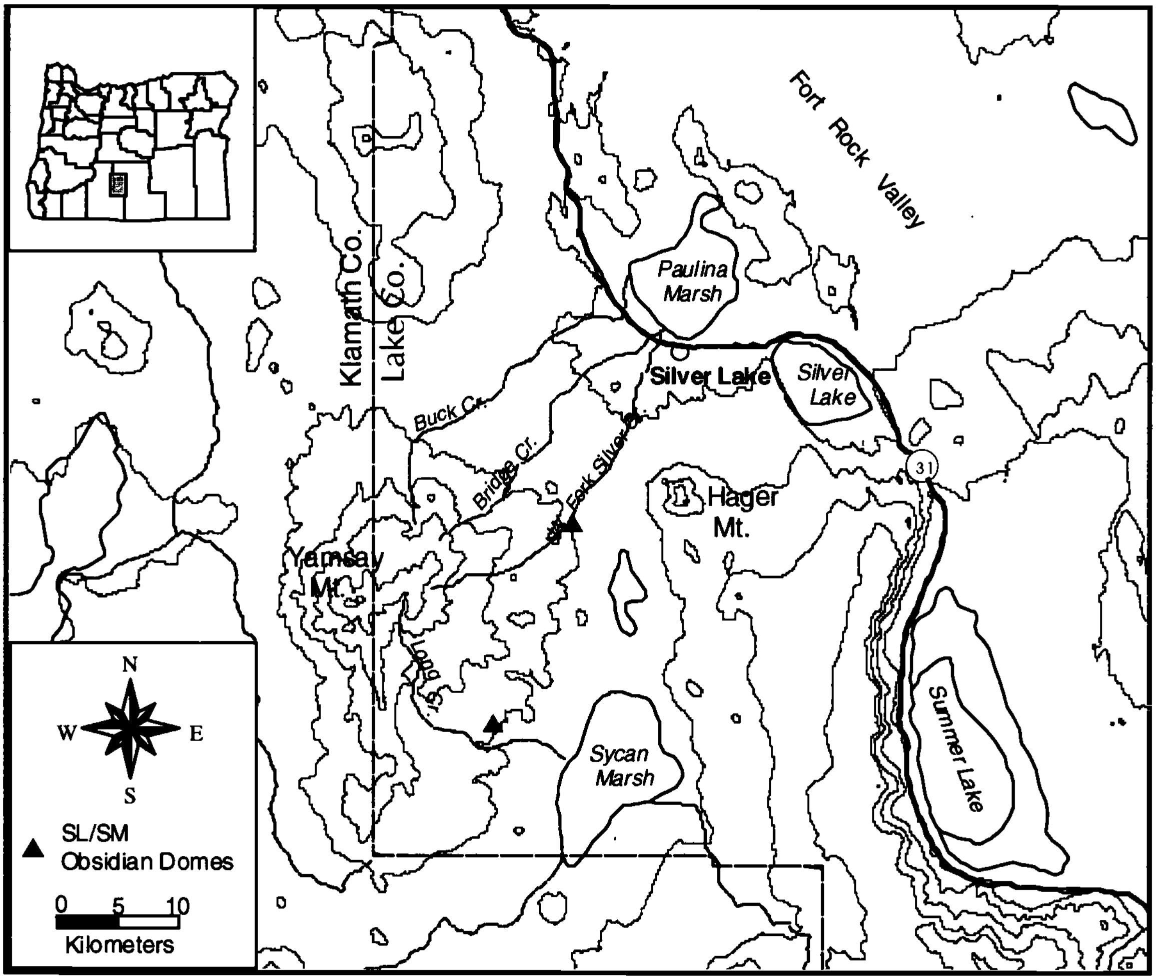


Figure 2.1. Locations of geologic study area and SL/SM obsidian domes.

Cascades and to the east by the Owyhee Uplands. The Basin and Range province falls within the Western Great Basin, a vast, internally drained region of the western United States. The northernmost section of the study area, the Fort Rock Valley, lies within the transition zone of the Basin and Range and the High Lava Plains provinces (Allison 1979:3; Franklin and Dyrness 1988:33-37; Orr et al. 1992:103).

The Basin and Range province is characterized by "a series of long and narrow, north-south trending fault-block mountain ranges alternating with broad basins"

(Orr et al. 1992:79). The fault troughs are deep and in the SL/SM obsidian source region include the Klamath, Fort Rock and Summer Lake basins. Elevation ranges from an average low of about 1200 meters above sea level on the basin floor up to about 1830 meters above sea level at the fault-block rims (Hansen 1947:166). The region is geologically young, consisting of basalt flows, pyroclastics, and alluvium dating from the Miocene epoch to present.

The High Lava Plains, part of the Columbia Intermontane province, is a high plateau made up of lava flows, cinder cones and buttes, and scattered centers of silicic volcanism. Tectonic activity was frequent in this region during the Pleistocene and Holocene epochs as is evidenced by hundreds of fault lines that underlie this province. The vertical landform displacement is relatively minimal, and with the exception of cinder cones and buttes, the topographic relief of the High Lava Plains is smooth to moderate, maintaining a general elevation of about 1070 to 1200 meters (Aikens 1993:18; Franklin and Dyrness1988:32; MacLeod et al.1992). This province extends into the Fort Rock basin where it merges with the Basin and Range province. One prominent volcanic formation in this transition zone is Fort Rock, a rhyolitic tuff ring that was eroded on its southern margin during the Pleistocene by the wave action of pluvial Fort Rock Lake. This vast paleolake was one of many that were formed in area basins during the Pleistocene as a result of cooler and moister conditions (Antevs 1948, 1955; Hansen 1947). According to Freidel, at its peak shoreline elevation of 1384 meters, Fort Rock Lake "would have covered an area of 2310 km^2" (Freidel 1993:51).

2.1.2 Hydrology

Ephemeral and intermittent streams drain the uplands into shallow lakes, marshes, and playas. Exceptions in the Fort Rock Basin include Buck, Bridge, and Silver creeks, perennial streams that drain the northeastern slopes of Yamsay Mountain and Walker Mountain from the southwest into Paulina Marsh (Forbes 1973:23; Freidel 1994:29). Silver Lake, an ephemeral lake located on the southeastern edge of the Fort Rock Basin, serves as a shallow catch-basin for excess water flowing south from Paulina Marsh during seasons of increased precipitation (Freidel 1994:29). The hydrology of Silver Lake has varied in historical times ranging from dry during periods of reduced precipitation to marshy or wet in winter or moist seasons (Allison 1979:28; Friedel 1994:29; Russell 1884).

Within the uplands portion of the study area, to the south of the Fort Rock Basin, two perennial streams, Long Creek and the Sycan River, flow into Sycan Marsh. Long Creek drains into the marsh from the southwest side of Yamsay Mountain. The Sycan River passes through the southern tip of Sycan Marsh, flowing west and then south into the Sprague and Williamson river systems of the Klamath Basin. The rivers of the Klamath Basin, physiographically tied to the Oregon Great Basin region of the Basin and Range province, are part of a larger river system that drain into the Pacific Ocean (Orr et al. 1992:79).

2.1.3 Climate

The modern climate of the northwestern Great Basin varies according to regional topography. The Fort Rock Basin, situated at an average elevation of 1310 meters above sea level, has dry, hot summers, and cold, snowy winters. Annual precipitation averages about 15 to 25 centimeters, with summer temperature highs above 100° Fahrenheit and winter temperature lows below 0° Fahrenheit (Aikens 1993:18; Silvermoon 1985:15-16).

Extreme temperature ranges are also typical in the forested uplands that lie to the south of the Fort Rock Basin. Precipitation increases at the higher elevations, however, averaging from about 20 to 100 centimeters annually. The climate of the two regions is best described as semi-arid and is characterized by low annual precipitation, high summer and low winter temperatures, and low relative humidity.

2.1.4 Flora

Within the study area, there are three forest and steppe vegetation zones identified by Franklin and Dyrness (1988) and described by Hansen (1947) and Silvermoon (1985:16-18). These include the Pinus Ponderosa Zone, the Juniperus Occidentalis Zone, and the shrub-steppe zone. The Pinus Ponderosa Zone occurs on high slopes and ridges (1,450 - 2,300 meters in elevation), and consists of ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), mountain mahogany (*Cercocarpus ledifolis*), and quaking aspen (*Pinus tremuloides*). Shrubs such as bitterbrush (*Purshia tidentata*) and Idaho fescue (*Festuca idahoensis*), grasses, and sedges make up the understory environment. The Juniperus Occidentalis Zone (ranging between 1,200 - 1,600 meters elevation) is the transitional zone between the Pinus Ponderosa Zone and the shrub-steppe zone and consists of western juniper (*Juniperus occidentalis*) and a mixed sage environment. The shrub-steppe zone occurs on the basin floor and adjacent non-timbered slopes and ridges (1,200 - 1,400 meters). This zone is dominated by xeric species including sagebrush (*Artemisia tidentata*), greasewood (*Sarcobatus vermiculatus*), saltbrush (*Atriplex sp.*), and a variety of grasses. Within the wetlands environments located on the basin floor, the plant associations are dominated by tule (*Scirpus sp.*), cattail (*Typha latifolia*), and sedges (*Carex spp.*).

The paleoenvironment differed from the current environment in terms of climatic regimes and associated resource productivity (Jenkins et al. 2000). Changes in moisture and temperature resulting from variable climatic regimes affected the biota and subsequent resource availability throughout the Holocene. Periods of increased winter precipitation and temperate spring-time conditions are linked to biotic productivity, especially within the wetland environments. Extremes in temperature, however, are associated with decreased resource productivity. Paleobotanical evidence reveals that waada (*Chenopodium* and *Sueada*) and a variety of wetland grasses were important subsistence resources within the lowland areas during wet cycles that occurred throughout the Middle and Late Holocene. During the late Holocene, when the climate was drier, upland areas were exploited for edible roots including biscuit root, yampah, sego lily and wild onion (Housley 1994; Stenholm 1994).

2.1.5 Fauna

A wide variety of fauna inhabit the northwestern Great Basin and are summarized here by Aikens:

> Pronghorn antelope, mule deer and elk are common. Mountain sheep are ... occasionally seen, as are black bear, while bison were present in early historic times but are now locally extinct. Jackrabbits, cottontail rabbits, squirrels, pocket gophers, raccoons, badgers, weasels, and other rodents and small carnivores are well represented.

> Coyotes and bobcats are prevalent, and mountain lions still are occasionally reported. Native fishes include suckers, chub, and dace, as well as trout and salmon in certain situations. Over 150 avian species are known to occur in the northern Great Basin, with migratory birds particularly abundant in marshland situations (1982:141).

Comprehensive descriptions of modern fauna are well documented in the existing literature (Bailey 1936; Loy 1976; Minor et al. 1979).

Remains of artiodactyls, rabbits, waterfowl, and fish are commonly observed in regional archaeological assemblages (Jenkins et al. 2000:21). Faunal remains vary according to site location and climatic and temporal association. Within the wetland environments, fish, in particular the tui chub (*Gila bicolor*), and meat and eggs from waterfowl played an important role during periods of optimal conditions. The regional marshes, lakes, and rivers were also magnets for migratory terrestrial mammals, including mule deer and antelope. During periods of drought, animal populations diminished with the reduction of water resources. Mammals experienced reproductive stress due to a decline in available food resources. Tui chubs and other fish species reduced in number from an inability to tolerate increasing salinity levels of receding marshes and lakes (Jenkins et al. 2000).

2.2 Ethnographic Overview

The interpretation of cultural remains is dependent upon many factors, including the context, condition, and quantity of material recovered. The practice of inferring past human behaviors from the archaeological record is greatly enhanced by the use of ethnographic analogy, a means of examining relationships between living groups and prehistoric material culture. This method has long been a common practice in archaeology, but was formally recognized with the development of the New Archaeology in the 1960's (Ascher 1961; Binford 1967) and has since been regularly used to generate hypotheses about prehistoric cultures.

Unfortunately, ethnographic evidence frequently does not provide direct links to intangible aspects of past lifeways such as cultural affiliation or linguistic association. Moreover, early ethnographic accounts in the Great Basin and adjacent regions were often limited and biased. For example, the earliest ethnographies of the Oregon territory were geographically restricted to areas that were most desirable to the first explorers and settlers. For the most part, the Great Basin region of Oregon was avoided by Euro-Americans who sought navigable waterways and productive agricultural land (Suphan 1974:14). By the time ethnographies of the region's occupants were compiled, disease and displacement had already disrupted the aboriginal way of life.

Despite the inherent limitations and biases, much has been gained from existing ethnographic accounts of the linguistically distinct Northern Paiute and Klamath-Modoc groups who inhabited south central Oregon at the time of European contact. Both Klamath-Modoc and Northern Paiute groups occupied portions of south central Oregon within the study area (Figure 2.2) and had direct access to the SL/SM obsidian source region. The following discussion summarizes historical accounts of these two groups.

2.2.1 Tribal Distribution

Tribal distribution maps drawn at the time of contact generally place the eastern territorial boundary of the Klamath-Modoc to the east of Sycan Marsh and extending

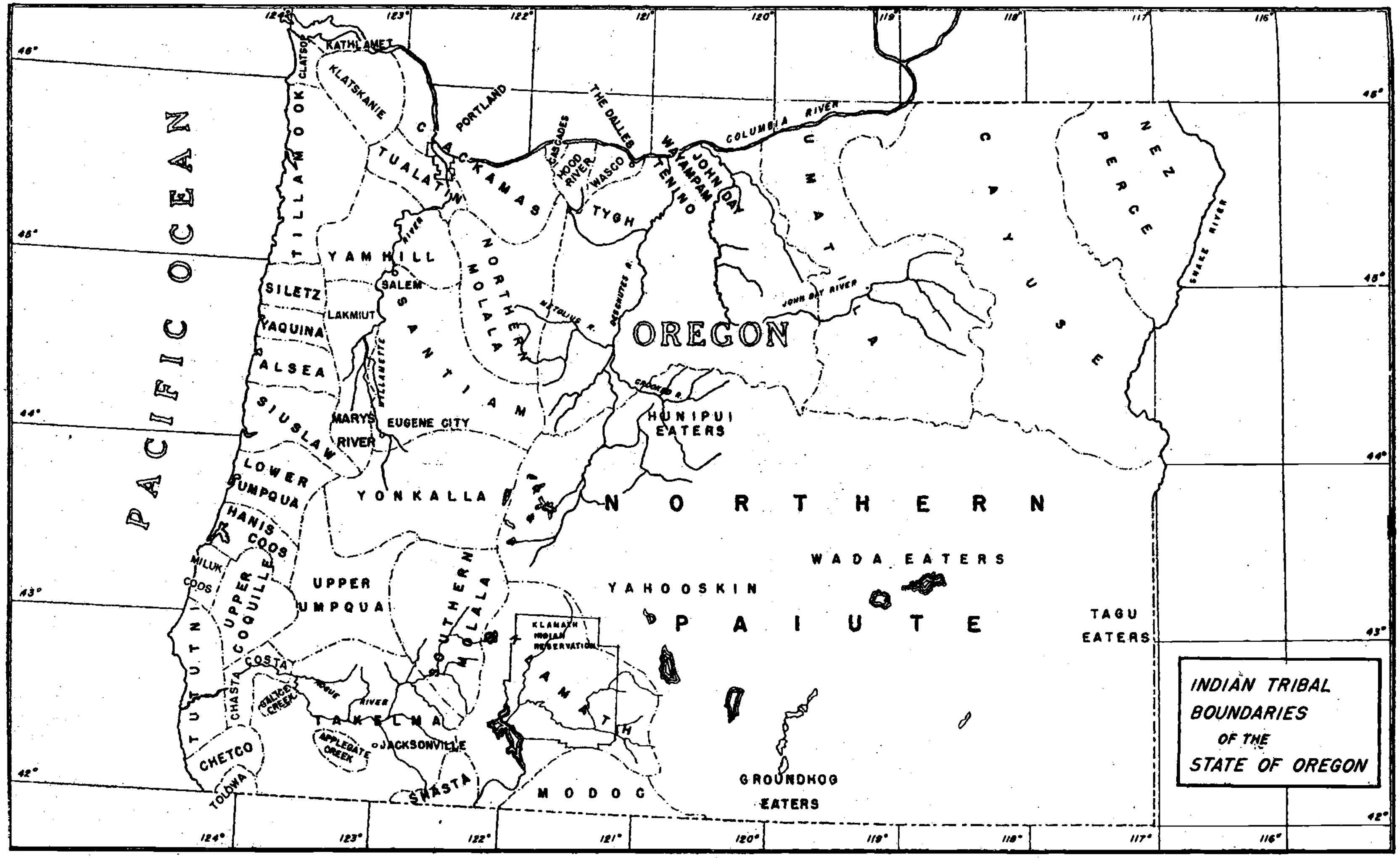


Figure 2.2. Oregon tribal distribution (from Stern 1965:279).

northwest towards Yamsay Mountain (Spier 1930; Stern 1966; Stewart 1939). Spier distinguishes five tribelets within the Klamath-Modoc territory, and describes the Sycan Marsh area as having been used for fishing, hunting waterfowl and harvesting plant resources during summer months by the Upland Klamath of the Sprague River Valley (1930:12-21).

Just east of the Klamath territory, the Yahuskin band of the Northern Paiute is thought to have occupied an 8,000 square kilometer area that included the Fort Rock Basin, Silver, Summer, and Abert lakes (Stewart 1939:132). However, the boundary lines are obscure around Sycan Marsh, as Stewart also notes use of the Sycan Marsh by the Yahuskin:

> Gatschet, writing that before 1864 the Yahuskin haunted Goose, Silver, Warner, and Harney lakes and Chewaukan and Sycan marshes, provides identification for the Indians seen at Summer Lake (near Silver Lake) by Fremont, who distinguished them from the Klamath in the mountains to the west. The Klamath-Paiute boundary of this vicinity has been considered by several anthropologists who agree on all except the area of Sycan Marsh, used by both peoples (1939:132).

The Klamath-Modoc inhabited marsh and riverine environments within the Klamath Basin and subsisted on a variety of plant and animal resources such as fish, roots, seeds and berries. The Northern Paiute groups were desert dwellers who mostly made use of widely distributed Great Basin resources including game, roots, and seeds. The Sycan Marsh region, which sits on a physiographic transitional zone between the Great Basin and the Klamath Basin, was probably shared by both culture groups on a seasonal basis in late prehistoric times. In earlier times, however, there is some indication that the Klamath-Modoc territory originally encompassed large areas of south-central and southeastern Oregon, and possibly extended to the Steens Mountain region (Kelly 1932; Oetting 1989:235).

2.2.2 Subsistence and Settlement Practices

Julian Steward has provided a wealth of information on the subsistence and settlement practices of aboriginal groups (Steward 1933, 1938, 1939). His seasonal round concept is the principle model used to interpret prehistoric hunter-gatherer resource procurement systems. The seasonal round emphasizes an interactive relationship between humans and their environment and embodies the ecological aspects of prehistoric resource procurement and settlement patterns.

Seasonal exploitation of available resources was documented in Steward's 1933 study of the Owens Valley Paiute (see also Figure 2.3). His ethnographic work among this group demonstrated that the subsistence strategies of hunter-gatherers represented an adaptation to the constraints and opportunities provided by the surrounding environment. Jennings (1957) applied this model to the Desert Culture concept in which he recognized a correlation between material culture and arid environments, stating that "small groups moved regularly from place to place, from valley to upland, in search of the seasonal animal or plant resources from centuries of experience had taught them were to be had." (1957:3). This type of mobility strategy led to social fragmentation (Steward 1963:105) and high mobility in areas that contained sparsely distributed resources, and in contrast, aggregation and semi-sedentism in areas with abundant resources.

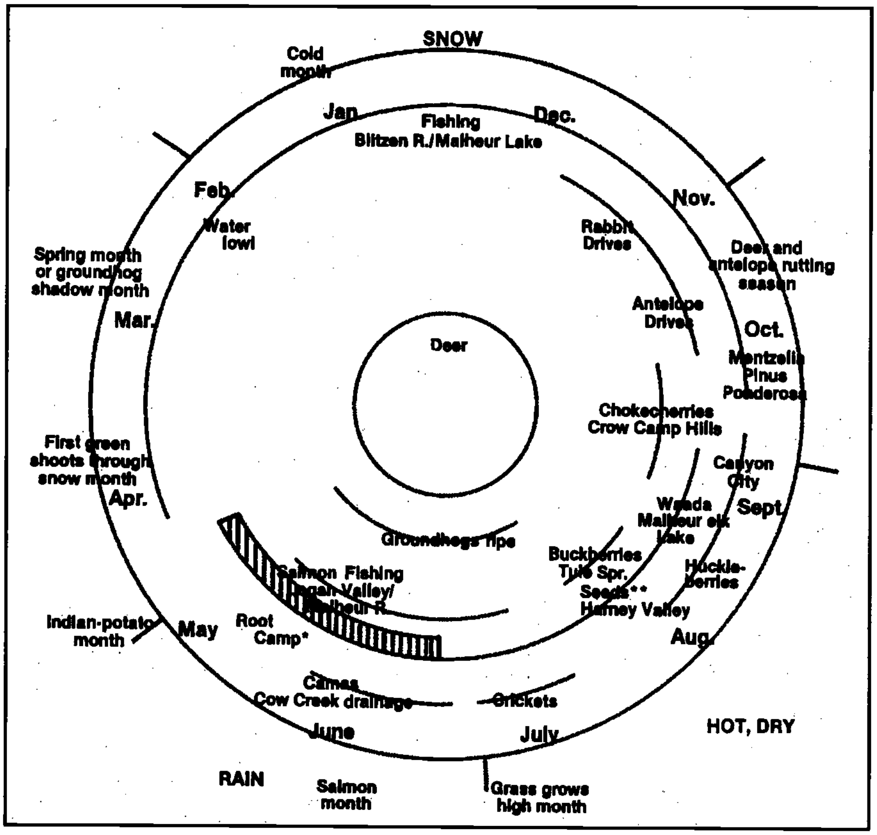


Figure 2.3. Harney Valley Paiute seasonal round (from Aikens 1993:16).

Within the northern Great Basin, settlement and subsistence systems are shown to adhere to the "fusion-fission" concept described by Thomas (1983:32). Kelly suggests that a stress-based model operated in Great Basin hunter-gatherer societies, from which "forced" sedentary behavior was manifested from lack of available resources (Kelly 1983:312). However, abundance-based models are prescribed for evidence of sedentism and semi-sedentism seen in regional wetland adaptations by many researchers who view environmentally productive environments as magnets to otherwise highly mobile groups (Aikens 1985; Aikens and Jenkins 1994; Bettinger 1978; Cannon et al. 1990; Musil 1995; Oetting 1989; Pettigrew 1985).

Ethnographically, both Klamath (Spier 1930; Stern 1966) and Northern Paiute (Kelly 1932) groups exhibited aggregation and dispersal behaviors, although the degree of seasonal movement and the types of resources procured differed in respect to resource availability. The Klamath bands took advantage of lake and marsh environments situated within their territory. Biota associated with Upper and Lower Klamath lakes and Klamath and Sycan marshes included a rich supply of waterfowl, fish, game, and plant resources, most notably seeds from the wocas (water lily) plant. The relative abundance of plant and animal resources permitted the Klamath population to follow a settlement pattern involving limited seasonal movement. Permanent villages consisting of semi-subterranean earth lodges were established in the Klamath Basin for winter months and were often located near resources that would be exploitable in the warmer seasons. Groups converged at the villages during the winter and subsisted on cached food and supplies procured earlier in the year. At the onset of spring, much of the population would leave the winter villages in smaller groups and disperse to sucker fishing camps, to fish, hunt, and gather other materials in preparation for the next winter. These small groups would erect temporary shelters at seasonal campsites to exploit available plant and animal resources before moving on to a new location and finally ending up back in the winter village. Sycan Marsh, which derives its name from the Klamath words *saiga* and *keni*, meaning the "level grassy place" (McArthur 1992:814), was used as a summer camp by the Upland Klamath tribelet (Minor et al. 1979:107).

In the spring, the Klamath fished for salmon, suckerfish, and trout from streams and rivers and began procuring of roots, shoots, seeds, and fruits. Summer villages were located along the streams and within walking distance to digging grounds. Throughout the summer and into the fall, the Klamath gathered camas, wapato, yarrow, balsamroot, biscuitroot, tarweed, tule, cattail, wild celery, mosses, shellfish, and waterfowl eggs. Wocas seeds, an abundant resource of particular importance to the Klamath diet, were collected during late summer from the lakes and marshes. In the fall, seeds and berries (serviceberry, western chokecherry, currants, and huckleberries) were collected from higher elevations along the slopes above the streams and rivers. Hunting for game was a year-round activity, but groups participated in long-distance hunting mostly during the fall.

Less is known about the particular subsistence and settlement practices of the Yahuskin Northern Paiute. Ethnographic accounts of the Yahuskin document fishing, hunting, and animal drives in the Silver Lake area (Kelly 1932:96) and evidence of root gathering and grass burning in the Chewaucan River Valley (Silvermoon 1985:48). In general, the Great Basin bands maintained seasonal rounds within established territories, sharing areas along the fringes of territorial boundaries. The lack of widely available resources in the Great Basin kept Northern Paiute bands highly mobile throughout most of the year. During spring, summer, and fall months, foraging groups were small, typically limited to the nuclear family. In the winter, semi-permanent villages made up of several families were constructed in the valleys near lakes, marshes, perennial streams, and caches of food (Minor et al. 1979:97). Winter subsistence in the Great Basin consisted of cached seeds, dried roots and meats, and fresh game.

In early spring, the fishing season commenced and the first available plant resources were gathered from low-lying hills, stream banks and lake shores. Villages were dismantled and families would disperse throughout the region to gather seeds and roots that became available in late spring and early summer, including cattail, rushes, sunflowers, common fescue, wheat grass, Indian rice grass, and bluegrass gathered from wetland environments in the basins. Roots were also important resources that were widely sought by Great Basin groups in the shallow, rocky soils of the upland areas, and included arrowroot, cattail root, tiger lily bulbs, tule, biscuitroot, camas, wild onion, bitterroot, sunflower, and balsamroot. In late summer, berries and other wild fruits were available along the slopes of the basin and near streams. Much of what was gathered during the spring and summer was preserved by cooking, drying and storing in caches for winter use. Hunting of small game and deer by individuals and small groups took place during the summer months, but communal hunting with a focus on waterfowl and rabbits was the norm during the fall and winter when villages were re-established.

2.3 Archaeological Overview

There is extensive literature on the prehistory of the Great Basin dealing with both specific and regional studies. Although broad generalizations can be made in a discussion of the overall paleo-environment, climate, and cultural adaptations of the Great Basin, it should be noted that much variation exists throughout the Basin, and the Basin, itself, should not necessarily be considered a single unit for the characterization of regional adaptations. The following overview briefly summarizes the prehistory of the Northern Great Basin and specifically focuses on the archaeology and known cultural chronology of the Fort Rock and Klamath basins.

2.3.1 Paleoclimate

A basic model presented by Antevs (1948, 1955) and Hansen (1947) introduced a dominant regime used to describe Great Basin climate from the end of the Pleistocene to present times. This model presented a series of three climatic phases: the Anathermal, Altithermal, and Medithermal. The Anathermal was defined as a cool and moist period that gradually gave way to warmer and drier conditions during the early Holocene (9,000 to 7,000 B.P.). The Altithermal (7,000 to 4,500 B.P.) was characterized by weather distinctly warmer and drier than present conditions. The Medithermal (4,500 to present) represented a return to the cool and moist conditions experienced today.

The work put forth by Hansen and Antevs, although a pioneering undertaking in determining early environments, was met with criticism for being too generalized and for not recognizing regional environmental variations. Subsequent modifications to their model have updated the earlier notion that paleoclimate followed a continuum in all areas of the Great Basin (Aschmann 1958; Baumhoff and Heizer 1965; Bryan and Gruhn 1964 among others). Current understanding of Great Basin paleoclimate accepts the general trend presented in Anvtevs' model, but includes the idea that micro-climates exist throughout the basin. Regional differences in climate are seen to have had a variable effect on local resources, and as a result, on cultural adaptations (Madsen and O'Connell 1982:2).

2.3.2 Late Pleistocene/Early Holocene

Early occupation in the Great Basin is marked by the Paleoindian tradition which spans the Pleistocene/Holocene interface from about 11,000 to 7,000 years B.P. The

Paleoindian culture period is characterized in North America by the presence of fluted projectiles, namely Clovis points which range in age from about 11,500 to 11,000 years B.P. to as late as 8,000 years B.P. in some areas. Only a handful of recently identified sites in the Far West, including the Dietz site in eastern Oregon and the Ritchie-Roberts cache in Washington, have produced notable quantities of identifiable Clovis artifacts (Willig and Aikens 1988). However, a time frame for Clovis in the Great Basin is not conclusive as fluted points in the Far West and Arctic regions extend later into the Holocene than they do in the eastern and southern areas of North America. Within the Great Basin, there is little stratigraphic context and no well-documented radiocarbon dates for Clovis points since most discoveries in the region consist of surface finds from deflated pluvial lake shore sediments. Unlike many other North American Clovis sites, Great Basin Clovis points have not been linked to large mammal kill sites.

Presently, Great Basin Clovis point chronology falls within the range of dates provided for reliably dated Clovis points found throughout North America. There are debates over the initial appearance of Clovis in the Great Basin, and it is suggested that the tradition may have coincided with (Grayson 1993; Willig and Aikens 1988; Basgall and Hall 1991) or was perhaps preceded by (Bryan 1988) the Western Stemmed tradition. Fagan (1988) sees a separation of the two traditions and considers Clovis to be the antecedent. Western Stemmed points, which are technologically distinct from fluted points and which show a significant amount of morphological and functional diversity (Beck and Jones 1993), are well dated, spanning a period of time from 11,200 to 7,500 B.P. Not coincidentally, this technology ceases to appear around the time most pluvial lakes were undergoing dessication at the end of the Anathermal.

Both Great Basin Clovis and Western Stemmed points have been found in association with lake-marsh environments. This scenario has provided some indication of early adaptive strategies and subsistence methods that relied on the exploitation of lake, marsh and grassland resources including waterfowl, small and large game, and some plant material. Stephen Bedwell referred to this strategy during the latter part of the Pleistocene through the early Holocene as the Western Pluvial Lakes Tradition (1973:170). Bedwell's terminology described a basic wetlands subsistence model, but over the years his nomenclature has grown to encompass a host of regionally diverse adaptations, many of which are not tethered solely to a lacustrine environment (Grayson 1993:243).

Luther Cressman and Jesse Jennings provided the theoretical framework for Bedwell's interpretation of early Great Basin subsistence and adaptation. Jennings' Desert Culture model articulated Steward's concept of the hunter-gatherer seasonal round and mobility strategy, and was a reflection of Cressman's perception of the prehistoric nomadic aboriginal lifestyle. Based on the material culture from Cressman's early excavations in the northern Great Basin, ethnographic analogy was used to conceptualize prehistoric lifeways of Great Basin occupants. Cressman conducted a series of investigations at south-central Oregon cave sites during the late 1930's (Cressman et al. 1940; 1942). His findings were among the first to provide evidence for early occupation in the Great Basin.

Although Cressman conducted his research prior to the advent of radiocarbon dating methods, the cave sites yielded insurmountable evidence of human antiquity based on the stratigraphic association of artifacts with relatively dated geologic features. His investigations revealed the presence of early occupations below tephra layers originating from Mt. Mazama (Crater Lake) that were then tentatively dated to between 5,000 and 10,000 B.P. (Aikens 1982:142; Cressman et al.1940). Radiocarbon samples later confirmed the antiquity of occupation and provided a more accurate chronological profile of northern Great Basin sites. Samples recovered from Fort Rock Basin cave sites including Fort Rock Cave, Cougar Mountain Cave No. 2, and the Connley Caves, pushed back the earliest occupation dates to over 11,000 years B.P. and possibly as old as 13,200 ± 700 years B.P.

Continued work in the Fort Rock Basin has provided increased clarification of early site function. Western Stemmed points, once thought to have been strictly a lacustrine adaptation and a technology used for large game, have been associated with 9,000 year old rabbit processing sites (Aikens 1993:29). The presence of stemmed points in such a context reflects the adaptation of a tool technology to a change in subsistence methods probably resulting from increased aridity and decreased lacustrine environments. Also reflected is the establishment of a diverse subsistence economy by the latter part of the early Holocene (Oetting 1994).

2.3.3 Middle Holocene

In the northern Great Basin, the Middle Holocene (7,000 to 5,000 B.P.), also referred to as the Early Archaic, is characterized by a replacement of the fluted and stemmed point traditions with Northern Side Notched points, and to a lesser degree, Elko series points (Oetting 1994:58). Notable, however, is the variation in the level of site use. Some regions, such as the Surprise Valley in northeastern California, show evidence of continued site occupation (O'Connell 1975), while others, including cave sites in the Fort Rock Basin, exhibit intervals of abandonment or drastically reduced use (Aikens et al. 1977; Bedwell 1973). Gaps in the Fort Rock Basin archaeological record during the mid-Holocene correspond with the onset of increasingly arid conditions and with the eruption of Mt. Mazama around 6,850 radiocarbon years ago (Bacon 1983:57). However, while the ash fall from the eruption had short-term effects on some local animal populations, the eruption is not shown to have directly resulted in the decline of human occupation of cave sites during this period (Grayson 1979).

Bedwell correlated a hiatus from 7,000 to 5,000 B.P. at the Connley Caves to the dessication of nearby Paulina Marsh and suggested that habitation sites in the area during this time were relocated to existing wetland environments (Bedwell 1973:176). Grayson (1993:248) concurs with this analysis and posits that cave utilization was dependent upon the availability of local water. In keeping with Bedwell's assumptions, investigations of upland spring sites in the northern Great Basin and surrounding region have demonstrated the increase in human occupation at higher elevations during the mid-postglacial period. Kawumkan Springs (Aikens and Minor 1978; Cressman 1956), Medicine Rock Cave (Cressman 1956) and West Lost River (Wilson et al. 1996) in the Klamath Basin, Nightfire Island in northeast California (Sampson 1985), and other upland sites (Fagan 1974) are illustrative of mid-Holocene occupation, some showing evidence of continuous habitation from around 6,000 B.P. to the late Holocene period.

Dune sites located on the Fort Rock Basin floor adjacent to small pluvial lakes and sloughs have also yielded dates that correspond with an early middle Holocene occupation. Radiocarbon dates from Kelly's Site and Locality I, II, and III in the Fort

Rock Valley indicate a sporadic, but well defined, sequence of pre- and post-Mazama occupation (Mehringer and Cannon 1994:320). As with spring sites, dune sites appear to have been preferred for their proximity to available wetlands resources.

2.3.4 Late Holocene

The late Holocene roughly corresponds to 5,000 B.P. to present, and is marked by a broad-scale return to cooler and moister conditions punctuated with intervals of aridity. In the Fort Rock Basin and adjacent regions, this period is culturally subdivided into the Middle Archaic (5,000 to 2,000 B.P.) and the Late Archaic (2,000 B.P. to Euroamerican contact) (Oetting 1994:58). Archaeologically, the Middle and Late Archaic exhibit significant diversity and richness not observed in the earlier periods.

Much of what is currently known about the Middle and Late Archaic comes from archaeological investigations conducted over the past decade by researchers affiliated with the University of Oregon's Fort Rock Basin Prehistory Project (FRBPP) (Aikens and Jenkins 1994; Jenkins et al. 1999). Using interdisciplinary methods and modern analytical tools, the FRBPP has continued research initiated by Luther Cressman with a focus on the past 5,000 years. A brief summary of the FRBPP findings is presented below.

2.3.4.1 Middle Archaic

Lowland Neopluvial hamlets (small villages), hunting camps, and collecting camps typify Middle Archaic site types (Aikens and Jenkins 1994:9). Intensive site occupation with a noticeable dependance on fishing is observed in the cultural deposits of open sites located near lowland stream channels. In both the uplands and lowlands, evidence of hunting and gathering is observed, although site densities are greatest on the basin floor (Aikens and Jenkins 1994:12). Dietary evidence is diverse, and includes waterfowl, fish, small and large game, seeds, and bulbs. An increased significance of plant and seed processing is reflected by an abundance of ground stone artifacts. Reliance on upland roots also appears to have increased during the latter part of this period and may be related to a warming climate and a population expansion (Prouty 1994:592).

Projectile point types associated with the Middle Archaic include Gatecliff Split Stem and Elko series. The Elko series, also associated with pre-Mazama deposits in the Fort Rock Valley (Aikens 1982; Bedwell 1973; Oetting 1994:56), occur in greater numbers during the Middle Archaic than in the Early Archaic, and persist through the Late Archaic. Rosegate series points appear in the archaeological record toward the end of the Middle Archaic, becoming more prominent during the Late Archaic.

At the Big M site located along a now dry stream channel in the lowlands of the Fort Rock Basin, the diversity of the Middle Archaic period is well represented. Included in the artifact assemblage are "stone, bone, and ceramic pipes, bone spoons, and bone and shell beads" (Aikens and Jenkins 1994:9). Projectile points, bifaces, scrapers, knives, lithic debitage, grinding slabs and pestles are also present in the assemblage. Stone balls, whose function has not been identified, have also been recovered from the Bowling Dune site just over a kilometer from the Big M site.

Diverse artifact assemblages are also found in the Klamath Basin. At Kawumkan Springs, the artifact inventory consists of a wide variety of ground stone tools, including manos, metates, mortars and pestles, hammerstones, grinding tools, atlatl weights and bola stones. Lithic artifacts include projectile points, drills, bifaces, a graver, and choppers. Utilitarian and ornamental bone and antler artifacts are also present (Cressman 1956:410-432).

2.3.4.2 Late Archaic

After 2,000 B.P. in the Fort Rock Basin, site aggregation shifts from the basin floor to higher elevations, perhaps in response to increasingly arid conditions and less reliable lowland water sources. A change in dietary focus is also observed as plant resources begin to play a more dominant role in the subsistence strategy. Boulder Village, located in the uplands east of Silver Lake, exemplifies this economic shift. Nestled on the margins of a lava flow, Boulder village consists of over 120 stone house rings and almost 50 cache pits and is thought to be linked to the presence of abundant root crops that grow throughout the Boulder Village Uplands (Aikens and Jenkins 1994:10).

Similar patterns of Late Archaic site intensification are seen at the Peninsula Site in the Klamath Basin. The Peninsula Site is characterized by stone ring features and abundant ground stone artifacts, and is located in a region "associated with root crop exploitation" (Silvermoon 1994:149). Data presented by Silvermoon suggest that environmental and cultural changes in the Klamath Basin affected site location and subsistence methods much as they did in the Fort Rock Basin.

The artifact assemblage of the Late Archaic is relatively consistent with that of the Middle Archaic. Elko series points continue to co-occur with Rosegate series points, although the latter are more frequently observed in the later part of this period. Desert

Side-notched and Cottonwood Triangular points also appear in the record during the Late Archaic. By the Historic period, trade items such as glass beads and metal fragments begin to appear in site contexts.

2.4 Summary

The geologic study area, located in the extreme northwestern corner of the Great Basin, exhibits a wide range of prehistoric and environmental diversity. The region has undergone a long history of fluctuating climatic conditions that have had variable effects on local resources. Throughout the Holocene, these changes in biota have influenced the cultural adaptations of prehistoric populations. Human settlement and subsistence strategies, as evidenced in the archaeological record and in ethnographic accounts, have shifted through time in response to the changing environment. Obsidian procurement strategies were most likely linked to variations in settlement and subsistence practices and are reflected by artifact obsidian distribution patterns. These patterns are shaped by a host of cultural and environmental variables such as territorial boundaries, social networks, ceremonial practices, population density, site type and function, physical barriers, transportation routes, availability of obsidian and distance to the source region. The current research uses geochemical characterization methods to describe aspects of local and regional prehistoric human behavior as observed in the spatial patterning of artifact obsidian from the SL/SM obsidian source. The following chapter presents an analysis of potential human behaviors reflected in obsidian distribution patterns.

3. THEORETICAL CONTEXT

3.1 Procurement and Exchange Systems

Artifact obsidian spatial distribution patterns reflect the prehistoric procurement and exchange of obsidian across a landscape. Archaeological distribution studies are commonly used to link the spatial distribution of artifact obsidian with reconstructions of prehistoric mobility strategies and trade networks. Distribution studies, which dovetail with numerous theoretical frameworks, are best approached through a careful analysis of the ecological, social, and economic factors that influence procurement and exchange systems.

The cultural distribution of artifact obsidian is the result of either exchange between individuals or groups of people or the direct procurement of resources from a source region. Exchange systems involve social networking and the reliance on trade relationships for the distribution of resources. When this occurs, artifact distribution is a consequence of the exchange of raw materials or artifacts (Ericson 1977:146). Direct procurement systems, on the other hand, are related to mobility and subsistence strategies and involve local direct access or long-distance travel to source regions. Among prehistoric hunter-gatherer groups, the direct procurement of obsidian and other non-food resources was most often embedded in subsistence foraging strategies (Binford 1979:259; Shackley 1996:12).

The characteristics of obsidian procurement and exchange systems are influenced by many factors, including territoriality, the nature of access to a source, the type, quality and quantity of material, and the demand for or the need of the resource (Earle 1982:2;

Skinner 1983:88). In order to interpret the patterns of obsidian procurement and exchange systems, it is necessary to identify and characterize the obsidian source (i.e., through trace element studies), identify the geographic extent of the geologic source area, describe and visually analyze spatial distribution patterns, and assess the potential variables that may influence artifact obsidian distribution (Earle 1982:3).

3.2 Characteristics of Procurement and Exchange Systems

The determination of specific distributive processes using spatial distribution patterns has long been a challenge in obsidian distribution studies (Earle 1982; Hodder 1980, 1984; Hughes 1994:366, 1998:110). Early distribution studies using obsidian characterization applications (Cann and Renfrew 1964; Cann et al. 1970; Ericson 1977), established ground-breaking methods for the spatial analysis of obsidian artifacts. However, these studies failed to satisfactorily distinguish between direct procurement and indirect (exchange) methods and tended to assume that all long-distance distribution resulted from exchange.

At the onset of geochemical characterization studies, a common approach to understanding obsidian distribution was the application of regression analysis (Hughes 1998). In regression analysis of artifact obsidian distribution patterns, a distance-decay model is used to identify and compare relationships between two variables such as the percentage of artifact obsidian from multiple sites and the distance between the identified geologic obsidian source and the sites. The distance-decay model is based on the premise that the frequency or magnitude of an occurrence decreases with increased geographic distance from a source (Renfrew 1977). In lithic studies, the cost of collecting raw material resources is expected to rise with increased distance from a source (Ericson 1982:131; Findlow and Bolognese 1982:79) due to socio-political complexities and geographic constraints. "Fall-off" curves generated from regression analysis indicate that direct procurement will give way to other methods of acquisition as the distance increases to reach a source region (Renfrew 1977:77). Exchange may be the only alternative if direct access is challenged by territorial conflicts or physiographic barriers.

Although the method of regression analysis is successful at quantifying the magnitude of an occurrence and its distance from a source, the geographic context is not considered. Distance models "assume spatial symmetry to the obsidian with the source as the focus," a situation that infrequently occurs in artifact obsidian distribution (Skinner 1983:91a). In practice, distribution patterns are rarely symmetrical. Non-local materials can be acquired intentionally or incidentally through exchange (Renfrew 1977:77), gathered during seasonal rounds (Meighan 1992:2), during exploration of outside territories (Shackley 1996:7), during special-purpose trips to source areas (Morrow and Jeffries 1989:28), or through the exploitation of specific sources for non-utilitarian purposes (Hughes 1990, 1994; Hughes and Bettinger 1984).

In a departure from the early obsidian studies, more recent attempts have been made (Bettinger 1982; Hughes 1990; Hughes and Bettinger 1984) to look beyond ecological and economic factors conditioning obsidian distribution through studies of "people-artifact" relationships (Schiffer 1999:166). Studies of this type rely on data with temporal and typological control to address specific questions about cultural factors affecting distribution. Environmental and economic variables also play key roles, but are not the primary focus of obsidian studies as they were in earlier investigations. Using this approach, analyses of procurement and exchange systems can be refined for such aspects of culture as territory and social boundaries (Bettinger 1982; Harro 1997; Van de Hoek 1990), population (Hamusek 1993); mobility and procurement ranges (Shackley 1990, 1996; Skinner 1997), and socio-ceremonial use of obsidian (Hughes 1990; 1994). In these types of studies, many methods of analyses are used to portray attributes of procurement and exchange systems, including dot distribution, choropleth, and isarithmic maps and trend surface analysis. Trend surface models are particularly effective in illustrating quantitative characteristics of procurement such as magnitude of source use. Dot distribution maps are useful in depicting qualitative attributes such as boundaries and the geographic shape of artifact distribution.

Studies such as the current one, which are wide in scope and span a broad continuum of space, time, and artifact types, are restricted to generalized descriptions of the spatial data. However, the analytical objectives of even the most basic obsidian distribution studies are not necessarily limited when relying on interpretations of "human behavior" and not "obsidian behavior" (Hughes and Bettinger 1984:169). That is, obsidian distribution studies are most effective when the characteristics of procurement and exchange systems and the potential variables affecting spatial distribution are considered.

Procurement and exchange systems are best described by a number of different attributes that, when identified in distribution studies, may be quantitatively or qualitatively described and analyzed (Table 3.1). These attributes are significant to spatial distribution studies because they provide a basis for conceptualizing the structure of procurement and exchange systems and because they reflect patterns of variation

Table 3.1. Characteristics of procurement and exchange systems. Adapted from Plog 1977:129 and Skinner 1983:87-88; 1997:15.

Characteristic	**Description**
Content	The raw material type being procured or exchanged, e.g., obsidian.
Magnitude	The quantity of items being procured or exchanged.
Diversity	The variation of raw material and artifact types present in the procurement or exchange system.
Boundaries	The geographic limits of a procurement or exchange system.
Procurement Range and Size	The procurement range is the geographic area covered during seasonal subsistence activities. Raw material procurement may be embedded in (and incidental to) foraging strategies, or may be intentional. Size refers to the territory within which procurement or exchange systems operate.
Acquisition	*Direct vs. Indirect*: collection of raw material at the source by means of direct procurement (direct) as opposed to the acquisition of raw materials or produced goods through exchange (indirect).
	Embedded vs. Intentional: the incidental direct procurement of raw materials during subsistence foraging (reflected by localized distribution patterns) versus the intentional acquisition of raw materials, perhaps outside of a procurement range (reflected by a wide distribution).
	Local vs. Non-local: Raw material obtained from local sources versus raw material obtained from distant sources via long distance travel or exchange.
Temporal Traits: Duration and Change	Duration is the period of time during which prehistoric procurement and exchange systems functioned. Change (diachronic traits) corresponds to changes in procurement or exchange systems through time.
Distance-Decay	The frequency of raw material use in relation to distance from a source area.
Directionality	Related to the flow of goods and whether resources are moving in one or more direction. This attribute is typical of an exchange system where trade implies the exchange of goods and may exhibit a reciprocal movement of resources.
Shape	Refers to the appearance or overall shape of boundaries and includes attributes of symmetry (reflecting the quantity of goods flowing in one direction or another) and centralization (marked by an abundance of resources in a particular area).
Value	Associated with function and the distinction between utilitarian and non-utilitarian goods.
Complexity	The amount of variation found in the above characteristics. Uniform patterns of procurement and exchange indicate simplicity in a system, whereas a high degree of variation is characteristic of a more complex system.

caused by cultural and environmental influences (Plog 1977:130). It is sometimes possible to discern direct procurement from indirect methods by examining the characteristics of procurement and exchange systems. However, interpretations must be cautiously approached because both strategies generate very similar to identical patterns of distribution.

Direct procurement is typically evident at locations closest to the source. This may be reflected by high frequencies in the occurrence of source material observed locally or within an effective distance (Renfrew 1977:72) in which access to the source is unhindered. Local source use is often indicated by lithic assemblages that include early stages of tool manufacture such as the presence of cortex, an abundance of debitage relative to formed tools (Hughes and Bettinger 1982), and overall larger size of artifacts. Conversely, long distance procurement methods (both direct and indirect) tend to produce different types of evidence such as the recycling, rejuvenation, and reuse of lithic artifacts. Time and energy costs associated with long distance acquisition methods imply a relationship between distance and the value of obsidian. High quality non-local glass may be sought in cases where alternative lithic resources are not available or preferred (Morrow and Jeffries 1989). In such areas, a high incidence of source diversity would point to long distance procurement methods.

Exchange is often viewed as more a efficient means of distribution than non-local direct procurement methods (Renfrew 1977; Ericson 1977; Findlow and Bolognese 1982). However, if direct procurement is embedded in subsistence strategies (Shackley 1996) then no extra expenditure of energy is required. Furthermore, if the value of a resource outweighs the procurement costs then raw material may be also obtained as a result of special purpose trips (Heizer 1942; Morrow and Jeffries 1989; Myer 1928). Meighan (1992:3) points out that without evidence to support the exchange of one material for another (e.g., shells for obsidian), it is difficult to conclusively identify which strategy was used.

3.3 Variables Affecting the Spatial Distribution of Archaeological Obsidian

An important consideration in the interpretation of distribution patterns is an understanding of the wide range of variables that shape the distribution of artifact obsidian. The characteristics of obsidian procurement and exchange systems are influenced and controlled by a number of variables which subsequently affect the spatial distribution of obsidian. These include cultural and environmental factors and variables that result in sampling bias (Table 3.2).

Table 3.2. Variables affecting obsidian distribution. Adapted from Skinner 1983:88-90.

Type	Variable
Cultural	Ethnolinguistic, territorial, and sociopolitical boundaries Population stability, mobility and density Cultural preference (color, size, and quality of raw material) Cultural significance (restrictions, prestige) Site function
Environmental	Location of and distance to source and alternate sources Location of trails, routes, and lines of transportation Location of navigable bodies of water (lakes, rivers, streams) Physical barriers (mountain ranges, non-navigable waterbodies) Formation processes
Sampling Bias	Recovery methods Sample size (quantity) Artifact type Minimum specimen sample size required for analytical methods

3.3.1 Cultural Variables

Social, demographic, ideological and technical aspects of culture influence the distribution of artifact obsidian. Variables such as cultural boundaries, population variables, cultural preferences, and site function have a direct bearing on the procurement and exchange of obsidian resources.

3.3.1.1 Cultural Boundaries

Obsidian distribution can be examined at large and small scales, ranging from the inter-regional and inter-site level to inter-site to household level. Large scale distribution is sometimes associated with extensive exchange and procurement networks covering hundreds of kilometers and linking multiple ethnolinguistic regions. In western North America, this type of network proliferated in California (Ericson 1981; Jackson and Ericson 1994), the Midwest (see Hayden and Shulting 1997; Struever and Houart 1972 on the Hopewell Interaction Sphere), the Great Plains (Vehik and Baugh 1994; Wood 1980), and the Southwest (Baugh and Nelson 1987; Ford 1983; Hudson 1978; Spielmann 1982). Ethnographic evidence also documents major trade centers in the Pacific Northwest (Murdock 1965:202, 1980:132; Ray 1938; Ray et al. 1938) where regional groups gathered to exchange a wide variety of goods, including obsidian. The circulation of non-local obsidian in this region is evidenced in the Interior Plateau by the presence of obsidian artifacts from adjacent Great Basin, British Columbia and Columbia Plateau sources (Carlson 1994:394; Galm 1994:281).

Large scale distribution patterns describe generalized systems of procurement and exchange among ethnolinguistic groups but do not necessarily recognize discrete social or territorial groups. Hughes and Bettinger (1984:155-156) point out that ethnolinguistic groups are not homogenous units contained within a single boundary, but instead represent mutually intelligible language groups made up of diverse "tribelets" (Kroeber 1932:258). Small scale distribution, then, may account for patterns visible on a regional landscape and may be reflected in tribal, band, or kin-group territorial boundaries. At this level, territorial boundaries may be implied by spatial distribution frequencies of source material, such as those represented in "plateau and kink" fall-off curves (Hodder 1980:152). In this type of pattern, local source access is indicated by high frequencies of material near the source within the boundary and trade or restricted direct access is indicated by low frequencies of material along the periphery or outside the boundary (Bettinger 1982). Defended territories, where outside groups were not permitted access, would have prevented direct acquisition of source material.

3.3.1.2 Population Variables

In the Great Basin, the adaptive foraging strategy typically involved the fragmentation of large groups into smaller groups. In areas with less abundant resources and subsequently smaller population densities, high mobility and foraging subsistence strategies facilitate the direct procurement of lithic materials. In sparsely populated regions, for instance, obsidian procurement was likely embedded in subsistence foraging (Shackley 1996:12) although exchange and special-purpose trips may have also played a role in the acquisition of lithic resources.

In some cases, the formation of large groups was linked to sedentism which, like smaller mobile groups, also allowed for resource exchange and a subsistence based on an economy of local resource exploitation. A classic example of a stable and sedentary Great Basin population is that of the Owen's Valley Paiute in east-central California. The Owens Valley Paiute inhabited a unique ecological niche that, unlike other areas of the Great Basin, provided abundant and varied resources within a relatively small area. The sedentary lifestyle practiced by the Owen's Valley Paiute featured the exchange of resources between territorial regions (Bettinger 1982:125) and the primary use of the local Fish Springs obsidian source by groups occupying the valley (Hughes and Bettinger 1984:168).

3.3.1.3 Cultural Preferences

A variety of cultural preferences such as color, size, and tool manufacturing quality may have affected prehistoric obsidian distribution (Zeitlin 1982:265). Preference for high quality material may have influenced the collection of distant source material over procurement of inferior local material. Using this logic, it might be expected that particular sources were exploited for appearance (color, translucence, banding, sheen), volume and size, or ritual significance.

Preference for particular source material may also imply prestige, wealth or status. In a study of characterized obsidian artifacts from archaeological sites in northwest California and southwest Oregon (Hughes 1990; Hughes and Bettinger 1984), results of XRF analysis showed that utilitarian tools were manufactured from local obsidian sources whereas ceremonial blades were manufactured from distant obsidian sources. Based on these data, Hughes (1990:54) suggests that "ceremonial strictures" motivated the acquisition of distant source material for non-utilitarian items. In this case, and assuming that cost is a function of distance to source, the procurement or exchange of obsidian for ceremonial purposes would have been costly and subsequently limited to wealthy or elite members of a group. Socio-economic restrictions on obsidian source use, therefore, would have affected non-elites who could not afford to obtain obsidian from the desired sources, or who were not in the appropriate social ranking (Renfrew 1977:77).

However, restrictions of obsidian source use may also be attributed to cultural taboos. Such was the case with the Owen's Valley Paiute who considered obsidian from the Mono Craters source in California to be "poisonous" and therefore unusable (Ericson et al. 1976:225; Heizer and Treganza 1944:305).

3.3.1.4 Site Function

Site function is frequently determined from characteristics of lithic assemblages. Depending on the activities carried out at a site, lithic assemblages vary in terms of the quantity of lithic material, raw material types, and stages of manufacture. Additionally, lithic toolkits differ from site to site as a direct result of raw material availability, visibility, site function and cultural formation processes (discard, reclamation, disturbance, and reuse) (Shiffer 1987). Economizing behavior, for instance, tends to occur as a response to scarce resources and may be manifest in scavenging or recycling activities (Odell 1996:62). Tool conservation, reuse, and rejuvenation is expected at sites characterized by low residential mobility in areas lacking abundant raw material (Kelly 1988:720). However, if raw material is available or if mobility strategies enable direct procurement, different patterns emerge. In such cases, temporary camps will likely show evidence of expedient tool manufacturing activities and residential sites will tend to yield all stages of tool manufacturing debris (Nelson 1991:79).

3.3.2 Environmental Variables

Environmental variables must also be taken into account when reconstructing artifact obsidian distribution patterns. A range of environmental factors affect artifact obsidian including source location, access, and natural formation processes.

3.3.2.1 Source Location

The location of obsidian sources relative to human populations is a major determining factor in the exploitation of obsidian. Typically, local material is favored over more distant sources. In regions where few obsidian sources are found, this type of procurement strategy is fairly straightforward and may be demonstrated by "fall-off" patterns (Renfrew 1977:72). However, regions containing many obsidian sources present more complex distribution patterns as a result of direct procurement and exchange networks. Mobility strategies may account for some circulation of obsidian resources throughout a region where obsidian sources are located adjacent to subsistence resources (Binford 1979:259; Shackley 1996:12). Distance to source or restricted access to a source may be overcome through exchange or "down-the-line" distribution of material where direct procurement is not possible or desired. In some cases, alternate sources of lithic raw material may be preferred if acquisition costs become too high (Ericson 1981:111) as a result of distance or territorial conflict.

3.3.2.2 Access: Transportation and Physical Barriers

Transportation routes, trails, and navigable waters (oceans, lakes, rivers and streams) provide access to source regions and enable the circulation of obsidian via contact with distant or neighboring territories. In California, prehistoric trails have been linked to regional exchange networks which coincide with obsidian artifact distribution (Davis 1961:2; Ericson 1981:111). In some cases, however, transportation may be limited or altogether restricted by physiographic barriers such as mountain ranges, impassable rivers, vast reaches of open water, or as previously mentioned, territorial boundaries.

3.3.2.3 Natural Formation Processes

Although obsidian artifacts are quite durable, they are subject to post-depositional disturbances (Schiffer 1987). At the site level, localized earth-movement processes like bioturbation and cryoturbation compromise the stratigraphic integrity within site deposits and can yield skewed spatial and chronologic information. Although temporal control can be established with artifact typologies, the lack of diagnostic elements at disturbed sites adversely influences the interpretation of obsidian source use through time. At the regional level, artifactual and source obsidian are susceptible to climatic and geologic forces (Schiffer 1987:235). Examples of these agents include mass-wasting, glacial transport, and fluvial transport (Butzer 1982:118; Skinner 1983:54).

3.3.3 Sampling Bias

Bias in the recovery and sampling of obsidian specimens can obscure obsidian source distribution patterns. As a result, several factors must be considered when compiling or using data for distribution studies. These factors include recovery methods, sample size (quantity of samples), artifact type, and the size of specimen required for analytical methods.

3.3.3.1 Recovery Methods

In the field, artifact recovery methods introduce bias at many levels - from the screen size used in excavation to the quantity and type of artifacts collected. The issue of artifact recovery methods may be clouded when relying on data from multiple sources. Generally, however, field sampling methods can be addressed by establishing some type of intra-site or inter-site control. For instance, if diachronic obsidian distribution is the goal of a study, then chronologic control should be established with methods such as projectile point typologies, obsidian hydration measurements, or radiocarbon dates.

3.3.3.2 Sample Size

The number of samples chosen for analysis plays a significant role in obsidian distribution studies, particularly in the determination of specific concepts such as territorial boundaries or social ranking. Distribution studies that use a large sample size or that distinguish between variables such as artifact type and site function will produce more reliable results than those studies that rely on a small sample size. A small sample size does not necessarily diminish the results of a study, however. Rare or unique artifacts, such as Clovis points or ornamental artifacts can provide meaningful source use information for time periods or ceremonial contexts about which little may be known.

3.3.3.3 Artifact Type

Distribution patterns can vary according to the type of artifact (debitage, projectile points, cores, etc.) represented in an analysis. Often, aesthetic artifacts such as complete and diagnostic formed tools may be preferentially chosen for analysis over debitage or tool fragments and subsequently over-represented in geochemical studies. However, the differentiation of artifact type will often reveal information about what kinds of activities were taking place at archeological sites, such as tool manufacture, recycling, or curation. These activities can hold significant meaning in the interpretation of obsidian distribution.

3.3.3.4 Specimen Size

The physical size of specimens is another factor to be considered in distribution studies. XRF analysis of obsidian requires that the minimum size of a specimen be at least 10 mm in diameter and between 1.2 and 2.5 mm thick for successful measurement of trace element values (Davis et al. 1998:178). Geochemical characterization of samples smaller than the minimum required size results in reduced analytical precision and unreliable source assignments. Due to the minimum size requirements, artifacts resulting from certain manufacturing techniques or formation processes are potentially excluded from geochemical analysis. Pressure flakes, micro-debitage from tool rejuvenation, and broken tools such as projectile point tips and bases are frequently too small for XRF analysis.

3.4 Summary

The reconstruction of prehistoric subsistence and mobility strategies derived from obsidian spatial data requires consideration of the procurement and exchange systems responsible for the movement of artifact obsidian. The cultural distribution of artifact obsidian resulting from direct and indirect procurement processes, may be inferred from distribution patterns as the intentional collection of material during special-purpose trips, as incidental procurement embedded in subsistence activities, or as the exchange of goods between individuals or groups of people. The difficulty in distinguishing between direct and indirect procurement activities necessitates the analysis of attributes that characterize procurement and exchange systems as well as an evaluation of the cultural and environmental variables that influence distribution.

Several approaches, including trend surface analysis and distribution mapping, are used in the current research to quantitatively and qualitatively measure the characteristics of the SL/SM obsidian procurement and exchange systems. A visual analysis of the spatial data, in conjunction with an assessment of the variables affecting SL/SM artifact obsidian distribution, provide a means of inferring prehistoric human behaviors from the observed distribution patterns.

4. METHODS

4.1 Obsidian Provenance Studies

Obsidian is a naturally occurring volcanic glass that is chemically related to igneous materials such as rhyolite, basalt and andesite. The chemical composition of obsidian is difficult, if not impossible, to determine visually and as such the term "obsidian" is treated as a textural designation for all natural glass. The sources identified in this thesis are highly silicic, or rhyolitic, in composition.

Obsidian fractures conchoidally when struck with force, a property that makes it particularly conducive to lithic tool manufacture. In addition, because obsidian is an amorphous crystalline glass, it produces extremely sharp edges and smooth surfaces when fractured. Some varieties of obsidian are less homogenous in structure than others, and may exhibit characteristics that are considered undesirable for lithic tool manufacture. An abundance of phenocrysts or other inclusions in obsidian will produce a grainy or sugary texture. This type of obsidian typically has poor fracturing properties and tends to be less functional for tool manufacture than a higher quality or "clean" glass. However, the overall qualities of obsidian make it a preferred raw material over harder and more difficult to work (although more durable) toolstones such as chert and basalt.

Megascopic and microscopic attributes of obsidian such as color, texture, presence of inclusions, luster, and light transmittance will vary depending on both the chemical composition and internal structure of an obsidian flow. These characteristics are useful in describing obsidian quality and appearance and are sometimes used to correlate specimens with parent obsidian sources. However, the use of these methods to visually characterize individual sources are only minimally or occasionally reliable, especially considering the potential range of intra-source variation that is often present. (Skinner 1983:75).

The use of megascopic and microscopic attributes as methods of obsidian characterization are rooted in early obsidian provenance studies (Wainwright 1927; Frankfort 1927). These techniques, and later physical, optical, and petrographic characterization methods use the presence of spherulites and phenocrysts, the refractive index, and density measurements as descriptive attributes (Cann and Renfrew 1964). In some areas of the world where obsidian source groups are limited, visual characterization methods are useful and to some degree adequate for source assignment. Yet, Cann and Renfrew (1964:114) issue a caveat for the sole use of visual attributes in characterization stating that "appearance is not a good guide to the provenance of obsidian, although when it is supported by [other] analyses. . .meaningful statements can be made." Other analyses that are used to characterize obsidian include studies of glass composition (isotopic, major, and trace element abundances), electrical conductivity, fission-track analysis, magnetic susceptibility, potassium-argon age, thermoluminescence characteristics, and alpha and beta counts (Glascock et al. 1998)

4.2 Trace Element Studies

Of the non-visual characterization techniques, trace element composition studies are most commonly used in archaeological research. Trace elements make up less than one percent of the total chemical composition of obsidian, while SiO_2, Al_2O_3, Na_2O, K_2O and Fe_2O_3 constitute the bulk of the composition of the glass. Geochemical characterization methods measure chemical abundances of trace elements which are then used to differentiate between discrete units of obsidian.

Interest in the trace element characterization of obsidian was initiated in the mid-1960's after researchers demonstrated the validity and usefulness of optical emission spectroscopy (OES) on Mediterranean samples (Dixon et al. 1968; Renfrew et al. 1965:233; 1966, 1968). Since then, numerous other applications using variable combinations of trace elements have been conducted (Skinner 1983:80; Glascock et al. 1998:19) including:

- Flame atomic absorption spectrophotometry (AAS)
- Particle-induced X-ray emission spectroscopy (PIXE)
- Proton-induced gamma-ray emission (PIGME)
- Inductively-coupled plasma emission spectroscopy (ICPES)
- Electron microprobe analysis
- Neutron activation analysis (NAA)(Ambroz 1997; Glascock et al. 1998)
- X-ray fluorescence (XRF) analysis (Hughes 1986)

XRF and NAA analysis have proven to be the most frequently used obsidian characterization methods. The preference for these methods is due to their ability to meet several criterion as outlined by Glascock et al. (1998:19):

> In order to be successful, a technique for chemical fingerprinting must be quantitative, capable of simultaneously measuring several elements, sensitive to the elements of interest, independent of sample matrix, and independent of artifact size and shape. In addition, the choice of a method for analysis may depend upon its availability, cost, speed, accuracy, ability to differentiate between sources, existence of comparative data, etc.

Although both analytical methods are ideal, each exhibits advantages and disadvantages. NAA has greater accuracy than XRF analysis, is able to detect a greater number of elements, and provides higher analytical precision. Furthermore, extremely small samples (approximately 10 mg) can be analyzed with this method. Some disadvantages of NAA, however, include the destruction of samples for preparation and the high costs involved to own, operate and maintain the equipment. On the other hand, XRF analysis is much more cost effective than NAA, is non-destructive, and requires less specialized and expensive analytical machinery. XRF analysis is also less time consuming and produces results with an adequately reliable degree of accuracy for most archaeological applications.

There are two types of XRF analysis: wavelength-dispersive XRF (WDXRF) and the more commonly used energy-dispersive XRF (EDXRF). In principle, both methods work to isolate selected elements from a spectrum emitted when samples are irradiated with a low-intensity X-ray beam (Williams 1987:7). The difference between the two techniques is that WDXRF uses a crystal-dispersive spectrometer to detect selected elements, whereas EDXRF uses an *energy-dispersive* spectrometer which uses more efficient electronic detection methods. With EDXRF, a number of elements can be detected simultaneously in contrast with the wavelength method which is only capable of analyzing a few elements at a time (Shackley 1990:173). The data used in this project are derived entirely from energy-dispersive XRF (EDXRF) analysis. The analytical methods are described in a later section.

4.3 Field Methods

The field methods used in this research focused on the problem of identifying the geographic extent of natural deposits of SL/SM obsidian. To meet this goal, geologic samples were collected from public lands in Klamath and Lake counties during two field seasons (1997 and 1998). A permit was not required for geologic sampling on public property (John Kaiser, personal communication 1997). A total of 392 geologic obsidian nodules were collected from 33 locales (see Table 5.1, Figure 5.3, and Appendix B).

Non-probabilistic field methods were used to recover non-cultural obsidian samples by using previously documented SL/SM deposits as points of reference (Atherton 1966; Hering 1981; Hughes 1985, 1986, 1990; Sappington 1981b; Skinner 1983, 1995, personal communication 1997; Skinner and Winkler 1994). Pedestrian surveys were conducted at high-probability sites that included road cuts, stream drainages, gullies, cut banks, marsh and playa shorelines and lakeshore terraces. Sample locations were selected on the basis of their association with and proximity to the primary source deposits, two rhyolitic obsidian domes. Drainages radiating from the domes and playa and marsh shorelines linked to these drainage systems were examined for the presence of obsidian nodules redeposited by erosional and fluvial processes. The survey technique consisted of a reconnaissance of the selected high probability sites in an effort to identify the presence or absence of obsidian nodules. Locations that failed to yield obsidian nodules were noted and locations that contained obsidian nodules were sampled.

A sample constituted an obsidian nodule characterized by a weathered cortex and an absence of cultural modification. To ensure an adequate sample size and thereby account for the presence of outside source groups, 15 nodules were collected from each source location whenever possible. In situations where deposits were limited in quantity, fewer nodules were collected. Where nodules were abundant, 20 or more samples were collected. In all cases, care was taken to select samples exhibiting a variety of megascopic traits, including shape, size, texture, color, and the presence or absence of phenocrysts or other distinctive inclusions.

At each productive locale, collected samples were placed in paper bags labeled with provenance information. Detailed notes describing the geography, hydrology, geology, vegetation, and archaeology (if applicable) were recorded on field forms. Most locations were also photographed and marked on a U.S. Geological Survey 7.5 minute topographic quadrangle map. A Magellan global positioning system (GPS) handheld unit was used to identify the latitude, longitude, and Universal Transverse Mercator (UTM) position for each designated location.

4.4 Analytical Methods

Sample preparation and XRF analysis of the collected geologic reference material was conducted by the author at the Northwest Research Obsidian Studies Laboratory (NWR), Corvallis, Oregon under the direction of Craig Skinner. XRF analyses of the artifact obsidian represented in this study were performed by NWR and additional outside laboratories including BioSystems Analysis Inc. and Geochemical Research (see Appendix F). Differences in the interlaboratory analytical methods were not considered significant enough to warrant further investigation here. The bulk of the artifact analytical data was culled from archaeological reports, letter reports and published sources and was selected on the basis of a correlation with the SL/SM obsidian source. XRF analysis of 168 artifacts from the Connley Caves site was performed by the author at NWR. The following is a brief discussion of the sample preparation and XRF analytical methods used at the NWR laboratory.

XRF analysis is used to determine the chemical composition of a thin surface layer of a sample and a clean surface is required for reliable results. If a sample is not properly prepared, elements present in surficial residues may be detected during analysis, producing results unrelated to the actual chemical composition of the sample. Because of this, the geologic samples were first washed with tap water and a toothbrush, and then sawn or fractured to produce an analyzable surface (flat and at least 10 mm diameter and 1.5 mm thick). Artifacts were prepared by gently washing them with a damp cloth. For those artifacts coated in patina or other surface encrustations, a 10 mm diameter or larger section was scraped with a razor blade to expose a clean surface. Surfaces covered with artifact labels were avoided due to the high iron and zinc content of most archival quality inks used in labeling. Once samples were cleaned, they were then analyzed for abundances of twelve trace elements (Rb, Sr, Y, Zr, Nb, Ba, Zn, Ti, Mn, Ga, Pb, and Th) and one major element (Fe_2O_3) using a Spectrace 5000 energy dispersive X-ray fluorescence spectrometer. Specific details about the XRF analytical procedures are presented in Appendix C.

In addition to geochemical characterization, thin sections from 13 non-cultural SL/SM obsidian nodules were prepared for microscopic analysis. The nodules were chosen from the analyzed geologic reference material and were selected on the basis of megascopically distinctive characteristics (banding, texture, color, luster, shape, etc.). Representative samples were selected from the primary source locations in an attempt to demonstrate the range of visual attributes present in the primary source material. The preparation and analysis of the thin sections was conducted at the Northwest Research Obsidian Studies Laboratory.

A lapidary saw fitted with 4-inch diameter diamond-impregnated .004-inch thick blades was used to make two parallel cuts in each sample. A small wedge produced from the cuts was removed from each sample and affixed to a petrographic microscope slide with Lakeside thermoplastic cement. The specimens were then ground on a plate glass lap in a slurry of corundum abrasive to a thickness of approximately 30 - 50 microns. An Olympus BHT petrographic microscope was used to inspect the prepared slides under a magnification of 500X. The images were directed from a Panasonic color CCTV camera mounted on the microscope to a Panasonic color video monitor and were captured with Snappy Video Snapshot software. The visual attributes of the samples are discussed in the following chapter, and the images and accompanying petrographic descriptions are presented in Appendix A.

4.5 Data Presentation

The display and evaluation of the geologic and artifact obsidian distribution patterns were accomplished by mapping the collection site and archaeological site locations. Many types of two- and three-dimensional analyses were then used to examine and visually portray spatial patterning of characterized obsidian (Table 4.1). Two-dimensional methods of analysis use qualitative or quantitative data and depend on two input variables such as latitude and longitude coordinates or units of distance and frequency. Three-dimensional analysis of distribution patterns require a third variable, such as time, to portray additional information about the spatial data.

Two-dimensional dot maps use geographic coordinates on the x and y axes effectively to demonstrate distribution pattern across a landscape, but are limited in their

Table 4.1. Analytical methods of spatial distribution patterns.

Method	Description
	Two-Dimensional Methods
Two-Dimensional Dot Distribution Maps	Portrays statistical surfaces with point data. Point symbols used in two-dimensional dot maps reflect qualitative information such as geographic location.
Regression Analysis	Distance decay, or fall-off models are the most common methods that use regression analysis. Distance-decay determines the frequency or magnitude of an occurrence at increased distances from a source.
	Three-Dimensional Methods
Three-Dimensional Dot Distribution Maps	Portrays statistical surfaces with point data. Point symbols used in three-dimensional dot maps may be graduated and vary in size, color, and style to reveal quantitative characteristics about the point data.
Graphs, Charts and Diagrams	Pie charts, prism or bar graphs, and spider diagrams may be used alone, or on a map at each point location to show the frequency or magnitude of an attribute for every occurrence.
Choropleth Maps	Displays the magnitude of an attribute within a unit boundary using range-graded symbols for each polygon.
Isarithmic Maps	Similar to contour lines used for elevation maps. Isometric lines portray a simulated three-dimensional surface with the "steepness" or magnitude based on z-values of point data.
Trend Surface Analysis	Displays spatial distribution over a continuous surface. The magnitude or frequency of an attribute (z-value) is interpolated for areas containing no data.

ability to portray frequencies per point (location) or other types of quantifiable data aside from the clustering of point symbols. Regression analysis, a two-dimensional method used to demonstrate the frequency of an occurrence at varying distances, was not used in this study due to the large number of sites and artifacts included in the data set. However, the distance drop-off concept is visually implied on some of the two-dimensional dot maps used in the research in which the density of obsidian artifacts at sites (represented as points), diminishes with an increasing distance from the source region.

Percentage, volume, frequency, magnitude and other quantitative variables are more successfully demonstrated with three-dimensional methods such as charts, choropleth maps, isarithmic maps, and trend surface analysis. Trend surface analysis, in particular, is an effective method of mapping spatial distribution patterns through the interpolation of point data across a continuous surface. The application of this method results in a contoured surface which illustrates z-values much as a topographic map portrays physical relief of landforms.

The data used in this research are visually portrayed in maps, charts, and trend surface images generated with ArcView and ArcInfo Geographic Information Systems (GIS) software and Surfer, a grid-based computer graphics program. Grapher, a statistical software package, was used to create scatterplots of geochemical source groups presented in Chapter 5. These tools facilitate the analysis of spatial data and are ideally suited for the interpretation of spatial distribution patterns. GIS software uses relational databases to provide links between mapped variables and their attributes and, like contour and 3-D surface mapping programs such as Surfer, also enable users to generate multiple perspectives of spatial data. Both GIS and grid-based programs are particularly effective in geoarchaeological applications that rely on the ability to relate material remains with geographic location.

5. RESULTS OF GEOLOGIC SOURCE ANALYSIS

5.1 Previous Studies

As a result of past research and ongoing geochemical investigations, a great deal is now known about Oregon obsidian sources. Over 100 discrete geochemical source groups have been identified in Oregon. Yet, based on a survey of over 20,000 geochemically analyzed obsidian artifacts from several hundred Oregon archaeological sites, the majority of artifact obsidian is derived from fewer than 20 of the identified chemical groups (Skinner 2000). The SL/SM chemical group is among the Oregon obsidian source groups that make up this majority, but aside from the current research, little descriptive information exists for the SL/SM obsidian source region.

Obsidian associated with the SL/SM chemical group is found at two primary source locations and in many secondary outcrops scattered along the southern margin of the Fort Rock Basin and in the general vicinity of the Sycan Marsh and the northeastern Klamath Basin. The SL/SM primary obsidian sources consist of two rhyolitic obsidian domes located low on the eastern flanks of Yamsay Mountain, a large Pliocene shield built up from a series of mafic and silicic volcanic events. The domes sit approximately 16 kilometers apart on a north-south axis along the extreme western edge of Lake County in what once was part of the Klamath Indian Reservation (Figure 5.1).

The SL/SM obsidian source region was first mentioned by Atherton (1966:30–33) in a brief discussion of the "Silver Lake quarry" (the northernmost primary source), so named for the nearby town of Silver Lake, Oregon. The nomenclature was adopted by Wright et al. (1969:27) who made a reference to "Silver Lake" obsidian in an early

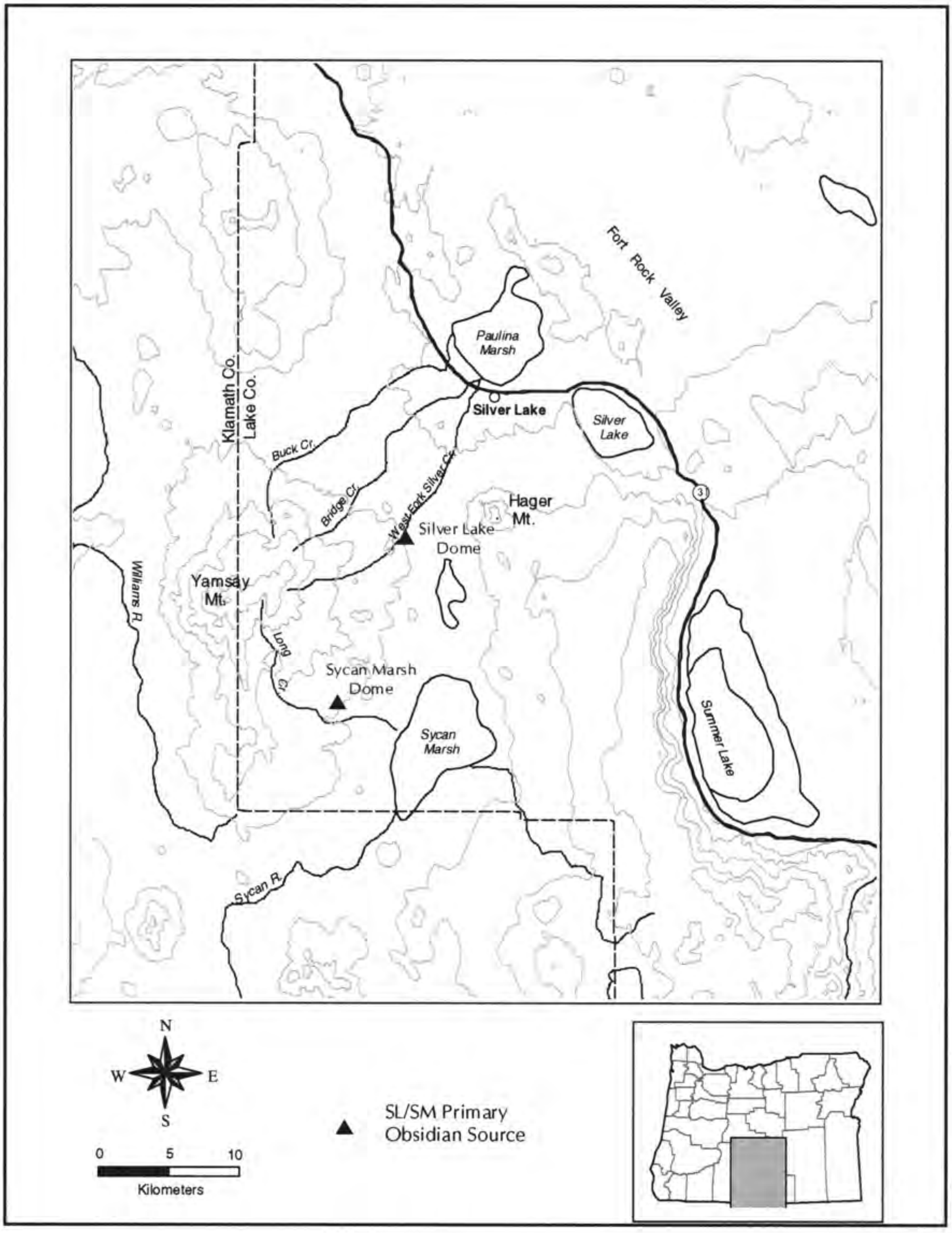


Figure 5.1. Locations of the primary SL/SM geologic obsidian sources.

obsidian characterization study of artifacts from Veratic Rockshelter, Idaho, and later by Skinner (1983:271) in a summary of the "Silver Lake area obsidian."

In a geologic investigation of the Yamsay Mountain geologic complex, Hering (1981:20) identified and mapped the two obsidian domes, later referred to as the "Yamsay Mountain" obsidian source by Sappington (1981b:4). In a description of the Yamsay Mountain area, Hering (1981:20) described the domes as:

> ...both composed of black, faintly banded obsidian, containing rare phenocrysts of plagioclase...These domes are both almost completely buried by younger basaltic-andesite flows, but the distribution of float in surrounding areas indicates that originally they were of much larger areal extent.

The legal description provided by Hering (1981:155) for the northern dome is consistent with the location of the Silver Lake quarry described by Atherton (1966:30). Obsidian from source localities adjacent to the southern dome, located due west of the Sycan Marsh, is chemically related to obsidian from the "Silver Lake" dome and was first reported by Hughes (1986:313-314) as the Silver Lake/Sycan Marsh chemical group.

Smaller secondary outcrops of SL/SM obsidian have been reported from scattered locations in the region surrounding the two primary sources. Nodules of obsidian from this chemical group are found in gravels and lakeshore deposits associated with Pluvial Fort Rock Lake in the Silver Lake sub-basin (McDonald et al. 1992:198-199; Skinner 2000) and in gravels along the margins of Sycan Marsh and the Sycan River (Hughes 1985:33; 1986:313-314). Obsidian nodules have also been found in association with archaeological sites near Paulina Marsh and at other locations in the Silver Lake sub-basin (Jenkins 1994:230; Jenkins and Aikens 1994a:270).

5.2 SL/SM Source Description

Obsidian from the SL/SM chemical group exhibits variable megascopic and microscopic traits. The visual appearance and physical characteristics are reported below and are presented in Appendix A. Descriptions of nodule shapes and sizes are based on standards outlined by Pettijohn (1975:30, 57). The terminology used to describe megascopic and microscopic attributes is derived from various sources (Adams 1980; American Geological Institute 1972; Dana 1959; Skinner 1983, 2000).

5.2.1 Megascopic Characteristics

Colors range from dark black to dark grey with occasional banding, and mostly opaque to somewhat translucent light transmittance. Depending on the crystallinity of the glass, the surface luster and texture range from vitreous and flawed to matte and grainy (almost sugary) in appearance. Nodule size and shape vary greatly and are dependent on the method of transport from the primary source and the distance of transport. The primary SL/SM deposits contain small angular and subangular boulders (400 mm to

256 mm), cobbles (256 mm to 64 mm), and some pebbles (64 mm to 4 mm) (Figure 5.2). Outcrops of obsidian located at short distances from the primary sources contain less angular and somewhat smaller nodule sizes, while more distantly located outcrops contain rounded nodules of increasingly diminished size (Figure 5.3).

5.2.2 Microscopic Characteristics

Microscopic inclusions are common in SL/SM obsidian and include varying densities of phenocrysts, prismatic microlites, and magnetite. High densities of

Figure 5.2. Primary source material. Obsidian boulders and cobbles located at the Silver Lake dome.

Figure 5.3. Secondary source material. Obsidian nodules mixed with gravels in a Fort Rock Basin drainage.

inclusions found in SL/SM obsidian are frequently associated with banding. The less common greyish-black material with matte surface textures exhibit a highly crystalline structure containing dense quantities of phenocrysts. Asteroidal and acicular trichites are observed in rare SL/SM obsidian specimen with megascopic traits of brown ribbon mottling typical of "mahogany" varieties of obsidian.

5.3 XRF Trace Element Analysis

During the summers of 1997 and 1998, a total of 392 geologic obsidian samples was collected from the two primary source areas and 30 secondary locations in the Fort Rock Basin and the Fremont National Forest. The samples were gathered from accessible high-probability areas, including drainages, lakeshore terraces, and road cuts. When possible, particularly at deposits containing abundant nodules, up to 20 samples of variable size, texture, color, and shape were selected. Specific details about collection methods are discussed in Chapter 4.

Using XRF analysis, the samples were measured for trace element abundances at Northwest Research Obsidian Studies Laboratory in Corvallis, Oregon. The analytical methods are summarized in Chapter 4 and described in Appendix C.

5.3.1 Results of Analysis

Thirteen geochemical source groups, twelve of which were correlated with known geologic sources, were identified among the 392 analyzed samples. The results of the XRF analysis are summarized in Table 5.1 and are presented in Appendix D. The locations of the known geochemical source groups identified in the research are shown in

Table 5.1. XRF analytical results from 1997 and 1998 geologic field sampling.

Collection Locality	Bald Butte	China Hat	Cougar Mt.	Cowhead Lk.	Duncan Cr.	Guyer Cr.	Hager Mt.	Quartz Mt.	SL/SM	Spodue Mt.	Variety 5	Witham Cr.	Unknown	Total
							1997							
97-1	–	–	–	–	–	–	–	–	15	–	–	–	–	15
97-2	–	–	–	–	–	–	–	–	15	–	–	–	–	15
97-3	–	–	–	–	–	–	–	–	15	–	–	–	–	15
97-4	–	–	–	–	–	–	–	–	15	–	–	–	–	15
97-5	–	–	–	–	–	–	–	–	20	–	–	–	–	20
97-6	–	–	–	–	–	–	–	–	11	–	–	9	–	20
97-7	–	–	–	–	–	–	3	–	12	–	–	–	–	15
97-8	–	–	–	–	–	–	–	–	1	2	–	–	–	3
97-9	–	–	–	–	–	2	–	–	–	–	–	–	–	2
1997 Total	**0**	**0**	**0**	**0**	**0**	**2**	**3**	**0**	**104**	**2**	**0**	**9**	**0**	**120**
							1998							
98-1	–	–	1	–	–	–	–	–	–	–	–	–	1	2
98-2	–	–	–	–	6	–	3	–	6	–	–	–	–	15
98-3	–	–	–	–	–	–	5	–	9	–	–	–	–	14
98-4	–	–	–	–	–	–	5	–	6	–	–	–	–	11
98-5	–	–	2	–	–	–	2	–	1	–	–	–	–	5
98-6	–	–	1	–	–	–	12	–	10	–	–	–	–	23
98-7	–	–	–	–	–	–	7	–	7	1	–	–	–	15
98-8	–	1	3	–	–	–	–	9	–	–	–	–	1	14
98-9	–	–	–	–	–	–	4	–	1	1	–	–	2	8
98-10	–	–	–	–	–	–	–	–	15	–	–	–	–	15
98-11	–	–	–	–	–	–	–	–	–	–	–	15	–	15
98-12	–	–	–	1	–	–	–	–	–	2	–	12	–	15
98-13	–	–	–	–	–	–	–	–	–	19	–	1	–	20
98-14	–	–	–	–	–	–	–	–	–	10	–	–	–	10
98-15	–	–	–	–	–	–	–	–	–	–	–	15	–	15
98-16	–	–	–	–	–	–	15	–	–	–	–	–	–	15
98-17	–	–	–	–	–	–	15	–	–	–	–	–	–	15
98-18	–	–	–	–	–	–	20	–	–	–	–	–	–	20
98-19	–	–	–	–	–	–	10	–	–	–	–	–	–	10
98-20	–	–	–	–	–	–	–	–	–	–	–	3	–	3
98-21	–	–	–	–	–	–	–	–	–	2	–	1	–	3
98-22	–	–	–	–	–	–	–	–	–	4	–	–	1	5
98-23	1	–	–	–	–	–	1	–	–	–	1	–	–	3
98-24	1	–	–	–	–	–	–	–	–	–	–	–	–	1
1998 Total	**2**	**1**	**7**	**1**	**6**	**0**	**99**	**9**	**55**	**39**	**1**	**47**	**5**	**272**
							Combined 1997 and 1998 Totals							
	2	**1**	**7**	**1**	**6**	**2**	**102**	**9**	**159**	**41**	**1**	**56**	**5**	**392**

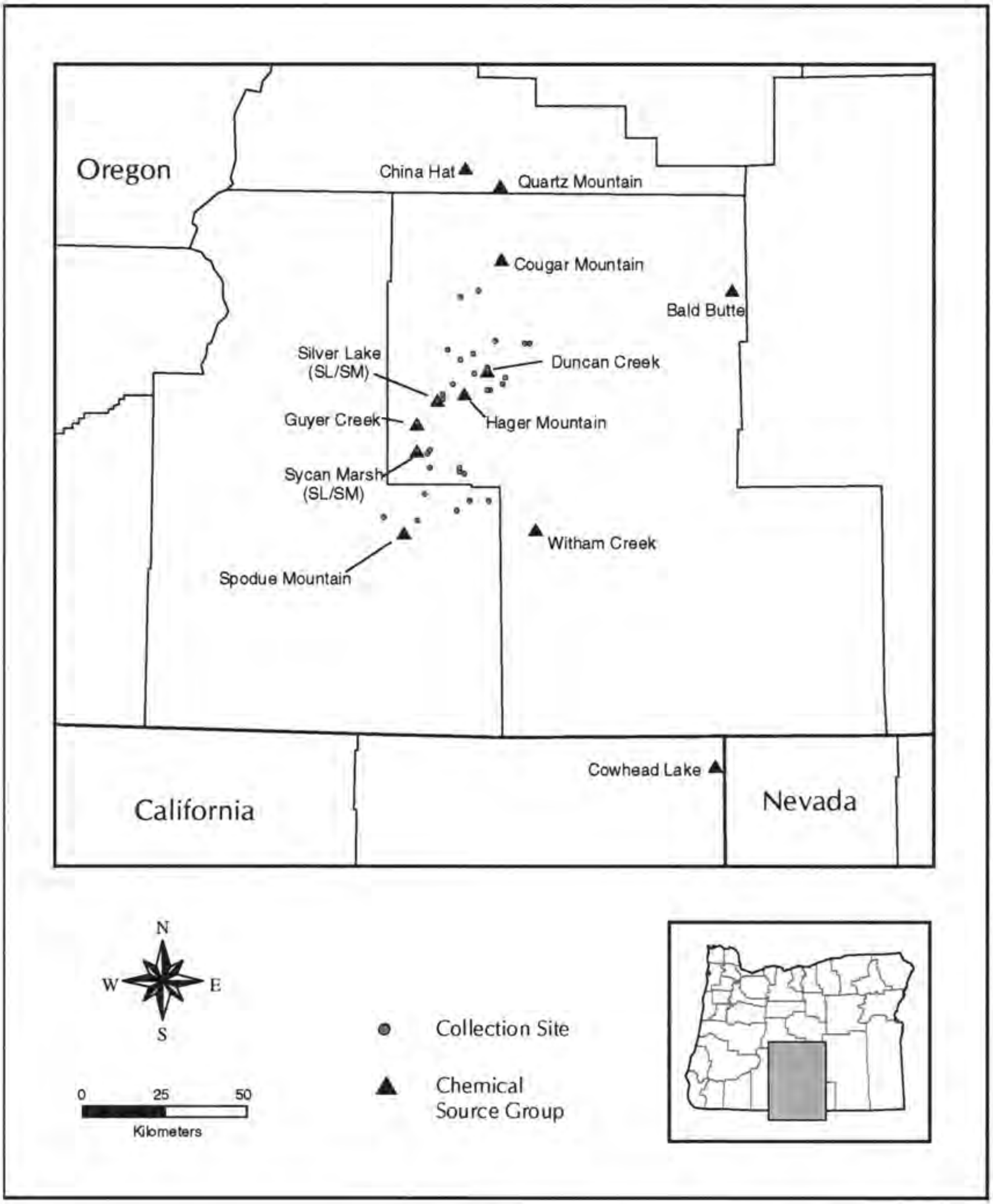


Figure 5.4. Locations of geologic collection sites and associated chemical source groups.

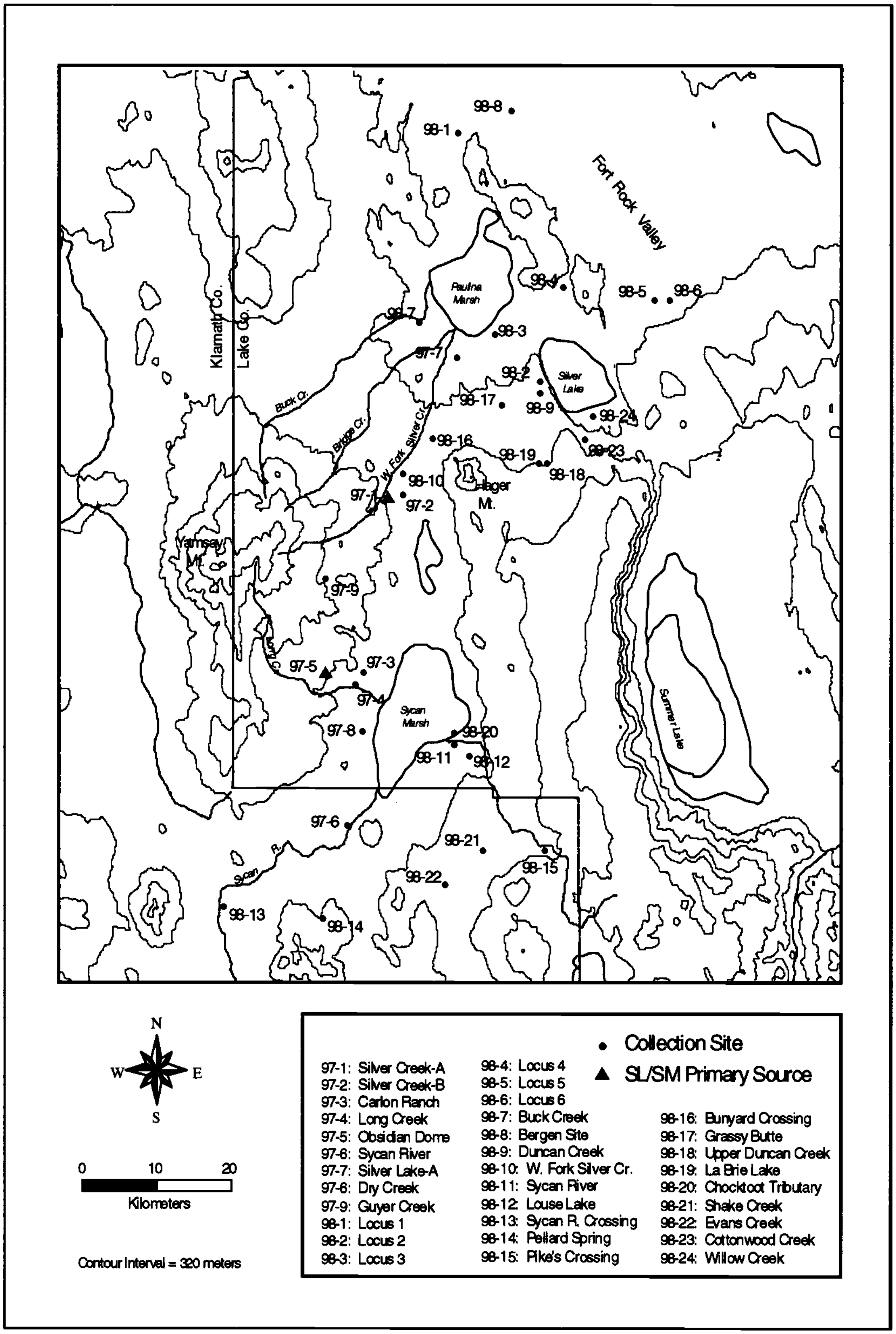


Figure 5.5. Geologic collection sites, Klamath and Lake Counties, Oregon.

Figure 5.4. The locations of the geologic collection sites are shown in Figure 5.5 and are described in Appendix B.

Sample collection during the 1997 field season was limited to areas situated in close proximity to the two primary source areas. Of the 120 samples gathered during 1997, 104 (87%) were assigned to the SL/SM source. The remaining samples included nine (7%) from the Witham Creek source, three (3%) from the Hager Mountain source, two (1.5%) from the Spodue Mountain source, and two (1.5%) from the newly recognized Guyer Creek source.

During the following season, survey work extended north into the Fort Rock Basin and south along tributaries of the Sycan River. The XRF results from the 1998 season yielded a greater diversity of obsidian source groups. Of the 272 samples gathered during the 1998 season, only 55 (20%) were correlated with the SL/SM source. Ninety-nine samples (36%) came from the Hager Mountain source, 47 (17%) from the Witham Creek source, and 39 (14%) from the Spodue Mountain source. The remaining sources represented in the 1998 XRF analytical results (13%) include Bald Butte, China Hat, Cougar Mountain, Cowhead Lake, Duncan Creek, Quartz Mountain, Variety 5, and several unknown sources (see Figure 5.6).

5.3.2 Description of the SL/SM Geochemical Source

The chemical source groups represented in the analysis of the geologic samples were identified through a comparison of existing geologic and artifact obsidian source reference collections. The 12 known chemical groups identified in the analysis are depicted in Figure 5.7, a scatterplot of zirconium (Zr) and strontium (Sr) values. Overall,

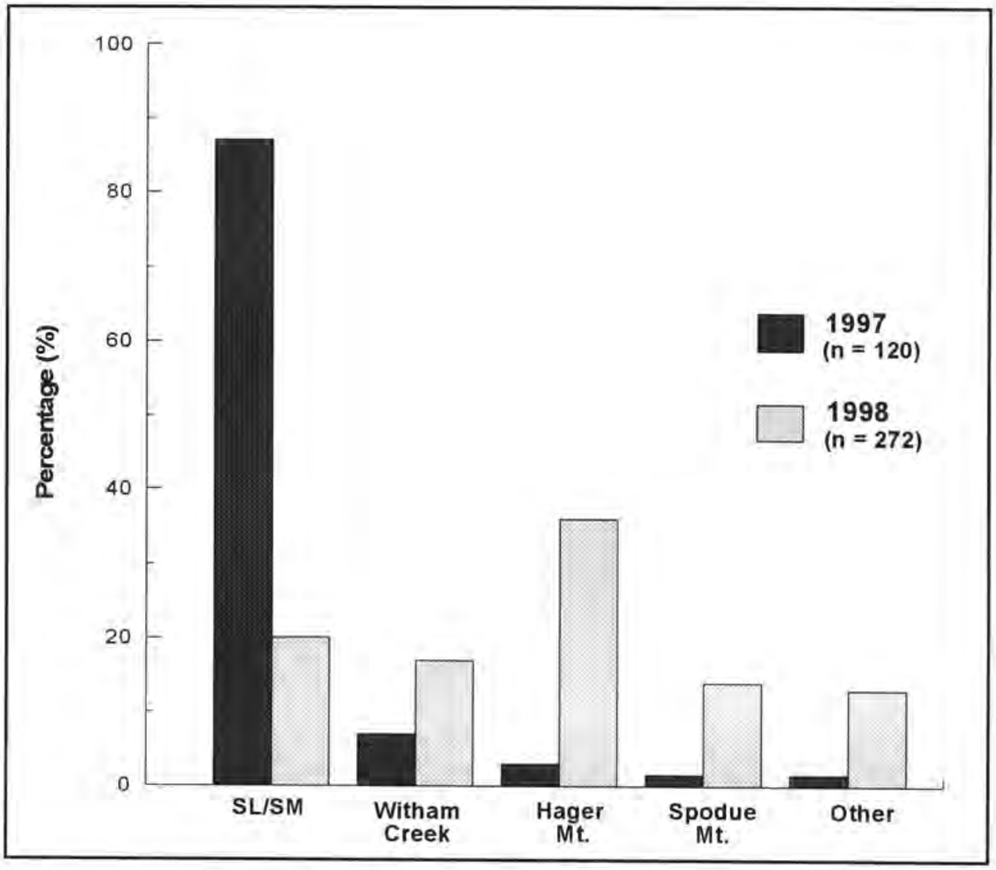


Figure 5.6. Percent of geologic obsidian source material collected during 1997 and 1998 field seasons.

the source groups are clearly visually separated on the basis of this pair of elements. However, for the chemical source groups that are not as easily distinguished (e.g., Hager Mountain and Spodue Mountain) other pairs of elements may be used to plot a more obvious separation.

The SL/SM chemical group is quite distinct in its geochemical signature and is easily identifiable as a single source group (see Figure 5.7). Summary statistics of trace element concentrations for the SL/SM geologic samples, presented in Figure 5.8 and Table 5.2, indicate that this source is relatively homogenous in chemical composition.

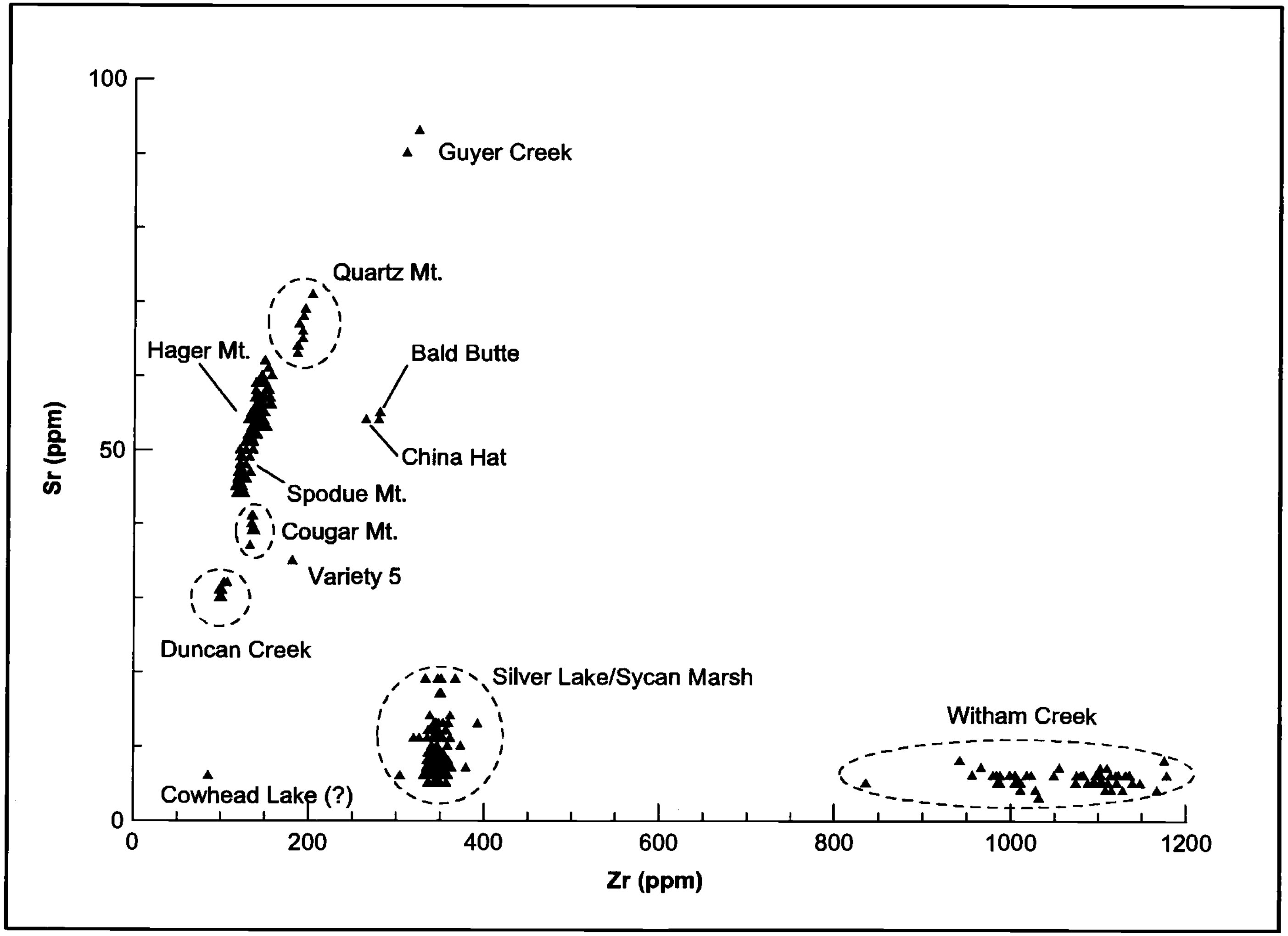


Figure 5.7. Scatterplot of strontium (Sr) plotted against zirconium (Zr) for all analyzed geologic samples.

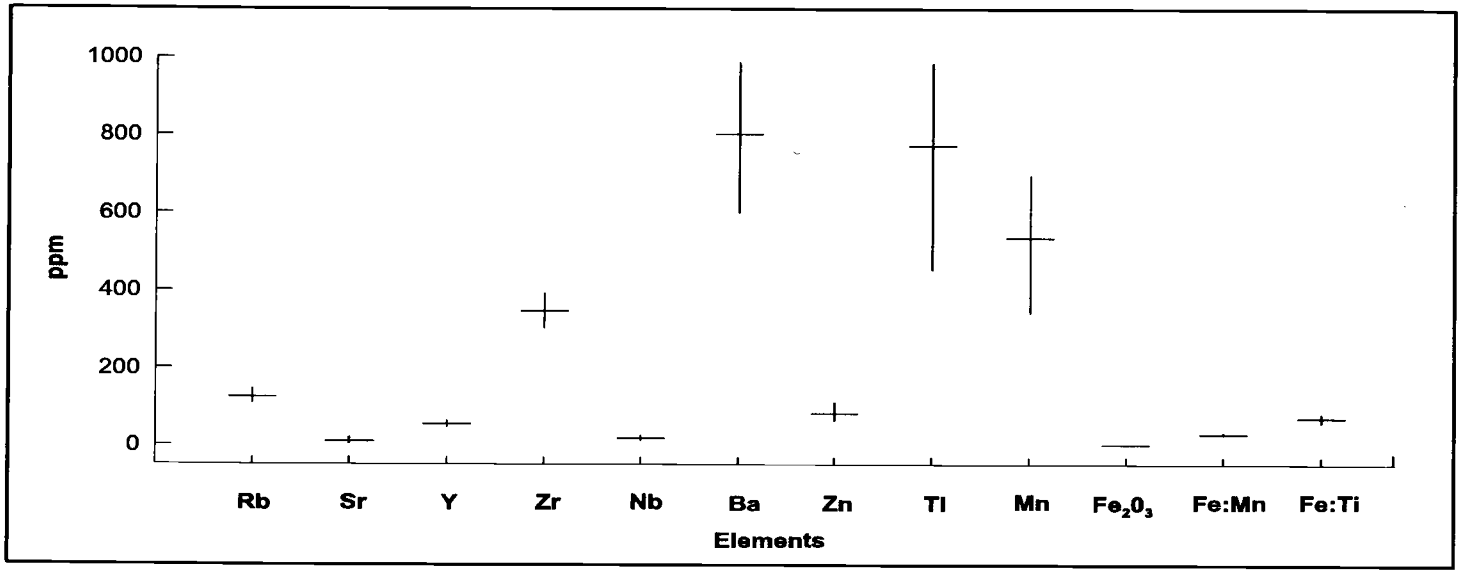


Figure 5.8. Range (vertical bars) and mean (horizontal bars) of trace element values in parts per million (ppm) for all SL/SM geologic samples.

Table 5.2. Summary statistics for trace element composition of geologic samples from the SL/SM geochemical group (n = 158).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	146	19	64	392	24	986	110	984	695	2.12	33	81
Minimum	110	5	49	304	13	602	64	455	345	1.02	27	60
Range	37	14	15	88	11	386	46	529	350	1.10	6	21
Mean	124	9	55	347	18	802	82	771	536	1.70	30	70
S.D.	6	3	2	10	2	58	9	105	66	0.23	1	4
C.V.%	4	34	4	3	11	7	10	14	12	13	3	5

The coefficient of variation (CV%) shown in Table 5.2 also indicates that the range of geochemical variability is relatively small for most of the measured trace elements.

Although the measured trace element abundances of the SL/SM geologic samples demonstrate overall homogeneity (see Figures 5.9 and 5.10), a single element, strontium (Sr), presents an interesting exception. The Sr concentrations for samples collected from the two primary sources reveal a slight chemical distinction between the two domes. A separation in elemental values is observed for the northern ("Silver Lake") dome where Sr concentrations range from 5 to 9 ppm and the southern ("Sycan Marsh") dome where Sr concentrations range from 10 to 13 ppm (Figure 5.11). In an analysis of all SL/SM geologic samples, a slightly less distinct division of Sr values occurs for samples collected from locations north of the Silver Lake dome and those collected south of the Sycan Marsh dome (Figure 5.12).

While the separation of Sr values is intriguing, similar patterns were not detected for the other measured trace elements. As a result, the ability to reliably distinguish a well-defined chemical separation between the two domes is greatly reduced. Due to the insufficiency and inaccuracy of identifying chemical sources solely on the basis of a single element, the separation of Sr values for material from the two domes is noted in this research as an intrasource variation and not as a designation of two discrete chemical groups. Obsidian provenance methods which measure a wider range of trace elements, such as neutron activation analysis (NAA), could produce additional patterns that support a more refined geochemical distinction between the primary source locations and should be considered in future research for the SL/SM chemical group.

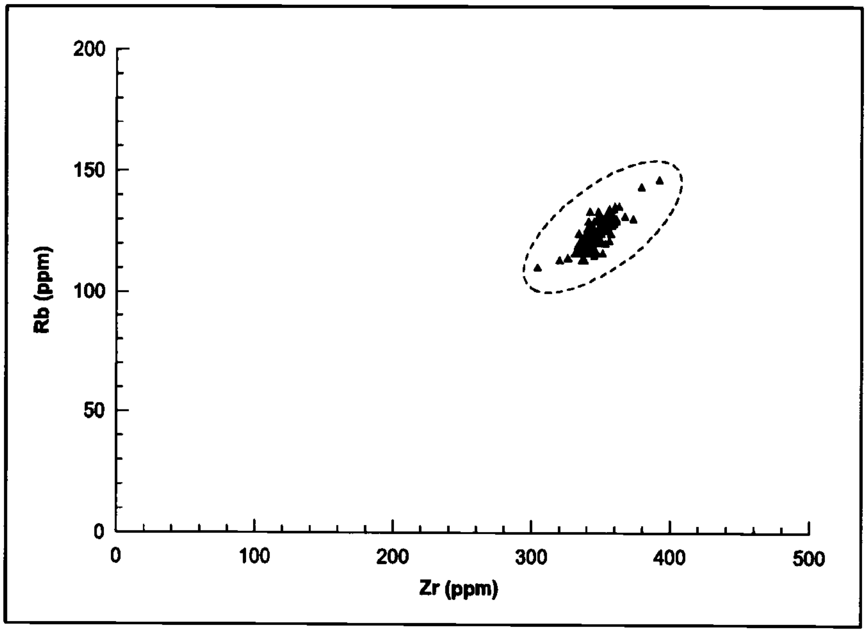


Figure 5.9. Scatterplot of rubidium (Rb) plotted against zirconium (Zr) for all SL/SM geologic samples.

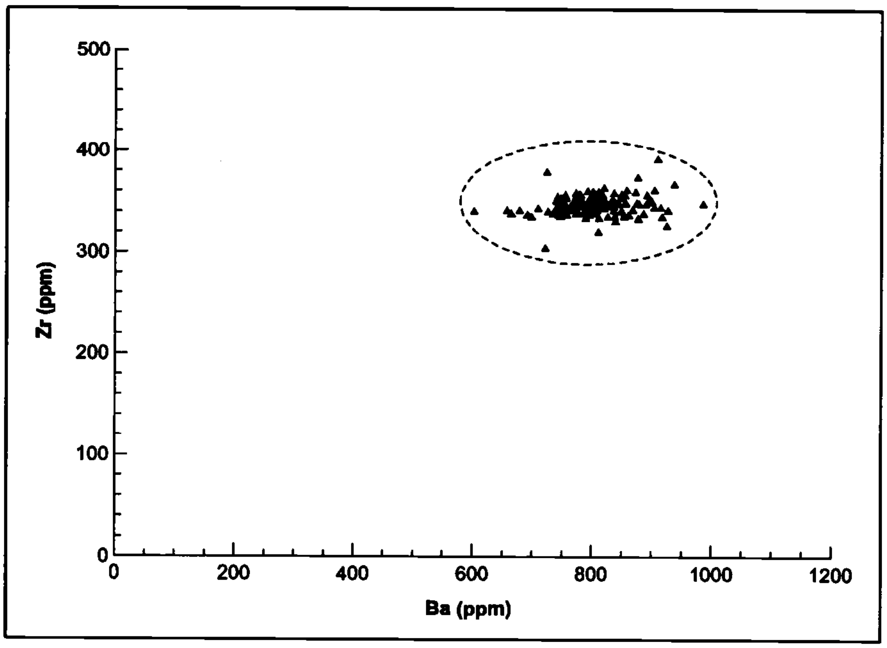


Figure 5.10. Scatterplot of barium (Ba) plotted against zirconium (Zr) for all SL/SM geologic samples.

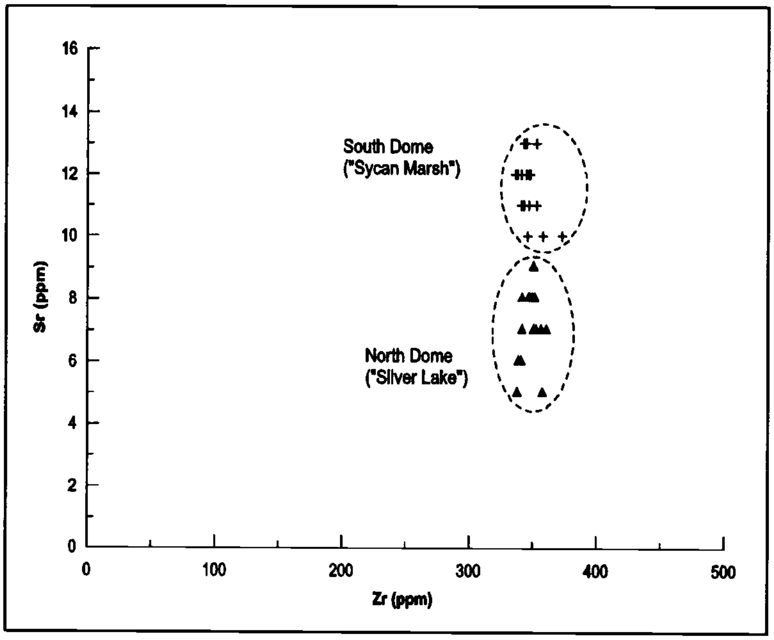


Figure 5.11. Scatterplot of strontium (Sr) plotted against zirconium (Zr) for geologic samples from the north obsidian dome (n = 15) and the south obsidian dome (n = 20).

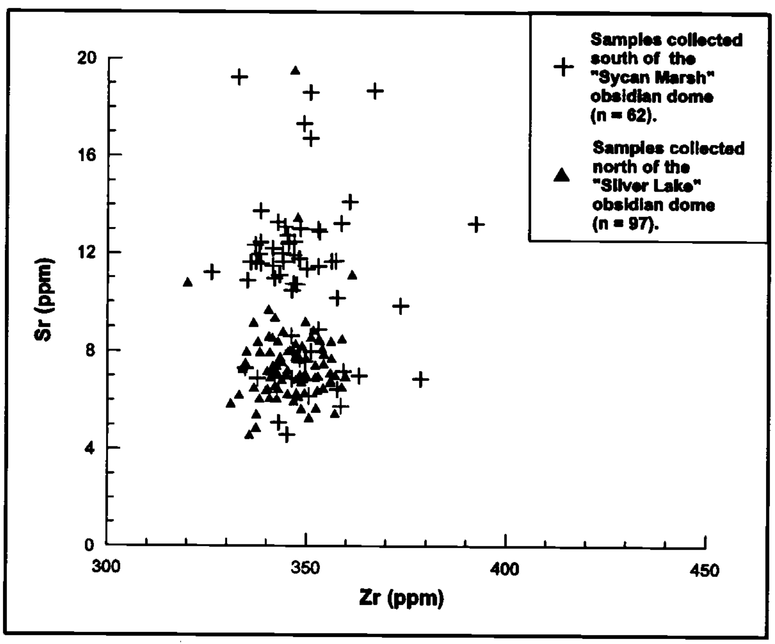


Figure 5.12. Scatterplot of strontium (Sr) plotted against zirconium (Zr) for all geologic samples correlated with the SL/SM chemical group.

5.4 Distribution of Primary and Secondary Geologic SL/SM Source Material

Based on the results of XRF analysis, two source boundaries that are associated with the Silver Lake and Sycan Marsh obsidian domes are identified for SL/SM geologic obsidian (Figure 5.13). The natural distribution of the geologic source material appears to be highly dependent upon the regional topography. An assortment of SL/SM obsidian nodules, cobbles and boulders occurs in the immediate vicinity of each dome and in the streams that drain these formations. Secondary SL/SM source material is dispersed downslope and downstream from the parent sources and decreases in frequency and size with increased distance from the primary source locations. An absence of SL/SM source material in the area that lies between the two domes, in conjunction with the regional topography, suggests the presence of two discrete SL/SM obsidian source areas.

5.4.1 Primary Geologic SL/SM Obsidian Source Distribution

Obsidian associated with the Silver Lake dome occurs from the northeastern slopes of an extensive ridge system along the northern edge of the Yamsay Mountain geologic complex. The extent of the primary source material as mapped by Hering (1981) is contained within one square kilometer area situated to the north of Alder Spring Ridge and immediately east of the West Fork of Silver Creek (Figure 5.14).

Obsidian associated with the Sycan Marsh dome occurs from the southeastern slopes of the Yamsay Mountain near the western margin of Sycan Marsh. The primary source material, as mapped by Hering (1981), covers several square kilometers (Figure 5.15) and encompasses the lower reach of the Long Creek drainage at the base of the dome.

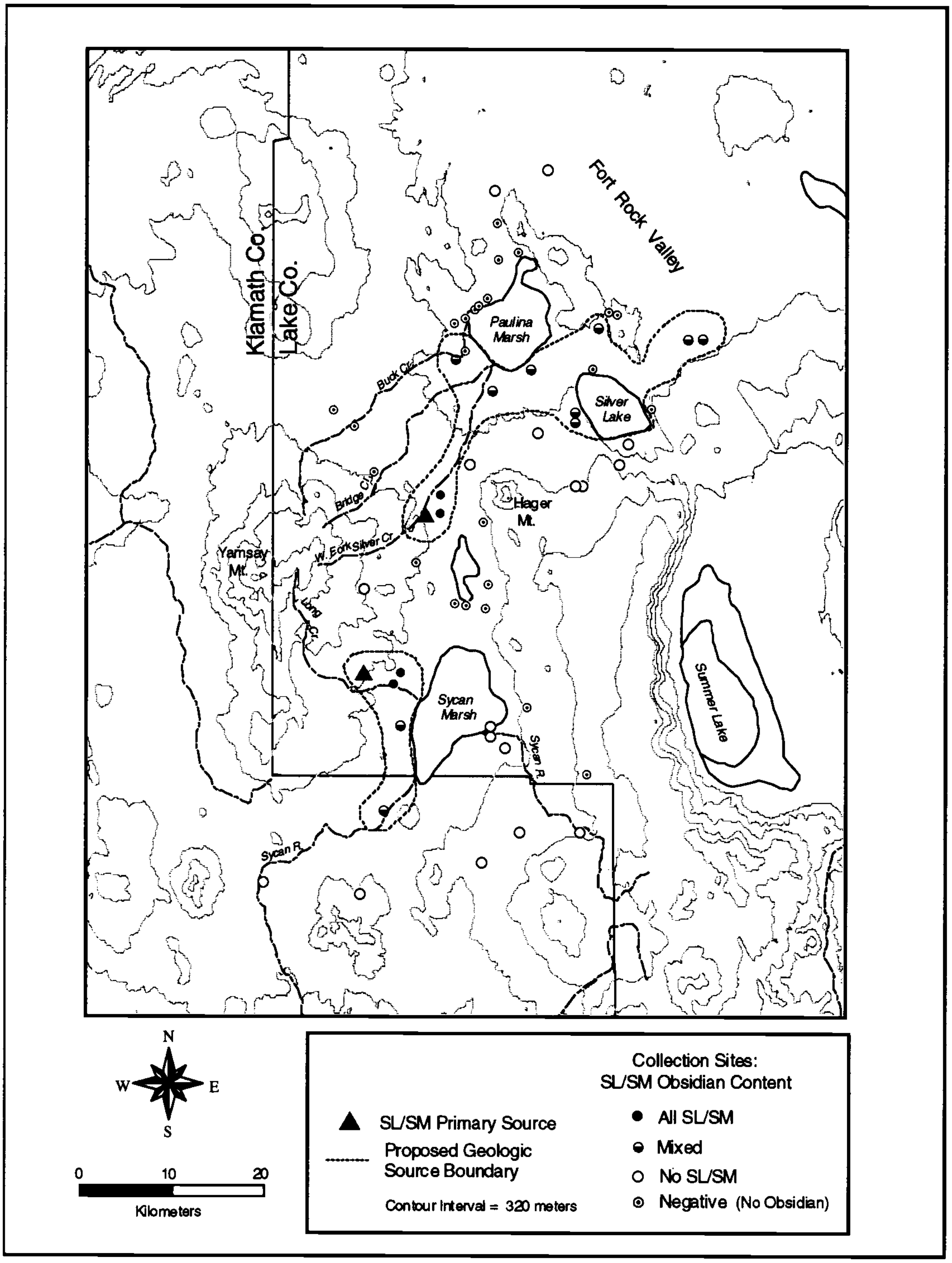


Figure 5.13. Proposed geologic source boundaries for the SL/SM chemical group.

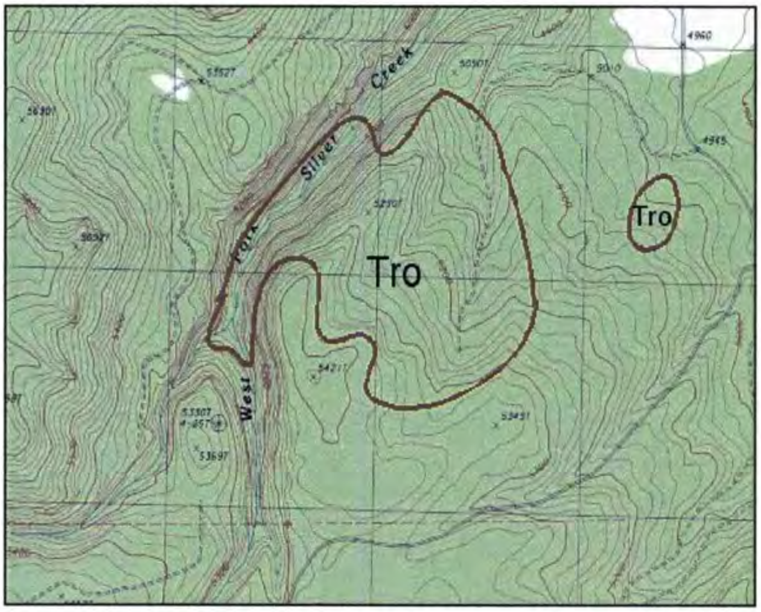


Figure 5.14. Extent of primary source material for the Silver Lake dome. Adapted from Hering 1981.

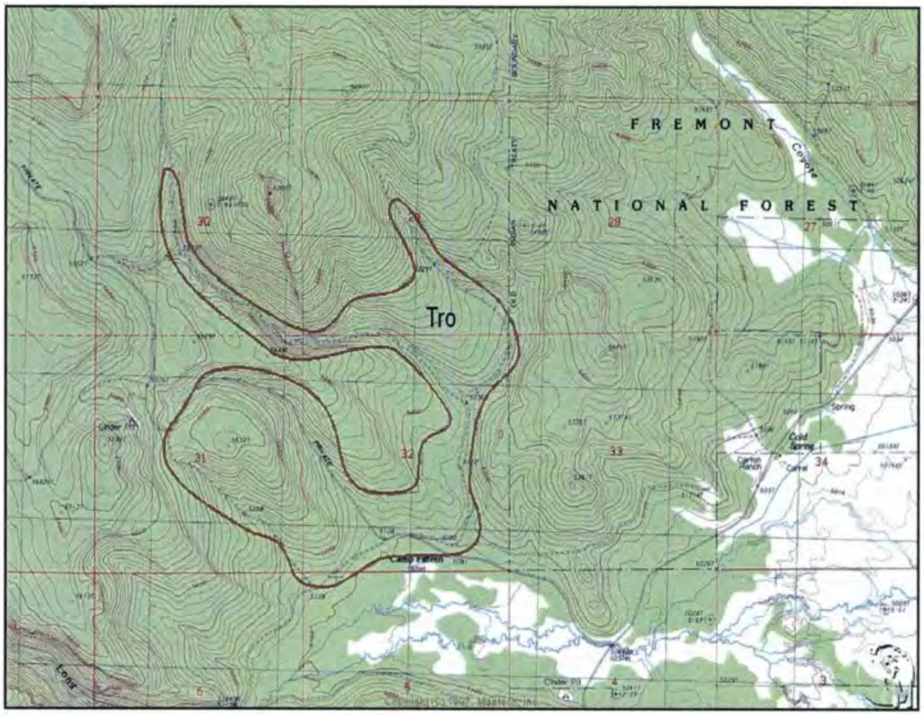


Figure 5.15. Extent of primary source material for the Sycan Marsh dome. Adapted from Hering 1981.

5.4.2 Secondary Geologic SL/SM Obsidian Source Distribution

Secondary source deposits of SL/SM obsidian occur in drainages, playa shorelines, wave-cut terraces, river and stream cut-banks, and road cuts. In general, nodules recovered from the secondary source locations are sub-angular to well-rounded, and are typically smaller in size (3 - 6 cm diameter) than those recovered from the primary source locations. Several of the secondary source locations yield scanty material of small dimensions (2 - 3 cm diameter) in contrast to the primary source locations which feature abundant, angular to sub-angular obsidian boulders and cobbles.

5.4.2.1 Silver Lake Dome

The secondary source region of the Silver Lake dome extends into the Fort Rock Basin downslope and to the north of the primary source. The West Fork of Silver Creek, a tributary of Silver Creek and one of three perennial streams flowing into the Fort Rock Basin, drains the dome and the adjoining ridges and terminates at Paulina Marsh in the Silver Lake sub-basin. During periods of increased precipitation, excess water from Paulina Marsh reportedly flows into Silver Lake (Freidel 1994:29). Pluvial lakes periodically filled this catchment in the Silver Lake sub-basin and the larger Fort Rock Basin during the Pleistocene. It is likely that obsidian originating from the Silver Lake dome has been redeposited over time by fluvial processes into areas of the southern Fort Rock Basin via the West Fork Silver Creek stream channel.

Within the northern boundary, obsidian from the SL/SM source appears to be confined to the southern Silver Lake sub-basin. The source area is bordered to the north by Paulina Marsh and the Connley Hills, to the west by Silver Creek, and to the east by

Thorn Lake near the base of the Egli Rim ridge system. Medium sized nodules of glass occur in relative abundance along the southern shore of pluvial Fort Rock Lake adjacent to the town of Silver Lake. The size and quantity of SL/SM material rapidly decreases with increased distance from this general area. In the uplands of the Fremont National Forest, the distribution is restricted to the primary source area on the slopes of the dome and within tributaries of the West Fork Silver Creek drainage. Obsidian was not found in stream channels on the western slopes of the dome, reaffirming the observation that the secondary source material identified in the study was most likely transported downslope into the Fort Rock Basin by fluvial action.

5.4.2.2 Sycan Marsh Dome

A similar explanation is provided for the distribution of SL/SM obsidian from the Sycan Marsh dome. Secondary material is found in Long Creek, a drainage that flows east into Sycan Marsh. SL/SM obsidian nodules also occur in terrace gravels along the lower Sycan River where the river intersects the southern tip of the marsh. Samples of SL/SM obsidian mixed with another chemical group (Witham Creek) were collected from the stream bed of the Sycan River at a locale situated several kilometers downstream from the Sycan Marsh and almost 18 kilometers southwest of the Sycan Marsh obsidian dome. This site was determined to be the approximate southernmost extent of the Sycan Marsh source area as SL/SM obsidian was absent from a collection site located further downstream. Hughes (1985:33) reports similar findings in a study of seven sites situated along the upper stretch of the Sycan River where it drains the Sycan Marsh.

Unlike the widespread distribution of obsidian found north of the Silver Lake dome, material eroding from the Sycan Marsh dome appears to be confined to a small network of drainages leading in an apparent southern descent from the primary source to the Sycan River via Sycan Marsh. Numerous streams diverge from Long Creek on the privately-owned western half of Sycan Marsh and undoubtedly contain gravels of SL/SM obsidian. Several collection sites on the eastern margin of Sycan Marsh failed to yield any samples associated with the SL/SM chemical group.

5.4.3 Discussion

The two identified source boundaries are approximations of the geographic extent of SL/SM geologic obsidian distribution. In both cases, samples from collection sites immediately adjacent to (and coincidentally, downslope from) the primary sources correlate with the SL/SM chemical group 100 percent of the time. As expected, the dispersal of material from the primary sources results in both secondary mixing with other chemical groups and a reduction in abundance of SL/SM nodules In general, the distance from the primary SL/SM source locations marks an increase in the occurrence of non-related obsidian source material and the decrease or complete absence of SL/SM material.

5.5 Geochemical Source Descriptions for Non-SL/SM Obsidian

In addition to the SL/SM chemical group, 11 known source groups were identified among the recovered geologic samples. The presence of these additional chemical source groups in secondary deposits provides rough guidelines for defining the boundaries of the SL/SM source. That is, obsidian source boundary lines may be drawn along transition zones where mixing of different sources occurs and where the presence and absence of particular source material is distinct. These sources, several of which have been described by Hughes (1986), are briefly summarized in the following section.

5.5.1 Hager Mountain

Obsidian from this chemical source is found along the slopes of Hager Mountain, located in the Fremont National Forest about 11 kilometers south of Silver Lake, Oregon, and approximately eight kilometers east of the northern SL/SM primary source. The close proximity of the two sources has resulted in the comingling of secondary material in some deposits found on lakeshore terraces in the Silver Lake sub-basin.

The demarcation of transition zones between chemically distinct sources is most applicable for source material that is adequately represented in the overall sample and characterized by large numbers of specimen recovered from multiple collection sites. The Hager Mountain chemical source best fits this criteria, as it makes up over 25 percent of the total analyzed samples. A provisional boundary, based only on data compiled for purposes of defining the SL/SM obsidian source boundaries, is presented for the Hager Mountain and SL/SM chemical groups in Figure 5.16. Nodules from the Hager Mountain chemical source are relatively abundant in stream drainages on the north-facing slopes of Hager Mountain and appear to be transported to the base of these slopes by colluvial and fluvial activity. Hager Mountain secondary source material clearly co-occurs with material from the SL/SM source in the Silver Lake sub-basin. However, additional fieldwork is required to more accurately and comprehensively determine the geographic extent of the Hager Mountain obsidian source.

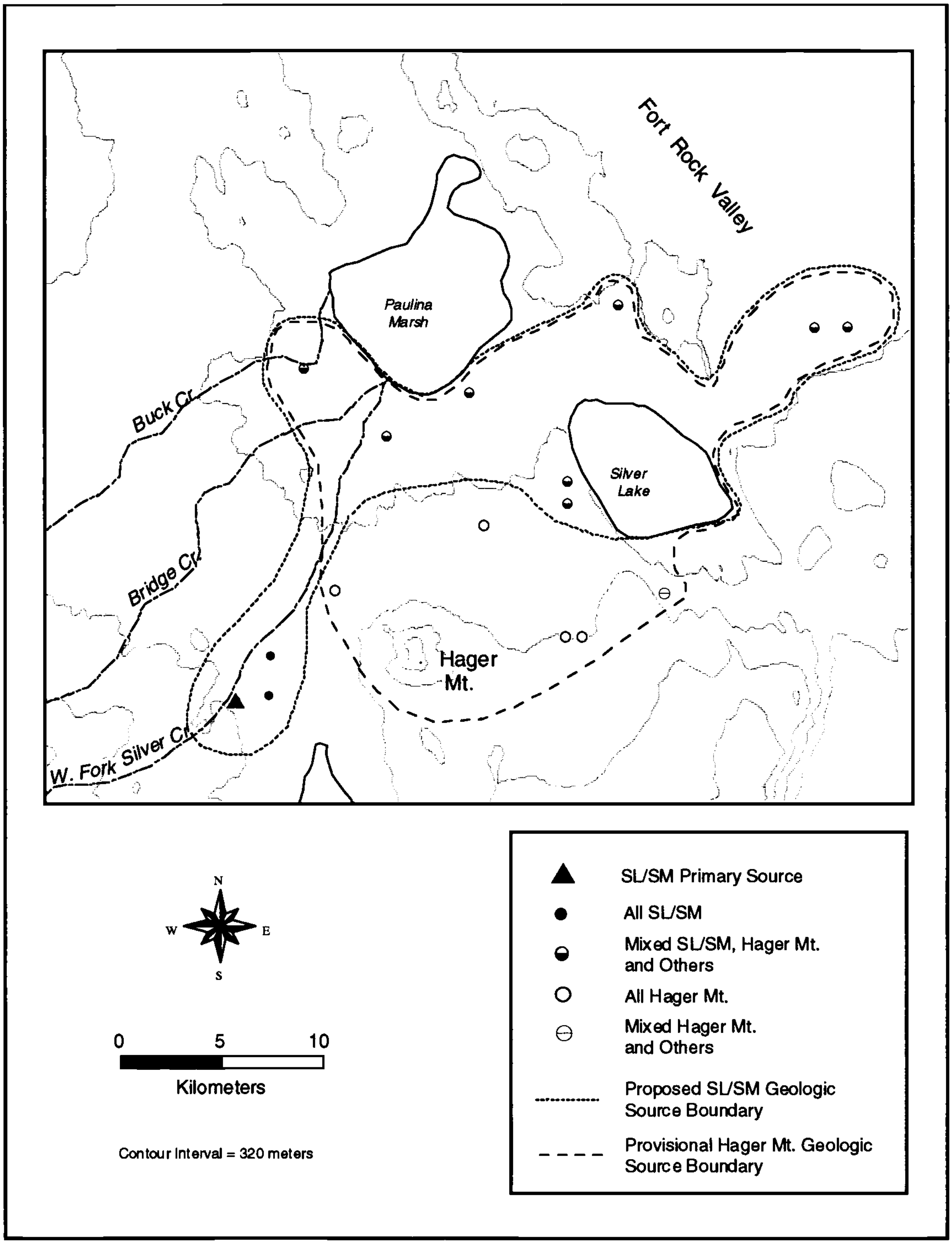


Figure 5.16. Provisional geologic source boundary for the Hager Mountain geochemical group.

5.5.2 Witham Creek

Obsidian nodules from this chemical group occur in river gravels along the Sycan River. The primary source is located in western Lake County near the headwaters of the Sycan River and adjacent to Witham Creek, a tributary of the Sprague River which lies to the south of the source area. Almost all Witham Creek obsidian samples gathered during fieldwork were collected from gravel deposits along the Sycan River. Not surprisingly, these nodules all display well-rounded, water-worn surfaces. One nodule from the Witham Creek source was recovered among Spodue Mountain gravels at the southernmost collection site along the Sycan River.

5.5.3 Spodue Mountain

Spodue Mountain, located in east-central Klamath County, lies over 16 kilometers to the southwest of the southern end of Sycan Marsh. Nodules from this source are abundant in Sycan River gravels and are found to co-occur in the Sycan River drainage with material from the Witham Creek and SL/SM obsidian sources.

5.5.4 Bald Butte

This source is reported to be located at the eastern edge of Lake county on the southwest slopes of Wagontire Mountain (Hughes 1993). It is chemically distinct from the adjacent Wagontire obsidian source. The only samples correlated with the Bald Butte source recovered in this study consisted of two medium-sized pebbles (2-4 cm in diameter).

5.5.5 China Hat and Quartz Mountain

The primary deposits for both of these sources are located in southern Deschutes County along the lower southeast slopes of Newberry Crater and along the extreme northwestern margin of the Fort Rock Basin. Small-to-medium sized obsidian pebbles (1-3 cm in diameter) originating from these sources are found mixed with beach gravels along the shorelines of a playita in the northwestern Fort Rock Basin some 32 kilometers from the primary source deposits.

5.5.6 Cougar Mountain

The primary Cougar Mountain obsidian source sits on the boundary of the High Lava Plains and the Northern Great Basin and lies 24 kilometers due south of the Quartz Mountain source. Nodules of Cougar Mountain obsidian co-occur with the Quartz Mountain, China Hat, SL/SM, and Hager Mountain sources in beach gravels and stream gravels found in scattered locations throughout the Fort Rock Valley.

5.5.7 Cowhead Lake

One nodule collected during fieldwork correlated with the Cowhead Lake chemical group. The single specimen was among hundreds of obsidian nodules found scattered in a dry creek bed on the Sycan Flat (see source description for site 98-12 in Appendix B). The presence of material from this source in east-central Lake County is curious considering that the primary source is located over 120 kilometers away in northeastern California. It is highly unlikely that material from this geochemical group would occur naturally at such an extreme distance from its primary source. As such, this specimen may actually represent an unknown source whose trace element abundances mimic those of the Cowhead Lake material.

5.5.8 Duncan Creek

The primary source location for the newly designated Duncan Creek chemical group is currently not known. Nodules correlated with this chemical source were collected in 1998 from secondary deposits located on the sloping terrain below Duncan Reservoir in Lake County by a University of Oregon archaeological field school crew.

5.5.9 Guyer Creek

An obsidian source reportedly exists in this area, to the north of Guyer Creek on the eastern slopes of Yamsay Mountain, Lake County (John Kaiser 1997, personal communication). A survey of the source area yielded a very small sample of pebbles (n = 2) that did not correlate with any currently known chemical groups. This material was assigned to the newly designated Guyer Creek chemical group (Craig Skinner 1997, personal communication).

5.5.10 Variety 5

The location of this source is currently unknown. Artifact obsidian from the Variety 5 chemical group is recovered with some frequency from Christmas Lake Valley and southern Fort Rock Basin archaeological sites. The prevalence of artifacts from this source at sites in the eastern end of the Silver Lake sub-basin suggests that the primary source or secondary source outcrops are located in the general vicinity of Silver Lake. During field work for this research, a single geologic sample of Variety 5 obsidian was collected from a drainage on Dead Indian Rim above the southern end of Silver Lake. This specimen, a small (2 cm diameter), rounded pebble, was one of only three obsidian nodules collected from this location (see source description for site 98-23 in Appendix B).

5.6 Summary

Non-cultural obsidian originating from the SL/SM geochemical group occurs along the southern margins of the Fort Rock Valley and in stream drainages along the western and southern edges of Sycan Marsh. Two discrete source boundaries are proposed for the geographic extent of SL/SM geologic obsidian. These boundaries are based on the distribution of primary and secondary material and are directly linked with the topography surrounding the two primary sources.

A boundary associated with the Silver Lake obsidian dome, located in the northern part of the study area, encompasses the southern portion of the Fort Rock Basin in the general vicinity of Paulina Marsh and the Silver Lake sub-basin. The West Fork of Silver Creek is thought to be the conduit for secondary material redeposited in the basin. Pluvial lake wave action also likely redistributed gravels of SL/SM source material to lakeshore terraces.

The second boundary, associated with the Sycan Marsh obsidian dome, hugs the western margin of Sycan Marsh and terminates on the Sycan River several kilometers downstream from the southern tip of Sycan Marsh. Nodules of SL/SM obsidian undoubtedly occur in the gravels of numerous drainages located on the privately owned western half of Sycan Marsh. The southern edge of the boundary is marked by an increase in the percentage of Spodue Mountain and Witham Creek material. The secondary distribution of obsidian from both primary source areas appears to closely follow the regional topography. Nodules of obsidian erode from the slopes of the domes and are distributed via a drainage network to a catchment downstream.

A very slight difference in the geochemistry of obsidian from the two domes was detected but concluded to be of no significant relevance in this research. However, future studies that use other analytical methods, such as NAA, may reveal a more distinct geochemical difference between the two domes.

Although an attempt to assign the analyzed SL/SM samples to a particular dome was not successful, the mapped distribution of the recovered samples indicate that obsidian from the two domes does not comingle. Based on the absence of SL/SM obsidian from the region separating the two domes, as well as the local topography which trends downslope to the north for the Silver Lake dome and downslope to the south for the Sycan Marsh dome, it appears that the two proposed boundaries more accurately portray the distribution than a single boundary encompassing both domes. Although distributive processes may have introduced a comingling of material from the two domes during periods of glacial activity or during extreme wet periods, the results of analysis presented in this research do not provide evidence for this scenario. Additional fieldwork and geochemical analysis will be needed to refine the proposed boundaries.

6. SPATIAL DISTRIBUTION OF ARTIFACT OBSIDIAN FROM THE SL/SM GEOCHEMICAL GROUP

6.1 Introduction

Obsidian toolstone resources are abundant throughout the northern Great Basin and were used extensively by the prehistoric populations who occupied the region. More than 100 geochemically-distinct obsidian sources have been identified in Oregon alone, and several of these sources lie within the general vicinity of the geologic study area (described in Chapter 5). Despite an increase in the use of XRF analysis and a resultant abundance of geochemical analytical data (Hughes 1986; Sappington 1981a, 1981b; Skinner 1983; Wright et al. 1969), there have been few geoarchaeological obsidian distribution studies carried out for Oregon obsidian sources, including those related to the SL/SM chemical group. The current research expands upon the limited existing distribution studies by describing the geologic SL/SM obsidian source boundaries and by mapping and evaluating the distribution of previously characterized obsidian artifacts that correlate with the SL/SM source group. The following discussion of the artifact distribution explores prehistoric use of the SL/SM source and associated lithic procurement behaviors.

The artifact data described in this chapter derive from a large database of over 40,000 geochemically-analyzed obsidian artifacts. Analytical results of 1,938 artifacts originating from the SL/SM obsidian source were culled from the database. These artifacts, which constitute all SL/SM obsidian artifacts recorded in the database, were recovered from 202 archaeological sites containing a total of 11,778 geochemically-characterized obsidian specimens. The majority of the 202 archaeological sites and isolates documented in this research are located in Oregon (n = 196). The remaining sites are located in the neighboring states of Washington (n = 3) and California (n = 3). The literature sources of XRF data for all sites represented in this research are listed in Appendix F. The locations of the sites are shown in Figure 6.1 and Appendix F.

6.1.1 Data Sources

The bulk of the data used in this research was drawn from an extensive database archived at Northwest Research (NWR) Obsidian Studies Laboratory, Corvallis, Oregon. The database contains XRF analytical results of over 40,000 geochemically-characterized obsidian artifacts, most of which correlate with obsidian sources from the far western United States. The analytical results contained in the database were generated by several obsidian studies laboratories, including BioSystems Analysis Inc., Geochemical Research, and NWR. The data originate from numerous archaeological projects undertaken by researchers associated with academic institutions, contract firms, and government agencies.

XRF analytical data were also obtained from records provided by the Douglas County Roseburg District BLM office, Roseburg, Oregon. The records include a comprehensive list of XRF analytical results for artifact obsidian from archaeological sites located on BLM and U.S. Forest Service (U.S.F.S) lands in Douglas County. Sites on the list that were found to contain SL/SM artifact obsidian were included in this research.

Additional artifacts for analysis were obtained from the University of Oregon Museum of Natural History, Eugene, Oregon. In 1998, a sample of 168 obsidian tools

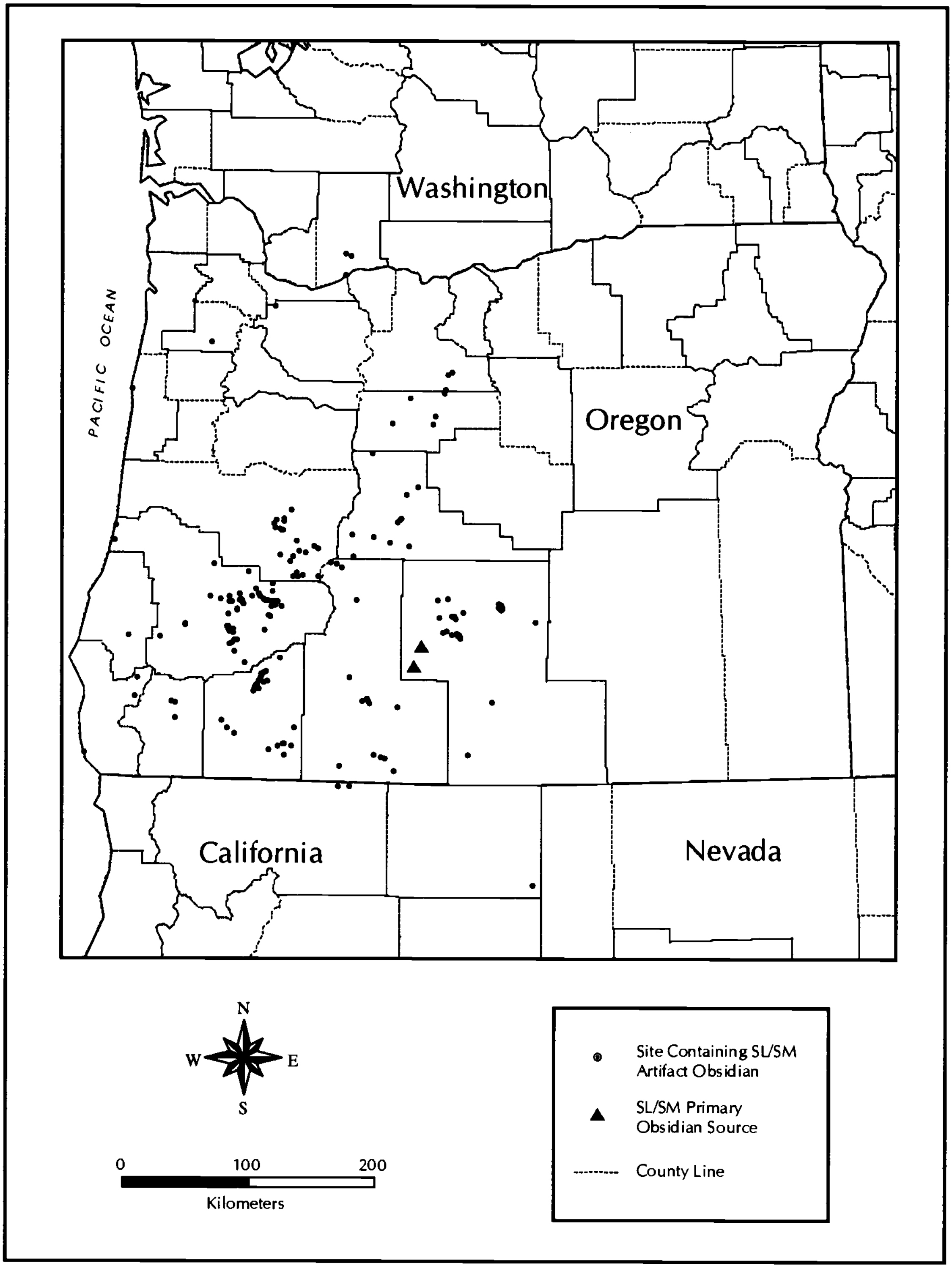


Figure 6.1. Distribution of archaeological sites containing artifact obsidian from the SL/SM chemical group.

from the Fort Rock Basin was taken on a temporary loan from the museum for XRF analysis at the NWR Laboratory. The artifacts were originally recovered from the Connley Caves in the late 1960's by archaeologist Stephen Bedwell under the direction of Luther Cressman (Bedwell 1969, 1973). Cressman, known as the father of Oregon archaeology, is credited with establishing the antiquity of prehistoric occupation in the Great Basin with his findings of 11,000 year-old woven juniper bark sandals from excavations at the renowned Fort Rock Cave site. Bedwell's excavations at the Connley Caves complemented those of Cressman and helped lay the foundation for subsequent archaeological research in the Fort Rock Basin.

The results of XRF analysis from the Connley Caves artifacts (see Appendix G) are incorporated in this research to provide additional information about obsidian source use and prehistoric mobility strategies within the Fort Rock Basin. The analytical results also contribute to previous smaller-scale XRF studies of obsidian from the Connley Caves (Sappington and Toepel 1981:235; Skinner 1983, Appendix IX).

Given the bulk of the data, the sources of the data, and the scope of the project, the site distribution analysis described in this chapter was subject to several limitations. First, the analysis considers only sites containing SL/SM artifact obsidian and does not account for sites with characterized obsidian artifacts that do not correlate with the SL/SM obsidian source. Second, due to incomplete or missing data and inconsistent use of terminology by researchers who submitted samples for characterization, the research does not attempt to distinguish between artifact types. Attempts to retrieve the artifacts for a controlled typological analysis from the various curation facilities where they are stored would have consumed much more time than the project allowed. Finally, as a result of the inconsistent and incomplete typological information, the research is synchronic. Temporal traits are not considered here because many of the samples lack chronologic information that could have been provided by temporally-diagnostic characteristics or by obsidian hydration rim measurements. Therefore, aside from some brief observations, the study does not document changes in SL/SM obsidian distribution through time.

6.1.2 Sampling Bias

The spatial distribution of geochemically characterized artifact obsidian often reflects uneven patterning due to variation in sample recovery methods. The archaeological sites represented in the current analysis are associated with multiple projects of varying size, function, and geographic location. As an inevitable outcome of this variability, the mapped site data visually demonstrate sampling bias (see Figure 6.2).

6.1.2.1 Project Type: Linear Transects

A conspicuous example of sampling bias results from the use of XRF data generated during the1989-1994 Pacific Gas Transmission & Pacific Gas & Electricity (PGT & PG&E) natural gas Pipeline Expansion Project (PEP) (Skinner 1995). The PEP intersected portions of Idaho, Washington, Oregon and California, extending from the U.S. border near Alberta, Canada to its point of termination in Fresno, California. Over 9,500 obsidian artifacts collected from archaeological sites identified along the pipeline route were submitted for geochemical characterization during the PEP. Of the analyzed artifacts, 501 specimens recovered from central and south-central Oregon sites correlate with the SL/SM chemical group and make up almost 26 percent of the total sample used

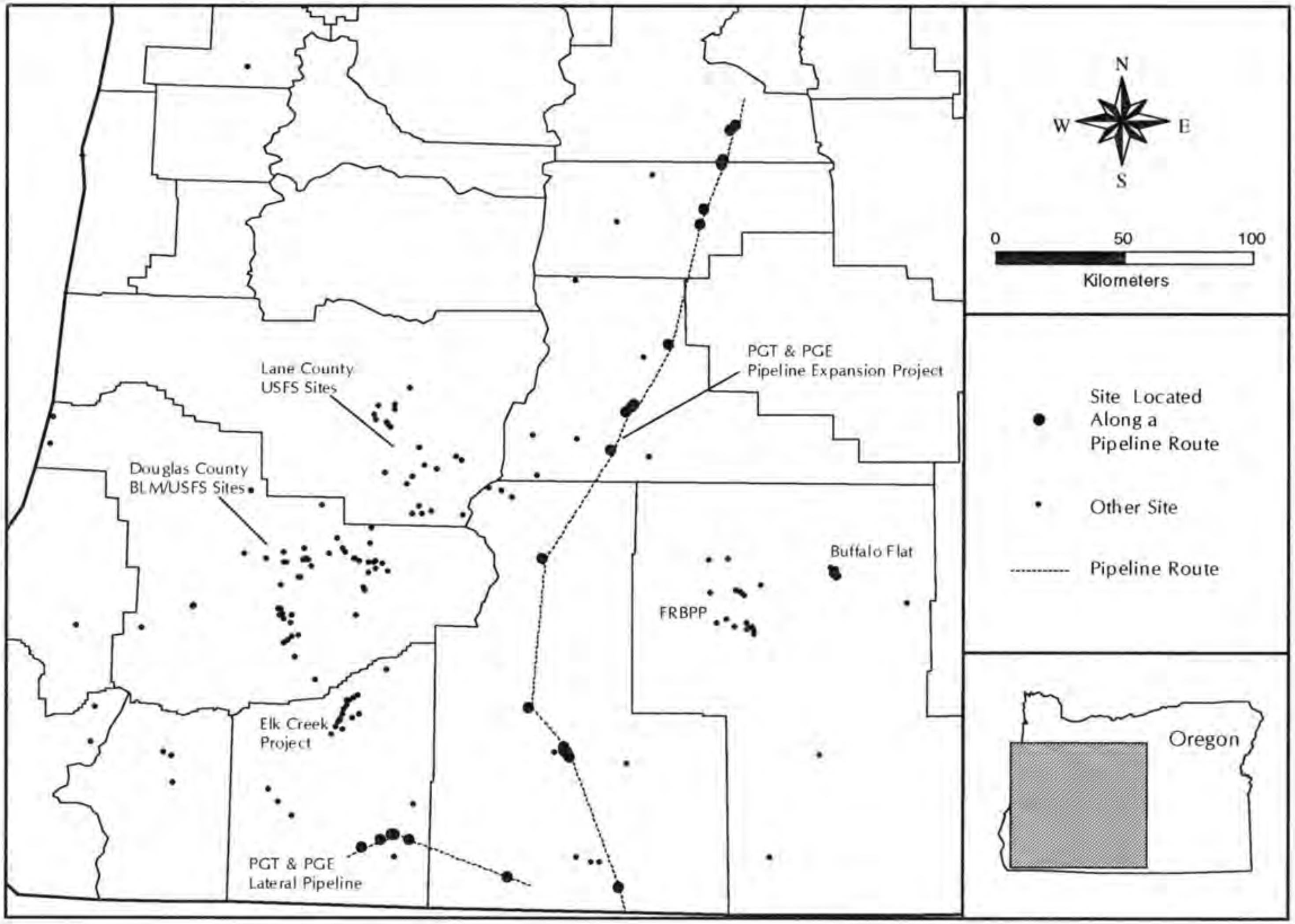


Figure 6.2. Sampling bias in mapped site distribution.

in the current research. Because a large proportion of the data derives from the PEP, a single project with distinctive physical characteristics (i.e., a linear transect), the mapped archaeological sites associated with the PEP are easily identified.

Other linear transects are also evident (see Figure 6.2). These include a smaller auxiliary PGT & PGE natural gas pipeline project in Jackson and Klamath counties and a series of excavations at sites along Elk Creek in northern Jackson County (see Appendix F). Sites associated with these projects produced far fewer SL/SM obsidian artifacts and a much smaller overall sample of geochemically-characterized obsidian than the PEP.

6.1.2.2 Geographic Restrictions

Sampling bias is also apparent in situations where archaeological investigations are geographically restricted to public lands. Spatial distribution patterns which display regional clustering often reflect the presence of sites on federal or state lands identified during cultural resource pedestrian surveys (e.g., for timber sales, land exchange, etc.). Noticeable clusters observed in this research occur within Lane and Douglas counties where timber sales are abundant and geochemical characterization of obsidian artifacts has been a research priority.

Site clusters also appear in northern Lake County, Oregon, where archaeological investigations conducted by the University of Oregon (FRBPP) have produced a high density of sites in the Fort Rock Valley. To the east, the Christmas Lake Valley exhibits another cluster of sites associated with an extended survey of the Buffalo Flat area (Oetting 1993).

6.2 Site Distribution

Artifact obsidian from the SL/SM source region occurs almost exclusively within the State of Oregon (Figure 6.1). The material is heavily concentrated in the southwest part of the state but is also present in smaller quantities at scattered locations throughout central and western Oregon, northwestern California, and southwestern Washington. To the east of the source area, there is a limited distribution of SL/SM artifact obsidian within the Fort Rock and Christmas Lake Valleys.

The most distant SL/SM obsidian artifact documented in the research is found almost 320 kilometers north of the source region at site 45-SA-222, Skamania County, Washington. This site marks the northern boundary of SL/SM artifact distribution. The eastern, western, and southern extent of the distribution varies in distance from the source region, and ranges from 190 kilometers to the south to 240 kilometers to the west (along the Oregon coast) to 80 kilometers to the east (Figure 6.3).

The sites are located, for the most part, west of the source region and are distributed among ten major drainage basins that fall within areas of Oregon, Washington and California (Figure 6.4). The occurrence of SL/SM artifact obsidian per basin is summarized in figures 6.5 and 6.6 and is described below. The relationship between site location and drainage basin, which has likely cultural implications, will be discussed in a later section of this chapter.

6.2.1 Distribution Within Drainage Basins

Most of the 1,938 SL/SM obsidian artifacts occur in sites located within major drainage basins that either occupy or are adjacent to the source region. The Silver Lake

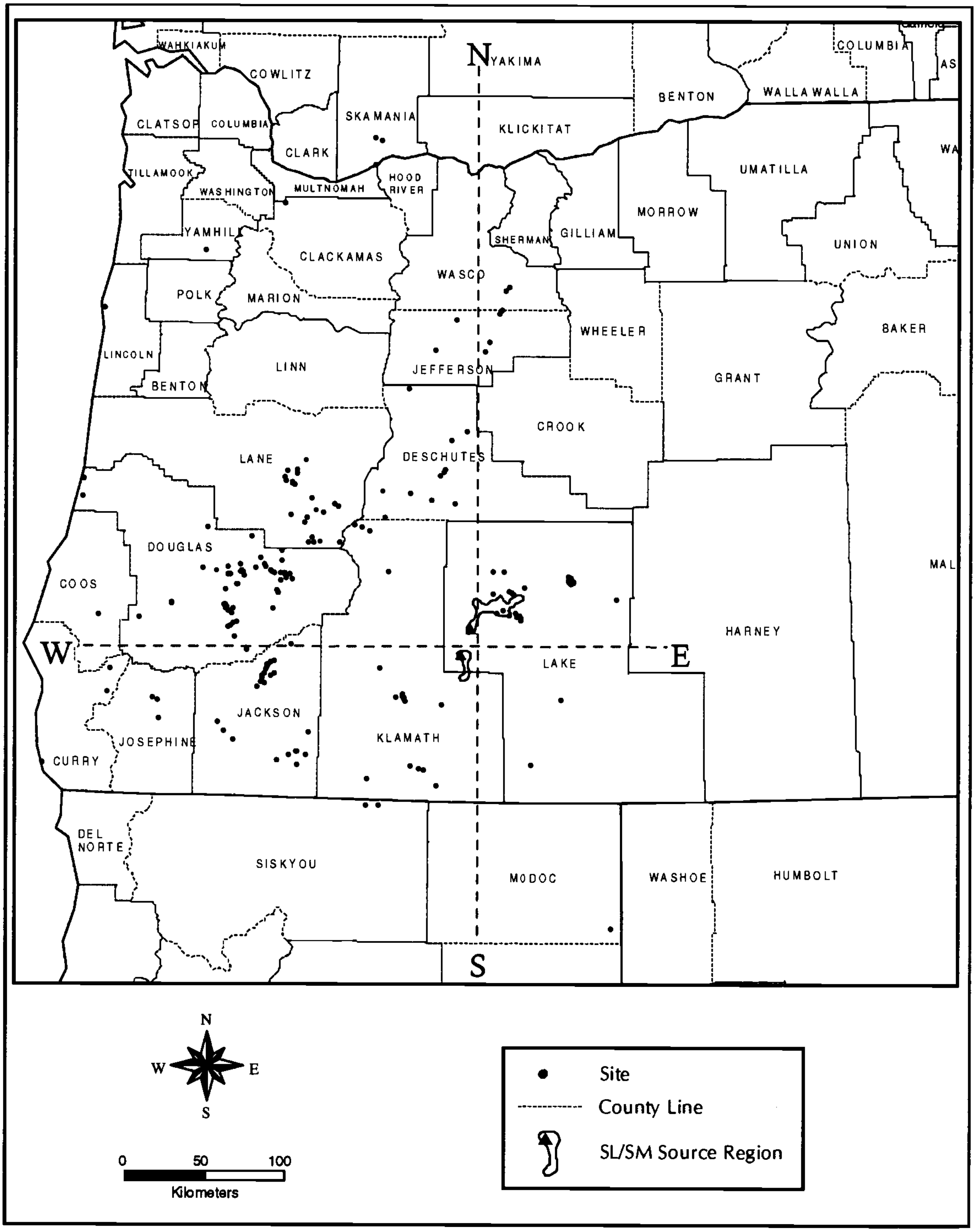


Figure 6.3. Direction of site distribution from the source region.

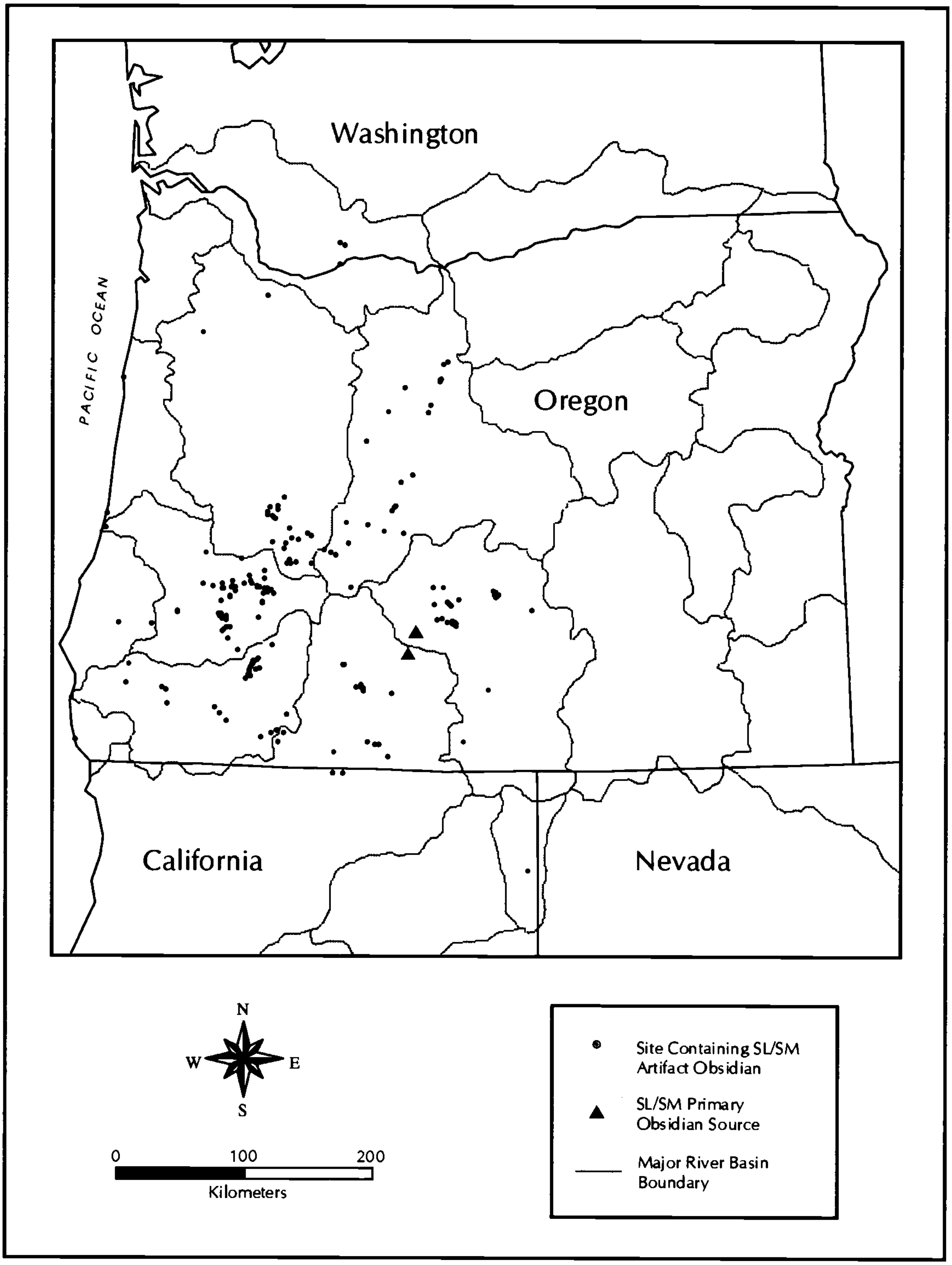


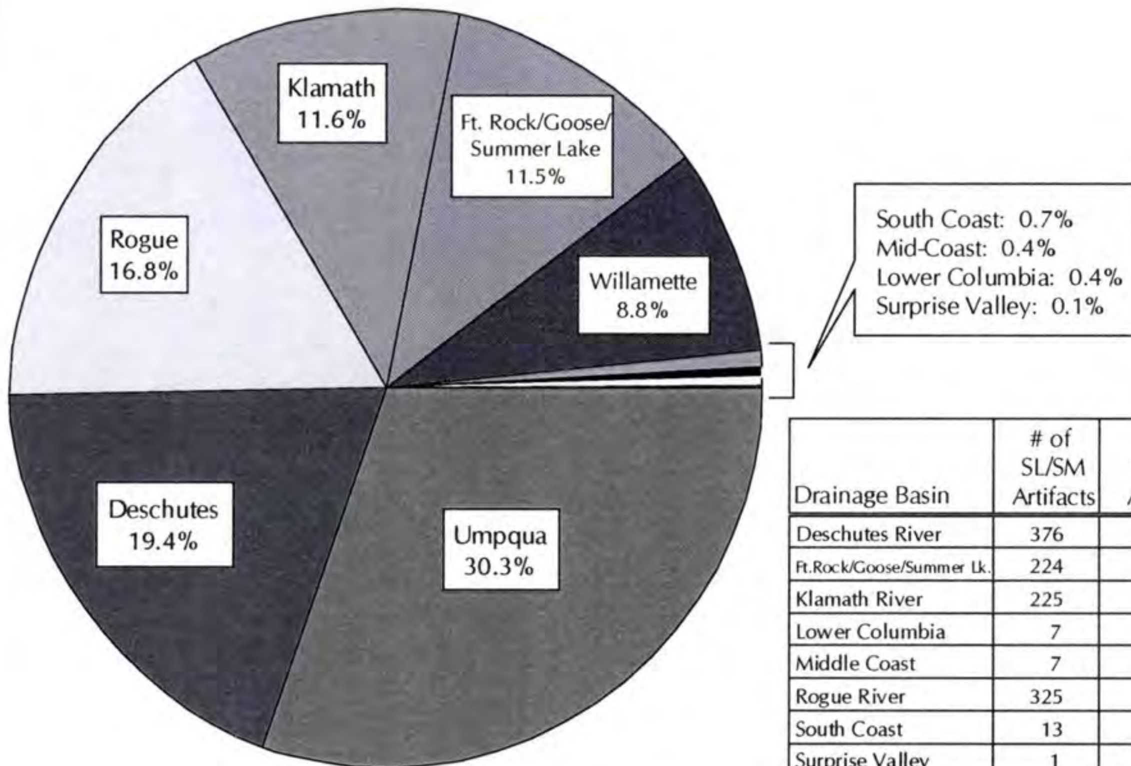
Figure 6.4. Distribution of archaeological sites within major drainage basins of Oregon, northern California, and southern Washington.

primary source is situated on the extreme northwestern edge of the Great Basin in a hydrologic sub-unit that contains the Fort Rock, Goose Lake, and Summer Lake basins. The Sycan Marsh primary source is on the northeastern edge of the Klamath Basin. The bulk of the SL/SM obsidian artifacts (98.4%) (Figure 6.5) is distributed among the Umpqua, Deschutes, Rogue, Klamath, Willamette and the Fort Rock basins. The remainder of the artifacts (1.5%) are located in basins that are geographically distant to the source region. An exception is a single artifact from one site located in the Surprise Valley Basin, a catchment that lies southeast of the Klamath Basin.

The percentage of SL/SM artifact obsidian from sites within the drainage basins is illustrated in Figure 6.6. The pie charts in the figure reflect the percentage of SL/SM artifact obsidian present in the geochemically-characterized obsidian artifact assemblage for sites within each basin. The percentages were calculated by dividing the number of SL/SM artifacts by the total number of characterized obsidian artifacts per basin. The calculations allow intra-basin comparisons of the presence of SL/SM obsidian with other non-specified obsidian sources.

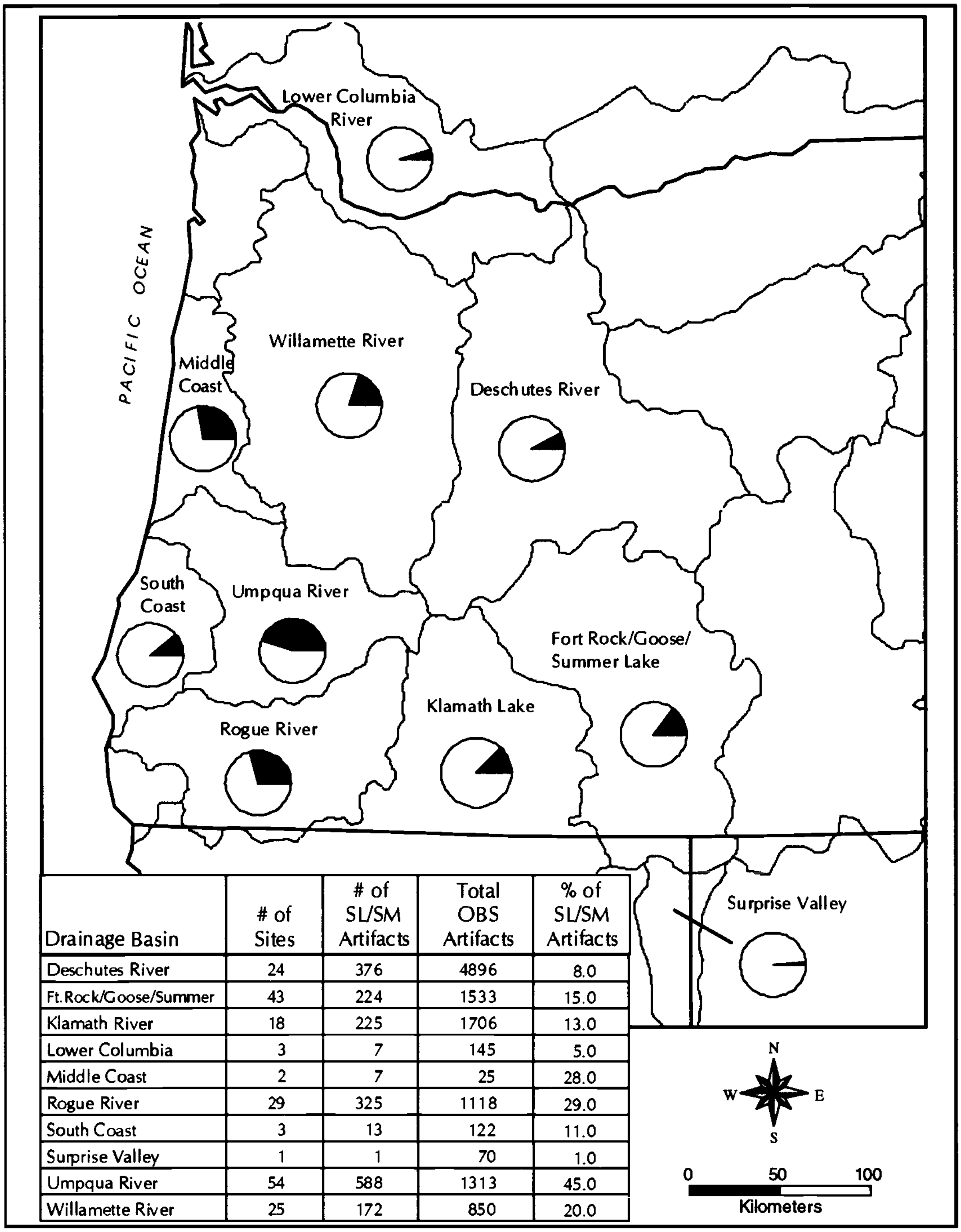
The SL/SM chemical group comprises over 25 percent of the total obsidian sources for sites in the Middle Coast, Umpqua and Rogue basins. SL/SM obsidian is less dominant at sites within the Willamette, Klamath Lake, Fort Rock and South Coast basins (approximately 13 to 20 percent). Within the Deschutes, Surprise Valley and Lower Columbia basin, SL/SM obsidian accounts for less than 10 percent of the characterized obsidian artifacts.

There is significant variation in the total number of obsidian artifacts sampled from each basin. For example, although the Rogue Basin and the Middle Coast Basin



Drainage Basin	# of SL/SM Artifacts	% of SL/SM Artifacts
Deschutes River	376	19.4
Ft.Rock/Goose/Summer Lk.	224	11.5
Klamath River	225	11.6
Lower Columbia	7	0.4
Middle Coast	7	0.4
Rogue River	325	16.8
South Coast	13	0.7
Surprise Valley	1	0.1
Umpqua River	588	30.3
Willamette River	172	8.8
TOTAL	1938	100.0

Figure 6.5. Percent of SL/SM artifact obsidian by major drainage basin for all SL/SM artifact obsidian represented (n = 1,938).



Drainage Basin	# of Sites	# of SL/SM Artifacts	Total OBS Artifacts	% of SL/SM Artifacts
Deschutes River	24	376	4896	8.0
Ft.Rock/Goose/Summer	43	224	1533	15.0
Klamath River	18	225	1706	13.0
Lower Columbia	3	7	145	5.0
Middle Coast	2	7	25	28.0
Rogue River	29	325	1118	29.0
South Coast	3	13	122	11.0
Surprise Valley	1	1	70	1.0
Umpqua River	54	588	1313	45.0
Willamette River	25	172	850	20.0

Figure 6.6. Percent of SL/SM artifact obsidian from archaeological sites within each represented major drainage basin.

share similar percentages of SL/SM obsidian, there is a distinct difference in the overall quantity of obsidian artifacts recovered from the two catchments (1,118 specimens from the Rogue Basin versus 25 specimens from the Middle Coast Basin). The differing quantities are, to some degree, factors of sampling bias but are more likely to be indicators of obsidian availability and distance to the source.

6.2.2 Distribution Across the Landscape

Areal differences in the SL/SM artifact obsidian distribution are effectively portrayed across continuous surfaces with maps developed from trend surface models. To generate trend surface maps of the distribution, a grid of the artifact data was produced using input values consisting of longitude (x), latitude (y) and the percent of SL/SM obsidian (z-value) for each site location. The values were interpolated with a radial basis function to determine the rate of change in the variance between the specified points and to produce a smoothed surface of the artifact distribution. Shaded relief images shown in Figures 6.7 through 6.9 demonstrate the distribution of SL/SM obsidian artifacts for a range of interpolated surfaces.

In an attempt to minimize bias in sample size, sites containing over 10 obsidian artifacts were selected for trend surface analysis (Figure 6.7). This grouping of sites demonstrates the most accurate portrayal of the spatial data when compared to other trend surface models including analysis of all sites and analysis of a sample of over 100 artifacts per site. Trend surface analysis of obsidian artifacts from all of the sites results in a skewed depiction of the magnitude of SL/SM obsidian (Figure 6.8). The entire data set includes several small samples with large SL/SM obsidian percentages that, when

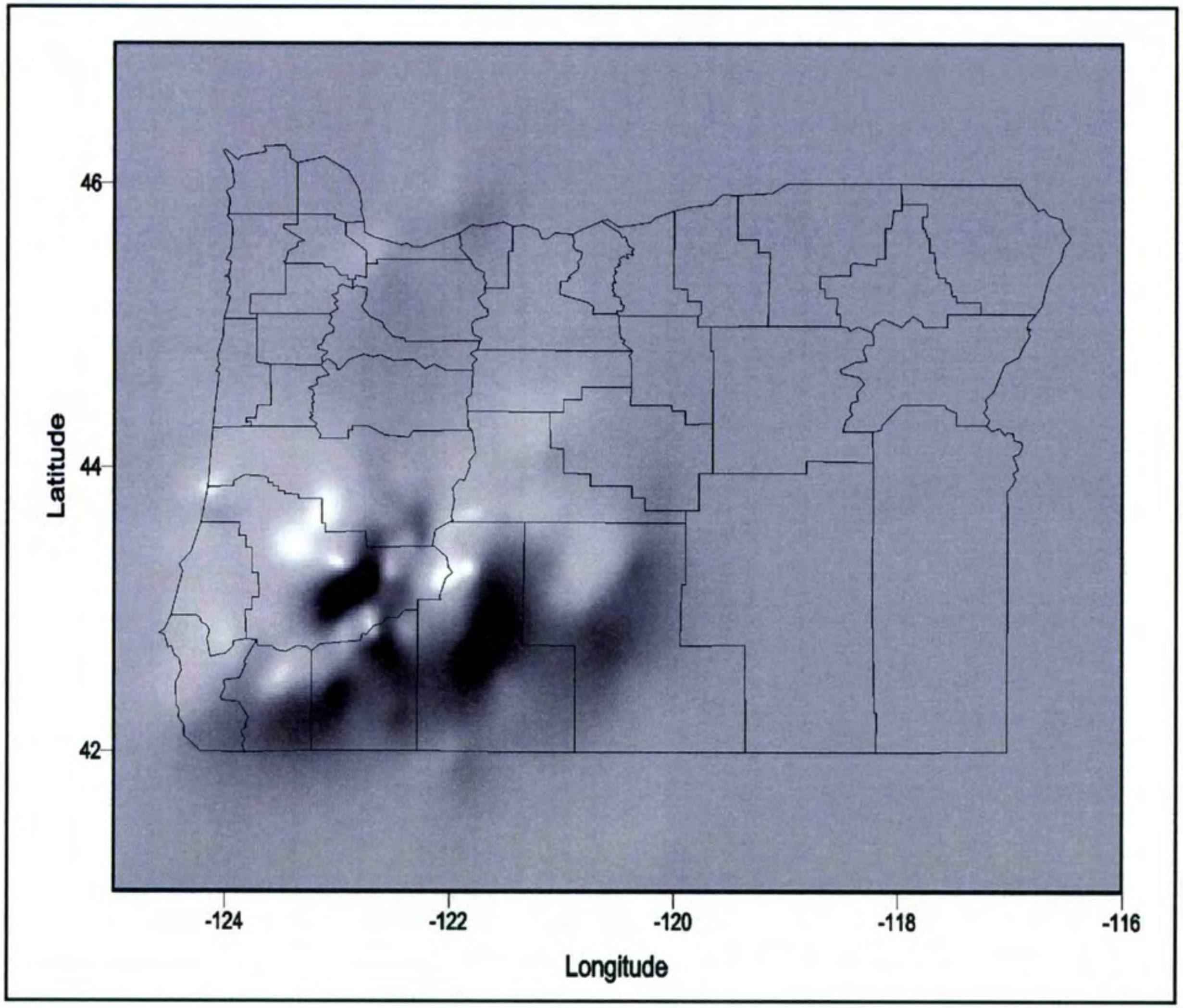


Figure 6.7. Shaded relief image of site distribution for all sites containing over 10 obsidian artifacts.

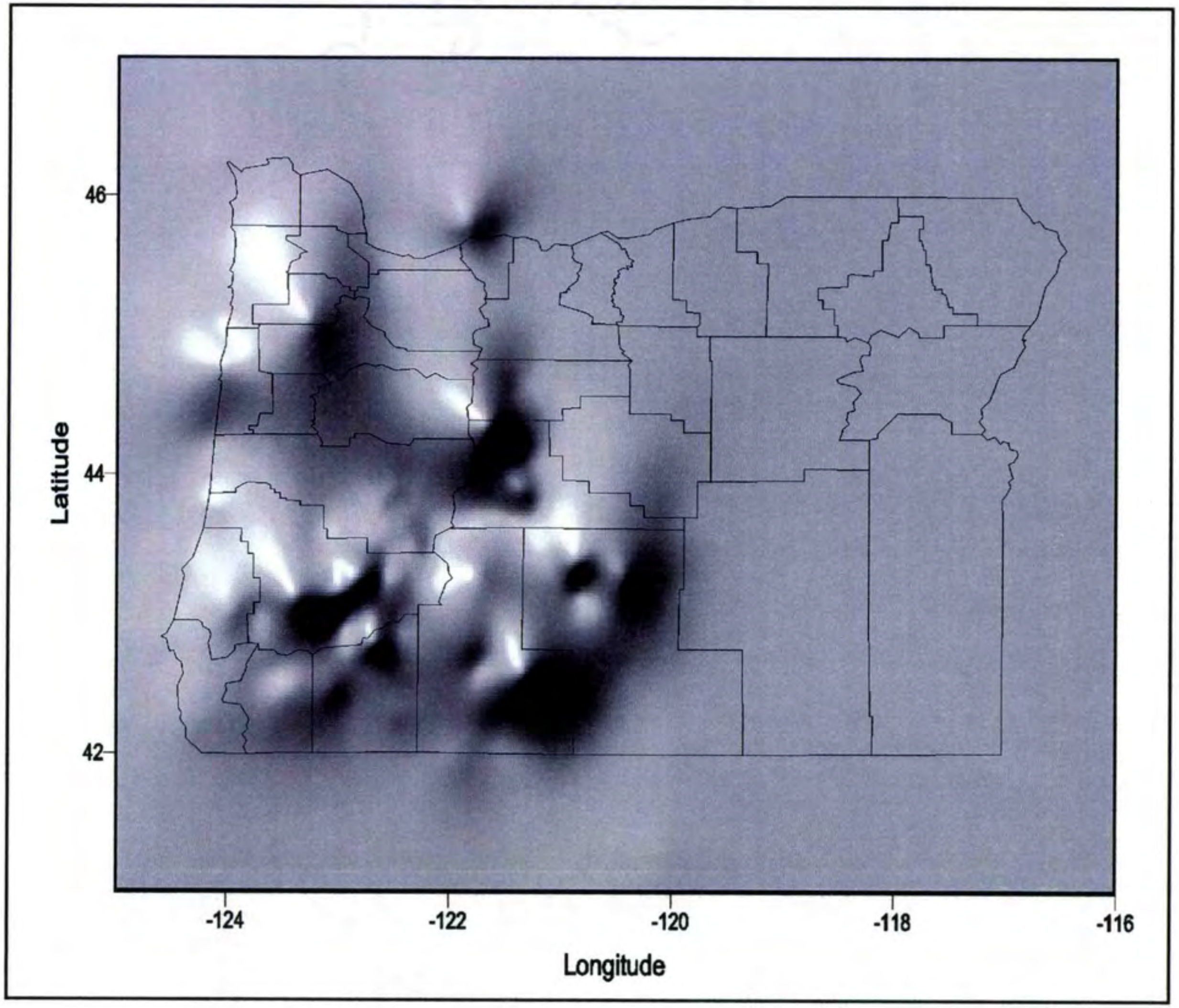


Figure 6.8. Shaded relief image of site distribution for all sites.

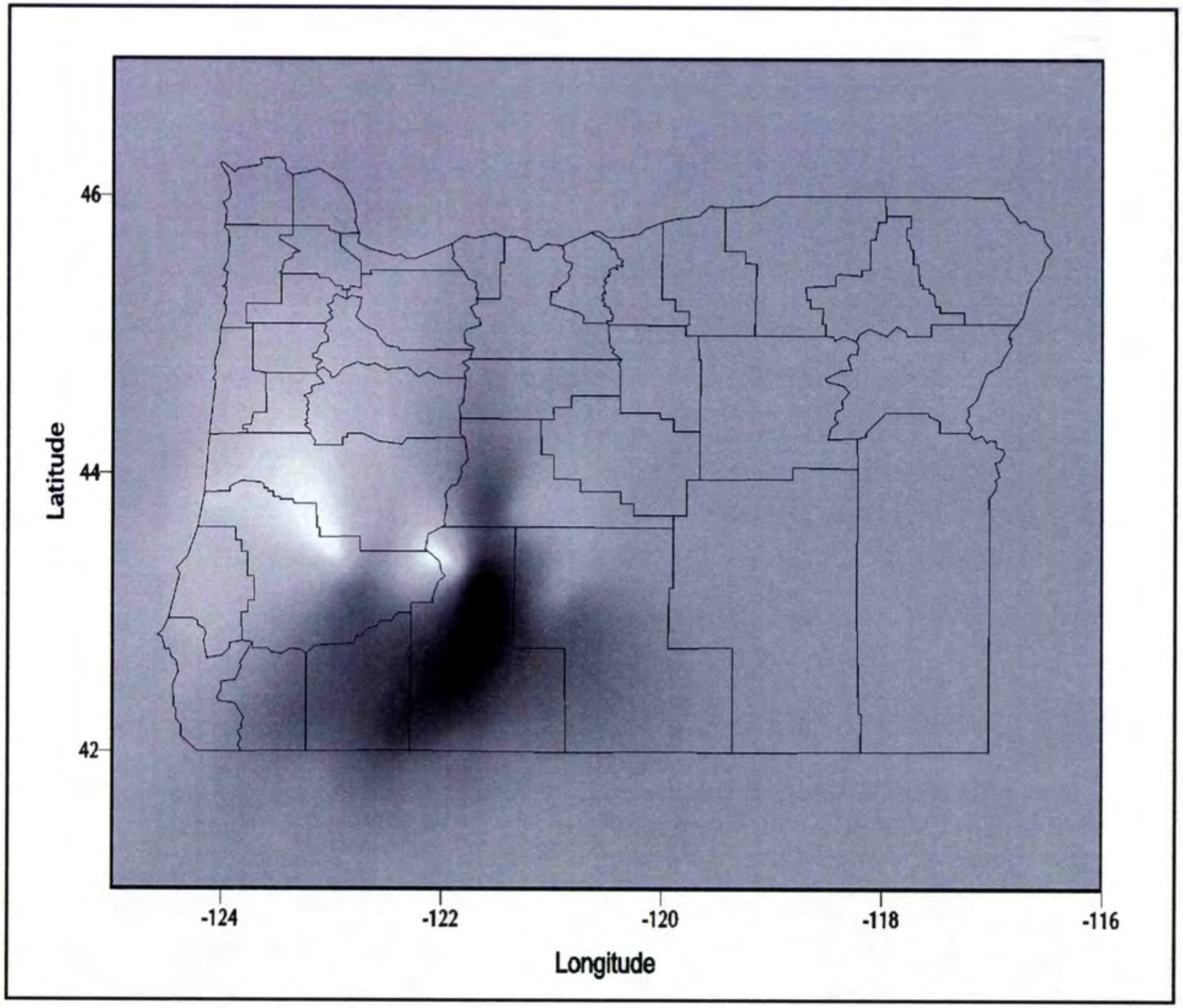


Figure 6.9. Shaded relief image of site distribution for all sites containing over 100 obsidian artifacts.

mapped, tend to amplify the actual quantity of SL/SM obsidian present in the site assemblages. The opposite is true of a selection of sites containing over 100 obsidian artifacts (Figure 6.9) wherein highly selective sampling results in the over-simplification of distribution patterns. The site distribution and magnitude is not adequately represented by such a selection because only 22 sites (11%) qualify.

6.3 Characteristics of the SL/SM Obsidian Procurement System

Since the late 1960's, geochemical characterization studies have been used to link obsidian artifact distribution to trade networks and exchange systems. Early obsidian studies focused on such aspects of artifact distribution as distance to source (Renfrew 1977) and cost analysis (Ericson 1982). Recently, however, there has been a shift in emphasis toward the reconstruction of mobility strategies and procurement systems (Hamusek 1993; Harro 1997; Roth 1998, 2000; Shackley 1990, 1996; Skinner 1997). This approach is commonly used in conjunction with typological and technological data to overcome the inherent difficulties in the identification and interpretation of procurement and exchange systems.

The reconstruction of prehistoric mobility strategies and exchange networks is often most effective with small-scale distribution patterns but may also be applied to large-scale distribution patterns such as those observed in the current research. Although the SL/SM artifact obsidian distribution patterns are broad in scope, they nonetheless provide important information about the prehistoric use of the SL/SM obsidian source. In an attempt to reconstruct patterns of SL/SM source use, the spatial distribution is described heuristically through an analysis of the characteristics of procurement and exchange systems and associated human behaviors that have undoubtedly influenced SL/SM obsidian distribution.

6.3.1 Artifact Magnitude

The magnitude of SL/SM obsidian, shown in Figure 6.10, is defined by a series of contour lines that overlay a shaded relief map. The peak areas of the shaded relief image correspond with the highest contour intervals and reflect the areas with the greatest volume of SL/SM artifact obsidian. Two major peaks exceeding densities of 35 percent are observed in the data.

The highest peak (70% SL/SM obsidian) is located in the northeastern portion of Douglas County, an area that geographically corresponds to the upper reaches of the North Umpqua River on the western slopes of the Cascades. Musil and O'Neill (1997:139) document a dominance of SL/SM obsidian at sites in this region and report the presence of 420 SL/SM obsidian artifacts out of a total of 754 (56%) geochemically-analyzed specimen from sites located along the North Umpqua River.

The second peak, visible at the northern tip of Klamath County, is coincident with a single site excavated during the PEP (35-KL-810). The presence of SL/SM obsidian at 35-KL-810 is robust: 283 out of 377 (75%) characterized obsidian artifacts correlate with the SL/SM source. While the peak is a likely function of sampling bias, it is also tempting to suggest that the predominance of SL/SM obsidian at this site is not anomalous for the immediate surrounding area, especially given the proximity of the site to the source region. However, additional geochemical data from other sites in the Klamath Basin are needed to support such a statement.

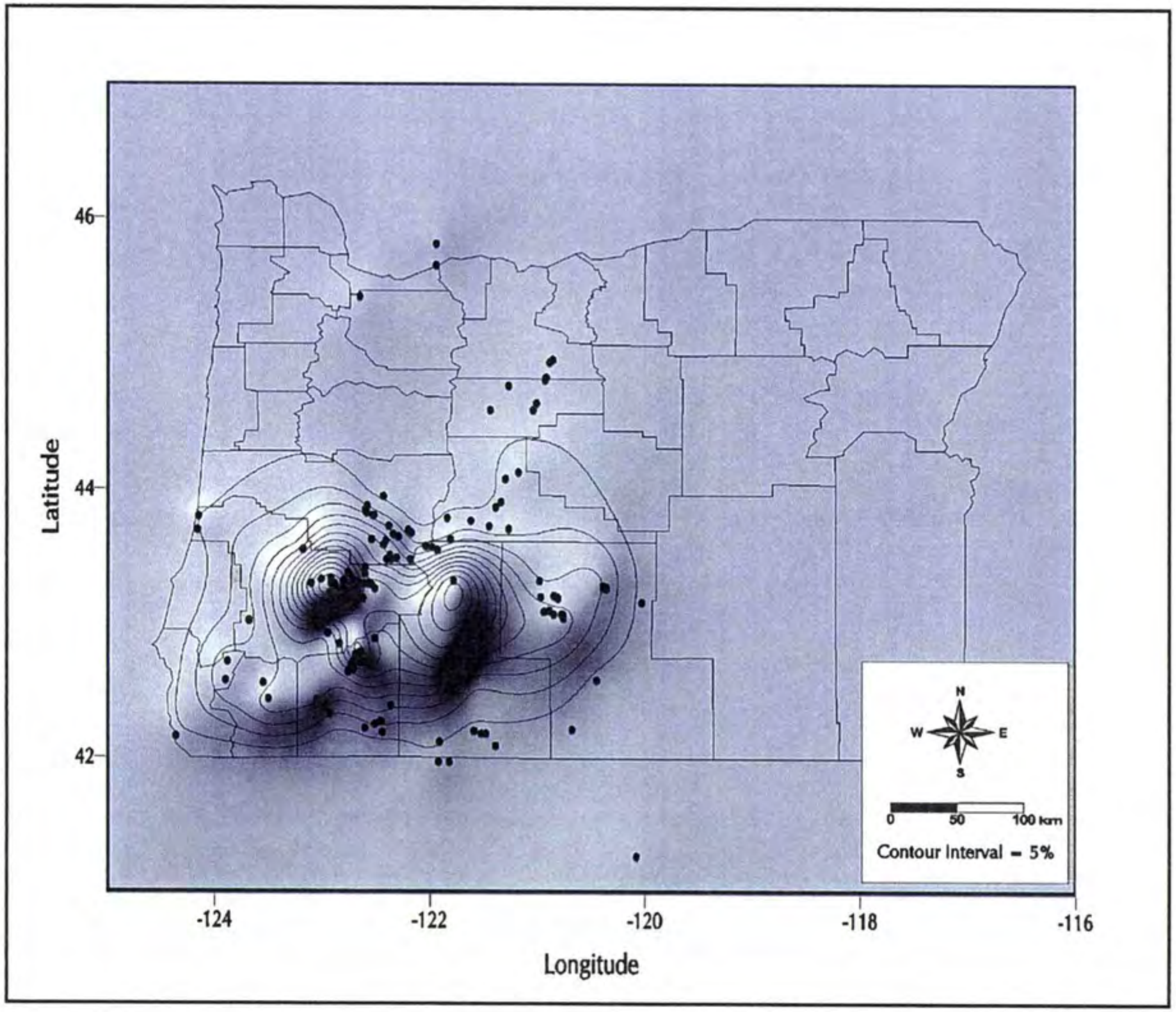


Figure 6.10. Trend surface and contour map of site distribution for sites containing over 10 geochemically characterized obsidian artifacts. Base contour is 5 percent.

The artifact distribution is tightly clustered around the two peaks within the 35 to 20 percent range but tapers off gradually with distance from 20 to 5 percent. Several sites fall just outside of the 5 percent range (depicted by the lowest contour interval in Figure 6.10) but are within relative proximity to the source area. Other, more distantly located outliers reflect a low density of SL/SM obsidian.

6.3.2 Distribution Shape and Directionality

The shape of the distribution, as defined here by the 5 percent contour line (Figure 6.10), is mostly ovoid along the horizontal axis with a slightly tapered midsection associated with the two areas of highest magnitude. Distribution of material from the source is asymmetrical and marked by the vast majority of sites situated north and west of the source region. The apparent bimodal distribution demonstrated at the peak areas, although influenced by sampling bias, may be a function of centralization where source use is highest. In general, however, the artifact distribution appears to reflect a westward flow of material from the source region.

The distribution of artifact obsidian does not extend far beyond the eastern boundary of the Fort Rock Basin near the border of Lake and Harney counties. The limited distribution of SL/SM artifact obsidian east of the source region is likely due to the presence of numerous competing obsidian sources located along the Fort Rock and Malheur/Harney basin divide (e.g., Bald Butte, Big Stick, Wagontire, Horse Mountain, Glass Buttes and Yreka Butte). Although SL/SM artifact obsidian occurs in relative abundance at Buffalo Flat, located on the extreme eastern edge of the Fort Rock Basin (Oetting 1989), use of the SL/SM source appears to decline abruptly with proximity to the competing sources.

Archaeological investigations in the adjacent Malheur/Harney Basin, although limited, have not shown evidence for the eastward movement of SL/SM artifact obsidian. It seems unlikely that the pattern will be greatly altered given the wide availability of high quality sources in the region. This assumption is reinforced by the complete absence of SL/SM obsidian from a sample of 618 obsidian artifacts recovered along a transect paralleling Highway 20 from Bend, Oregon to the Oregon-Idaho border (Skinner and Thatcher 1998).

6.3.3 Boundary, Procurement Range and Size

The boundary of the SL/SM procurement system is expressed as the geographic extent of the distributed source material (Figure 6.11). Multiple overlapping prehistoric procurement ranges, geographic areas covered during seasonal subsistence activities (Shackley 1990:60), are likely encompassed within the borders of the boundary. These procurement ranges are linked to tribal territories (Figure 6.12) but are not necessarily restricted to or defined by territorial boundaries. The size of the procurement ranges constitutes those areas within the overall boundary that were used for subsistence activities, exploration, or social networking over extended periods and across ethnic territories.

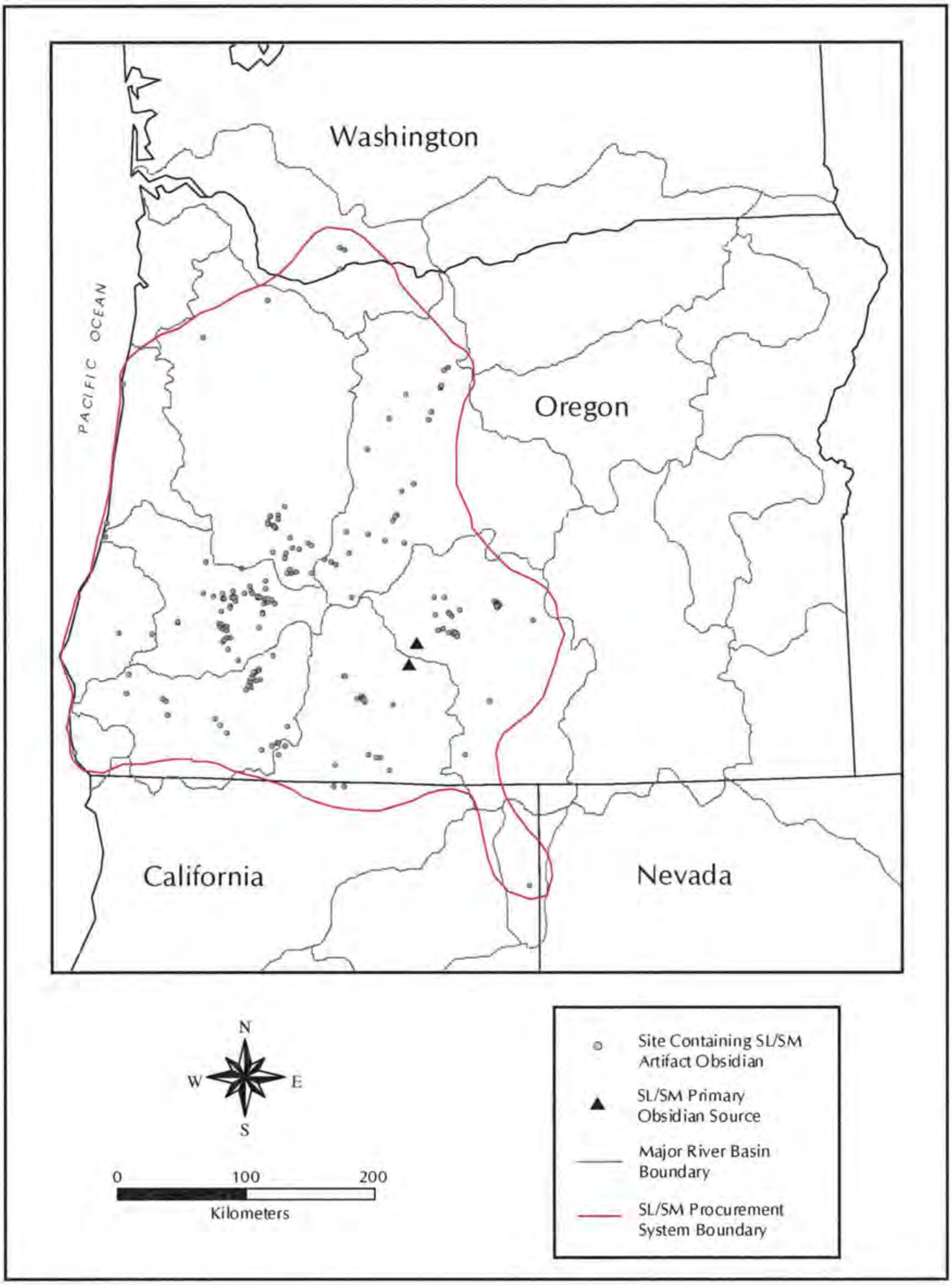


Figure 6.11. Estimated boundary of the SL/SM obsidian procurement system.

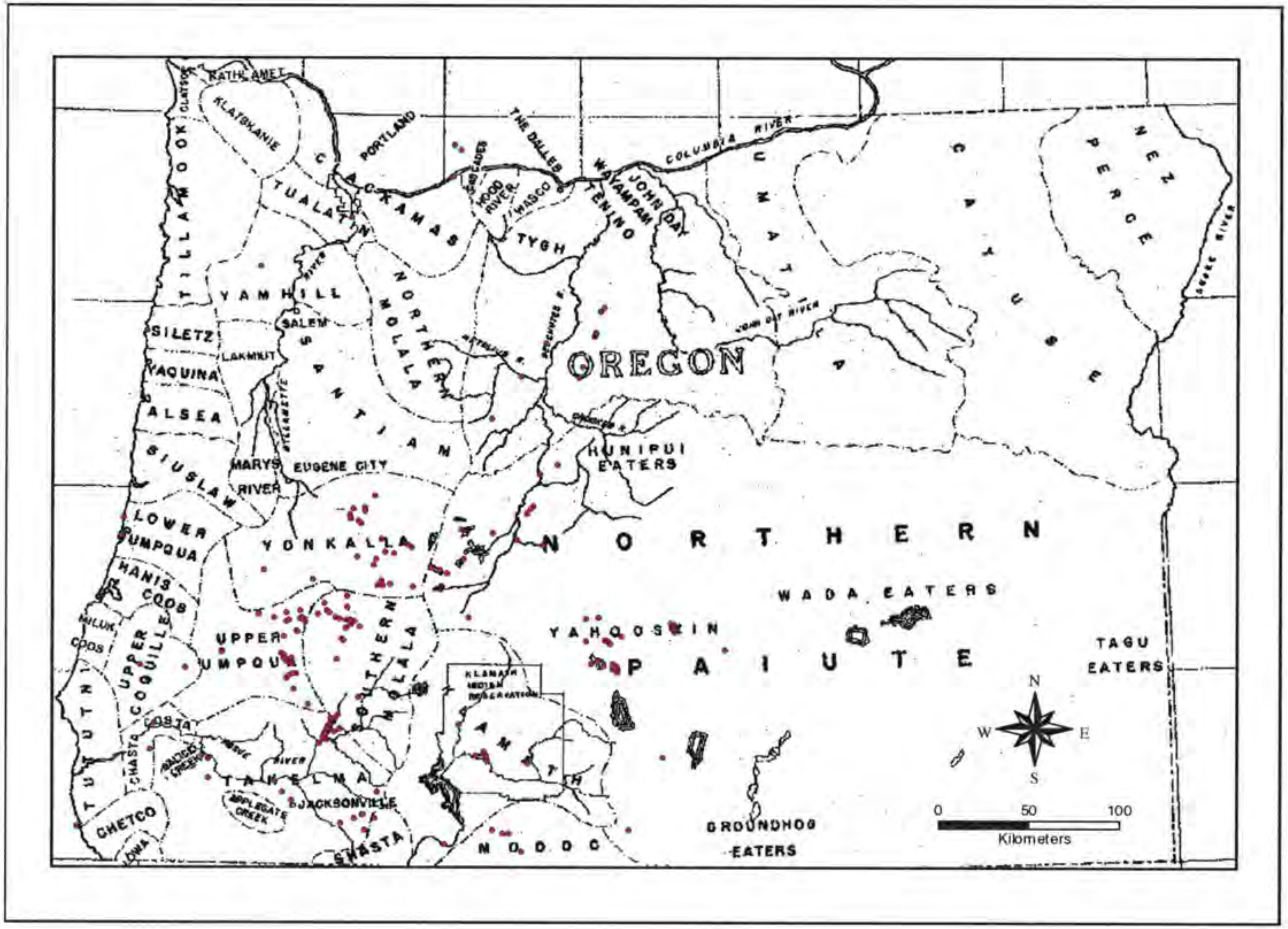


Figure 6.12. Oregon tribal distribution and site locations. Adopted from Stern 1965:279.

6.3.4 Acquisition and Distance to Source

The issue of obsidian acquisition is somewhat complex given the large geographic extent of the SL/SM procurement system. Several procurement ranges and exchange networks, although difficult to ascertain without additional information and temporal controls, are implied from the observed spatial distribution patterns. These systems were undoubtedly shaped by environmental aspects such as physical barriers and distance to the source and were influenced by a range of cultural variables, including territory and social networks. The following discussion describes possible prehistoric SL/SM obsidian procurement strategies and exchange networks in relation to the source location and with consideration of influential environmental and cultural factors.

6.3.4.1 Local Direct Procurement

The SL/SM source region straddles the border of the Klamath and Fort Rock basins (Figure 6.11). As detailed in Chapter 5, nodules of SL/SM obsidian occur at the primary sources, at numerous secondary outcrops within the Silver Lake sub-basin at the south end of the Fort Rock Basin, and among gravels in drainages within the general vicinity of Sycan Marsh. The source boundaries lie within two separate drainage basins: the Silver Lake primary and secondary source boundaries fall within the Fort Rock Basin and the Sycan Marsh primary and secondary source boundaries lie within the Klamath Basin. SL/SM obsidian was available for direct procurement by the region's occupants within these primary and secondary source boundaries.

At the time of Euro-American contact, the Klamath Basin was inhabited by Klamath-Modoc groups who made seasonal use of the Sycan Marsh area at the eastern edge of the basin. The adjacent Fort Rock Basin was occupied by Northern Paiute bands whose territory overlapped that of the Klamath within the Sycan Marsh region. Both groups frequented Sycan Marsh (Spier 1930:12; Steward 1939:132) and had direct access to the SL/SM source material in the uplands along the transition zone.

According to Paiute oral histories, pre-contact Klamath territory once extended into the northern Great Basin (Kelly 1932:72; Oetting 1989:235). However, sometime during the Late Archaic, Klamath occupants of the basin were apparently displaced by the arrival of Northern Paiute groups. Despite the shift in territorial boundaries, obsidian from the Silver Lake and Sycan Marsh source regions was likely exploited by the two groups. An analysis of the sites represented in this research, including site chronology and temporally diagnostic artifact data, could be used in future studies to further address this issue.

6.3.4.2 Local Source Use and Embedded Procurement Strategies

SL/SM obsidian was used locally at sites in the Fort Rock Basin and along areas of the Sycan and Sprague rivers in the Klamath Basin (Figure 6.12). Groups with direct access to the SL/SM obsidian source region also made use of the many other locally available obsidian sources. Within local prehistoric site assemblages, SL/SM artifact obsidian commonly co-occurs with other regional source groups.

Throughout the Holocene, highly mobile populations visited the Fort Rock Basin to exploit seasonally available resources (Aikens 1993; Aikens and Jenkins 1994; Jenkins 1994a). Frequent movement of these groups, as evidenced in part by the large number of sources identified in characterized artifact collections, suggest that obsidian procurement was embedded in seasonal subsistence activities or was exchanged during interaction with other groups. The circulation and diversity of obsidian source material within the region is well illustrated by a sample of 168 obsidian tools from the Connley Caves, a series of six cave sites located in the Fort Rock Basin (see Appendix G). Situated at the western base of the Connley Hills and overlooking Paulina Marsh to the south, the Connely Caves provided shelter to frequent visitors over the past 10,000 years (Bedwell 1973:172). During this time, obsidian from numerous widely-dispersed source areas (Figure 6.13) were used by occupants of the caves. The sources likely fell within various procurement ranges and interaction spheres.

Two local source groups, SL/SM and Cougar Mountain, lie within 24 kilometers of the Connley Caves and are well represented in the sample. The Cougar Mountain chemical group makes up 20 percent (n = 34) of the artifacts and SL/SM accounts for 17 percent (n = 28). The remaining 63 percent consists of 105 artifacts from 27 known geochemical source groups and two unknown sources. The source diversity observed in this sample may reflect periods of high mobility in the Fort Rock Basin, such as those brought about by fluctuations in the local climate (Jenkins 1994b:599). Exchange may also be a factor of the source diversity, although it is a less likely explanation given the relative abundance of local source material within the basin. If the source diversity is a function of mobility (Shackley 1996:11), it is likely that high frequencies of local materials (such as the SL/SM and Cougar Mountain sources) would indicate reduced mobility or even sedentary settlement patterns. That is, the procurement of obsidian from distant source areas would not be necessary if high quality glass was locally available. In fact, in a related study of diachronic obsidian use at sites in the Fort Rock Basin, both

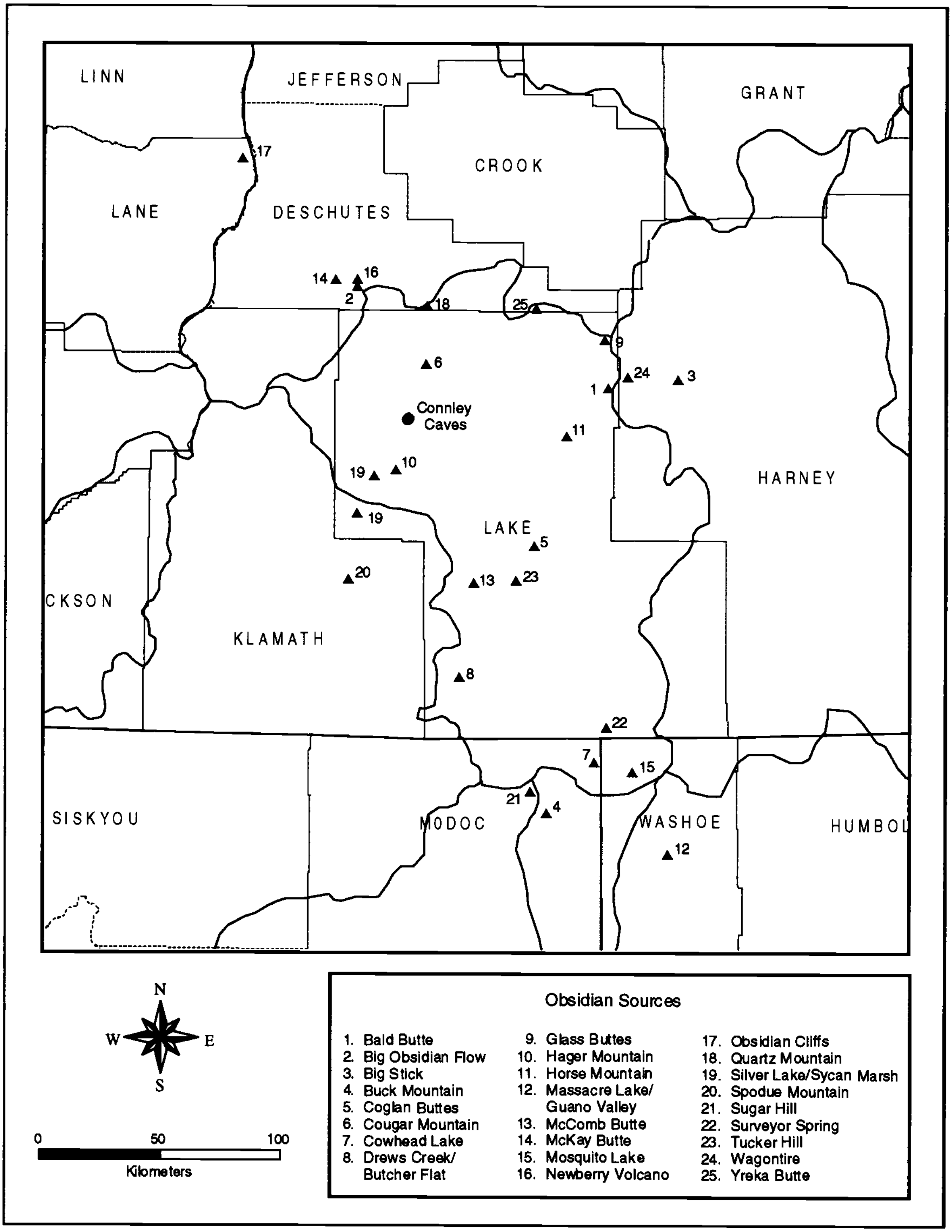


Figure 6.13. Locations of obsidian sources for all known chemical groups identified from the Connley Caves sample.

SL/SM and Cougar Mountain obsidian appear to have been more heavily exploited during periods of increased sedentism (Jenkins et al. 1999).

Within the Klamath Basin uplands located immediately south of the Fort Rock Basin, local use of the SL/SM obsidian source is evident at sites along the Sycan River and along the nearby Sprague River. SL/SM obsidian is abundant along the banks of the upper Sycan River where it drains the Sycan Marsh, a site ethnographically documented to have been used for root harvesting and wocas collection by groups inhabiting the Klamath Basin (Stern 1966:12). The Sycan Marsh primary source, as well as numerous secondary SL/SM obsidian outcrops, would have been directly available to groups from the Klamath Basin exploiting the upland resources on the western margin of the marsh and to the south along the Sycan River.

Clearly, the patterns of local source use were varied and dependent upon territory, mobility, and subsistence practices. Procurement of SL/SM obsidian was presumably an intentional activity carried out by occupants of the Fort Rock Basin and the Klamath Basin uplands. Local use was most likely embedded in subsistence activities by groups whose procurement range included the SL/SM source area. This type of incidental procurement was probably common for highly mobile populations requiring expedient tools in an obsidian-rich region.

6.3.4.3 Long-distance Direct Procurement and Indirect Procurement

Thus far, the discussion has focused on direct procurement by groups whose territories ethnographically encompassed or abutted the SL/SM source region. The conclusions presented above, although speculative, are perhaps more easily drawn than those derived from the analysis of spatial patterns associated with more distantly distributed source material. With increased distance from a given source, fall-off patterns typically emerge, suggesting alternative modes of acquisition, including long distance direct procurement and exchange networks (Findlow and Bolognese 1982; Renfrew 1977). The difficulty in interpreting these patterns lies in differentiating between direct and indirect procurement systems.

Long distance direct procurement implies unfettered access to a source region, either because access rights are granted to outside groups or because the source belongs to a non-territorial system in which "preemptive-use rights are lacking" (Bettinger 1982:112). Some obsidian source patterns exhibit well-defined and geographically restricted source boundaries indicative of tight territorial control over a source region (Bettinger 1982; Hughes and Bettinger 1984; Van de Houk 1990). However, the distribution of SL/SM obsidian is widespread throughout western Oregon and portions of north-central Oregon, affording the argument that both long-distance direct and indirect (exchange) procurement were in operation.

Several SL/SM artifacts, shown as outliers in Figure 6.10, were recovered more than 250 kilometers from the source region at sites located within the northern Willamette Basin, the Lower Columbia Basin, and along the Oregon coast. The majority of the artifacts from the outlying sites are formed tools, including projectile points and biface fragments. Given the distance of the artifacts from the SL/SM source and the limited availability of local obsidian, exchange is a viable explanation for the occurrence of SL/SM material at these sites where eastern Oregon obsidian sources are rare (Skinner and Winkler 1991, 1994).

Exchange is well documented for the Columbia Basin (Aikens 1993:91; Murdock 1965, 1980; Ray 1938; Ray et al. 1938; Wood 1972; Zucker et al.1983) where trade fairs drew groups from throughout the northwest. Klamath-Modoc tribelets reportedly traded slaves from the Pitt River, California area (Layton 1981:128; Zucker et al. 1983:42) and may have also included obsidian as an item of exchange. This type of long-distance exchange may account for the seven SL/SM obsidian artifacts recovered from three sites in the Lower Columbia Basin.

Obsidian is generally a rare commodity along the Oregon coast. Cultural obsidian recovered from central coastal sites typically correlates with the Inman Creek chemical group, a widely distributed geologic source in northwestern Oregon. Small nodules of Inman Creek obsidian occur naturally in many scattered locations in the Willamette Basin and were also locally available in gravel bars at the mouth of the Siuslaw River. SL/SM obsidian, less frequently observed in coastal site assemblages, is exotic to the region and was likely exchanged from the upper Umpqua and Rogue drainages where use of the material was prevalent. Along the southern Oregon Coast, SL/SM artifact obsidian often co-occurs with culturally modified obsidian from the Spodue Mountain and Medicine Lake sources.

SL/SM artifact obsidian is also scarce in the northern Willamette Basin and accounts for only two artifacts reported in this research, including a large ceremonial wealth blade from the Fuller Mound in Yamhill County (Laughlin 1943; Woodward et al. 1975). The blade is similar to those seen at Gold Hill in the Rogue Basin and Gunther Island in northwestern California where obsidian procurement is thought to play a socio-ceremonial role (Hughes 1990:54). Although it has not been directly related to ceremonial activities observed in southwest Oregon and northwest California, the Fuller Mound blade may well have been acquired through exchange with southern groups.

Exchange may be a less likely explanation for the occurrence of a single SL/SM obsidian artifact from a site in the Surprise Valley, California, where obsidian from the nearby Warner Mountains is abundant and widely available. Located almost 200 kilometers from the southern SL/SM obsidian source region, the Surprise Valley artifact, a northern side-notch projectile point, lies well beyond the 5 percent boundary (Figure 6.10) and represents the southernmost extent of the SL/SM artifact obsidian distribution. Interaction with groups from the Klamath Basin is documented (Kelly 1932:151–152) and may have resulted in the transport of the artifact into the Surprise Valley. Alternatively, the artifact may have been acquired by direct procurement from the source region during an extended excursion into the Northern Great Basin.

Non-local use of SL/SM obsidian appears to have been much more prolific within the upper Deschutes, Rogue, Umpqua and Willamette basins at distances averaging 130 kilometers from the source region. Noticeable densities of the material occur on the western slopes of the Cascades (Figure 6.10) and, with the exception of the previously mentioned outliers, account for over half (56 percent) of the SL/SM obsidian artifacts used in this research (Figure 6.5). Obsidian is not locally available in the Umpqua and Rogue basins but was obviously a highly valued material within the uplands of the western Cascades and the basin interiors. The pattern of SL/SM obsidian use in this region, based on the distribution and the distance to the SL/SM source, strongly suggests the presence of a trans-Cascade exchange network, a long-distance direct procurement system, or seasonal use of western Cascade resources by eastside groups with access to SL/SM obsidian.

In a detailed study of 917 obsidian artifacts from the Umpqua Basin, Musil and O'Neill (1997) document the predominance of SL/SM obsidian from sites within the basin. SL/SM comprised 75 percent of their overall sample and was proportionally highest at sites in the North Umpqua drainage. The authors demonstrate an overall trend in the distribution on the reliance of SL/SM obsidian, as well as additional northern and eastern obsidian sources, for a period of time spanning approximately 8,000 years. Musil and O'Neill cite Renfrew's (1977:72-73) concept of "effective distance"– related to ease of travel – as the overriding factor influencing obsidian distribution in the Umpqua Basin. They state that "the use of the major streams as travel corridors would seem to provide the most effective routes to the crest of the High Cascades" (Musil and O'Neill 1997:152). Once over the Cascade divide and on the relatively flat terrain of the central Oregon high desert, the SL/SM source area is easily accessible.

Groups traversing the Cascades may have done so in pursuit of seasonal resources (for instance, see Murdock 1980), for exchange purposes, or, in the case of western groups heading east, for direct access to the SL/SM obsidian source region. These activities were probably subject to territorial boundaries and may have required permission by groups seeking access to a neighboring area. Consequently, territorial boundaries and land use access or restrictions would have had a direct influence on the trans-Cascade distribution of SL/SM obsidian.

At the time of contact, groups occupying this region included the Klamath, whose territorial range encompassed the upper Klamath Basin and possibly parts of the western

Cascades (Winthrop and Gray 1987:10). To the east, the mountainous uplands of the western Cascades were inhabited by the Molala at the southern end of the Willamette Basin and along the extent of the upper Umpqua Basin. The Takelma, a southwestern Oregon group, occupied the uplands farther south, in the Rogue Basin. Interaction between these groups and the subsequent distribution of SL/SM obsidian may have been facilitated by shared trail systems (Starr 1983:88; Vernon 1934), overlapping procurement ranges, integrated hunting excursions (Zenk 1976:35–36) and trade fairs (Honey and Hogg 1980:75). Socio-ceremonial factors may have also played a role in the acquisition of obsidian and encouraged the establishment of social alliances to secure access rights or trade relationships.

Explanations of long distance direct procurement and exchange networks may also be applied to the scattered occurrences of SL/SM obsidian in the Deschutes Basin. As with the eastern boundary, there is a somewhat abrupt drop in the frequency of SL/SM obsidian to the north of the source region within the Deschutes Basin. The diminishing magnitude is, in all likelihood, attributable to territorial boundaries or procurement ranges and the presence of competing obsidian sources located within the basin, particularly those which occur at Newberry Crater. Chemical groups associated with Newberry Crater, located near the southern border of Deschutes County, were used extensively in the Deschutes Basin (Connolly 1999) and account for the majority of sources recovered from Deschutes Basin sites during the PEP (Skinner 1995).

A total of 376 SL/SM artifacts (19.4 percent) were found within the Deschutes Basin. Of those, 283 (almost 15 percent of the total sample) were recovered from a single site (35-KL-810) located in the upper part of the drainage near the Deschutes-

Klamath Basin boundary. An additional 76 artifacts come from 13 sites in the Upper Deschutes Basin and the remaining 17 artifacts originiate from nine sites in the Lower Deschutes Basin.

The distribution patterns demonstrate a higher incidence of SL/SM obsidian use in the Upper Deschutes Basin, most notably at 35-KL-810. This site sits in the high desert, just east of the Cascade divide where the Willamette, Umpqua, Klamath, Dechutes and Fort Rock basins converge. The headwaters of the North Umpqua River lie 20 kilometers away, almost due west across the divide. To the northwest, the northern tributaries of the Willamette River are under 30 kilometers away. The high percentage of SL/SM obsidian recovered from the site suggests occupation and use of the extreme Upper Deschutes Basin by groups with direct access to the source, including western groups involved in a trans-Cascade procurement or exchange system.

Distribution of SL/SM obsidian north of 35-KL-810 is much less pronounced and appears to have been the result of incidental source use embedded in subsistence pursuits by groups using the transition zone between the Klamath Basin, the Northern Great Basin and the High Lava Plains. Given the predominance of Newberry Crater obsidian sources within the basin, it is unlikely that SL/SM obsidian was used as an item of exchange. Instead, the SL/SM artifact obsidian was probably brought into the Deschutes Basin as part of an existing tool kit.

6.4 Summary

Many different cultural and environmental variables have influenced the spatial distribution of SL/SM artifact obsidian. The overall distribution is geographically widespread and shows a general west-trending direction from the source region. High concentrations of SL/SM artifact obsidian occur at sites within 130 kilometers of the source area and are most prevalent in the Umpqua Basin and in the extreme Upper Deschutes Basin. The increased magnitude of SL/SM obsidian on the western slopes of the Cascade Range in the Umpqua, Upper Willamette, and Rogue basins implies the existence of a trans-Cascade procurement and exchange system. Within the Klamath and Fort Rock basins, SL/SM obsidian was locally available and was collected directly from the source during seasonal subsistence activities by highly mobile populations. Obsidian source diversity in the Fort Rock Basin, as observed at the Connley Caves, demonstrates the widespread availability and use of regional sources. Outliers located along the Oregon coast and within the Lower Columbia, northern Willamette, and Surprise Valley basins are most likely attributed to indirect procurement and exchange systems and in the case of wealth blades from the Fuller Mound and the Gold Hill sites, indicate a potential socio-ceremonial context involved in the acquisition of SL/SM obsidian.

7. CONCLUSIONS AND RECOMMENDATIONS

This thesis uses a wealth of geochemical analytical data to accomplish two primary objectives. The first goal focuses on defining boundaries of the geographic extent of geologic SL/SM obsidian. The second goal centers on the display and evaluation of SL/SM artifact obsidian distribution. Several conclusions can be drawn from the data presented in this study.

7.1 Conclusions

Two discrete geologic source boundaries are proposed for the geographic extent of primary and secondary SL/SM obsidian source material. Each boundary corresponds to the primary source locations and associated secondary outcrops. Topography and natural formation processes appear to have been major factors in the source material distribution.

Obsidian associated with the northern, or Silver Lake, dome occurs in abundance at the primary source and in smaller quantities at secondary outcrops along the southern margin of the Fort Rock Basin. The West Fork of Silver Creek drains the slopes of the Silver Lake dome and is a likely channel for secondary material redeposited in the basin. Secondary deposits are found along pluvial lakeshore terraces at the southern margin of the basin and within drainages of the Silver Lake sub-basin. Physical characteristics of the material vary from location to location, but tend to be more rounded and smaller in size with increased distance from the primary source. The boundary for the Silver Lake dome encompasses the primary source and the numerous secondary sources within the southern portion of the Fort Rock Basin, including the Silver Lake sub-basin and the general vicinity of Paulina Marsh.

The southern, or Sycan Marsh, obsidian dome, lies in the Klamath Basin and is drained to the southeast by Long Creek. Obsidian from the primary source erodes downslope into the Long Creek drainage and from there is transported along the western margin of Sycan Marsh into the Sycan River. As with the Silver Lake dome, source material is abundant along the slopes of the Sycan Marsh dome but tends to diminish in size and quantity with increased distance from the primary source. Secondary deposits of obsidian from the Sycan Marsh dome occur in scattered locations at the base of the dome and in river gravels along the Sycan River. From the primary source, the boundary follows a drainage system along the western edge of Sycan Marsh and terminates several kilometers south of the marsh on the Sycan River.

Each boundary emanates from a primary source and encompasses numerous secondary deposits associated with each dome. The two domes are chemically related, and without more refined geochemical analysis cannot be differentiated from one another with confidence. To this end, the determination of two discrete source boundaries was based on the association of SL/SM geologic obsidian with distinct topographic features, namely the location of the domes and associated secondary deposits within separate drainage basins.

SL/SM artifact obsidian exhibits a wide geographic distribution at archaeological sites located throughout the western half of Oregon and in parts of northern California and southwestern Washington. The spatial distribution of SL/SM artifact obsidian was likely influenced by numerous cultural and environmental variables. Based on the wide distribution, it appears that prehistoric SL/SM obsidian procurement and exchange systems occurred at local and regional levels and involved intentional and incidental methods of acquisition including direct procurement activities, embedded strategies, and exchange networks.

Evidence of local use of the SL/SM source is seen at Fort Rock and Klamath basin sites. The magnitude of prehistoric SL/SM source use on a local level, however, is less prominent than that seen in adjacent regions due to the high availability of competing obsidian sources within the general vicinity of the SL/SM source area. To the west, high concentrations of SL/SM artifact obsidian on the western slopes of the Cascade Range indicate a reliance on SL/SM obsidian and suggest the presence of a prehistoric trans-Cascade procurement and exchange system. Interaction between groups likely played a key role in the distribution of SL/SM obsidian at sites located at long distances from the source region, specifically the outliers situated along the Oregon coast, within the northern Willamette Basin and within the Lower Columbia Basin. Exchange may have occurred within ceremonial contexts, during shared resource activities, or at social gatherings such as trade fairs.

7.2 Recommendations

Unlike earlier studies, the research presented in this thesis synthesizes a large set of geochemical data from multiple sources for both geologic and artifact obsidian from the SL/SM obsidian source. The compiled artifact XRF data provide a large-scale perspective of the overall site distribution. Moreover, the geologic fieldwork and subsequent XRF data elaborate on previous source descriptions (Atherton 1966;

Hering 1981; Hughes 1986; Sappington 1981b; Skinner 1983) and establish a set of boundaries to which reconstructions of procurement strategies can be linked.

Future studies could expand upon several aspects of the current research. The following recommendations are offered:

1. *Additional geologic fieldwork.* Continued geologic fieldwork in the SL/SM obsidian source region would provide an even more thorough understanding of the source boundaries. In particular, drainages within the Sycan Marsh area may contain gravels of SL/SM obsidian well beyond (east) the existing boundary. The marsh, owned and managed by the Nature Conservancy, covers over 24,000 acres and is comprised of an extensive stream network. Although SL/SM obsidian was not recovered from the eastern margin of the marsh, there is a strong likelihood that the material extends well into the center of the marsh. Within the Fort Rock Basin, additional geologic fieldwork along the margins of Paulina Marsh would refine the northern source boundaries for the Silver Lake source region. Continued geologic fieldwork would also serve to identify source boundaries for other local chemical groups.

2. *Neutron Activation Analysis (NAA).* The XRF analysis of the geologic obsidian revealed a slight difference in the strontium (Sr) abundances between the two domes. NAA studies could be used to detect measurable differences in the geochemistry of obsidian from the primary sources. The ability to distinguish between the source regions would have exciting implications in the reconstruction of procurement and exchange systems.

3. *Incorporation of negative site data.* The current research relied solely on the presence of SL/SM artifact obsidian at prehistoric sites. Within the existing data set of characterized obsidian, there are numerous archaeological sites that do not contain artifact obsidian from the SL/SM source. An analysis of the site distribution in relation to all sites in the database would further clarify the SL/SM artifact obsidian distribution.

4. *Consideration of artifact type.* Technological and morphological attributes were not considered in this study due to the large numbers of artifacts used in the distribution analysis as well as inconsistency in artifact type descriptions. However, a distribution study of the artifact type (as simple as debitage versus formed tools) would promote a greater understanding of procurement and exchange networks. A technological study of the domes as quarry sites would also shed light on the lithic procurement activities being carried out at the primary sources where material is most abundant.

5. *Consideration of temporal traits.* Many of the artifacts used in this research have been subjected to obsidian hydration analysis and could be organized to produce a chronology of SL/SM source use. A diachronic investigation of the Connley Caves sample, for instance, would provide an interesting case study of regional SL/SM obsidian use through time.

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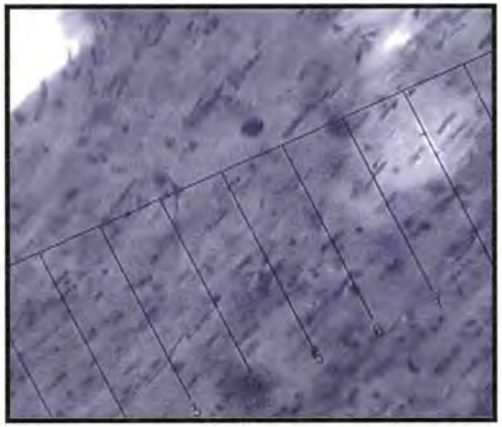
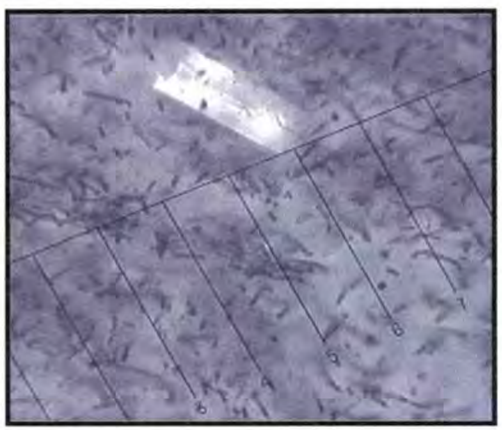
APPENDICES

Appendix A

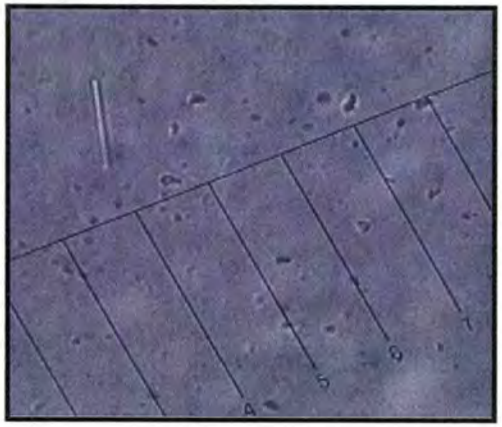
Geologic Sample Photomicrographs



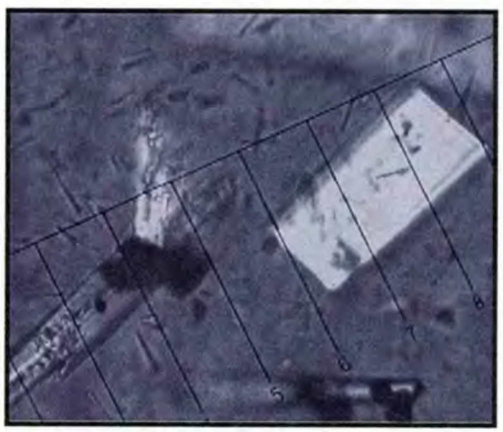
Sample No.	SLVCR-A1
Color: Munsell	Black (N 1/0)
Color: Texture	Banded, indistinct
Light Transmittance	Opaque
Surface Luster	Vitreous
Surface Texture	Matte
Megascopic Inclusions	Bubbles
Shape	Tabular
Microscopic Inclusions	Phenocrysts, prismatic microlites, magnetite; dense.
Comments	--



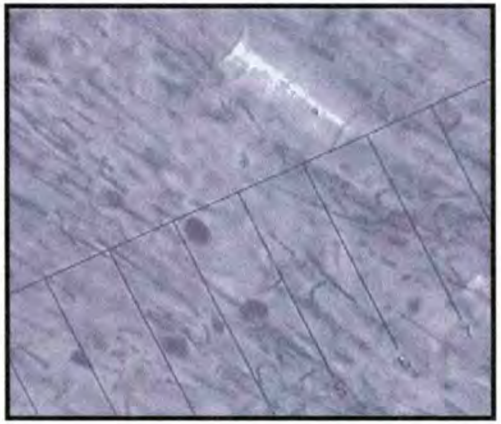
Sample No.	SLVCR-A6
Color: Munsell	Black (N 1/0)
Color: Texture	Uniform
Light Transmittance	Opaque
Surface Luster	Vitreous
Surface Texture	Flawed
Megascopic Inclusions	Microphenocrysts
Shape	Sub-rounded
Microscopic Inclusions	Phenocrysts, stretched vesicles.
Comments	--



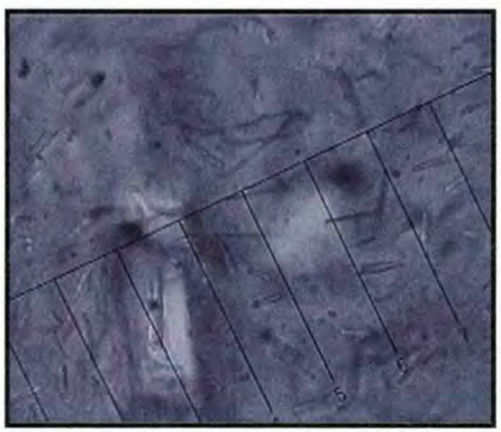
Sample No.	SLVCR-A14
Color: Munsell	Black (N 1/0)
Color: Texture	Uniform
Light Transmittance	Opaque
Surface Luster	Vitreous
Surface Texture	Flawed
Megascopic Inclusions	Microphenocrysts
Shape	Sub-angular
Microscopic Inclusions	Very clean glass; prismatic microlite observed.
Comments	Very few microscopic inclusions observed



Sample No.	SLVCR-A15
Color: Munsell	Black (N 1/0)
Color: Texture	Banded, indistinct
Light Transmittance	Translucent
Surface Luster	Vitreous
Surface Texture	Grainy
Megascopic Inclusions	--
Shape	Sub-angular
Microscopic Inclusions	Phenocrysts, prismatic microlites, magnetite; sparse.
Comments	--



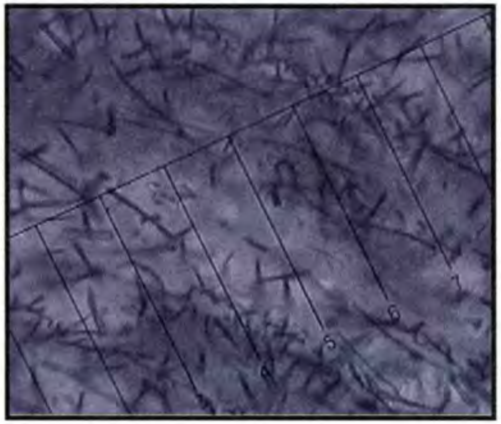
Sample No.	SLVCR-B9
Color: Munsell	Black (N 1/0)
Color: Texture	Veined
Light Transmittance	Opaque
Surface Luster	Vitreous
Surface Texture	Grainy
Megascopic Inclusions	--
Shape	Sub-angular
Microscopic Inclusions	Phenocrysts, prismatic microlites, magnetite; medium density.
Comments	--



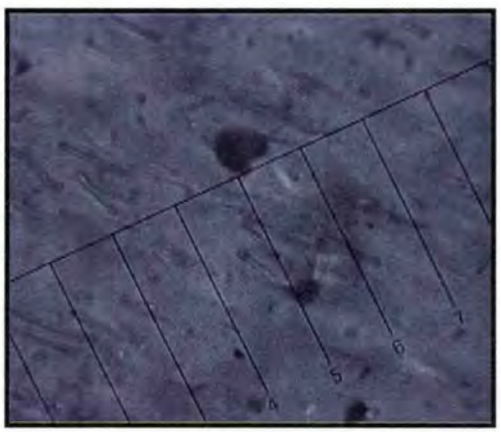
Sample No.	SLVCL-A11
Color: Munsell	Black (N 1/0)
Color: Texture	Uniform
Light Transmittance	Translucent
Surface Luster	Vitreous
Surface Texture	Grainy
Megascopic Inclusions	--
Shape	Rounded
Microscopic Inclusions	Phenocrysts, prismatic microlites, magnetite; medium density.
Comments	–

Sample No.	CARLN-A1
Color: Munsell	Black (N 1/0)
Color: Texture	Uniform
Light Transmittance	Translucent
Surface Luster	Vitreous
Surface Texture	Grainy
Megascopic Inclusions	--
Shape	Rounded
Microscopic Inclusions	Medium density phenocrysts, low density microlites, magnetite.
Comments	--

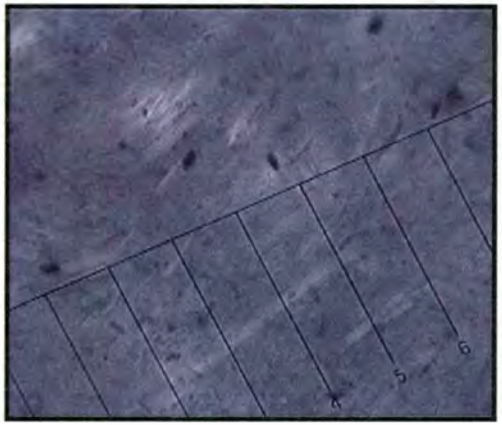
Sample No.	LONGC-A7
Color: Munsell	Black (N 1/0)
Color: Texture	Mottled (Mahogany)
Light Transmittance	Opaque
Surface Luster	Vitreous
Surface Texture	Smooth
Megascopic Inclusions	--
Shape	Sub-Angular
Microscopic Inclusions	Asteroidal /acicular trichites, brown ribbon mottling.
Comments	--



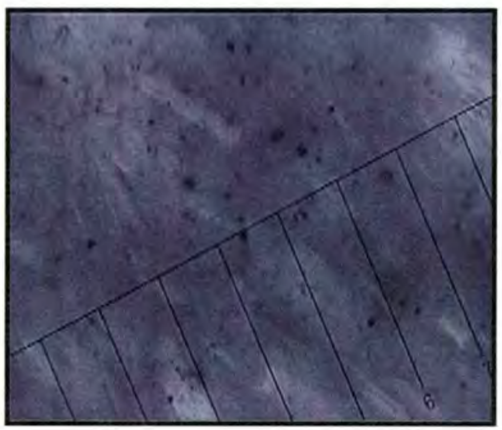
Sample No	LONGA-10
Color: Munsell	Black (N 1/0)
Color: Texture	Banded, distinct
Light Transmittance	Translucent
Surface Luster	Vitreous
Surface Texture	Flawed
Megascopic Inclusions	Microphenocryst
Shape	Sub-angular
Microscopic Inclusions	Acicular trichites, phenocrysts, prismatic microlites, magnetite; medium density.
Comments	--



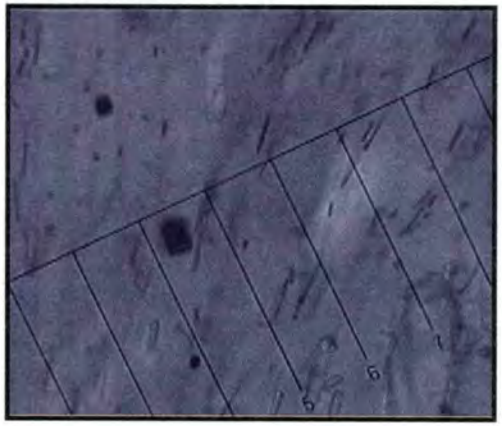
Sample No.	LONGA-13
Color: Munsell	Black (N 1/0)
Color: Texture	Uniform
Light Transmittance	Translucent
Surface Luster	Vitreous
Surface Texture	Matte
Megascopic Inclusions	--
Shape	Sub-angular
Microscopic Inclusions	Phenocrysts, prismatic microlites, magnetite; sparse.
Comments	--



Sample No.	OBSDM-A1
Color: Munsell	Greyish black (N 2/0)
Color: Texture	Uniform
Light Transmittance	Translucent
Surface Luster	Vitreous
Surface Texture	Mattte
Megascopic Inclusions	--
Shape	Tabular
Microscopic Inclusions	Crystalline structure; dense phenocrysts, prismatic microlites, magnetite.
Comments	--



Sample No.	OBSDM-A2
Color: Munsell	Greyish black (N 2/0)
Color: Texture	Banded, distinct
Light Transmittance	Opaque
Surface Luster	Vitreous
Surface Texture	Mattte
Megascopic Inclusions	--
Shape	Angular
Microscopic Inclusions	Crystalline structure; dense phenocrysts, prismatic microlites, magnetite.
Comments	--



Sample No.	OBSDM-A17
Color: Munsell	Greyish black (N 2/0)
Color: Texture	Banded, indistinct
Light Transmittance	Translucent
Surface Luster	Vitreous
Surface Texture	Smooth
Megascopic Inclusions	--
Shape	Sub-angular
Microscopic Inclusions	Phenocrysts, prismatic microlites, magnetite; sparse.
Comments	--

Appendix B

Geologic Collection Site Descriptions

Site No.	Collection Site Name	County	Legal Description	U.S.G.S 7.5' Quadrangle	Source Description
97-1	Silver Creek-A (SLVRC-A)	Lake	T30S, R13E, NE 1/4 of Sec. 11	Partin Butte	This is one of two primary source locations for SL/SM obsidian (see 97-5 for a description of the other primary source location). The source area is a small dome situated on the NE flanks of the Yamsay Mountain geologic complex. Source material is abundant and covers over 140 acres. Sub-angular and sub-rounded pebbles, cobbles, and boulders* cover the surface and are found eroding out of the slopes. Evidence of prehistoric tool manufacturing and historic hunting and quarrying activities is found throughout the area. A wide range of megascopic characteristics is observed, including: banding, veins and small inclusions; grainy and glassy textures; opaque to slightly translucent light transmittance; and dark grey to black color. All samples analyzed (n=15) correlate with the SL/SM geochemical source.
97-2	Silver Creek-B (SLVRC-B)	Lake	T30S, R13E, SW 1/4 of Sec. 1	Partin Butte	Small numbers of sub-rounded and sub-angular pebbles and small cobbles (approximately 5/meter^2) are found on the surface and in exposures along a logging road. This site is located downslope from the Silver Creek-A source. All samples analyzed (n=15) correlate with the SL/SM geochemical source.
97-3	Carlon Ranch (CARLN-A)	Lake	T31S, R13E, NW 1/4 of Sec. 34	Sycan Marsh West	Abundant sub-rounded and sub-angular pebbles and small cobbles (most no larger than 10cm diameter) are exposed on the surface along an upper terrace due west of the Sycan Marsh area. This site is located to the north and east of the Obsidian Dome site (see description for 97-5). All samples analyzed (n=15) correlate with the SL/SM geochemical source.
97-4	Long Creek (LONGC-A)	Lake	T31S, R13E, NW 1/4 of Sec. 4	Sycan Marsh West	A low density of sub-rounded and sub-angular pebbles and small cobbles (no larger than 10cm diameter) are present in the banks of Long Creek and along the west side of Forest Service Road 27. Long Creek drains the southern primary SL/SM obsidian source (see 97-5) and empties into Sycan Marsh to the east. All samples analyzed (n=15) correlate with the SL/SM geochemical source.

Site No.	Collection Site Name	County	Legal Description	U.S.G.S 7.5' Quadrangle	Source Description
97-5	Obsidian Dome (OBSDM-A)	Lake	T31S, R13E, Sec. 31	Sycan Marsh West	This is one of two primary source locations for SL/SM obsidian (see 97-1 for a description of the other primary source). The source area is located on a high dome (5500' elevation) along the SE flanks of the Yamsay Mountain geologic complex. High densities of sub-angular and sub-rounded pebbles, cobbles, and boulders cover the upper portions and the eastern slopes of the butte. Evidence of prehistoric tool manufacturing and historic hunting and quarrying activities is found throughout the area. A wide range of megascopic characteristics is observed, including: banding, veins and spherulites; grainy, matte, and glassy textures; opaque to slightly translucent light transmittance; and dark grey to black color. All samples analyzed (n=20) correlate with the SL/SM geochemical source
97-6	Sycan River (SYCAN-AA)	Klamath	T33S, R13E, NE 1/4 of Sec. 16	Riverbed Butte Spring	Well rounded obsidian pebbles are found scattered in moderate abundance among exposed gravel bars. Eleven of 20 samples analyzed correlate with the SL/SM geochemical source.
97-7	Silver Lake-A (SLVRL-A)	Lake	T28S, R14E, E ½ of Sec. 27 and W ½ of Sec. 28	Hager Mountain	Small to moderate quantities of sub-rounded pebbles and small cobbles are found on a pluvial lake terrace just south of the town of Silver Lake. Twelve of 15 samples analyzed correlate with the SL/SM geochemical source.
97-8	Dry Creek (DRYCR-A)	Lake	T32S, R13E, Sec. 16	Sycan Marsh West	Obsidian nodules are very scarce at this site. Only three sub-rounded pebbles were collected from the creek bed. Of the three samples analyzed, one correlates with the SL/SM geochemical source.

Site No.	Collection Site Name	County	Legal Description	U.S.G.S 7.5' Quadrangle	Source Description
97-9	Guyer Creek (GUYER-A)	Lake	T30S, R13E, Sec. 31	Partin Butte	An obsidian source reportedly exists in this area, to the north of Guyer Creek (Kaiser 1997, personal communication). However, only two pebbles were found and recovered from the surface. The analytical results did not compare with any sources currently found in the Northwest Research Obsidian Laboratory obsidian database. The samples have been assigned to the tentatively named Guyer Creek geochemical source.
98-1	Silver Lake Locus 1 (LOC-1)	Lake	T26S, R14E, NE 1/4 of Sec. 21	Fort Rock	Two small obsidian pebbles were collected from beach gravels found on a low terrace. The site is situated in the Fort Rock Basin just south of Morehouse Lake (dry) and several miles northwest of the Connley Hills. Neither of the samples correlate with the SL/SM geochemical source.
98-2	Silver Lake Locus 2 (LOC-2)	Lake	T29S, R15E, SE 1/4 of Sec. 4	Duncan Reservoir	This site is one of several collection sites in the Duncan Reservoir area. University of Oregon field school crews have also found obsidian nodules dispersed on the low hills just north of the reservoir (see 98-8). Small quantities of obsidian pebbles and gravels are found mixed with basalt gravels and the occasional sparse lithic scatter. Six of 15 samples analyzed correlate with the SL/SM geochemical source. Another six of the samples were assigned to the Duncan Creek source, an new designation based on samples found at this site and the 98-8 site.
98-3	Silver Lake Locus 3 (LOC-3)	Lake	T28S, R14E, SW 1/4 of Sec. 24	Silver Lake	This site is located just south of Oregon Highway 31and approximately two miles east of the town of Silver Lake. Large pebbles are found sparsely scattered along a dirt road adjacent to a gravel quarry. Nine of 14 samples analyzed correlate with the SL/SM geochemical source.
98-4	Silver Lake Locus 4 (LOC-4)	Lake	T28S, R15E, SW 1/4 of Sec. 2	Tuff Butte	A low density of small to medium sized pebbles is present at this site located on a small rise southwest of Table Rock. Six of 11samples analyzed correlate with the SL/SM geochemical source.

Site No.	Collection Site Name	County	Legal Description	U.S.G.S 7.5' Quadrangle	Source Description
98-5	Silver Lake Locus 5 (LOC-5)	Lake	T27S, R16E, Sec. 35	Thorn Lake	Very few small to medium sized pebbles are present on the surface of a low-lying terrace adjacent to a large lithic scatter. The site is located one mile east of Bottomless Lake (dry) on the southern edge of the Fort Rock Valley. One of five samples analyzed correlates with the SL/SM geochemical source.
98-6	Silver Lake Locus 6 (LOC-6)	Lake	T28S, R16E, SE 1/4 of Sec. 1	Thorn Lake	Located on the southern edge of the Fort Rock Valley approximately 1.5 miles southeast of Locus-5, this site contains a moderate abundance of well rounded and smooth small-to-medium sized pebbles mixed in with colluvial gravels. The samples were collected from a dry creek bed at the base of a northwest trending fault system east of Egli Rim. Ten of 23 samples analyzed correlated with the SL/SM geochemical source.
98-7	Buck Creek (BUCKC)	Lake	T28S, R 14E, SE 1/4 of Sec. 18	Silver Lake	This site is located on a bluff overlooking Buck Creek in a designated public lookout and picnic area. Sub-rounded and rounded pebbles and small cobbles were collected from a dirt road leading to the lookout site. Small quantities of obsidian were found in the road, and there were no nodules visible along the embankment above the creek or off of the road The analytical results (see Appendix C) and presence of obsidian exclusively within a disturbed area suggest that the material was not naturally transported to the site.

Site No.	Collection Site Name	County	Legal Description	U.S.G.S 7.5' Quadrangle	Source Description
98-8	Bergen Site (BERG)	Lake	T26S, R15E	Schaub Lake	Small beach gravels (1-3 cm diameter) are sparsely scattered among beach gravels found along the edges of a playita north of the Connley Hills in the Fort Rock Basin. The collection area is named after an extensive archaeological site located nearby. An abundance of large obsidian flakes cover the aeolian dunes above the playita and likely originate from the Cougar Mountain obsidian source located about 7 miles to the north. None of the samples analyzed correlate with the SL/SM geochemical source. Interestingly, however nine of the 15 samples come from the Quartz Mountain source located over 20 miles to the north of the site. XRF analysis of artifact obsidian recovered from the Bergen Site by the University of Oregon archaeological field school during 1998 and 1999 is briefly discussed in Chapter 5.
98-9	Duncan Creek (DUNCR)	Lake	T29S, R15E, E ½ of Sec. 4	Duncan Reservoir	Eight medium-sized, rounded and sub-rounded pebbles were collected by the University of Oregon field school in 1998. The samples were found on the sloping terrain below Duncan Reservoir in the general vicinity described in the source description for site number 98-2. One of the eight samples is correlated with the SL/SM geochemical source.
98-10	West Fork Silver Creek (SLVCR-C)	Lake	T29S, R13E, NE 1/4 of Sec. 36	Hager Mountain	A low to moderate abundance of medium, sub-angular and sub-rounded pebbles are present on the banks of the West Fork Silver Creek. This area is located approximately two miles from the Silver Creek-A SL/SM primary source (see source description for site number 97-1). All samples analyzed (n=15) correlate with the SL/SM geochemical source.

Site No.	Collection Site Name	County	Legal Description	U.S.G.S 7.5' Quadrangle	Source Description
98-11	Sycan River (SYCAN-BB)	Lake	T32S, R14E, SW 1/4 of Sec. 22	Sycan Marsh East	Obsidian nodules are ubiquitous at this site. Thousands of well rounded pebbles and small cobbles cover exposed stream banks and gravel bars. Material is also found eroding out of the cut bank. The site is located about 3 miles south of the Sycan Marsh. None of the samples analyzed (n=15) correlate with the SL/SM geochemical source.
98-12	Louse Lake (LOUSE)	Lake	T32S, R14E, SW 1/4 of Sec. 26	Sycan Marsh East	An abundance of sub-angular obsidian pebbles and small cobbles are present in a shallow, dry drainage. The site is located on the Sycan Flat some 4 miles southeast of the Sycan Marsh and approximately one-half mile northeast of Louse Lake. Vesicular basalt nodules are mixed in with the obsidian nodules. None of the samples analyzed (n=15) correlate with the SL/SM geochemical source. Curiously, one of the samples was correlated with the Cowhead Lake source located in northeastern California.
98-13	Sycan River Crossing (SYCAN-CC)	Klamath	T34S, R11E, NE 1/4 of Sec. 12	Silver Dollar Flat	Hundreds of sub-rounded and rounded pebbles and small cobbles are found on exposed gravel bars in the riverbed, in the cut bank, and on the beach terrace. This site is located over 15 miles downstream (SW) from Sycan Marsh. Spodue Mountain lies approximately five miles southeast of the site. None of the samples analyzed (n=20) correlate with the SL/SM geochemical source.
98-14	Pellard Spring (PELLSP)	Klamath	T34S, R13E, SE 1/4 of Sec. 18	Riverbed Butte Spring	An abundance of sub-angular and sub-rounded cobbles and pebbles cover the ground and adjacent stream bank. This site is located at the northern base of Spodue Mountain, a large obsidian source. Not surprisingly, all samples analyzed (n=10) correlate with the Spodue Mountain geochemical source.

Site No.	Collection Site Name	County	Legal Description	U.S.G.S 7.5' Quadrangle	Source Description
98-15	Pike's Crossing (PIKE)	Klamath	T33S, R15E, NW 1/4 of Sec. 22	Shake Butte	Well-rounded and rounded pebbles and small cobbles are found in moderate abundance along the banks of the river. This site is located approximately 10 miles upstream (SE) from Sycan Marsh. None of the samples analyzed (n=15) correlate with the SL/SM geochemical source.
98-16	Bunyard Crossing (BUNY)	Lake	T29S, R14E, NE 1/4 of Sec. 20	Hager Mountain	Sub-rounded and sub-angular pebbles and small cobbles were collected from colluvial and fluvial wash along the banks of Silver Creek. The site is located several miles north of Thompson Reservoir in a small canyon near an established campground. None of the samples analyzed (n=15) correlate with the SL/SM geochemical source.
98-17	Grassy Butte (GRASSY)	Lake	T29S, R15E, SE 1/4 of Sec. 7	Duncan Reservoir	This site is situated on the gently sloping terrain along the southern margin of the Fort Rock Basin. Sub-rounded pebbles and small cobbles were collected from a drainage (dry) located along the northwestern edge of Grassy Butte. Small quantities of obsidian nodules were observed scattered over a 1/4 mile area. None of the samples analyzed (n=15) correlate with the SL/SM geochemical source.
98-18	Duncan Creek (DUNCR-C)	Lake	T29S, R15E, NW 1/4 of Sec. 34	Duncan Reservoir	Samples were collected from the upper reaches of Duncan Creek, approximately three miles south of Duncan Reservoir. Small quantities of sub-rounded and rounded pebbles were observed scattered in the dry creek bed. None of the samples analyzed (n=20) correlate with the SL/SM geochemical source.
98-19	La Brie Lake (LABRIE)	Lake	T29S, R15E, SE 1/4 of Sec. 28	Duncan Reservoir	A sparse scattering of medium to large sub-rounded and rounded pebbles was observed at this site. Samples were collected along the marshy edges of the small lake. None of the samples analyzed (n=10) correlate with the SL/SM geochemical source.

Site No.	Collection Site Name	County	Legal Description	U.S.G.S 7.5' Quadrangle	Source Description
98-20	Chocktoot Tributary (CHOCK)	Lake	T32S, R14E, SW 1/4 of Sec. 15	Sycan Marsh East	Obsidian nodules are very scarce at this site. Only three sub-rounded pebbles were collected from a dry creek bed. Some water-worn flakes were observed in the drainage. The site sits on a low terrace on the southeastern margin of Sycan Marsh. None of the analyzed samples correlate with the SL/SM geochemical source.
98-21	Shake Creek (SHAKE)	Klamath	T33S, R14E, SW 1/4 of Sec. 24	Riverbed Butte	The presence of obsidian is very sparse at this location. Three medium-sized sub-rounded pebbles were collected from the dry drainage. The samples were found scattered among basalt and river rock. None of the analyzed samples correlate with the SL/SM geochemical source.
98-22	Evans Creek (EVANS)	Klamath	T33S, R14E, NE 1/4 of Sec. 33	Riverbed Butte	Obsidian nodules are very scarce at this site. Five medium sized, sub-rounded pebbles were collected from an exposure at the base of a small butte. The site is named after the closest source of water, Evans Creek, but is not located in that drainage. None of the samples analyzed (n=5) correlate with the SL/SM geochemical source.
98-23	Cottonwood Creek (COTTON)	Lake	T29S, R15E, NE 1/4 of Sec. 24	Duncan Reservoir	Obsidian nodules are very scare and scattered at this site. Three small to medium-sized rounded pebbles were collected from a large, dry drainage located on Dead Indian Rim above Silver Lake. None of the samples analyzed (n=3) correlate with the SL/SM geochemical source.
98-24	Willow Creek (WILLW)	Lake	T29S, R16E, NW 1/4 of Sec. 18	Egli Rim	This site, a dry creek bed, is located at the southern edge of Silver Lake, and is within a mile of a large prehistoric village site. Obsidian lithic scatters are prevalent in this area, but the presence of nodules is rare. Only one sample, a small rounded pebble, was recovered. This sample does not correlate with the SL/SM geochemical source.

* Size terminology is based on common geologic rock terms outlined by Pettijohn (1975:30). Pebbles range in size from 4 mm to 64 mm; cobbles range from 64 mm to 256 mm; and boulders are greater than 256 mm.

Appendix C

XRF Analytical Methods

X-Ray Fluorescence Analytical Methods

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Analysis of samples are completed using a Spectrace 5000 energy dispersive X-ray fluorescence spectrometer. The system is equipped with a Si(Li) detector with a resolution of 155 eV FHWM for 5.9 keV X-rays (at 1000 counts per second) in an area 30 mm^2. Signals from the spectrometer are amplified and filtered by a time variant pulse processor and sent to a 100 MHZ Wilkinson type analog-to-digital converter. The X-ray tube employed is a Bremsstrahlung type, with a rhodium target, and 5 mil Be window. The tube is driven by a 50 kV 1 mA high voltage power supply, providing a voltage range of 4 to 50 kV. The principles of X-ray fluorescence analytical methods are reviewed in detail by Norrish and Chappell (1967), Potts and Webb (1992), and Williams (1987). X-ray fluorescence analytical procedures used in the analysis of all obsidian samples were originally developed by M. Kathleen Davis (BioSystems Analysis and Northwest Research Obsidian Studies Laboratory).

For analysis of the elements zinc (Zn), lead (Pb), thorium (Th), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb), the X-ray tube is operated at 30 kV, 0.30 mA (pulsed), with a 0.127 mm Pd filter. Analytical lines used are Zn (K-alpha), Pb (L-alpha), Th (L-alpha), Rb (K-alpha), Sr (K-alpha), Y (K-alpha), Zr (K-alpha) and Nb (K-alpha). Samples are scanned for 200 seconds live-time in an air path.

Peak intensities for the above elements are calculated as ratios to the Compton scatter peak of rhodium, and converted to parts-per-million (ppm) by weight using linear regressions derived from the analysis of twenty rock standards from the U.S. Geological Survey, the Geologic Survey of Japan, and the National Bureau of Standards. The analyte to Compton scatter peak ratio is employed to correct for variation in sample size, surface irregularities, and variation in the sample matrix.

For analysis of the elements titanium (Ti), manganese (Mn), and iron ($Fe_2O_3^T$), the X-ray tube is operated at 12 kV, 0.27 mA with a 0.127 mm aluminum filter. Samples are scanned for 200 seconds live-time in a vacuum path. Analytical lines used are Ti (K-alpha), Mn (K-alpha), and Fe (K-alpha).

Concentration values (parts per million for titanium and manganese, weight percent for iron) are calculated using linear regressions derived from the analysis of thirteen standards from the U.S. Geological Survey, the Geologic Survey of Japan and the National Bureau of Standards. However, these values are *not* corrected against the Compton scatter peak or other scatter regions, resulting in lower than normal trace element values for small samples that fall below the minimum size requirement. Iron/titanium (Fe/Ti) and iron/manganese (Fe/Mn) peak ratios are supplied for use as corrected values. In order to ensure comparability among samples of different sizes, source assignments in all reports are based upon these ratios, and not on the absolute concentration values.

For analysis of the elements barium (Ba), lanthanum (La) and cerium (Ce), the X-ray tube is operated at 50 kV, 0.25 mA with a 0.63 mm copper filter in the X-ray path. Analytical lines used are Ba (K-alpha), La (K-alpha), and Ce (K-alpha). Samples are scanned in an air path for 100 to 600 seconds live-time, depending upon trace element concentration. Trace element intensities are calculated as ratios to the Bremsstrahlung region between 25.0 and 30.98 keV, and converted to parts-per-million by weight using a polynomial fit routine derived from the analysis of sixteen rock standards from the U.S. Geological Survey and the Geologic Survey of Japan. It should be noted that the Bremsstrahlung region corrects for sample mass only and does not account for matrix effects.

All samples are scanned as unmodified rock specimens. Reported errors represent counting and fitting error uncertainty only, and do not account for instrumental precision or effects related to the analysis of unmodified obsidian. When the latter effects are considered, relative analytical uncertainty is estimated to be between three and five percent.

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In traditional X-ray fluorescence trace element studies, samples are powdered and pelletized before analysis (Norrish and Chappell 1967; Potts and Webb 1992). In theory, the irregular surfaces of most obsidian artifacts should induce measurement problems related to shifts in artifact-to-detector reflection geometry (Hughes 1986:35). Early experiments with intact obsidian flakes by Robert N. Jack, and later by Richard Hughes, however, indicate that analytical results from lenticular or biconvex obsidian surfaces are comparable to those from flat surfaces and pressed powder pellets, paving the way for the nondestructive analysis characterization of glass artifacts (Hughes 1986:35–37; Jack 1976). The minimum optimal sample size for analysis has been found to be approximately 10 mm in diameter and 1.5–2.0 mm thick. Later experimental studies conducted by Shackley and Hampel (1993) using samples with flat and slightly irregular surface geometries have corroborated Hughes' initial observations. In a similar experiment, Jackson and Hampel (1993) determined that for accurate results the minimum size of an artifact should be about 10 mm in diameter and 1.5 mm thick. Agreement between the U. S. Geological Survey standard RGM-1 (Glass Mountain obsidian) values and obsidian test samples was good at 1 mm thickness and improved markedly to a thickness of 3 mm. Details about the effects of sample size and surface geometry are discussed by Davis et al. (1998).

Correlation of Artifacts and Geologic Sources. The diagnostic trace element values used to characterize the samples are compared directly to those for known obsidian sources such as those reported in the literature and with unpublished trace element data collected through analysis of geologic source samples (Skinner 2000). Artifacts are correlated to a parent obsidian source or chemical source group if diagnostic trace element values fall within about two standard deviations of the analytical uncertainty of the known upper and lower limits of chemical variability recorded for the source. Occasionally, visual attributes are used to corroborate the source assignments although sources are never assigned on the basis of only megascopic characteristics.

Diagnostic trace elements, as the term is used here, refer to trace element abundances that show low intrasource variation and uncertainty along with distinguishable intersource variability. In addition, this refers to elements measured by X-ray fluorescence analysis with high precision and low analytical uncertainty. In short, diagnostic elements are those that allow the clearest geochemical distinction between sources. Trace elements generally refer to those elements that occur in abundances of less than about 1000 ppm in a sample. For simplicity in this report, we use the term synonymously with major and minor elements such as iron, titanium, and manganese, which may be present in somewhat larger quantities.

Northwest Research Obsidian Studies Laboratory

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Appendix D

XRF Data Tables for Geologic Samples

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Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Silver Creek-A	1	SLVRC-A1		79	25	127	7	57	352	23	863	587	795	1.90	30.3	70.0	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	2	SLVRC-A2		90	24	135	7	57	360	16	887	609	793	1.92	29.3	68.5	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	3	SLVRC-A3		73	24	126	7	57	350	17	846	551	748	1.83	31.2	68.5	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	4	SLVRC-A4		85	27	127	8	55	349	19	868	593	743	1.99	31.3	72.7	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	1	96	48	13	0.11			
Silver Creek-A	5	SLVRC-A5		78	26	126	8	54	351	18	884	575	740	1.91	31.1	68.5	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	6	SLVRC-A6		71	18	117	6	54	338	13	596	430	664	1.42	32.2	75.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	7	SLVRC-A7		91	24	132	5	55	357	18	925	601	779	1.99	30.9	68.3	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Silver Creek-A	8	SLVRC-A8		88	27	125	8	56	347	19	729	473	747	1.52	31.0	66.6	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	9	SLVRC-A9		82	24	124	6	57	340	19	781	551	726	1.78	30.4	72.3	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	10	SLVRC-A10		91	24	124	9	55	350	22	831	576	810	1.84	29.9	70.2	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	11	SLVRC-A11		81	25	123	8	53	341	15	729	525	657	1.64	29.8	71.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-A	12	SLVRC-A12		80	27	130	7	56	356	18	901	617	818	2.04	30.7	71.7	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	1	97	48	13	0.11			
Silver Creek-A	13	SLVRC-A13		75	19	122	5	53	337	17	697	518	691	1.69	31.0	76.9	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

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Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations: Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios: Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Silver Creek-A	14	SLVRC-A14		78	27	124	7	55	341	20	806	597	793	1.95	30.5	76.5	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Silver Creek-A	15	SLVRC-A15		77	23	121	8	55	346	18	882	577	796	1.97	31.9	70.6	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Silver Creek-B	16	SLVCR-B1		89	24	121	9	53	342	16	611	459	868	1.39	29.5	72.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	13	0.11			
Silver Creek-B	17	SLVCR-B2		80	21	124	7	54	348	20	798	537	754	1.75	30.8	69.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	18	SLVCR-B3		87	24	130	7	54	348	17	681	456	775	1.51	32.1	70.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	13	0.11			
Silver Creek-B	19	SLVCR-B4		78	26	129	8	58	353	17	838	579	747	1.90	30.8	72.1	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	20	SLVCR-B5		76	25	127	8	57	350	16	799	569	752	1.86	30.7	73.8	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	21	SLVCR-B6		87	24	131	6	54	354	14	880	572	798	1.84	30.2	66.4	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	22	SILVCR-B7		75	27	125	6	55	348	17	860	580	773	1.94	31.3	71.5	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	23	SILVCR-B8		90	25	122	5	55	336	16	513	379	747	1.14	30.4	71.6	Silver Lake/Sycan Marsh
			±	7	3	3	8	3	7	2	96	47	14	0.11			
Silver Creek-B	24	SILVCR-B9		82	24	131	6	59	359	17	830	536	801	1.72	30.3	66.0	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	25	SILVCR-B10		86	27	130	6	56	347	19	833	602	753	1.90	29.4	72.1	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	26	SILVCR-B11		86	24	124	7	52	342	17	714	491	744	1.56	30.5	69.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
				Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Silver Creek-B	27	SILVCR-B12		88	25	123	7	54	341	14	747	540	759	1.71	30.0	72.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	28	SILVCR-B13		89	24	123	6	55	342	19	766	536	748	1.77	31.2	73.5	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	29	SILVCR-B14		76	25	120	6	56	345	18	758	576	793	1.85	30.2	77.3	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Creek-B	30	SILVCR-B15		75	23	122	5	56	337	22	760	552	743	1.76	30.0	73.5	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	31	CARLN-A1		101	35	143	7	64	379	18	725	478	724	1.45	29.3	64.2	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	13	0.11			
Carlon Ranch	32	CARLN-A2		93	24	123	9	55	346	19	930	644	794	2.01	28.9	68.6	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	1	96	48	13	0.11			
Carlon Ranch	33	CARLN-A3		94	30	135	7	56	363	21	731	542	820	1.58	27.7	68.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	14	0.11			
Carlon Ranch	34	CARLN-A4		81	25	129	5	51	345	19	775	522	836	1.73	31.4	70.9	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	1	96	48	13	0.11			
Carlon Ranch	35	CARLN-A5		71	25	132	6	56	358	19	874	574	773	1.86	30.4	67.7	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	36	CARLN-A6		94	22	128	8	53	350	20	792	553	744	1.77	30.1	70.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	37	CARLN-A7		87	26	134	7	53	359	23	748	536	802	1.70	30.0	72.1	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	38	CARLN-A8		98	25	131	6	55	350	20	736	556	741	1.76	29.9	75.9	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	39	CARLN-A9		90	26	131	6	57	358	14	792	542	773	1.74	30.3	69.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Carlon Ranch	40	CARLN-A10	89	25	127	8	57	351	17	800	489	820	1.66	32.5	66.1	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	41	CARLN-A11	91	25	133	8	55	348	20	754	495	812	1.61	31.2	68.1	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	42	CARLN-A12	71	25	118	7	52	335	17	694	492	698	1.61	31.3	73.8	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	43	CARLN-A13	79	21	124	7	51	346	19	586	415	773	1.33	31.6	72.5	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	14	0.11			
Carlon Ranch	44	CARLN-A14	75	25	120	7	54	338	18	641	489	735	1.57	30.7	77.7	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Carlon Ranch	45	CARLN-A15	79	28	123	5	54	343	16	861	581	755	1.95	31.3	71.6	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	2	96	48	13	0.11			
Long Creek	46	LONGC-A1	83	25	128	13	59	359	19	841	595	873	1.83	28.7	69.0	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Long Creek	47	LONGC-A2	79	24	113	12	55	338	17	756	547	797	1.63	28.2	68.5	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Long Creek	48	LONGC-A3	102	31	146	13	60	392	20	703	461	910	1.38	29.2	63.1	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	14	0.11			
Long Creek	49	LONGC-A4	83	23	120	13	57	353	18	742	555	756	1.71	29.2	73.3	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Long Creek	50	LONGC-A5	83	26	122	13	55	348	18	643	480	875	1.50	30.1	74.2	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	14	0.11			
Long Creek	51	LONGC-A6	88	24	122	12	57	344	18	605	437	915	1.32	29.6	69.9	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	13	0.11			
Long Creek	52	LONGC-A7	75	27	122	11	57	347	21	962	695	840	2.11	28.0	69.5	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	97	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
Long Creek	53	LONGC-A8		90	26	124	12	54	357	21	732	532	807	1.66	29.7	72.3	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Long Creek	54	LONGC-A9		82	24	121	14	54	338	17	749	535	773	1.68	29.8	71.3	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Long Creek	55	LONGC-A10		80	28	124	13	59	348	21	893	617	857	1.93	29.1	68.5	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	97	48	13	0.11			
Long Creek	56	LONGC-A11		86	23	128	11	55	350	20	781	573	819	1.77	29.0	71.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Long Creek	57	LONGC-A12		82	24	120	12	54	338	20	779	553	777	1.74	29.8	71.2	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Long Creek	58	LONGC-A13		74	21	123	12	54	347	20	861	595	828	1.88	29.5	69.3	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	97	48	13	0.11			
Long Creek	59	LONGC-A14		84	22	119	12	53	344	18	746	520	790	1.65	30.1	70.3	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Long Creek	60	LONGC-A15		77	21	116	11	49	335	18	489	389	917	1.12	29.0	73.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	14	0.11			
Obsidian Dome	61	OBSDM-A1		75	19	123	11	54	343	14	916	590	817	1.94	30.6	67.1	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Obsidian Dome	62	OBSDM-A2		77	20	122	11	55	347	18	916	591	890	1.94	30.6	67.2	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	1	97	48	13	0.11			
Obsidian Dome	63	OBSDM-A3		93	23	121	12	57	347	20	935	607	879	1.95	30.0	66.3	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	1	97	48	13	0.11			
Obsidian Dome	64	OBSDM-A4		85	22	116	12	57	341	17	670	394	927	1.23	31.3	59.6	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	14	0.11			
Obsidian Dome	65	OBSDM-A5		83	21	123	10	54	346	15	899	581	814	1.93	31.1	68.1	Silver Lake/Sycan Marsh
			±	6	3	3	7	3	7	2	96	48	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Obsidian Dome	66	OBSDM-A6	73	25	125	13	55	353	24	730	482	847	1.51	30.2	66.2	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Obsidian Dome	67	OBSDM-A7	83	25	127	10	55	358	18	888	587	837	1.93	30.7	68.9	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	97	48	13	0.11			
Obsidian Dome	68	OBSDM-A8	102	23	130	10	63	373	21	671	462	877	1.34	28.3	64.1	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	14	0.11			
Obsidian Dome	69	OBSDM-A9	89	23	121	11	55	341	18	956	622	793	1.99	29.6	65.9	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	97	48	13	0.11			
Obsidian Dome	70	OBSDM-A10	101	25	127	11	53	353	18	779	518	802	1.61	29.6	66.0	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Obsidian Dome	71	OBSDM-A11	67	21	113	12	52	336	17	848	564	854	1.84	30.7	69.0	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Obsidian Dome	72	OBSDM-A12	80	21	116	13	52	345	20	771	546	786	1.71	29.6	70.5	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Obsidian Dome	73	OBSDM-A13	73	25	117	12	55	337	18	792	549	757	1.73	29.7	69.3	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Obsidian Dome	74	OBSDM-A14	80	26	119	13	54	343	16	931	613	820	2.04	30.9	69.5	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	97	48	13	0.11			
Obsidian Dome	75	OBSDM-A15	71	23	117	12	55	345	18	973	658	827	2.12	29.7	69.0	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	97	48	13	0.11			
Obsidian Dome	76	OBSDM-A16	104	21	120	12	53	338	15	967	638	806	1.99	28.9	65.3	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	97	48	13	0.11			
Obsidian Dome	77	OBSDM-A17	107	21	120	12	55	348	16	984	682	841	2.07	28.0	66.7	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	1	97	48	13	0.11			
Obsidian Dome	78	OBSDM-A18	85	21	116	11	55	342	19	822	528	769	1.74	31.2	67.4	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
			Trace Element Concentrations											Ratios		
Obsidian Dome	79	OBSDM-A19	78	22	115	12	55	345	15	856	578	808	1.87	30.3	69.4	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Obsidian Dome	80	OBSDM-A20	90	25	124	12	57	348	18	786	552	799	1.79	30.6	72.5	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Sycan River	81	SYCAN-AA1	189	36	204	5	108	1005	98	900	695	4	4.23	54.8	145.4	Witham Creek
			± 8	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	82	SYCAN-AA2	204	36	189	8	93	942	88	659	554	10	3.19	53.0	149.6	Witham Creek
			± 8	3	4	7	3	7	2	96	48	19	0.11			
Sycan River	83	SYCAN-AA3	93	23	129	8	57	347	17	746	541	782	1.67	29.3	71.2	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Sycan River	84	SYCAN-AA4	217	45	218	4	101	1028	96	819	633	10	3.77	54.1	142.4	Witham Creek
			± 8	3	4	8	3	8	2	96	48	20	0.11			
Sycan River	85	SYCAN-AA5	86	28	129	14	55	361	19	841	554	858	1.71	29.2	64.9	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	14	0.11			
Sycan River	86	SYCAN-AA6	221	47	231	6	112	1178	104	867	688	18	4.21	55.2	150.3	Witham Creek
			± 7	3	4	7	3	8	2	96	48	13	0.11			
Sycan River	87	SYCAN-AA7	189	37	200	5	103	1011	90	831	670	-0	3.98	53.6	147.9	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	88	SYCAN-AA8	74	22	121	12	55	356	17	661	498	892	1.49	28.7	71.9	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Sycan River	89	SYCAN-AA9	72	21	116	19	54	351	18	817	558	895	1.65	28.0	64.5	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Sycan River	90	SYCAN-AA10	84	28	119	19	50	333	17	715	475	877	1.44	29.3	64.6	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	15	0.11			
Sycan River	91	SYCAN-AA11	167	41	207	7	98	1055	90	693	553	6	3.48	57.8	155.1	Witham Creek
			± 7	3	3	7	3	7	2	96	48	12	0.11			

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Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations: Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios: Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Sycan River	92	SYCAN-AA12	76	22	114	12	55	337	20	910	620	861	1.89	28.4	66.1	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	93	SYCAN-AA13	81	20	122	13	55	344	14	611	470	904	1.32	27.4	69.3	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	15	0.11			
Sycan River	94	SYCAN-AA14	199	40	209	6	105	1018	95	607	475	10	2.81	55.6	143.1	Witham Creek
			± 8	3	4	7	3	8	2	95	48	21	0.11			
Sycan River	95	SYCAN-AA15	82	25	120	17	56	351	16	895	575	899	1.80	29.4	64.1	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Sycan River	96	SYCAN-AA16	189	36	201	6	96	980	94	979	735	8	4.59	55.9	145.1	Witham Creek
			± 7	3	3	7	3	7	2	96	48	25	0.11			
Sycan River	97	SYCAN-AA17	77	20	121	17	58	349	16	973	652	901	1.93	27.4	62.9	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	2	97	48	13	0.11			
Sycan River	98	SYCAN-AA18	103	28	131	19	59	367	18	717	486	938	1.43	28.4	63.9	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	14	0.11			
Sycan River	99	SYCAN-AA19	188	41	234	6	106	1131	97	880	600	8	3.95	60.0	139.2	Witham Creek
			± 7	3	4	7	3	7	2	96	48	33	0.11			
Sycan River	100	SYCAN-AA20	72	28	126	9	53	353	21	734	505	798	1.63	30.8	70.7	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake-A	101	SLVRL-A1	87	26	129	9	54	352	19	830	551	835	1.82	31.1	69.5	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake-A	102	SLVRL-A2	110	23	125	7	56	344	16	845	653	772	2.00	28.4	75.0	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	97	48	13	0.11			
Silver Lake-A	103	SLVRL-A3	81	19	121	7	54	342	18	840	624	749	1.95	29.1	73.6	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Silver Lake-A	104	SLVRL-A4	86	29	126	7	54	345	16	694	486	768	1.55	30.7	71.2	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Silver Lake-A	105	SLVRL-A5	86	21	125	7	56	343	20	824	587	739	1.94	30.9	74.5	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake-A	106	SLVRL-A6	66	21	115	57	32	143	10	189	641	889	1.30	19.2	205.6	Hager Mountain
			± 6	2	3	7	3	7	2	95	48	13	0.11			
Silver Lake-A	107	SLVRL-A7	89	25	125	8	52	354	19	816	583	742	1.85	29.7	71.8	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake-A	108	SLVRL-A8	71	22	122	6	53	343	21	724	527	709	1.68	30.2	73.5	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake-A	109	SLVRL-A9	88	27	122	8	53	343	22	738	553	746	1.73	29.6	74.5	Silver Lake/Sycan Marsh
			± 6	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake-A	110	SLVRL-A10	87	28	130	8	56	359	19	601	449	811	1.43	31.0	75.8	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	14	0.11			
Silver Lake-A	111	SLVRL-A11	76	25	131	8	55	356	16	774	560	781	1.77	29.8	72.6	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake-A	112	SLVRL-A12	78	27	125	8	55	348	18	888	635	803	2.10	30.6	74.6	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	97	48	13	0.11			
Silver Lake-A	113	SLVRL-A13	63	22	112	56	31	143	10	199	682	848	1.40	19.3	210.8	Hager Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Silver Lake-A	114	SLVRL-A14	77	27	124	7	55	345	18	841	599	763	1.99	31.0	75.0	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	97	48	13	0.11			
Silver Lake-A	115	SLVRL-A15	71	21	115	57	32	142	9	149	517	873	0.93	17.8	186.3	Hager Mountain
			± 7	3	3	7	3	7	2	95	47	14	0.11			
Dry Creek	116	DRYCR-A1	47	19	105	47	28	125	11	553	674	804	0.91	13.1	54.2	Spodue Mountain
			± 6	2	3	7	3	7	2	96	48	13	0.11			
Dry Creek	117	DRYCR-A2	82	29	114	11	50	326	19	455	345	925	1.02	30.4	72.2	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	15	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
Dry Creek	118	DRYCR-A3		53	22	105	46	28	126	16	631	738	836	0.99	12.9	51.7	Spodue Mountain
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Guyer Creek	119	GUYER-A1		58	17	99	90	37	310	16	1540	464	1011	1.85	38.2	38.6	Guyer Creek
			±	7	3	3	7	3	7	2	97	48	14	0.11			
Guyer Creek	120	GUYER-A2		65	21	99	93	38	324	13	1478	474	1011	1.69	34.2	36.9	Guyer Creek
			±	6	2	3	7	3	7	2	97	47	13	0.11			
Silver Lake	1	LOC-1-1		48	25	107	38	29	103	17	119	523	797	0.93	17.6	226.7	Unknown 1
			±	8	3	3	7	3	7	2	95	48	14	0.11			
Silver Lake	2	LOC-1-2		80	22	98	39	55	135	11	271	260	1308	0.92	38.8	107.9	Cougar Mountain
			±	7	3	3	7	3	7	2	96	47	15	0.11			
Silver Lake	3	LOC-1-3		72	14	91	144	48	341	20	2085	526	880	2.72	48.1	41.3	Not Obsidian
			±	7	3	3	7	3	7	2	98	48	14	0.11			
Silver Lake	4	LOC-1-4		97	ND	13	542	26	115	10	6628	657	443	6.77	92.4	32.0	Silver Lake Basalt 1
			±	8	ND	3	8	3	7	2	102	48	13	0.11			
Silver Lake	1	LOC-2-1		91	22	130	11	56	361	19	629	419	904	1.31	30.8	66.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	13	0.11			
Silver Lake	2	LOC-2-2		59	19	131	32	40	103	17	155	536	630	0.77	14.4	152.0	Duncan Creek
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Silver Lake	3	LOC-2-3		72	21	112	53	34	136	10	247	428	919	0.86	20.5	110.3	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	4	LOC-2-4		70	25	126	6	51	340	16	726	531	602	1.80	32.1	78.6	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Silver Lake	5	LOC-2-5		58	20	140	32	38	107	20	144	516	713	0.75	14.8	159.8	Duncan Creek
			±	6	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	6	LOC-2-6		55	26	103	54	29	142	9	140	386	940	0.72	19.6	157.2	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	14	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
Silver Lake	7	LOC-2-7		90	24	119	10	54	340	19	827	538	849	1.75	30.8	67.4	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake	8	LOC-2-8		70	23	127	7	56	342	18	791	535	762	1.77	31.3	71.1	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	9	LOC-2-9		58	23	132	30	39	99	19	187	466	700	0.70	15.4	117.8	Duncan Creek
			±	7	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	10	LOC-2-10		52	23	104	54	36	144	12	214	637	875	1.27	19.0	180.8	Hager Mountain
			±	6	2	3	7	3	7	1	95	48	13	0.11			
Silver Lake	11	LOC-2-11		55	17	131	31	40	101	18	149	492	681	0.71	14.8	147.4	Duncan Creek
			±	7	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	12	LOC-2-12		55	18	125	30	38	98	17	149	547	670	0.80	14.7	164.0	Duncan Creek
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Silver Lake	13	LOC-2-13		84	29	110	6	50	304	19	516	376	721	1.12	30.0	69.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	15	0.11			
Silver Lake	14	LOC-2-14		86	20	116	19	52	347	17	736	491	986	1.44	28.2	62.6	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	14	0.11			
Silver Lake	15	LOC-2-15		58	23	134	30	40	99	21	105	342	667	0.45	15.0	133.8	Duncan Creek
			±	7	3	4	7	3	7	2	95	47	15	0.11			
Silver Lake	1	LOC-3-1		84	31	129	6	55	352	20	834	601	771	1.91	29.7	72.6	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	2	LOC-3-2		76	25	130	7	57	347	17	806	560	772	1.81	30.4	71.4	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake	3	LOC-3-3		74	21	114	55	33	146	13	241	576	872	1.15	19.2	146.8	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Silver Lake	4	LOC-3-4		78	22	123	8	57	348	16	793	559	815	1.74	29.4	69.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Silver Lake	5	LOC-3-5		60	23	107	53	34	138	12	162	624	823	1.22	18.7	224.0	Hager Mountain
			±	7	2	3	7	3	7	2	95	48	13	0.11			
Silver Lake	6	LOC-3-6		69	14	106	56	35	157	8	217	641	820	1.29	19.1	180.6	Hager Mountain
			±	6	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake	7	LOC-3-7		78	23	129	6	53	353	20	726	537	796	1.85	32.6	80.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake	8	LOC-3-8		71	22	119	6	54	341	18	776	594	808	1.89	29.8	77.2	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Silver Lake	9	LOC-3-9		84	32	131	8	54	353	18	724	532	813	1.67	29.8	73.3	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	14	0.11			
Silver Lake	10	LOC-3-10		93	25	123	13	56	348	20	821	565	800	1.79	29.8	69.4	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake	11	LOC-3-11		75	24	120	7	56	342	17	827	583	755	1.89	30.3	72.4	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	12	LOC-3-12		86	21	133	7	54	342	20	590	449	406	1.42	30.8	76.9	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	13	0.11			
Silver Lake	13	LOC-3-13		90	15	61	191	45	349	17	2031	374	761	2.28	59.2	35.8	Not Obsidian
			±	7	3	3	7	3	7	2	97	47	14	0.11			
Silver Lake	14	LOC-3-14		64	22	109	50	33	136	8	220	577	865	1.17	19.5	162.7	Hager Mountain
			±	7	2	3	7	3	7	2	95	48	13	0.11			
Silver Lake	15	LOC-3-15		73	21	115	54	32	145	13	206	506	871	0.95	18.7	143.2	Hager Mountain
			±	6	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	1	LOC-4-1		67	22	108	56	32	148	14	243	677	881	1.40	19.5	176.2	Hager Mountain
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Silver Lake	2	LOC-4-2		59	22	105	57	30	138	7	237	640	812	1.29	19.2	166.9	Hager Mountain
			±	6	2	3	7	3	7	2	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Silver Lake	3	LOC-4-3		81	20	126	7	55	345	18	911	602	813	1.99	30.7	69.2	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	1	97	48	13	0.11			
Silver Lake	4	LOC-4-4		62	19	107	52	37	133	12	177	512	892	1.06	20.3	181.3	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	14	0.11			
Silver Lake	5	LOC-4-5		58	17	91	134	29	301	12	1532	274	1130	1.97	73.6	41.1	Not Obsidian
			±	6	3	3	7	3	7	2	97	47	15	0.11			
Silver Lake	6	LOC-4-6		76	22	122	9	53	340	14	777	507	786	1.64	30.9	67.3	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake	7	LOC-4-7		84	25	121	6	53	337	16	707	537	795	1.76	31.0	78.9	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	8	LOC-4-8		80	21	123	6	56	347	17	584	423	846	1.31	30.4	71.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	14	0.11			
Silver Lake	9	LOC-4-9		87	22	131	7	55	357	20	570	372	850	1.23	33.1	69.2	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	15	0.11			
Silver Lake	10	LOC-4-10		60	25	109	56	30	146	8	156	423	849	0.84	20.3	163.6	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	15	0.11			
Silver Lake	11	LOC-4-11		66	22	126	9	56	344	17	749	510	798	1.68	31.4	71.2	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	14	0.11			
Silver Lake	12	LOC-4-12		63	25	110	54	31	142	10	247	636	788	1.34	20.0	166.3	Hager Mountain
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	1	LOC-5-1		187	36	132	5	102	620	40	638	341	45	1.85	53.9	91.3	Horse Mountain
			±	8	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	2	LOC-5-2		81	18	101	41	54	135	12	302	250	1305	0.75	33.7	81.0	Cougar Mountain
			±	7	3	3	7	3	7	2	96	47	15	0.11			
Silver Lake	3	LOC-5-3		56	17	117	56	33	140	10	186	556	849	1.11	19.4	181.2	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

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Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
Silver Lake	4	LOC-5-4		66	20	108	56	30	154	10	194	469	872	0.89	19.1	142.1	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	5	LOC-5-5		74	27	130	5	54	350	20	667	503	832	1.60	30.3	76.1	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	14	0.11			
Silver Lake	6	LOC-5-6		73	19	96	39	57	138	13	217	247	1369	0.89	39.7	127.6	Cougar Mountain
			±	7	3	3	7	3	7	2	96	47	14	0.11			
Silver Lake	1	LOC-6-1		52	18	107	53	33	141	14	216	629	802	1.23	18.7	173.6	Hager Mountain
			±	6	2	3	7	3	7	1	95	48	13	0.11			
Silver Lake	2	LOC-6-2		61	20	104	52	33	137	12	179	585	819	1.17	19.2	195.6	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	14	0.11			
Silver Lake	3	LOC-6-3		63	19	112	58	30	154	14	235	586	913	1.20	19.6	156.1	Hager Mountain
			±	7	2	3	7	3	7	1	95	48	13	0.11			
Silver Lake	4	LOC-6-4		62	17	104	53	33	141	13	143	464	915	0.93	20.1	194.3	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	5	LOC-6-5		71	29	129	7	52	341	15	652	469	771	1.48	30.4	72.2	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	47	15	0.11			
Silver Lake	6	LOC-6-6		49	17	98	50	31	128	13	103	372	915	0.70	19.8	197.7	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	13	0.11			
Silver Lake	7	LOC-6-7		65	23	109	54	33	148	11	166	621	864	1.24	19.1	221.5	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	13	0.11			
Silver Lake	8	LOC-6-8		70	20	112	56	34	147	11	187	619	849	1.23	19.0	197.4	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	13	0.11			
Silver Lake	9	LOC-6-9		76	23	119	8	51	338	16	522	385	886	1.20	31.2	73.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	13	0.11			
Silver Lake	10	LOC-6-10		67	23	113	53	32	142	11	155	476	852	0.93	19.5	180.9	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	14	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

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Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
				Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Silver Lake	11	LOC-6-11		75	17	96	41	58	136	12	194	232	1274	0.76	37.5	123.9	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	14	0.11			
Silver Lake	12	LOC-6-12		81	24	123	8	58	347	21	765	522	845	1.67	30.4	69.4	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	13	LOC-6-13		83	22	127	8	55	356	21	830	584	817	1.85	29.6	70.6	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake	14	LOC-6-14		66	23	112	57	33	144	9	225	649	854	1.31	19.1	177.2	Hager Mountain
			±	6	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	15	LOC-6-15		76	25	119	8	54	341	19	626	466	836	1.48	30.6	75.2	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	2	96	47	14	0.11			
Silver Lake	16	LOC-6-16		67	21	109	55	31	149	9	129	434	916	0.84	19.7	192.3	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	14	0.11			
Silver Lake	17	LOC-6-17		71	26	117	6	51	333	18	665	463	878	1.49	31.1	71.5	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	18	LOC-6-18		57	22	114	57	35	144	12	167	533	919	1.07	19.7	192.5	Hager Mountain
			±	7	2	3	7	3	7	2	95	48	14	0.11			
Silver Lake	19	LOC-6-19		63	20	110	55	33	148	12	196	579	885	1.11	18.5	171.6	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	14	0.11			
Silver Lake	20	LOC-6-20		83	20	119	8	55	343	18	777	527	811	1.71	30.8	70.0	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Silver Lake	21	LOC-6-21		87	22	122	7	53	349	17	769	543	798	1.83	31.8	75.4	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	22	LOC-6-22		82	26	124	6	56	349	17	861	569	793	1.89	31.1	69.6	Silver Lake/Sycan Marsh
			±	6	2	3	7	3	7	2	96	48	13	0.11			
Silver Lake	23	LOC-6-23		73	23	121	7	55	335	18	761	491	838	1.63	31.7	68.2	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory
Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations: Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios: Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Buck Creek	1	BUCKC-1		85	24	124	8	56	347	17	908	617	839	1.90	28.7	66.5	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Buck Creek	2	BUCKC-2		79	19	106	54	34	136	12	272	731	854	1.42	18.2	160.3	Hager Mountain
			±	7	2	3	7	3	7	1	96	48	13	0.11			
Buck Creek	3	BUCKC-3		41	22	104	49	23	122	18	501	578	798	0.76	13.2	50.6	Spodue Mountain
			±	6	2	3	7	3	7	2	96	48	14	0.11			
Buck Creek	4	BUCKC-4		90	24	134	7	56	356	19	762	549	755	1.70	29.3	71.1	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Buck Creek	5	BUCKC-5		88	26	130	6	58	348	16	890	590	778	1.92	30.3	68.4	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Buck Creek	6	BUCKC-6		84	23	129	7	54	352	21	717	509	782	1.62	30.4	72.1	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
Buck Creek	7	BUCKC-7		59	22	104	54	29	139	12	218	599	827	1.24	19.8	173.3	Hager Mountain
			±	6	2	3	7	3	7	1	95	48	13	0.11			
Buck Creek	8	BUCKC-8		64	23	111	55	34	146	11	229	655	855	1.26	18.3	168.2	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	13	0.11			
Buck Creek	9	BUCKC-9		73	22	116	7	52	334	16	670	478	811	1.57	31.5	74.4	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
Buck Creek	10	BUCKC-10		59	23	114	57	33	146	14	169	491	874	0.96	19.4	171.9	Hager Mountain
			±	7	2	3	7	3	7	2	95	47	14	0.11			
Buck Creek	11	BUCKC-11		71	26	115	60	33	146	11	205	523	857	1.05	19.7	157.3	Hager Mountain
			±	7	2	3	7	3	7	2	95	48	14	0.11			
Buck Creek	12	BUCKC-12		68	21	113	52	35	141	10	219	609	874	1.22	19.2	169.8	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	13	0.11			
Buck Creek	13	BUCKC-13		78	28	123	62	34	149	14	215	571	849	1.09	18.5	155.2	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			

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Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Buck Creek	14	BUCKC-14	76	28	126	7	55	349	17	752	522	856	1.67	30.4	70.8	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Buck Creek	15	BUCKC-15	91	27	129	7	56	354	18	794	577	756	1.80	29.3	71.9	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Bergen Site	1	BERG -1	69	26	150	69	44	195	10	510	255	937	1.43	59.5	89.1	Quartz Mountain
			± 7	3	3	7	3	7	2	96	47	13	0.11			
Bergen Site	2	BERG -2	73	23	99	40	55	135	14	223	235	1338	0.79	38.0	112.2	Cougar Mountain
			± 7	3	3	7	3	7	2	95	47	15	0.11			
Bergen Site	3	BERG -3	83	21	106	39	55	139	10	246	271	1337	0.92	36.9	118.2	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
Bergen Site	4	BERG -4	83	24	125	10	58	233	14	417	203	494	1.15	64.0	87.6	Unknown 2
			± 6	2	3	7	3	7	2	95	47	13	0.11			
Bergen Site	5	BERG -5	73	28	151	71	47	203	11	481	255	961	1.27	53.1	84.1	Quartz Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
Bergen Site	6	BERG -6	70	23	97	37	56	133	13	341	326	1291	1.25	39.1	114.9	Cougar Mountain
			± 6	2	3	7	3	7	1	96	47	14	0.11			
Bergen Site	7	BERG -7	66	30	140	63	44	186	9	541	291	900	1.60	56.5	93.5	Quartz Mountain
			± 6	2	3	7	3	7	2	96	47	13	0.11			
Bergen Site	8	BERG -8	83	17	101	135	49	352	18	2050	566	874	2.88	46.9	44.4	Rhyolite
			± 7	3	3	7	3	7	2	98	48	13	0.11			
Bergen Site	9	BERG -9	70	28	123	54	51	264	11	648	329	948	1.94	58.8	94.2	China Hat
			± 6	2	3	7	3	7	1	96	47	13	0.11			
Bergen Site	10	BERG -10	57	29	138	67	44	188	10	434	226	975	1.24	60.4	91.2	Quartz Mountain
			± 7	2	3	7	3	7	2	96	47	14	0.11			
Bergen Site	11	BERG -11	80	29	147	68	45	193	9	499	237	968	1.29	58.9	82.4	Quartz Mountain
			± 7	2	3	7	3	7	2	96	47	14	0.11			

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Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations: Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios: Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Bergen Site	12	BERG -12	65	23	140	64	42	186	8	559	272	920	1.49	57.2	84.5	Quartz Mountain
			± 6	2	3	7	3	7	2	96	47	13	0.11			
Bergen Site	13	BERG -13	69	28	138	65	42	192	10	410	247	960	1.26	55.1	97.5	Quartz Mountain
			± 6	2	3	7	3	7	2	96	47	14	0.11			
Bergen Site	14	BERG -14	64	27	137	64	44	187	13	476	282	887	1.54	56.5	101.9	Quartz Mountain
			± 6	2	3	7	3	7	2	96	47	13	0.11			
Bergen Site	15	BERG -15	66	28	165	66	45	192	15	378	216	946	1.18	60.6	98.7	Quartz Mountain
			± 7	2	3	7	3	7	2	96	47	14	0.11			
Duncan Creek	1	DUNCR-1	48	20	102	52	30	131	16	178	667	874	1.31	18.6	219.3	Hager Mountain
			± 6	2	3	7	3	7	1	95	48	13	0.11			
Duncan Creek	2	DUNCR-2	69	23	108	55	32	138	11	223	657	789	1.30	18.7	177.0	Hager Mountain
			± 6	2	3	7	3	7	2	96	48	13	0.11			
Duncan Creek	3	DUNCR-3	55	17	106	48	24	121	11	626	559	772	0.76	13.7	41.1	Spodue Mountain
			± 7	3	3	7	3	7	2	96	47	13	0.11			
Duncan Creek	4	DUNCR-4	69	25	117	58	35	150	14	190	564	885	1.11	19.1	177.4	Hager Mountain
			± 7	3	3	7	3	7	2	95	48	14	0.11			
Duncan Creek	5	DUNCR-5	62	23	126	30	42	101	17	273	601	623	0.93	15.1	107.9	Duncan Creek
			± 6	2	3	7	3	7	1	95	48	13	0.11			
Duncan Creek	6	DUNCR-6	73	21	113	11	49	320	15	648	461	810	1.48	31.1	72.8	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	13	0.11			
Duncan Creek	7	DUNCR-7	53	23	101	55	33	135	12	244	598	858	1.25	19.9	157.1	Hager Mountain
			± 6	2	3	7	3	7	1	95	48	13	0.11			
Duncan Creek	8	DUNCR-8	70	24	135	31	37	98	15	188	442	681	0.62	14.7	105.8	Duncan Creek
			± 6	3	3	7	3	7	2	95	47	13	0.11			
West Fork Silver	1	SLVCR-C1	90	27	122	7	55	341	19	819	568	678	1.81	29.9	70.0	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			

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Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
West Fork Silver	2	SLVCR-C2	67	25	125	7	56	349	16	632	420	823	1.31	30.7	66.5	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	14	0.11			
West Fork Silver	3	SLVCR-C3	91	22	122	7	53	342	19	833	548	803	1.80	31.0	68.8	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
West Fork Silver	4	SLVCR-C4	83	27	131	7	57	353	16	808	554	796	1.69	28.8	66.5	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
West Fork Silver	5	SLVCR-C5	67	24	126	8	54	345	22	797	558	819	1.81	30.5	72.0	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	1	96	48	13	0.11			
West Fork Silver	6	SLVCR-C6	67	25	121	7	53	341	18	716	514	849	1.65	30.5	73.1	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	14	0.11			
West Fork Silver	7	SLVCR-C7	81	29	130	7	55	356	19	506	376	855	1.11	29.7	70.6	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	14	0.11			
West Fork Silver	8	SLVCR-C8	76	24	123	8	55	338	21	778	538	776	1.74	30.6	71.2	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	2	96	48	13	0.11			
West Fork Silver	9	SLVCR-C9	74	20	124	7	54	334	15	607	434	789	1.36	30.7	71.7	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	13	0.11			
West Fork Silver	10	SLVCR-C10	73	25	118	8	52	335	16	753	519	826	1.68	30.8	70.9	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	14	0.11			
West Fork Silver	11	SLVCR-C11	70	22	116	6	52	331	19	746	547	839	1.80	31.1	76.5	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	96	48	13	0.11			
West Fork Silver	12	SLVCR-C12	83	21	126	8	54	354	19	754	446	772	1.40	30.6	59.6	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	15	0.11			
West Fork Silver	13	SLVCR-C13	64	24	118	9	53	336	18	734	513	746	1.64	30.4	71.1	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	48	13	0.11			
West Fork Silver	14	SLVCR-C14	78	21	124	7	54	340	21	771	558	755	1.76	29.6	72.3	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	1	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations: Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios: Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
West Fork Silver	15	SLVCR-C15	76	24	121	7	54	344	16	813	559	747	1.89	31.7	73.5	Silver Lake/Sycan Marsh
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	1	SYCAN-BB-1	151	36	183	5	79	676	74	891	550	11	3.44	57.5	119.9	Witham Creek 3
			± 7	3	3	7	3	7	2	96	48	16	0.11			
Sycan River	2	SYCAN-BB-2	204	47	227	6	105	1136	99	591	445	10	2.77	58.8	144.7	Witham Creek
			± 8	3	4	7	3	8	2	95	48	20	0.11			
Sycan River	3	SYCAN-BB-3	209	41	235	6	107	1135	99	650	510	2	3.10	56.4	147.4	Witham Creek
			± 8	3	4	7	3	8	2	96	48	12	0.11			
Sycan River	4	SYCAN-BB-4	210	44	214	5	102	1005	92	867	657	0	3.90	53.7	139.4	Witham Creek
			± 8	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	5	SYCAN-BB-5	193	38	200	6	95	999	91	788	664	0	3.88	52.9	152.2	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	6	SYCAN-BB-6	183	51	226	6	105	1120	99	658	505	23	3.33	61.1	155.9	Witham Creek
			± 8	3	4	7	3	8	2	96	48	13	0.11			
Sycan River	7	SYCAN-BB-7	191	39	201	5	101	988	96	825	665	3	3.91	53.2	146.6	Witham Creek
			± 8	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	8	SYCAN-BB-8	183	49	228	6	102	1097	94	796	614	7	3.87	57.4	150.3	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	9	SYCAN-BB-9	200	39	213	4	105	1011	95	815	633	14	3.79	54.4	143.9	Witham Creek
			± 8	3	4	8	3	8	2	96	48	14	0.11			
Sycan River	10	SYCAN-BB-10	196	44	214	6	105	1023	98	712	576	23	3.34	53.2	145.3	Witham Creek
			± 8	3	4	7	3	8	2	96	48	13	0.11			
Sycan River	11	SYCAN-BB-11	212	40	215	3	110	1032	100	692	554	9	3.17	52.9	141.9	Witham Creek
			± 8	3	4	31	3	8	2	96	48	21	0.11			
Sycan River	12	SYCAN-BB-12	190	43	223	7	104	1110	96	669	485	0	2.97	57.4	137.7	Witham Creek
			± 8	3	4	7	3	8	2	96	48	12	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

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Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Sycan River	13	SYCAN-BB-13	181	41	225	5	98	1111	97	816	575	0	3.75	59.6	142.1	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	14	SYCAN-BB-14	185	49	218	5	106	1103	99	743	556	0	3.65	60.3	151.8	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	15	SYCAN-BB-15	180	44	220	6	105	1114	93	816	602	18	3.88	58.8	147.2	Witham Creek
			± 7	3	4	7	3	7	2	96	48	13	0.11			
Louse Lake	1	LOUSE-1	48	19	105	47	23	124	15	590	624	838	0.87	13.6	48.6	Spodue Mountain
			± 7	3	3	7	3	7	2	96	48	14	0.11			
Louse Lake	2	LOUSE-2	68	20	121	6	30	86	15	139	832	22	0.76	9.0	166.9	Cowhead Lake
			± 7	3	3	7	3	7	1	95	48	13	0.11			
Louse Lake	3	LOUSE-3	157	42	212	6	97	1075	95	582	449	12	2.97	62.5	157.7	Witham Creek
			± 7	3	4	7	3	8	2	95	48	14	0.11			
Louse Lake	4	LOUSE-4	200	48	231	4	104	1115	96	682	520	11	3.16	56.4	143.6	Witham Creek
			± 8	3	4	11	3	8	2	96	48	16	0.11			
Louse Lake	5	LOUSE-5	208	39	236	5	107	1139	94	761	533	7	3.55	61.4	144.3	Witham Creek
			± 7	3	4	7	3	8	2	96	48	12	0.11			
Louse Lake	6	LOUSE-6	200	45	200	6	94	956	90	591	457	0	2.66	54.9	139.2	Witham Creek
			± 8	3	4	7	3	8	2	95	48	12	0.11			
Louse Lake	7	LOUSE-7	188	41	220	6	103	1100	98	867	611	16	3.96	59.1	141.6	Witham Creek
			± 7	3	4	7	3	7	2	96	48	13	0.11			
Louse Lake	8	LOUSE-8	192	43	220	6	102	1103	98	710	515	13	3.35	60.4	146.1	Witham Creek
			± 7	3	4	7	3	8	2	96	48	15	0.11			
Louse Lake	9	LOUSE-9	178	42	217	6	104	1103	99	666	520	9	3.28	58.4	152.0	Witham Creek
			± 7	3	4	7	3	8	2	96	48	21	0.11			
Louse Lake	10	LOUSE-10	177	42	211	6	97	1049	88	605	479	10	2.95	57.8	150.7	Witham Creek
			± 8	3	4	7	3	8	2	96	48	19	0.11			

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Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Louse Lake	11	LOUSE-11	198	38	222	5	104	1105	96	683	541	13	3.48	59.4	157.3	Witham Creek
			± 7	3	4	7	3	8	2	96	48	15	0.11			
Louse Lake	12	LOUSE-12	218	44	242	4	107	1167	102	618	448	8	2.77	58.3	138.5	Witham Creek
			± 8	3	4	8	3	8	2	96	48	37	0.11			
Louse Lake	13	LOUSE-13	189	44	229	6	102	1123	100	769	544	18	3.72	62.8	149.4	Witham Creek
			± 7	3	4	7	3	8	2	96	48	13	0.11			
Louse Lake	14	LOUSE-14	38	16	100	46	25	121	15	582	652	776	0.89	13.3	50.4	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Louse Lake	15	LOUSE-15	193	42	227	4	104	1108	98	796	573	16	3.69	59.0	143.7	Witham Creek
			± 7	3	4	8	3	7	2	96	48	13	0.11			
Sycan River	1	SYCAN-CC-1	43	14	104	49	21	124	17	701	684	775	0.98	13.8	46.1	Spodue Mountain
			± 7	3	3	7	3	7	1	96	48	13	0.11			
Sycan River	2	SYCAN-CC-2	41	18	109	44	25	117	16	617	652	829	0.86	13.0	46.4	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	3	SYCAN-CC-3	40	15	108	47	23	125	14	584	614	752	0.84	13.6	48.0	Spodue Mountain
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Sycan River	4	SYCAN-CC-4	54	14	109	44	26	125	16	654	687	848	0.93	13.1	46.7	Spodue Mountain
			± 6	3	3	7	3	7	1	96	48	13	0.11			
Sycan River	5	SYCAN-CC-5	45	18	111	49	24	123	15	617	666	854	0.91	13.3	48.8	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	6	SYCAN-CC-6	46	17	111	50	26	128	12	546	643	864	0.87	13.2	52.5	Spodue Mountain
			± 6	3	3	7	3	7	2	96	48	14	0.11			
Sycan River	7	SYCAN-CC-7	45	17	105	49	23	122	15	598	635	829	0.88	13.6	48.7	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	8	SYCAN-CC-8	52	17	101	47	22	120	13	466	573	718	0.77	13.5	55.3	Spodue Mountain
			± 6	3	3	7	3	7	2	96	48	13	0.11			

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Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Sycan River	9	SYCAN-CC-9	181	44	219	5	101	1088	93	782	590	5	3.83	59.3	151.6	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Sycan River	10	SYCAN-CC-10	42	18	104	47	24	124	15	598	649	778	0.86	13.0	47.7	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	11	SYCAN-CC-11	41	19	114	46	24	127	17	599	629	797	0.84	13.1	46.4	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	12	SYCAN-CC-12	44	20	107	46	23	124	18	553	571	846	0.77	13.5	46.6	Spodue Mountain
			± 6	3	3	7	3	7	2	96	48	13	0.11			
Sycan River	13	SYCAN-CC-13	39	15	105	44	25	122	14	632	658	869	0.90	13.4	47.2	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	14	SYCAN-CC-14	49	16	102	45	23	121	15	544	612	814	0.84	13.5	51.2	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	15	SYCAN-CC-15	48	18	106	48	27	122	14	607	621	851	0.78	12.6	43.3	Spodue Mountain
			± 6	2	3	7	3	7	2	96	48	13	0.11			
Sycan River	16	SYCAN-CC-16	50	16	110	45	27	120	15	747	626	842	0.83	13.1	37.2	Spodue Mountain
			± 7	3	3	7	3	7	2	96	48	14	0.11			
Sycan River	17	SYCAN-CC-17	54	12	102	44	24	120	13	596	664	861	0.90	13.2	49.7	Spodue Mountain
			± 6	3	3	7	3	7	1	96	48	13	0.11			
Sycan River	18	SYCAN-CC-18	41	19	105	45	24	120	18	607	644	856	0.86	13.1	47.0	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Sycan River	19	SYCAN-CC-19	49	18	102	45	26	117	15	544	535	837	0.72	13.6	44.4	Spodue Mountain
			± 6	2	3	7	3	7	2	96	48	14	0.11			
Sycan River	20	SYCAN-CC-20	40	18	111	44	25	127	16	491	548	841	0.69	12.8	47.3	Spodue Mountain
			± 7	3	3	7	3	7	2	96	47	13	0.11			
Pellard Spring	1	PELLSP-1	44	17	105	45	24	123	16	631	620	771	0.82	13.1	43.4	Spodue Mountain
			± 6	3	3	7	3	7	1	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
			Trace Element Concentrations											Ratios		
Pellard Spring	2	PELLSP-2	42	20	105	45	23	124	17	666	694	890	0.93	12.9	45.9	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Pellard Spring	3	PELLSP-3	41	16	105	47	23	119	16	656	699	782	0.96	13.3	48.4	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Pellard Spring	4	PELLSP-4	43	17	110	48	25	128	16	567	595	822	0.80	13.3	46.9	Spodue Mountain
			± 6	3	3	7	3	7	2	96	48	13	0.11			
Pellard Spring	5	PELLSP-5	43	20	101	45	24	116	17	625	677	781	0.93	13.3	49.0	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Pellard Spring	6	PELLSP-6	36	19	103	47	24	133	13	560	618	815	0.81	13.0	48.4	Spodue Mountain
			± 6	2	3	7	3	7	2	96	48	13	0.11			
Pellard Spring	7	PELLSP-7	54	16	102	47	22	122	16	592	602	816	0.78	12.9	44.3	Spodue Mountain
			± 6	3	3	7	3	7	2	96	48	13	0.11			
Pellard Spring	8	PELLSP-8	41	16	108	51	24	127	16	616	661	827	0.88	13.0	47.2	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Pellard Spring	9	PELLSP-9	42	17	103	49	25	121	17	572	612	857	0.84	13.5	48.8	Spodue Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Pellard Spring	10	PELLSP-10	43	18	101	46	27	118	13	558	629	791	0.83	13.0	49.5	Spodue Mountain
			± 6	3	3	7	3	7	2	96	48	13	0.11			
Pike's Crossing	1	PIKE-1	179	32	180	5	93	836	83	1079	759	9	4.34	51.2	125.0	Witham Creek 2
			± 7	3	3	7	3	7	2	96	48	20	0.11			
Pike's Crossing	2	PIKE-2	175	40	216	6	99	1080	95	794	576	2	3.74	59.4	145.6	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Pike's Crossing	3	PIKE-3	203	40	206	6	101	988	91	933	733	0	4.27	52.2	141.6	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Pike's Crossing	4	PIKE-4	183	39	221	7	102	1102	97	712	582	15	3.65	57.4	158.2	Witham Creek
			± 7	3	4	7	3	8	2	96	48	14	0.11			

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Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
			Trace Element Concentrations											Ratios		
Pike's Crossing	5	PIKE-5	190	41	202	5	97	985	95	886	659	7	4.03	55.3	140.8	Witham Creek
			± 7	3	4	7	3	7	2	96	48	135	0.11			
Pike's Crossing	6	PIKE-6	228	48	237	8	112	1175	109	728	547	10	3.35	56.4	142.3	Witham Creek
			± 8	3	4	7	3	8	2	96	48	20	0.11			
Pike's Crossing	7	PIKE-7	213	42	212	6	103	1005	95	853	650	19	3.91	54.4	141.7	Witham Creek
			± 7	3	4	7	3	7	2	96	48	13	0.11			
Pike's Crossing	8	PIKE-8	215	43	234	5	106	1121	91	770	561	14	3.56	58.3	143.2	Witham Creek
			± 7	3	4	7	3	8	2	96	48	14	0.11			
Pike's Crossing	9	PIKE-9	182	40	193	7	97	966	90	860	693	4	4.21	54.7	151.3	Witham Creek
			± 7	3	3	7	3	7	2	96	48	12	0.11			
Pike's Crossing	10	PIKE-10	211	39	204	5	102	1008	95	494	402	15	2.21	53.0	138.5	Witham Creek
			± 9	3	4	7	3	8	2	95	47	14	0.11			
Pike's Crossing	11	PIKE-11	187	39	216	5	97	1074	89	632	463	13	2.97	60.3	145.4	Witham Creek
			± 8	3	4	7	3	8	2	95	48	14	0.11			
Pike's Crossing	12	PIKE-12	203	43	195	6	100	984	95	908	693	4	4.31	55.9	146.7	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Pike's Crossing	13	PIKE-13	189	41	225	5	102	1102	94	832	570	1	3.83	61.5	142.4	Witham Creek
			± 7	3	4	7	3	7	2	96	48	12	0.11			
Pike's Crossing	14	PIKE-14	190	38	222	6	105	1101	96	736	512	6	3.38	61.3	142.2	Witham Creek
			± 8	3	4	7	3	8	2	96	48	12	0.11			
Pike's Crossing	15	PIKE-15	197	47	231	5	111	1148	99	861	717	8	4.43	55.4	158.8	Witham Creek
			± 7	3	4	7	3	7	2	96	48	33	0.11			
Bunyard	1	BUNY-1	68	20	102	55	28	145	11	251	575	726	1.21	20.3	148.8	Hager Mountain
			± 7	3	3	7	3	7	2	96	48	13	0.11			
Bunyard	2	BUNY-2	55	18	104	53	31	135	11	278	675	811	1.39	19.3	153.4	Hager Mountain
			± 7	3	3	7	3	7	1	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Bunyard	3	BUNY-3	66	18	104	52	30	134	9	276	660	825	1.33	19.0	148.7	Hager Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Bunyard	4	BUNY-4	70	21	112	59	34	146	14	273	582	927	1.14	18.9	130.2	Hager Mountain
			± 7	3	3	7	3	7	2	95	48	13	0.11			
Bunyard	5	BUNY-5	55	19	111	54	29	130	10	279	640	878	1.25	18.6	139.3	Hager Mountain
			± 6	2	3	7	3	7	2	96	48	13	0.11			
Bunyard	6	BUNY-6	64	17	104	54	33	132	13	278	675	844	1.34	18.7	148.1	Hager Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Bunyard	7	BUNY-7	63	22	106	59	31	143	13	293	603	905	1.24	19.6	131.2	Hager Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Bunyard	8	BUNY-8	64	22	110	60	32	157	11	261	660	813	1.37	19.6	161.7	Hager Mountain
			± 6	3	3	7	3	7	2	96	48	13	0.11			
Bunyard	9	BUNY-9	52	22	105	52	30	130	9	219	579	866	1.14	19.1	160.1	Hager Mountain
			± 6	2	3	7	3	7	2	95	48	14	0.11			
Bunyard	10	BUNY-10	49	22	106	53	33	136	12	278	656	750	1.36	19.5	150.3	Hager Mountain
			± 7	2	3	7	3	7	1	96	48	13	0.11			
Bunyard	11	BUNY-11	47	21	104	55	32	134	10	247	643	799	1.33	19.6	164.2	Hager Mountain
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Bunyard	12	BUNY-12	66	19	102	51	30	132	11	230	552	754	1.13	19.9	151.1	Hager Mountain
			± 7	3	3	7	3	7	2	95	48	13	0.11			
Bunyard	13	BUNY-13	60	17	101	53	29	134	12	273	687	864	1.43	19.6	161.0	Hager Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Bunyard	14	BUNY-14	58	25	112	54	34	136	13	204	527	862	1.07	19.9	160.9	Hager Mountain
			± 7	3	3	7	3	7	2	95	48	13	0.11			
Bunyard	15	BUNY-15	67	18	103	56	32	140	14	298	655	833	1.37	19.7	142.0	Hager Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			

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Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.	Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
			Trace Element Concentrations											Ratios		
Grassy Butte	1	GRASSY-1	57	27	113	54	32	145	11	224	463	892	0.90	19.6	125.8	Hager Mountain
			± 7	3	3	7	3	7	2	95	47	15	0.11			
Grassy Butte	2	GRASSY-2	67	23	112	53	35	150	9	214	652	788	1.27	18.5	180.1	Hager Mountain
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Grassy Butte	3	GRASSY-3	59	21	111	56	32	142	14	158	573	813	1.09	18.4	204.2	Hager Mountain
			± 7	3	3	7	3	7	2	95	48	13	0.11			
Grassy Butte	4	GRASSY-4	64	19	111	55	32	146	10	205	628	851	1.24	18.8	182.8	Hager Mountain
			± 7	3	3	7	3	7	2	95	48	13	0.11			
Grassy Butte	5	GRASSY-5	68	26	114	55	30	145	10	172	569	851	1.10	18.7	192.1	Hager Mountain
			± 7	2	3	7	3	7	2	95	48	14	0.11			
Grassy Butte	6	GRASSY-6	57	21	109	56	34	145	13	206	629	794	1.25	18.9	183.1	Hager Mountain
			± 7	2	3	7	3	7	2	96	48	13	0.11			
Grassy Butte	7	GRASSY-7	67	22	114	55	33	140	12	239	632	810	1.26	19.0	162.3	Hager Mountain
			± 6	3	3	7	3	7	2	96	48	13	0.11			
Grassy Butte	8	GRASSY-8	61	20	111	59	31	145	14	189	677	854	1.36	18.9	214.9	Hager Mountain
			± 6	2	3	7	3	7	1	96	48	13	0.11			
Grassy Butte	9	GRASSY-9	68	19	111	54	32	144	10	208	574	820	1.16	19.4	169.4	Hager Mountain
			± 7	3	3	7	3	7	2	95	48	13	0.11			
Grassy Butte	10	GRASSY-10	58	22	105	51	31	137	17	221	616	839	1.26	19.4	173.0	Hager Mountain
			± 6	2	3	7	3	7	1	95	48	14	0.11			
Grassy Butte	11	GRASSY-11	59	17	112	55	32	144	13	176	649	817	1.31	19.1	221.5	Hager Mountain
			± 6	3	3	7	3	7	1	95	48	13	0.11			
Grassy Butte	12	GRASSY-12	59	21	112	53	30	146	9	208	662	761	1.34	19.1	194.2	Hager Mountain
			± 6	2	3	7	3	7	2	96	48	13	0.11			
Grassy Butte	13	GRASSY-13	51	15	101	52	33	139	9	240	648	821	1.37	20.0	174.2	Hager Mountain
			± 6	2	3	7	3	7	2	96	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
Grassy Butte	14	GRASSY-14		64	22	117	57	35	140	11	167	612	850	1.15	18.0	204.9	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	14	0.11			
Grassy Butte	15	GRASSY-15		60	18	110	54	35	148	12	247	686	804	1.37	18.7	169.1	Hager Mountain
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Duncan Creek	1	DUNCR-C1		66	22	120	57	35	154	11	157	581	863	1.15	19.1	217.3	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	2	DUNCR-C2		68	25	110	57	32	143	9	196	613	769	1.19	18.6	183.0	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	3	DUNCR-C3		58	18	110	56	32	141	13	240	683	791	1.37	18.9	173.5	Hager Mountain
			±	7	3	3	7	3	7	1	96	48	13	0.11			
Duncan Creek	4	DUNCR-C4		58	22	108	56	33	145	13	241	659	798	1.29	18.6	164.0	Hager Mountain
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Duncan Creek	5	DUNCR-C5		72	21	115	59	32	147	16	218	578	793	1.17	19.4	163.5	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	6	DUNCR-C6		56	24	107	55	34	148	8	165	620	788	1.22	18.7	218.9	Hager Mountain
			±	7	2	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	7	DUNCR-C7		63	22	113	59	33	150	15	198	672	838	1.28	18.1	195.8	Hager Mountain
			±	7	2	3	7	3	7	1	96	48	13	0.11			
Duncan Creek	8	DUNCR-C8		75	25	122	61	37	153	12	193	585	876	1.11	18.4	175.1	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	9	DUNCR-C9		56	21	109	52	33	141	13	229	686	889	1.34	18.4	178.4	Hager Mountain
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Duncan Creek	10	DUNCR-C10		65	19	107	53	33	139	11	194	646	830	1.23	18.2	191.6	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	11	DUNCR-C11		59	22	109	53	35	142	11	181	575	786	1.11	18.6	183.9	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			

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NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

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Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
				Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Duncan Creek	12	DUNCR-C12		56	24	108	56	35	145	13	163	585	843	1.13	18.6	205.9	Hager Mountain
			±	7	2	3	7	3	7	2	95	48	14	0.11			
Duncan Creek	13	DUNCR-C13		56	21	106	54	33	139	9	148	594	735	1.17	18.9	232.0	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	14	DUNCR-C14		58	23	110	56	32	157	16	133	477	930	0.89	18.7	199.1	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	14	0.11			
Duncan Creek	15	DUNCR-C15		62	28	114	57	32	155	14	143	582	869	1.16	19.1	236.4	Hager Mountain
			±	6	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	16	DUNCR-C16		65	22	114	54	36	147	12	196	554	862	1.16	20.2	178.8	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	17	DUNCR-C17		61	21	107	54	30	141	13	227	642	788	1.28	18.9	171.2	Hager Mountain
			±	7	3	3	7	3	7	1	96	48	13	0.11			
Duncan Creek	18	DUNCR-C18		58	20	114	56	33	144	12	204	570	775	1.14	19.3	170.2	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	19	DUNCR-C19		59	17	114	54	31	139	13	191	598	768	1.21	19.5	192.0	Hager Mountain
			±	7	3	3	7	3	7	2	95	48	13	0.11			
Duncan Creek	20	DUNCR-C20		63	26	110	57	32	145	13	266	605	818	1.19	18.9	138.7	Hager Mountain
			±	7	2	3	7	3	7	2	95	48	13	0.11			
La Brie Lake	1	LABRIE-1		57	27	110	56	32	147	10	238	485	903	0.96	19.7	126.4	Hager Mountain
			±	7	2	3	7	3	7	2	95	47	13	0.11			
La Brie Lake	2	LABRIE-2		58	20	102	49	30	132	12	183	491	874	0.92	18.7	154.1	Hager Mountain
			±	6	3	3	7	3	7	2	95	47	13	0.11			
La Brie Lake	3	LABRIE-3		67	15	107	54	34	145	11	275	683	813	1.42	19.5	158.3	Hager Mountain
			±	6	2	3	7	3	7	1	96	48	13	0.11			
La Brie Lake	4	LABRIE-4		60	23	110	58	33	139	10	232	620	888	1.27	19.5	167.6	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	14	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
La Brie Lake	5	LABRIE-5		79	17	114	56	36	157	13	148	549	882	1.07	19.0	214.4	Hager Mountain
			±	6	3	3	7	3	7	2	95	48	13	0.11			
La Brie Lake	6	LABRIE-6		58	21	104	52	31	135	12	220	563	844	1.13	19.4	157.4	Hager Mountain
			±	7	2	3	7	3	7	2	95	48	13	0.11			
La Brie Lake	7	LABRIE-7		56	25	110	56	36	139	10	220	596	870	1.18	19.0	163.7	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	13	0.11			
La Brie Lake	8	LABRIE-8		61	22	108	53	33	152	9	212	629	808	1.26	19.0	179.3	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	13	0.11			
La Brie Lake	9	LABRIE-9		64	18	107	53	31	148	11	207	542	889	1.08	19.4	159.1	Hager Mountain
			±	6	3	3	7	3	7	2	95	48	13	0.11			
La Brie Lake	10	LABRIE-10		63	22	106	57	33	149	11	237	653	854	1.31	19.0	168.5	Hager Mountain
			±	6	2	3	7	3	7	1	96	48	13	0.11			
Chocktoot	1	CHOCK-1		177	44	217	5	102	1094	98	624	495	9	3.06	57.6	151.3	Witham Creek
			±	7	3	4	7	3	7	2	96	48	20	0.11			
Chocktoot	2	CHOCK-2		177	44	211	6	93	1083	98	581	480	10	3.00	58.5	159.2	Witham Creek
			±	7	3	4	7	3	8	2	95	48	18	0.11			
Chocktoot	3	CHOCK-3		193	41	219	4	104	1128	98	566	501	29	2.92	54.4	159.0	Witham Creek
			±	8	3	4	8	3	8	2	95	48	14	0.11			
Shake Creek	1	SHAKE-1		177	48	226	5	103	1096	94	482	359	24	2.29	62.3	146.7	Witham Creek
			±	8	3	4	7	3	8	2	95	47	13	0.11			
Shake Creek	2	SHAKE-2		53	19	101	46	24	129	16	482	544	841	0.79	14.5	54.3	Spodue Mountain
			±	6	3	3	7	3	7	2	96	48	13	0.11			
Shake Creek	3	SHAKE-3		45	19	106	47	23	123	16	475	512	841	0.65	13.1	46.6	Spodue Mountain
			±	6	3	3	7	3	7	2	96	47	13	0.11			
Evans Creek	1	EVANS-1		39	16	108	47	23	123	12	593	641	842	0.85	13.1	47.7	Spodue Mountain
			±	6	2	3	7	3	7	2	96	48	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Results of XRF studies: geologic samples from the Fort Rock Basin and Fremont National Forest, south-central Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
Evans Creek	2	EVANS-2		42	18	102	47	22	119	14	520	553	824	0.68	12.6	44.5	Spodue Mountain
			±	6	2	3	7	3	7	1	97	48	13	0.11			
Evans Creek	3	EVANS-3		53	17	106	50	23	121	11	577	623	899	0.86	13.5	49.3	Spodue Mountain
			±	6	2	3	7	3	7	2	96	47	13	0.11			
Evans Creek	4	EVANS-4		41	21	105	28	24	95	12	385	286	91	0.68	26.4	59.4	Unknown 3
			±	7	3	3	7	3	7	2	95	47	13	0.11			
Evans Creek	5	EVANS-5		42	17	104	46	24	125	17	507	526	871	0.71	13.8	47.4	Spodue Mountain
			±	6	3	3	7	3	7	2	96	47	14	0.11			
Cottonwood	1	COTTON-1		58	17	110	59	32	139	10	196	583	868	1.16	19.2	180.0	Hager Mountain
			±	6	2	3	7	3	7	2	95	48	13	0.11			
Cottonwood	2	COTTON-2		52	25	109	35	36	181	11	498	428	1178	1.38	31.6	87.9	Variety 5
			±	6	2	3	7	3	7	1	96	48	14	0.11			
Cottonwood	3	COTTON-3		74	28	114	54	44	279	10	711	412	1265	1.69	40.0	75.6	Bald Butte
			±	7	2	3	7	3	7	2	96	48	14	0.11			
Willow Creek	1	WILLW-1		75	28	109	55	43	280	14	493	307	1344	1.16	39.4	75.8	Bald Butte
			±	7	3	3	7	3	7	2	96	47	14	0.11			
NA	RGM-1	RGM-1		33	27	152	106	29	226	10	1559	278	758	1.87	69.2	38.5	RGM-1 Reference Standard
			±	7	2	3	7	3	7	1	97	47	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Appendix E

Geologic Sample Summary Statistics

Bald Butte geochemical group (n = 2).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	114	55	44	280	14	1344	75	711	412	1.69	40	76
Minimum	109	54	43	279	10	1265	74	493	307	1.16	39	76
Range	5	1	1	2	4	79	1	219	106	0.53	1	0
Mean	112	55	44	279	12	1304	75	602	359	1.43	40	76
S.D.	4	1	1	1	3	56	1	155	75	0.38	0	0
C.V.%	3	1	2	0	24	4	1	26	21	26	1	0

China Hat geochemical group (n = 1).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	123	54	51	264	11	948	70	648	329	1.94	59	94
Minimum	123	54	51	264	11	948	70	648	329	1.94	59	94
Range	0	0	0	0	0	0	0	0	0	0.00	0	0
Mean	123	54	51	264	11	948	70	648	329	1.94	59	94
S.D.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C.V.%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

All Trace element values reported in parts per million. Iron content is reported as weight percent oxide. NA = Not Available.

Cougar Mountain geochemical group (n = 7).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	106	41	58	139	14	1369	83	341	326	1.25	40	128
Minimum	96	37	54	133	10	1274	70	194	232	0.75	34	81
Range	11	4	4	7	4	95	13	147	94	0.50	6	47
Mean	99	39	56	136	12	1318	76	256	260	0.90	38	112
S.D.	4	1	1	2	1	32	5	52	32	0.17	2	15
C.V.%	4	4	2	2	11	2	6	20	12	19	5	14

Cowhead Lake geochemical group (n = 1).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	121	6	30	86	15	22	68	139	832	0.76	9	167
Minimum	121	6	30	86	15	22	68	139	832	0.76	9	167
Range	0	0	0	0	0	0	0	0	0	0.00	0	0
Mean	121	66	30	86	15	22	68	139	832	0.76	9	167
S.D.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C.V.%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

All Trace element values reported in parts per million. Iron content is reported as weight percent oxide. NA = Not Available.

Duncan Creek geochemical group (n = 6).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	140	32	42	107	21	713	70	273	601	0.93	15	164
Minimum	125	30	37	98	15	623	55	105	342	0.45	14	106
Range	15	2	6	9	5	89	15	168	259	0.48	1	58
Mean	132	31	39	101	18	671	59	169	493	0.72	15	136
S.D.	5	1	2	3	2	31	5	50	79	0.14	0	23
C.V.%	4	3	4	3	10	5	8	29	16	20	2	17

Guyer Creek geochemical group (n = 2).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	99	93	38	324	16	1011	65	1540	477	1.85	38	39
Minimum	99	90	37	310	13	1011	58	1478	464	1.69	34	37
Range	0	3	1	14	2	1	7	61	10	0.16	4	2
Mean	99	91	38	317	15	1011	61	1509	469	1.77	36	38
S.D.	0	2	0	10	2	0	5	43	7	0.11	3	1
C.V.%	0	2	1	3	11	0	8	3	2	6	8	3

All Trace element values reported in parts per million. Iron content is reported as weight percent oxide. NA = Not Available.

Hager Mountain geochemical group (n = 102).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	123	62	37	157	17	940	79	298	731	1.43	20	236
Minimum	98	49	28	128	7	726	47	103	372	0.70	18	110
Range	25	14	9	29	9	214	32	195	359	0.74	3	126
Mean	109	55	32	143	12	845	62	209	593	1.18	19	175
S.D.	5	2	2	6	2	45	7	41	72	0.16	1	25
C.V.%	4	4	6	5	17	5	11	19	12	13	3	14

Quartz Mountain geochemical group (n = 9).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	165	71	47	203	15	975	80	559	291	1.60	61	102
Minimum	137	63	42	186	8	887	57	378	216	1.18	53	82
Range	28	7	5	16	7	88	23	181	75	0.43	8	20
Mean	145	66	44	191	11	939	68	476	254	1.37	58	91
S.D.	9	2	1	5	2	31	6	60	25	0.15	3	7
C.V.%	6	4	3	3	22	3	10	13	10	11	4	8

All Trace element values reported in parts per million. Iron content is reported as weight percent oxide. NA = Not Available.

Spodue Mountain geochemical group (n = 41).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	114	51	28	133	18	899	55	747	738	0.99	15	55
Minimum	100	44	21	116	11	718	36	466	512	0.65	13	37
Range	14	7	7	17	7	181	19	282	226	0.34	2	18
Mean	105	47	24	123	15	823	45	585	623	0.84	13	48
S.D.	3	2	2	4	2	39	5	60	52	0.08	0	3
C.V.%	3	4	7	3	12	5	11	10	8	10	3	7

Variety 5 geochemical group (n = 1).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_2O_3	Fe:Mn	Fe:Ti
Maximum	109	35	36	181	11	1178	52	498	428	1.38	32	88
Minimum	109	35	36	181	11	1178	52	498	428	1.38	32	88
Range	0	0	0	0	0	0	0	0	0	0.00	0	0
Mean	109	35	36	181	11	1178	52	498	428	1.38	32	88
S.D.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C.V.%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

All Trace element values reported in parts per million. Iron content is reported as weight percent oxide. NA = Not Available.

Witham Creek geochemical group (n = 56).

	Rb	Sr	Y	Zr	Nb	Ba	Zn	Ti	Mn	Fe_20_3	Fe:Mn	Fe:Ti
Maximum	242	8	112	1178	109	29	228	1079	759	4.59	63	159
Minimum	180	3	79	676	74	0	151	482	359	2.21	51	120
Range	62	4	33	501	35	30	77	597	401	2.38	12	39
Mean	216	5	102	1059	95	9	192	750	570	3.53	57	146
S.D.	14	1	6	86	5	7	15	124	90	0.54	3	7
C.V.%	6	17	5	8	5	73	8	17	16	15	5	5

All Trace element values reported in parts per million. Iron content is reported as weight percent oxide. NA = Not Available.

Appendix F

Prehistoric Site Data

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
Burnett (Lake Oswego)	35-CL-96	Clackamas	OR	1	14	7	Burnett 1995
Lancaster Farm	35-CS-161	Coos	OR	4	10	40	Skinner and Thatcher 1999b
Indian Sands	35-CU-67	Curry	OR	5	72	7	Skinner 1997b
Marial	35-CU-84	Curry	OR	6	30	20	Skinner and Davis 1998b
Marial	35-CU-84	Curry	OR	7	23	30	Skinner and Davis 1998a
Marial	35-CU-84	Curry	OR	3	26	12	Jackson, Davis, and King 1994a
Squirrel Camp	35-CU-186	Curry	OR	4	19	21	Jackson, Jackson, and Davis 1992
Lava Flow CG	61200219	Deschutes	OR	3	66	5	Skinner, Davis, and Thatcher 1997a
Quinn River CG	61100358	Deschutes	OR	6	62	10	Skinner, Davis, and Thatcher 1997a
Lava Butte	35-DS-33	Deschutes	OR	7	964	1	Skinner 1995
Lava Butte	35-DS-33	Deschutes	OR	2	42	5	Hughes 1989b; Davis and Scott 1991
Paulina Lake	35-DS-34	Deschutes	OR	16	189	8	Hughes 1994b
Black Butte Ranch Spire	35-DS-419	Deschutes	OR	1	1	100	Skinner, Davis, and Allred 1996
Dusty Mink	35-DS-502	Deschutes	OR	1	15	7	Hughes 1987c
35-DS-555	35-DS-555	Deschutes	OR	17	137	12	Skinner 1995
35-DS-557	35-DS-557	Deschutes	OR	4	652	1	Skinner 1995
Bon Site	35-DS-608	Deschutes	OR	2	40	5	Skinner and Davis 1995a
35-DS-808	35-DS-808	Deschutes	OR	2	2	100	Skinner 1995
35-DS-985	35-DS-985	Deschutes	OR	2	16	13	Skinner 1995
Tiller Ranger Station	35-DO-37	Douglas	OR	5	40	13	Hughes 1994c
Cavitt Creek Falls	35-DO-40	Douglas	OR	5	10	50	Hughes 1995a
Dry Gulch	35-DO-50	Douglas	OR	11	20	55	Hughes 1998c
Scaredman	35-DO-57	Douglas	OR	10	23	43	Hughes 1999b
Glide Ranger Station	35-DO-58	Douglas	OR	13	19	68	Hughes 1998d
North Bank	35-DO-61	Douglas	OR	3	6	50	Hughes 1998b

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
Brockway Creek	35-DO-77	Douglas	OR	2	8	25	Skinner, Thatcher, and Davis 1997b
Umpqua/Eden	35-DO-83	Douglas	OR	1	21	5	Skinner 1996a
Umpqua/Eden	35-DO-83	Douglas	OR	19	166	11	Skinner 1997c
White Rock Trail	35-DO-87	Douglas	OR	4	7	57	Hughes 1997d
Running Cougar	35-DO-97	Douglas	OR	3	8	38	Hughes 1999a
Susan Creek	35-DO-100	Douglas	OR	46	70	66	Hughes 1994h
Honey Creek	35-DO-101	Douglas	OR	9	14	64	Hughes 1995b
Maude Schultz	35-DO-119	Douglas	OR	1	4	25	Hughes 1998a
Tahkenitch Landing	35-DO-130	Douglas	OR	6	23	26	Skinner 1997a
The Narrows	35-DO-153	Douglas	OR	25	35	71	Hughes 1992b
Standley	35-DO-182	Douglas	OR	4	40	10	Hughes 1989f
Times Square Rockshelter	35-DO-212	Douglas	OR	5	10	50	Hughes 1988d
Section Creek	35-DO-219	Douglas	OR	11	38	29	Hughes 1991
Apple Creek	35-DO-265	Douglas	OR	10	18	56	Hughes 1990a
Apple Creek	35-DO-265	Douglas	OR	1	6	17	O'Neill 1991
Apple Creek	35-DO-265	Douglas	OR	6	9	67	Hughes 1987d
Bogus Creek	35-DO-278	Douglas	OR	32	39	82	Hughes 1988a
Little Oak Flat	35-DO-289	Douglas	OR	5	9	56	Hughes 1987b
Texas Gulch	35-DO-363	Douglas	OR	4	13	31	Hughes 1999b
Sugar Pine Flat	35-DO-364	Douglas	OR	5	7	71	Hughes 1992b
Snuff Out	35-DO-379	Douglas	OR	29	42	69	Hughes 1989e
Muddy Road	35-DO-382	Douglas	OR	11	14	79	Hughes 1994d
Susan Creek Campground	35-DO-383	Douglas	OR	29	45	64	Hughes 1997b
Susan Creek Campground	35-DO-383	Douglas	OR	34	50	68	Hughes 1993a
Susan Creek Campground	35-DO-383	Douglas	OR	1	10	10	Hughes 1994e

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
Shivigny East	35-DO-397	Douglas	OR	9	12	75	Hughes 1992b
Snowbird	35-DO-399	Douglas	OR	6	10	60	Hughes 1988e
Horseshoe #6	35-DO-400	Douglas	OR	2	6	33	Hughes 1988c
Dry Creek	35-DO-401	Douglas	OR	25	49	51	Hughes 1994i
Dry Creek	35-DO-401	Douglas	OR	11	18	61	Hughes 1988b
Dry Creek	35-DO-401	Douglas	OR	14	27	52	Skinner, Davis, and Allred 1995c
Dry Creek	35-DO-401	Douglas	OR	5	12	42	Hughes 1990a
Calapooya Intersection	35-DO-410	Douglas	OR	1	5	20	Hughes 1992b
Steamboat Point	35-DO-417	Douglas	OR	7	9	78	Skinner, Davis, and Allred 1995b
Apple Creek Bench	35-DO-418	Douglas	OR	1	6	17	Hughes 1990a
Apple Creek Bench	35-DO-418	Douglas	OR	11	29	38	Hughes 1994g
Copeland Creek	35-DO-421	Douglas	OR	8	16	50	Hughes 1994j
Copeland Creek	35-DO-421	Douglas	OR	4	6	67	Hughes 1990a
Island Campground	35-DO-422	Douglas	OR	12	18	67	Hughes 1994j
Island Campground	35-DO-422	Douglas	OR	4	9	44	Hughes 1990a
Susan's Picnic	35-DO-458	Douglas	OR	31	60	52	Hughes 1993b
Bend Creek	35-DO-459	Douglas	OR	5	18	28	Hughes 1992a
Wild Singe Rockshelters	35-DO-476	Douglas	OR	6	20	30	Hughes 1992c
Milltown Terrace	35-DO-478	Douglas	OR	4	27	15	Jackson, Davis, and King 1994b
Dry Gulch	35-DO-550	Douglas	OR	6	20	30	Hughes 1994m
Curtin Call	35-DO-565	Douglas	OR	12	21	57	Hughes 1994f
Snowalla	35-DO-569	Douglas	OR	5	20	25	Hughes 1995c
Sugar Pine Spring	35-DO-579	Douglas	OR	17	23	74	Hughes 1994d
Engles Tie	35-DO-587	Douglas	OR	1	5	20	Hughes 1994a
The Marshall Place	35-DO-595	Douglas	OR	4	10	40	Hughes 1994f

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
Harmon's Hunch	35-DO-635	Douglas	OR	2	10	20	Hughes 1994l
Loughs Terrace	35-DO-641	Douglas	OR	12	23	52	Skinner, Davis, and Allred 1995b
Windy Spring	35-DO-667	Douglas	OR	4	12	33	Hughes 1997a
Johnson Creek HD	35-DO-694	Douglas	OR	3	6	50	Hughes 1997d
Lower Tater	35-DO-697	Douglas	OR	1	4	25	Hughes 1997c
Terrace Hamlet	35-DO-704	Douglas	OR	1	1	100	Skinner, Thatcher, and Davis 1997b
Terrace Hamlet	35-DO-706	Douglas	OR	1	3	33	Skinner, Thatcher, and Davis 1997b
Peninsula	35-DO-707	Douglas	OR	1	4	25	Skinner, Thatcher, and Davis 1997b
Fairway	35-DO-709	Douglas	OR	4	7	57	Skinner, Thatcher, and Davis 1997b
Illahee Meadow	35-DO-728	Douglas	OR	3	20	15	Hughes 1998e
South Mytrle Head	35-DO-737	Douglas	OR	4	5	80	Hughes 1997c
Myrtle Head	35-DO-750	Douglas	OR	1	1	100	Hughes 1998a
Saltsgaver	35-JA-21	Jackson	OR	2	23	9	Hughes 1987e
Fawn Butte	35-JA-23	Jackson	OR	2	40	5	NA
Elk Creek JA 27A	35-JA-27A	Jackson	OR	22	49	45	Hughes 1987a
Elk Creek JA 59/Stump Site	35-JA-59	Jackson	OR	13	42	31	Hughes 1987a
Elk Creek JA 100	35-JA-100	Jackson	OR	14	37	38	Hughes 1987a
35-JA-101	35-JA-101	Jackson	OR	1	44	2	NA
35-JA-105	35-JA-105	Jackson	OR	5	5	100	NA
35-JA-110	35-JA-110	Jackson	OR	1	4	25	NA
Gold Hill	35-JA-130	Jackson	OR	7	20	35	Hughes 1990b
Fish Lake Summer Home	35-JA-163	Jackson	OR	6	50	12	Jackson, Davis, and King 1993b
Woodruff Meadows	35-JA-177	Jackson	OR	2	11	18	Skinner and Davis 1996
Trail-Casey State Park	35-JA-189	Jackson	OR	16	35	46	Hughes 1994o
Blue Gulch	35-JA-205	Jackson	OR	10	15	67	Skinner, Davis, and Thatcher 1996a

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
35-JA-218	35-JA-218	Jackson	OR	15	45	33	Skinner, Thatcher, and Davis 1998a
35-JA-218	35-JA-218	Jackson	OR	13	25	52	Skinner, Davis, and Origer 1995b
35-JA-220	35-JA-220	Jackson	OR	5	11	45	Skinner, Davis, and Origer 1995b
35-JA-221	35-JA-221	Jackson	OR	36	91	40	Skinner, Davis, and Origer 1995b
35-JA-221	35-JA-221	Jackson	OR	10	29	34	Skinner, Thatcher, and Davis 1998a
Colvard	35-JA-222	Jackson	OR	2	64	3	Jackson, Davis, and King 1993e
Brush Creek	35-JA-279	Jackson	OR	2	12	17	Skinner, Davis, and Thatcher 1996a
Tree Fall Rootwad	35-JA-295	Jackson	OR	20	114	18	Skinner, Davis, and Thatcher 1995b
Dead Indian Memorial Creek	35-JA-300	Jackson	OR	2	18	11	Skinner, Davis, and Thatcher 1995b
Ridgeline Meadow	35-JA-301	Jackson	OR	4	26	15	Skinner, Davis, and Thatcher 1995b
Hairpin Thistle	35-JA-302	Jackson	OR	3	69	4	Skinner, Davis, and Thatcher 1995b
Hoxie Creek	35-JA-305	Jackson	OR	1	7	14	Skinner, Davis, and Thatcher 1995b
35-JA-329	35-JA-329	Jackson	OR	33	56	59	Skinner, Thatcher, and Davis 1998a
35-JA-329	35-JA-329	Jackson	OR	2	3	67	Skinner, Davis, and Origer 1995b
35-JA-330	35-JA-330	Jackson	OR	35	36	97	Skinner, Thatcher, and Davis 1998a
35-JA-408	35-JA-408	Jackson	OR	1	17	6	Skinner and Davis 1998c
35-JE-49	35-JE-49	Jefferson	OR	1	468	0	Skinner 1995
Johnson	35-JE-51B	Jefferson	OR	3	528	1	Skinner 1995
35-JE-293	35-JE-293	Jefferson	OR	1	45	2	Skinner 1995
Perry South Campground	35-JE-295	Jefferson	OR	1	142	1	Skinner, Thatcher, and Davis 1998d
35-JE-298	35-JE-298	Jefferson	OR	1	58	2	Skinner 1995
Heath Cliffs	35-JE-319	Jefferson	OR	1	105	1	Hughes 1996
Hog Creek	35-JO-13	Joshephine	OR	1	5	20	Skinner, Davis, and Thatcher 1996a
Mouth of Stratton Creek	35-JO-21	Joshephine	OR	2	29	7	Jackson, Davis, and King 1993d
Limpy Creek	35-JO-39	Joshephine	OR	20	59	34	Skinner and Davis 1997b

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
Kawumkan Springs	-	Klamath	OR	27	109	25	Hughes 1986
Essex Springs	-	Klamath	OR	1	1	100	Skinner 1998 (personal
Odell Lake	35-KL-231	Klamath	OR	2	20	10	Hughes 1994k
West Odell	35-KL-482	Klamath	OR	10	86	12	Skinner and Davis 1995b
35-KL-810	35-KL-810	Klamath	OR	283	377	75	Skinner 1995
35-KL-812	35-KL-812	Klamath	OR	76	154	49	Skinner 1995
35-KL-813	35-KL-813	Klamath	OR	45	110	41	Skinner 1995
35-KL-814	35-KL-814	Klamath	OR	42	259	16	Skinner 1995
35-KL-815	35-KL-815	Klamath	OR	2	22	9	Skinner 1995
35-KL-816	35-KL-816	Klamath	OR	1	1	100	Skinner 1995
35-KL-818	35-KL-818	Klamath	OR	1	53	2	Skinner 1995
35-KL-834	35-KL-834	Klamath	OR	2	9	22	Skinner 1995
35-KL-835	35-KL-835	Klamath	OR	3	29	10	Skinner 1995
Bull Master	35-KL-973	Klamath	OR	1	15	7	Jackson and Jackson 1992
North Poe Valley	35-KL-976	Klamath	OR	2	59	3	Jackson and Jackson 1992
Stanley C. Masten	35-KL-978	Klamath	OR	3	168	2	Jackson and Jackson 1992
Four Bulls	35-KL-1459	Klamath	OR	7	256	3	Skinner, Davis, and Thatcher 1995b
Quita Creek	35-KL-1500	Klamath	OR	2	14	14	Skinner and Davis 1995b
Bowling Dune	-	Lake	OR	5	23	22	Hughes 1995a
Tucker Hill	-	Lake	OR	1	76	1	Hutchins and Simons 1999
14DJ	14DJ	Lake	OR	1	3	33	Skinner, Thatcher, and Davis 1998c
Silver Lake	-	Lake	OR	7	51	14	Skinner and Thatcher 1998b
Buffalo Flat	-	Lake	OR	7	56	13	NA
Buffalo Flat/Christmas Valley	-	Lake	OR	11	160	7	NA
Connley Caves	35-LK-13	Lake	OR	1	4	25	Skinner 1983

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
Connley Caves	35-LK-50	Lake	OR	28	168	17	See Appendix D of this thesis.
Early X-mas Present	35-LK-963	Lake	OR	2	4	50	Hughes 1993c
Sage	35-LK-1003	Lake	OR	1	1	100	Skinner, Davis, and Origer 1995a
First Point Found	35-LK-1174	Lake	OR	1	2	50	Hughes 1993c
Susan's Site	35-LK-1180	Lake	OR	3	9	33	Hughes 1993c
Susan's Site	35-LK-1180	Lake	OR	1	1	100	Hughes 1993c
Buffalo Flat	35-LK-1421	Lake	OR	1	2	50	Hughes 1993c
Buffalo Flat	35-LK-1425	Lake	OR	1	4	25	Hughes 1993c
Buffalo Flat	35-LK-1430	Lake	OR	3	10	30	Hughes 1993c
Buffalo Flat	35-LK-1433	Lake	OR	1	8	13	Hughes 1993c
Buffalo Flat	35-LK-1434	Lake	OR	1	10	10	Hughes 1993c
Dietz Site	35-LK-1529	Lake	OR	2	73	3	Fagan 1988
Buffalo Flat	35-LK-1868	Lake	OR	1	2	50	Hughes 1993c
Out of Bounds	35-LK-1869	Lake	OR	1	2	50	Hughes 1993c
Oh Man!	35-LK-1870	Lake	OR	4	14	29	Hughes 1993c
Vegamatic	35-LK-1871	Lake	OR	2	5	40	Hughes 1993c
Santa's Workshop	35-LK-1878	Lake	OR	2	18	11	Hughes 1993c
Buffalo Flat	35-LK-1880	Lake	OR	3	10	30	Hughes 1993c
Buffalo Flat	35-LK-1881	Lake	OR	1	3	33	Hughes 1993c
Buffalo Flat	35-LK-1881	Lake	OR	2	4	50	Hughes 1993c
Buffalo Flat	35-LK-2066	Lake	OR	1	3	33	Hughes 1993c
Buffalo Flat	35-LK-2075	Lake	OR	1	2	50	Hughes 1993c
Buffalo Flat	35-LK-2076	Lake	OR	2	16	13	Hughes 1993c
Buffalo Flat	35-LK-2095	Lake	OR	1	1	100	Hughes 1993c
Buffalo Flat	35-LK-2097	Lake	OR	2	4	50	Hughes 1993c

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
35-LK-2102	35-LK-2102	Lake	OR	1	78	1	Jackson and Davis 1994
Ratz Nest	35-LK-2463	Lake	OR	4	14	29	Skinner 1998a
Carlon Village	35-LK-2736	Lake	OR	33	130	25	Skinner, Thatcher, and Davis 1997c
Carlon Village	35-LK-2736	Lake	OR	6	34	18	Skinner 1998c
Carlon Village	35-LK-2736	Lake	OR	1	6	17	Skinner 1998b
DJ Ranch	35-LK-2758	Lake	OR	6	27	22	Hughes 1995a
GP-2	35-LK-2778	Lake	OR	3	23	13	Skinner, Davis, and Origer 1995a
10 U.S.	35-LK-2831/32	Lake	OR	6	18	33	Skinner 1998a
8 USA	35-LK-2837	Lake	OR	1	10	10	Skinner 1998a
Scott's Village	35-LK-2844	Lake	OR	2	32	6	Skinner 1998a
Boulder Village	35-LK-2846	Lake	OR	15	104	14	Skinner, Thatcher, and Davis 1998c
Playa 9	35-LK-2909	Lake	OR	5	14	36	Skinner 1998a
Locality III	35-LK-3035	Lake	OR	10	75	13	Skinner, Davis, and Thatcher 1996b
Locality III	35-LK-3035	Lake	OR	9	56	16	Skinner, Davis, and Origer 1995a
Bergen	35-LK-3175	Lake	OR	7	50	14	Skinner and Thatcher 1999a
Bergen	35-LK-3175	Lake	OR	6	60	10	Skinner and Thatcher 1998c
Bergen	35-LK-3175	Lake	OR	6	47	13	Skinner and Thatcher 1999c
Claim A1	35-LK-3176	Lake	OR	2	6	33	Skinner and Thatcher 1999a
Lodge Site	35-LA-26	Lane	OR	1	30	3	Hughes 1997e
Horsepasture Cave	35-LA-39	Lane	OR	13	51	25	Jackson, Davis, and King 1993f
Baby Rock Shelter	35-LA-53	Lane	OR	6	70	9	Jackson, Davis, and Allred 1994
Olsen 1 Rockshelter	35-LA-190	Lane	OR	3	52	6	Jackson, Davis, and King 1993g
Gold Point Saddle	35-LA-258	Lane	OR	1	20	5	Jackson and Davis 1993
Gate Creek #1	35-LA-295	Lane	OR	7	30	23	Hughes 1989d
Vine Rockshelter	35-LA-304	Lane	OR	4	60	7	Skinner and Thatcher 1998a

Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
Tire Creek	35-LA-320	Lane	OR	1	10	10	Hughes 1989a
Rigdon Meadows	35-LA-343	Lane	OR	6	29	21	Skinner, Davis, and Allred 1995a
Rigdon Meadows	35-LA-343	Lane	OR	36	71	51	Skinner, Davis, and Thatcher 1995a
Rigdon Meadows	35-LA-343	Lane	OR	25	60	42	Jackson, Davis, and Allred 1994
Brenda Site	35-LA-424	Lane	OR	6	20	30	Hughes 1997e
Carpet Saddle	35-LA-483	Lane	OR	6	10	60	Jackson and Davis 1993
Carpet Saddle	35-LA-483	Lane	OR	18	60	30	Jackson and Davis 1993
Warner Fire/Eagle Bench	35-LA-512	Lane	OR	2	42	5	Jackson, Davis, and King 1993a
McFarland Site	35-LA-564	Lane	OR	5	16	31	Hughes 1997e
Dingo Boots	35-LA-584	Lane	OR	2	22	9	Hughes 1997e
Salix	35-LA-600	Lane	OR	5	20	25	Hughes 1997e
Lupher's Road	35-LA-632	Lane	OR	4	10	40	Hughes 1989a
Oakridge Spur	35-LA-633	Lane	OR	2	10	20	Hughes 1989a
Deadhorse Rockshelter	35-LA-656	Lane	OR	8	28	29	Hughes 1989c
Burnt Ridge	35-LA-850	Lane	OR	1	21	5	Jackson and Davis 1993
Lilligren	35-LA-852	Lane	OR	6	40	15	Jackson and Davis 1993
Winberry Saddle	35-LA-995	Lane	OR	1	42	2	Jackson and Davis 1993
Warner Fire/Big Bunch Shelter	35-LA-1047	Lane	OR	1	11	9	Jackson, Davis, and King 1993c
Whale Cove	35-LNC-60	Lincoln	OR	1	2	50	Skinner 1996b
35-WS-120	35-WS-120	Wasco	OR	1	40	3	Skinner 1995
35-WS-225	35-WS-225	Wasco	OR	4	361	1	Skinner 1995
35-WS-231	35-WS-231	Wasco	OR	3	466	1	Skinner 1995
Fuller Mound	-	Yamhill	OR	1	1	100	Lauglin 1941; Hughes 1990b
Menlo Baths	CA-MOD-197	Modoc	CA	1	70	1	Hughes 1986
Nightfire Island	CA-SIS-4	Siskyou	CA	6	353	2	Hughes 1985

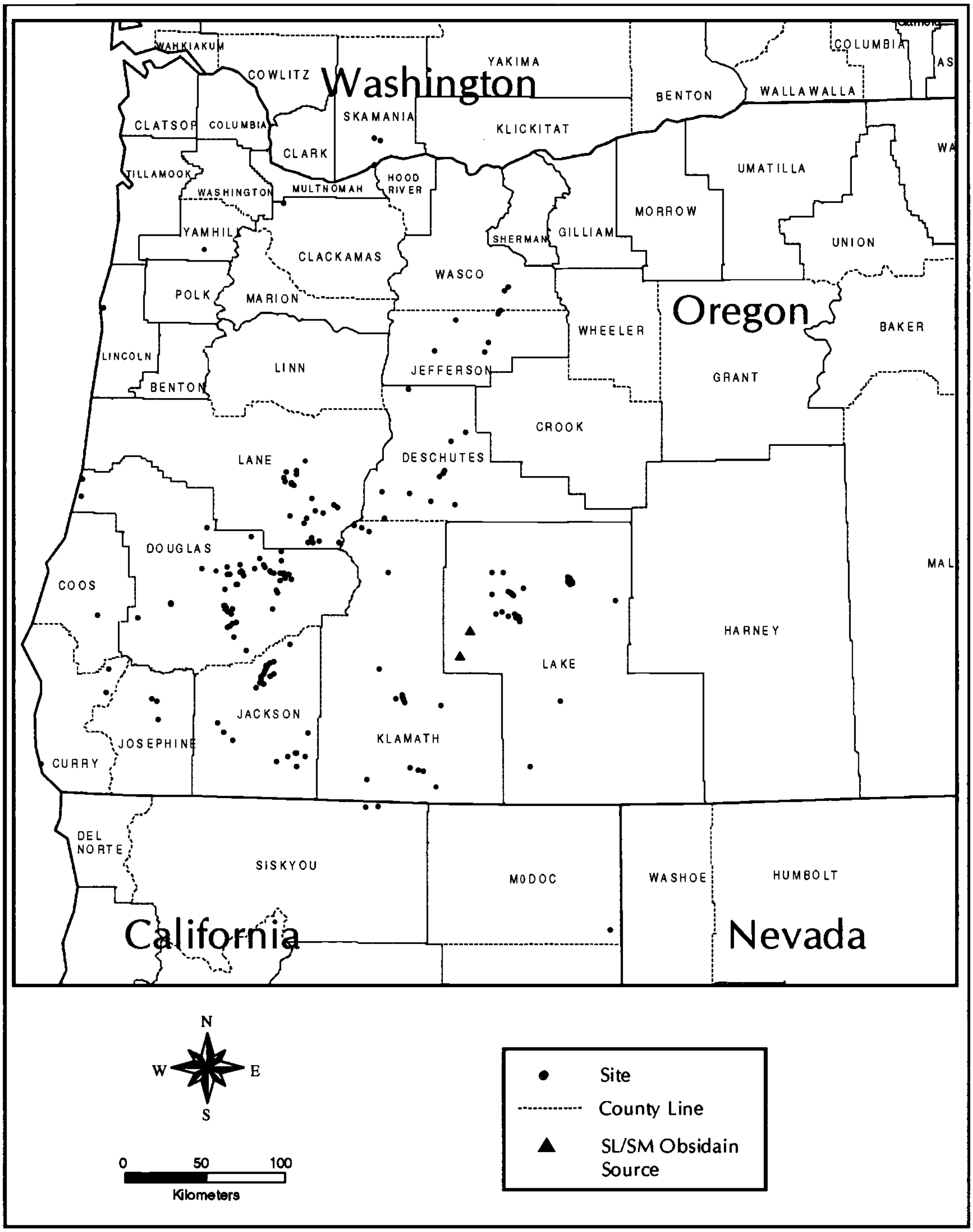
Table F.1. Prehistoric Site Data

Site Name	Trinomial	County	State	Total SLSM	Total OBS	% SLSM	XRF Reference
Mt. Hebron, CA	-	Siskyou	CA	3	37	8	Skinner and Davis 1997a
Clachclehlah	45-SA-11	Skamania	WA	5	127	4	Skinner 1999
45-SA-222	45-SA-222	Skamania	WA	1	16	6	Hughes 1994n
45-SA-316	45-SA-316	Skamania	WA	1	2	50	Skinner, Thatcher, and Davis 1998b

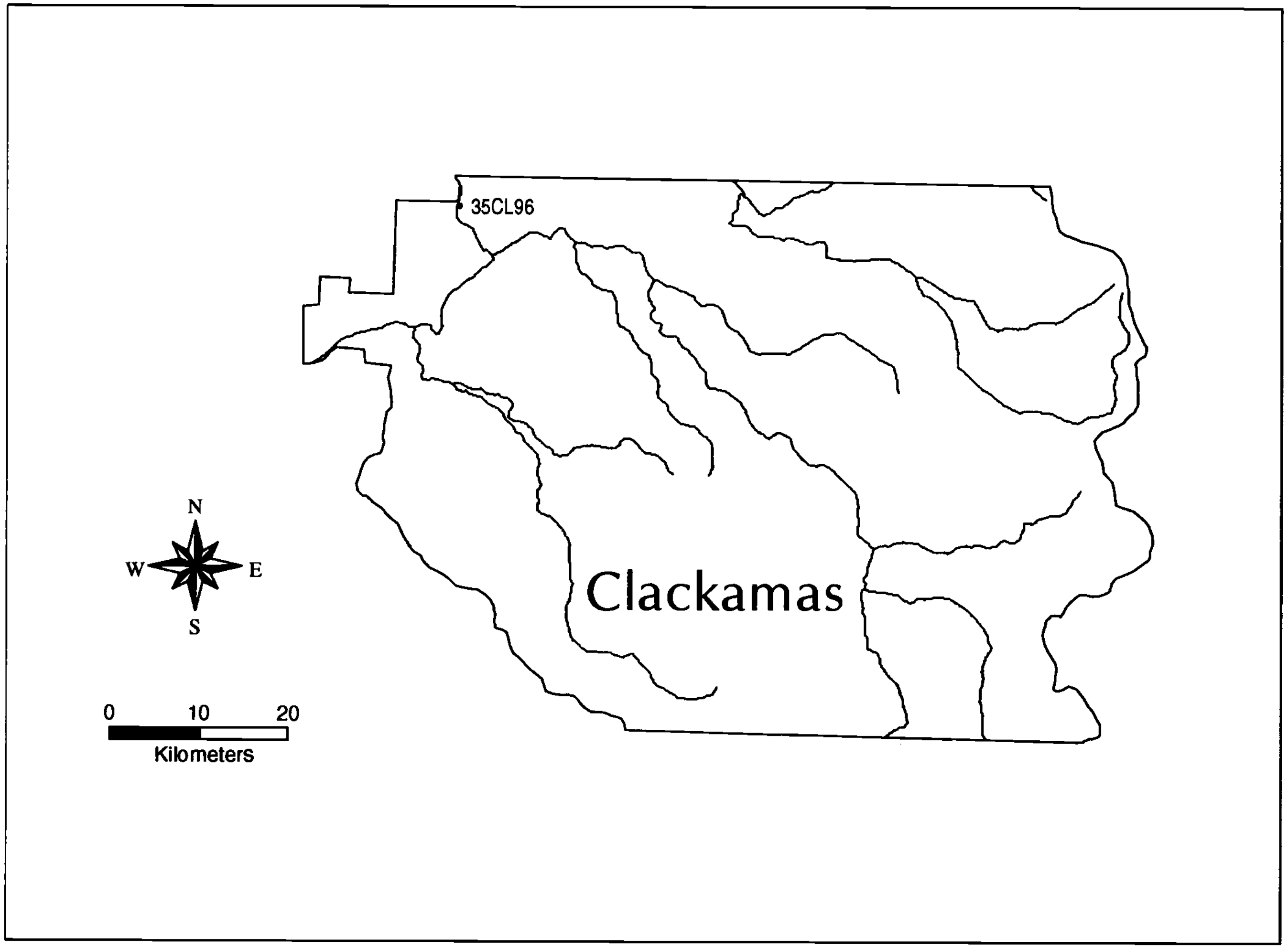
Table F.2. Total archaeological sites containing SL/SM obsidian listed by county for Oregon, Washington and California.

County Name	**Sites with SL/SM Obsidian (n =)**
Oregon	
Clackamas	1
Coos	1
Curry	3
Deschutes	11
Douglas	56
Jackson	26
Jefferson	6
Joseph	3
Klamath	18
Lake	43
Lane	23
Lincoln	1
Wasco	3
Yamhill	1
Oregon Total	**196**
Washington	
Skamania	3
Washington Total	**3**
California	
Modoc	1
Siskyou	2
California Total	**3**
Total	**202**

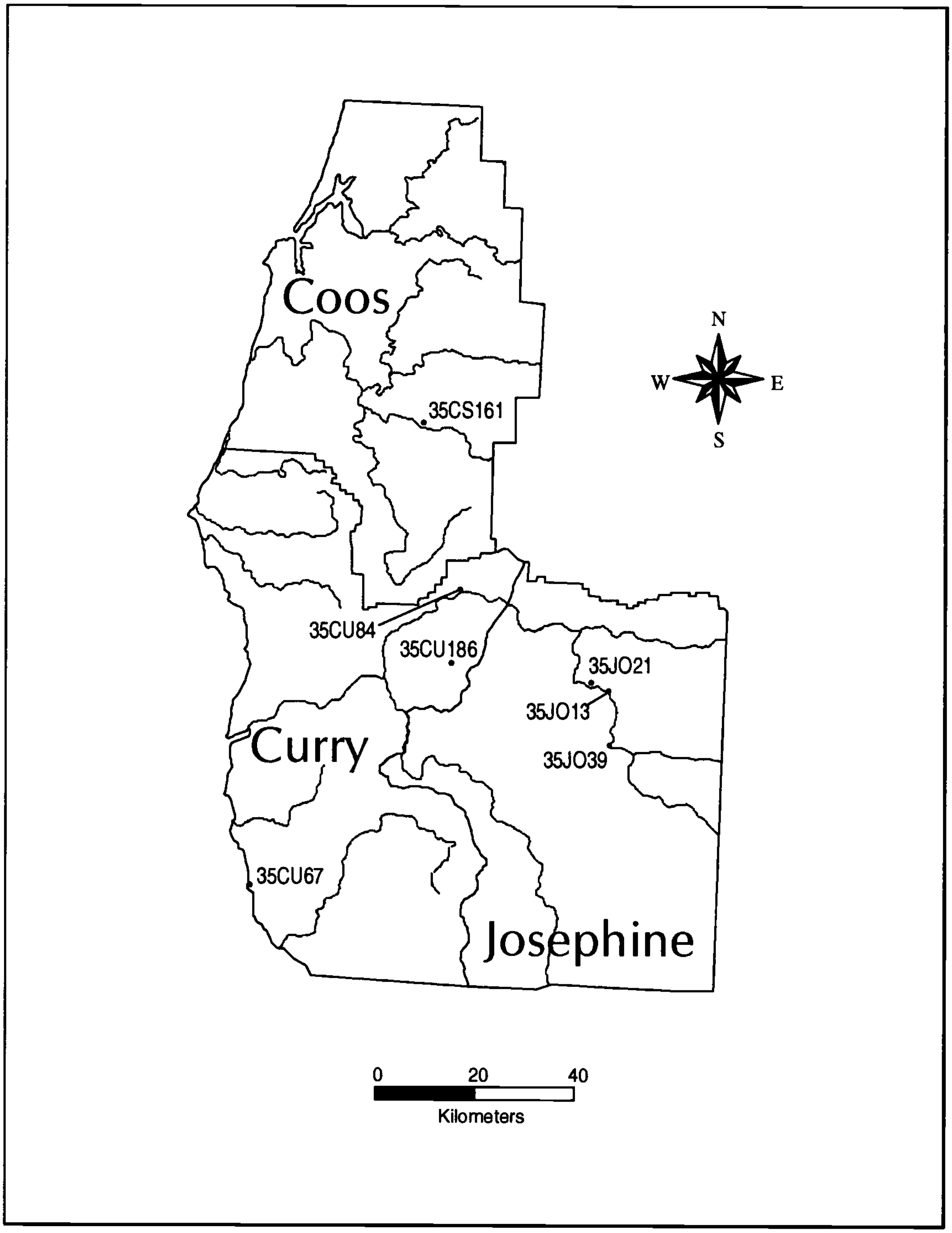
Site Distribution Maps by County



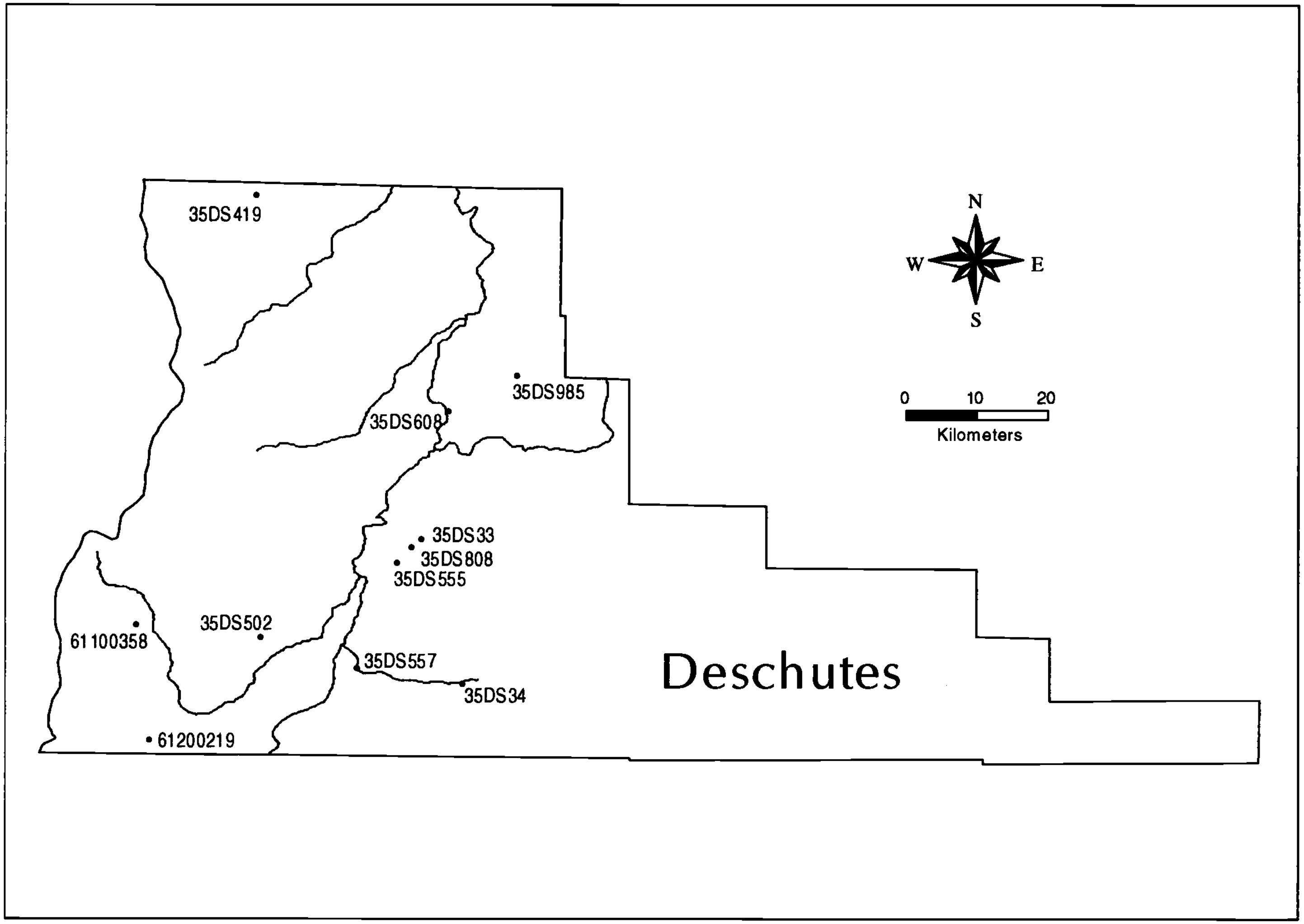
Distribution of sites containing SL/SM artifact obsidian per county for Oregon, California and Washington.



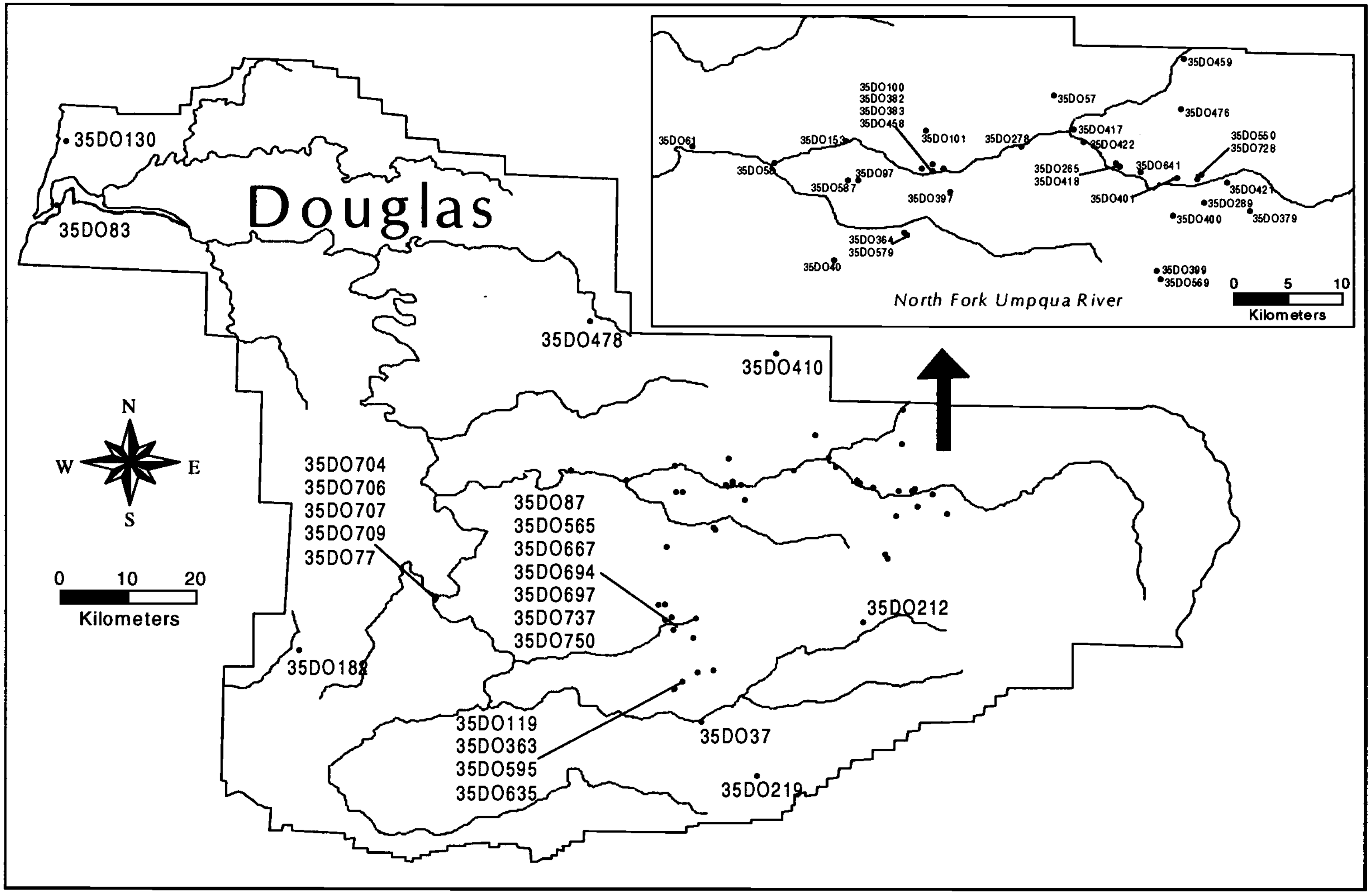
Clackamas County, Oregon



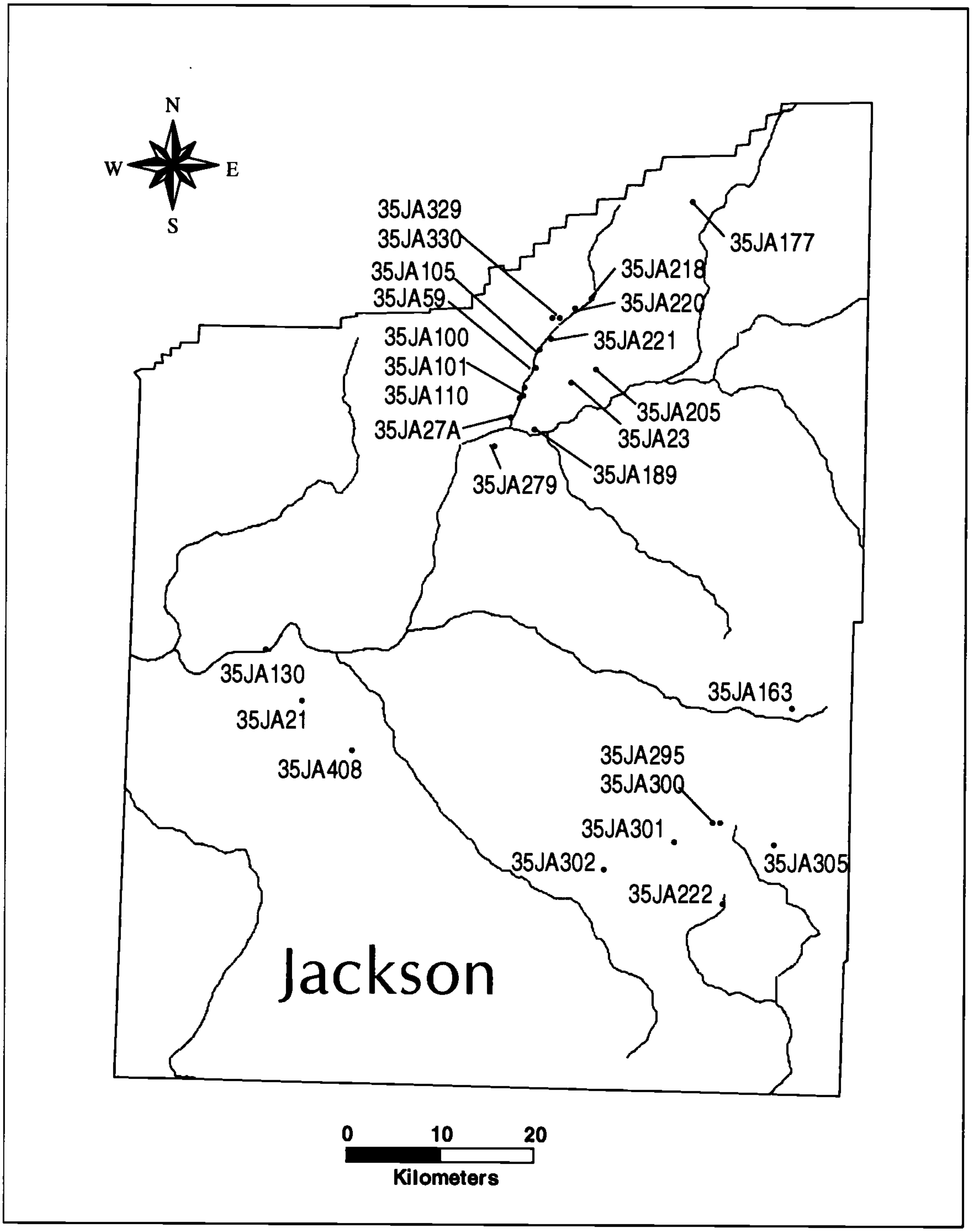
Coos, Curry and Josephine counties, Oregon



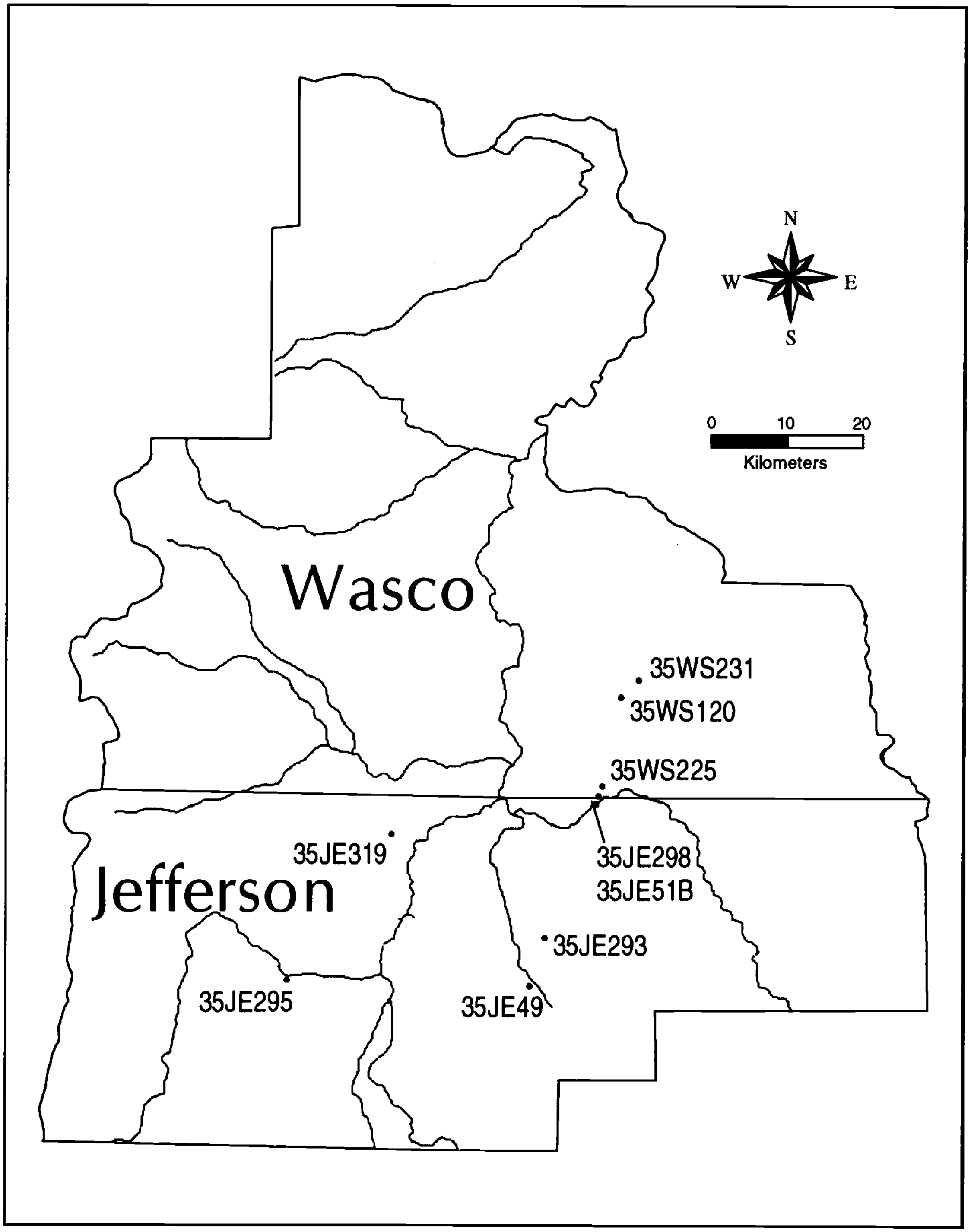
Deschutes County, Oregon



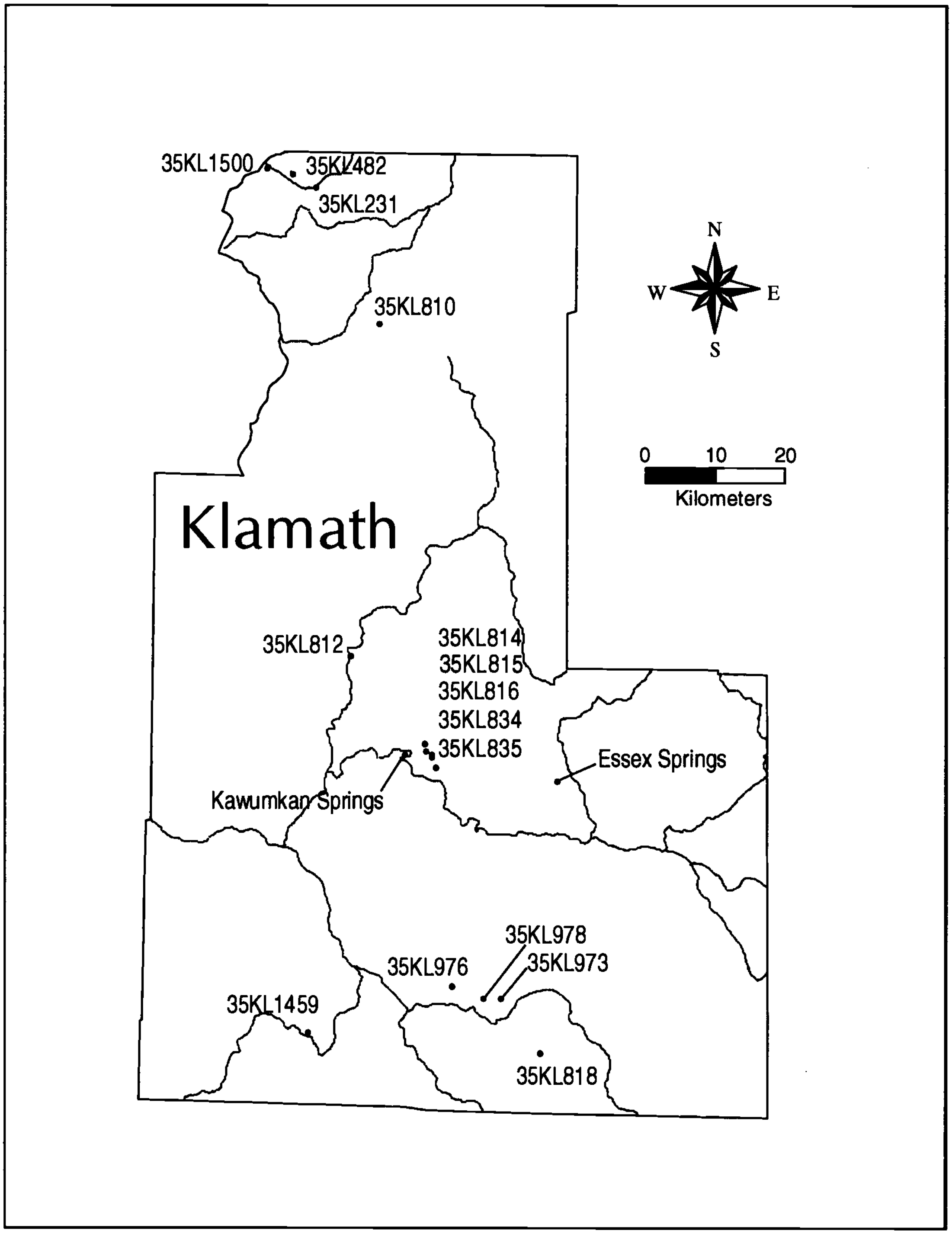
Douglas County, Oregon



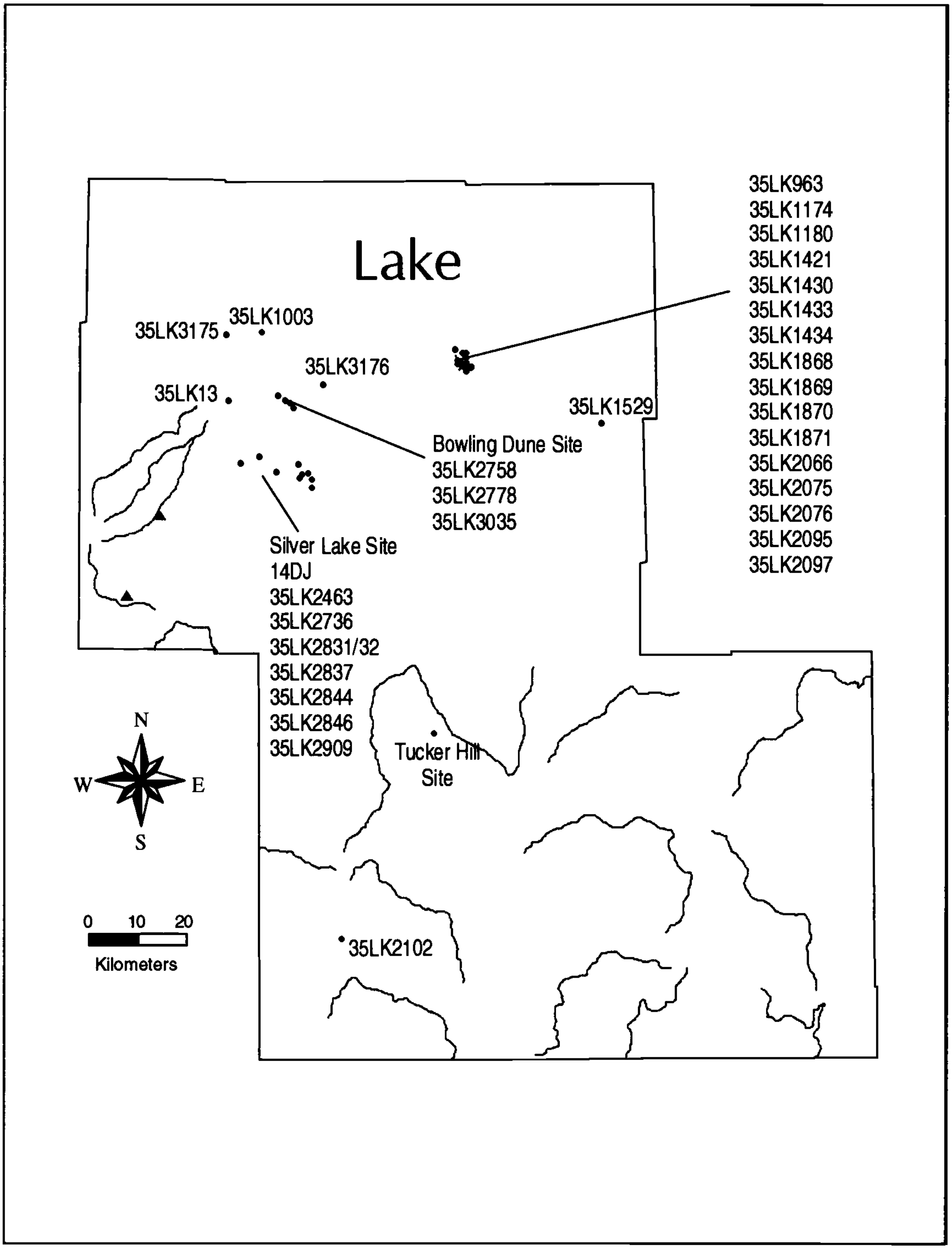
Jackson County, Oregon



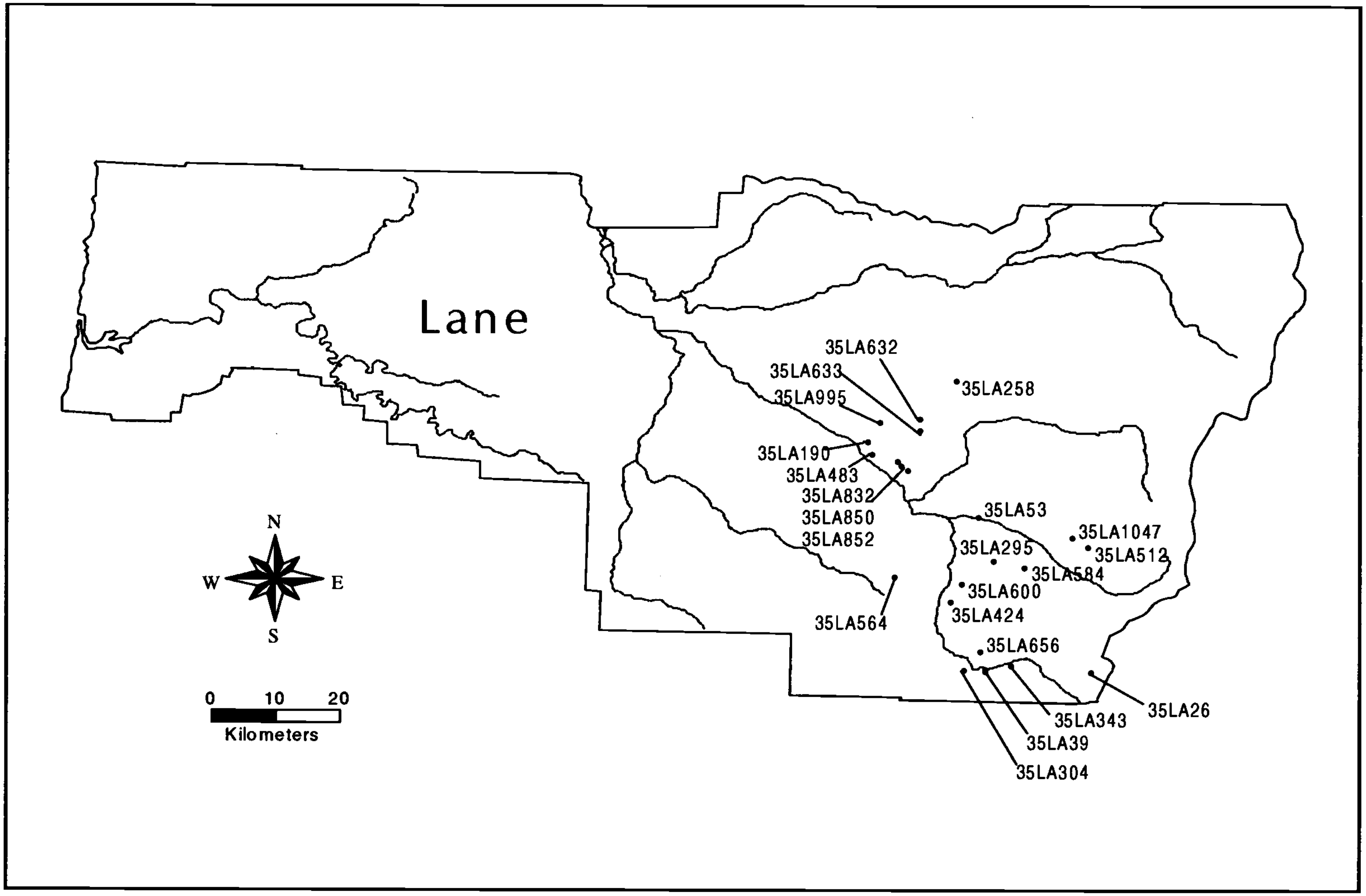
Jefferson and Wasco counties, Oregon



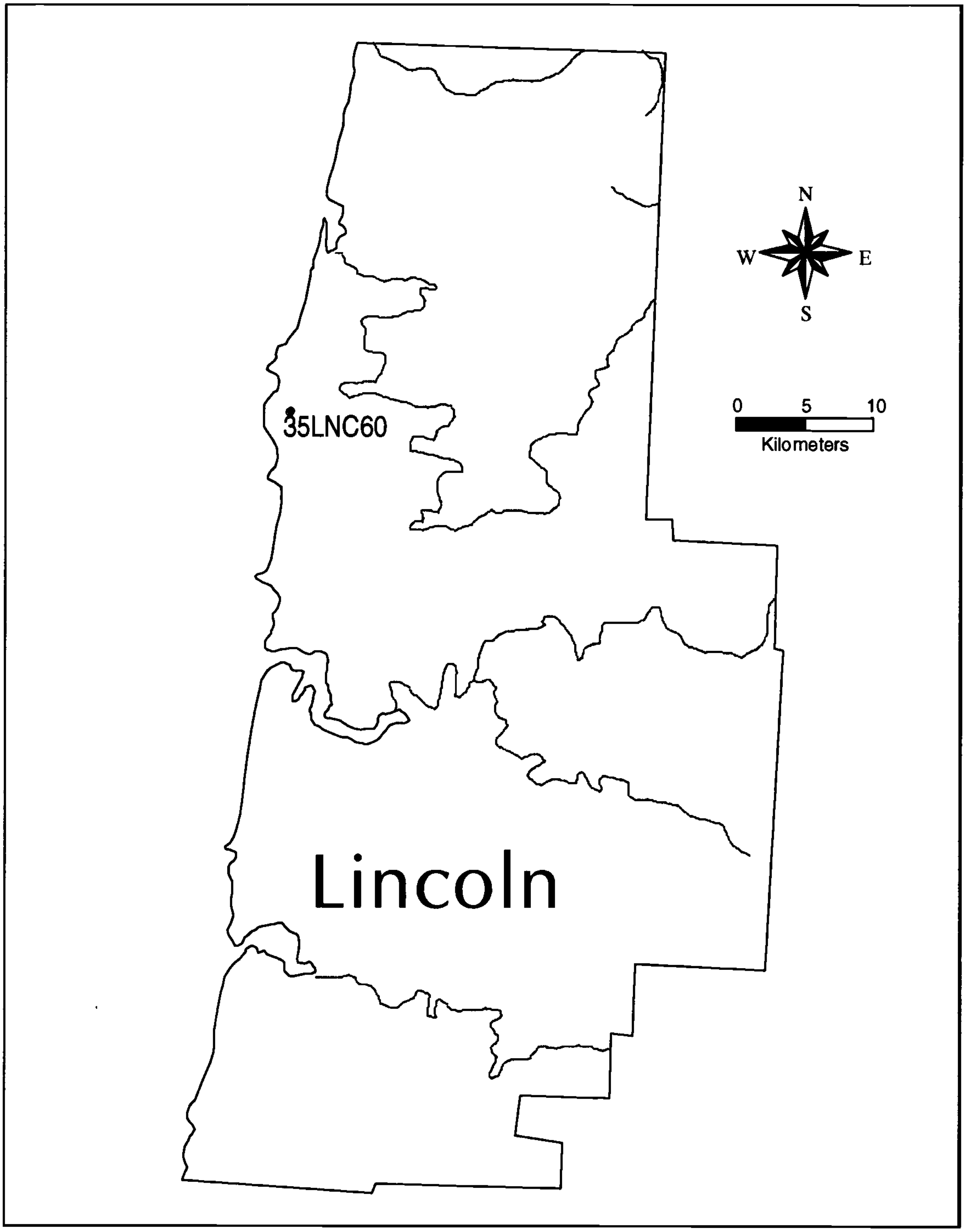
Klamath County, Oregon



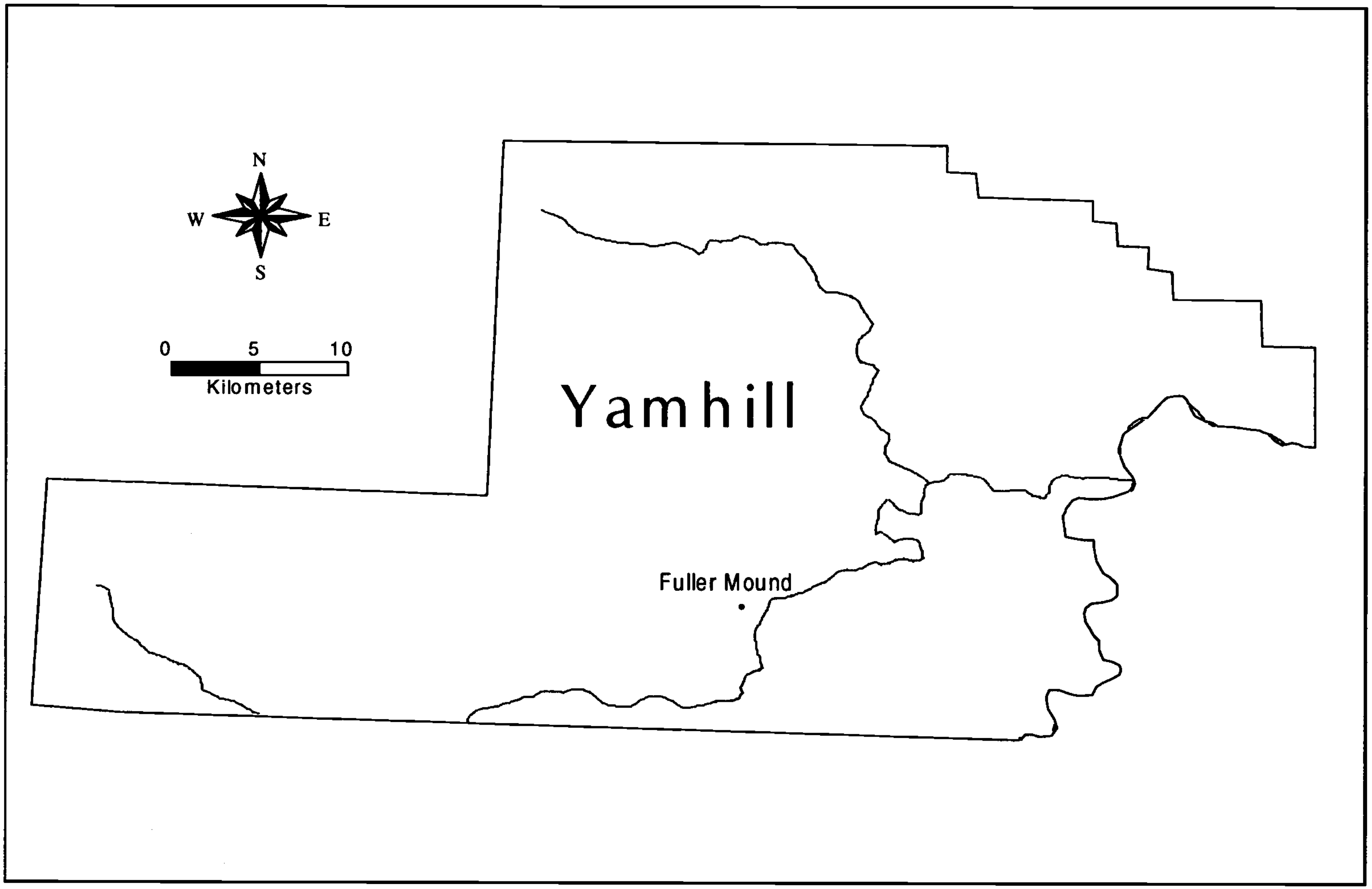
Lake County, Oregon



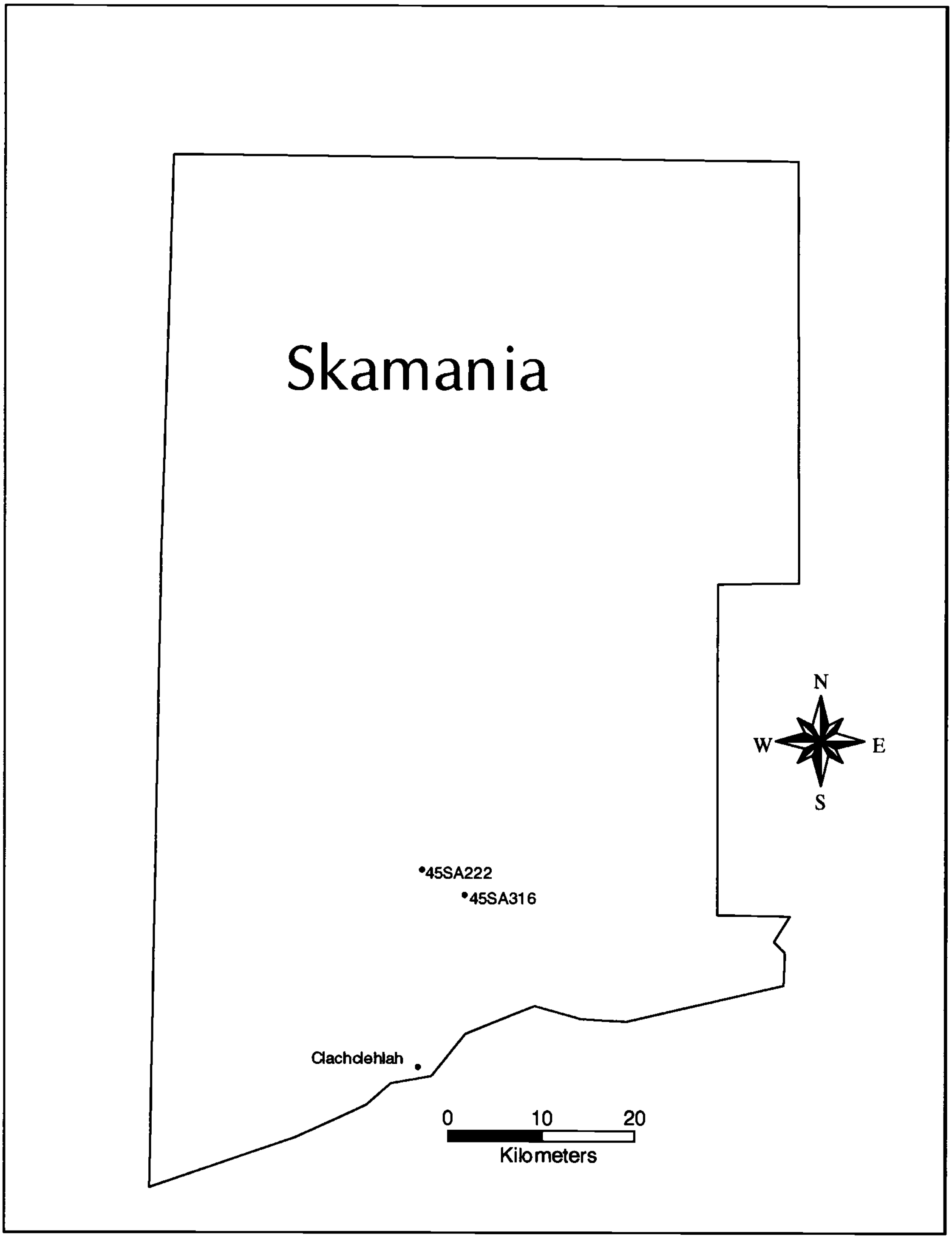
Lane County, Oregon



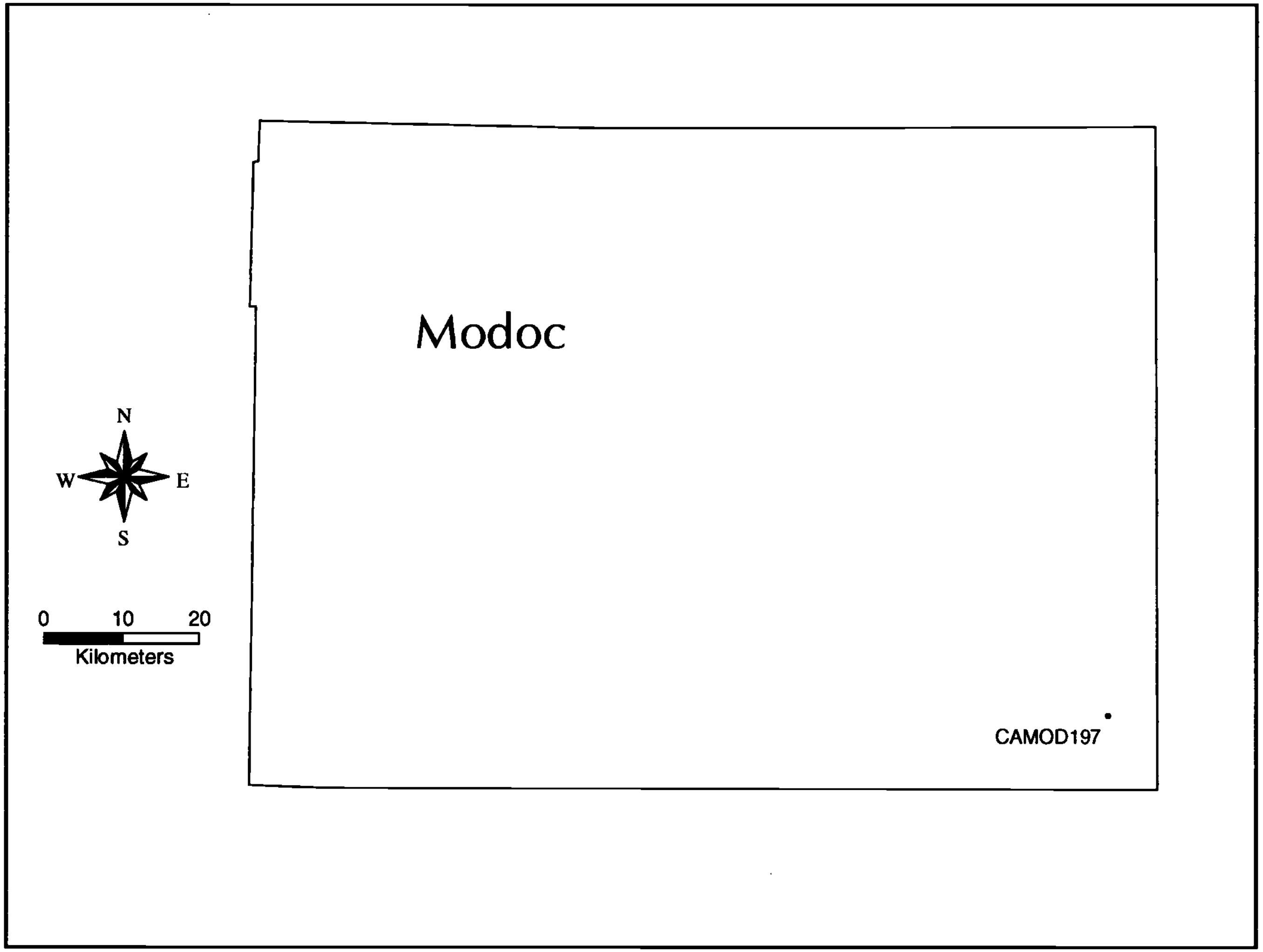
Lincoln County, Oregon



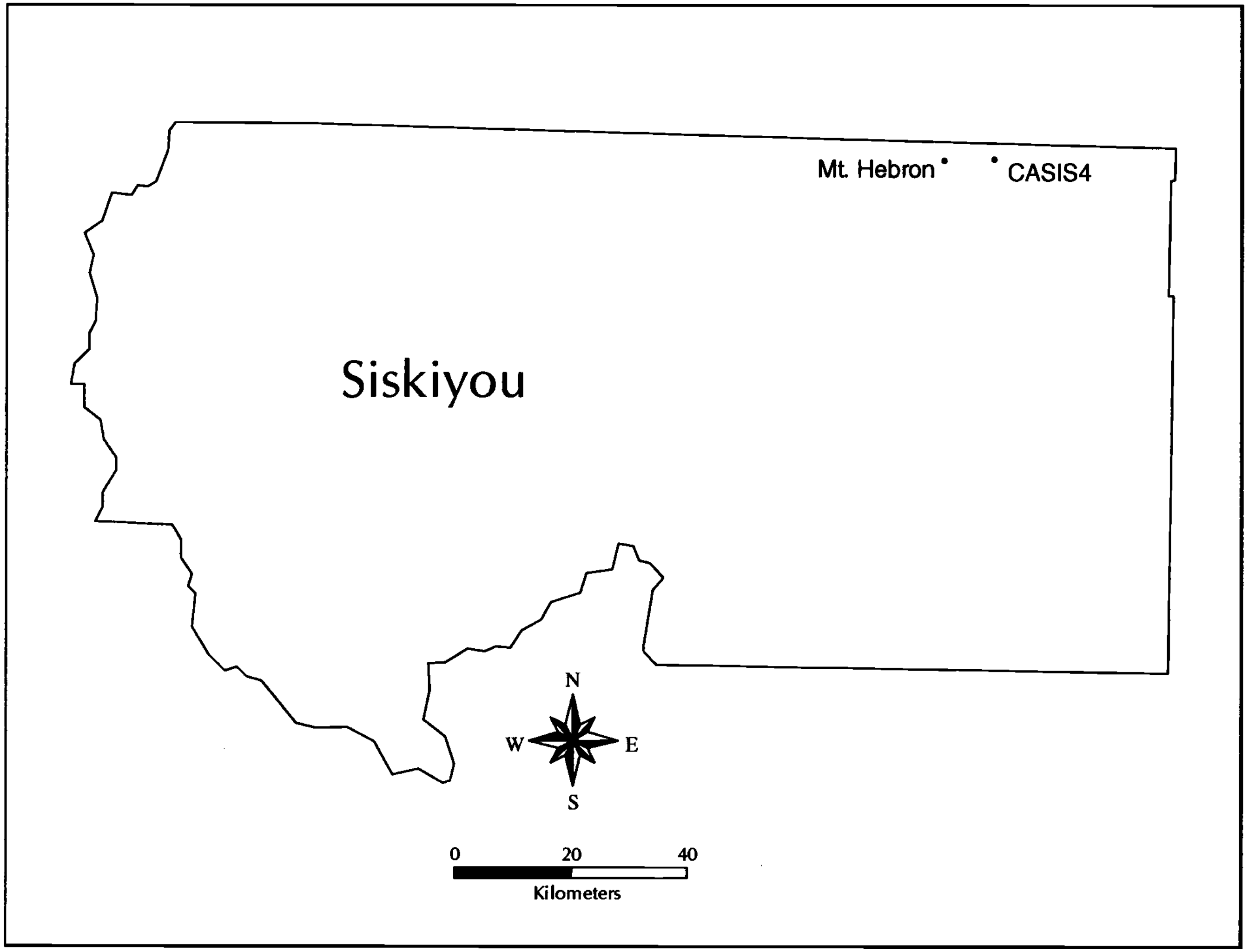
Yamhill County, Oregon



Skamania County, Washington



Modoc County, California



Siskiyou County, California

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Appendix G

Connley Caves Artifact Data

Table G.1. Geochemical source groups represented at the Connley Caves site (35-LK-50).

Obsidian Source	**Cave**					**N =**
	1	**3**	**4**	**5**	**6**	
Bald Butte	1		–	1	–	2
Big Obsidian Flow	–	1	–	–	1	2
Big Stick	–	–	3	1	–	4
Buck Mountain	–	–	4	1	–	5
Coglan Buttes	–	–	–	1	1	2
Cougar Mountain	5	1	9	11	8	34
Cowhead Lake	–	–	2	–	–	2
Drews Creek/Butcher Flat	–	–	–	–	1	1
Glass Buttes 1	–	–	–	1	1	2
Glass Buttes 2	–	–	2	2	1	5
Glass Buttes 3	–	–	3	1	3	7
Glass Buttes 6	–	–	–	1	–	1
Glass Buttes 7	–	–	–	–	1	1
Hager Mountain	1	–	1	1	3	6
Horse Mountain	–	–	4	1	1	6
Massacre Lake/Guano Valley	–	1	–	1	–	2
McComb Butte	–	–	–	1	–	1
McKay Butte	–	–	–	2	1	3
Mosquito Lake	–	–	–	1	–	1
Newberry Volcano	1	–	–	–	–	1
Not Obsidian	–	–	–	1	–	1
Obsidian Cliffs	–	–	–	–	2	2
Quartz Mountain	–	–	1	8	3	12
Silver Lake/Sycan Marsh	7	2	5	6	8	28
Spodue Mountain	1	2	2	2	5	12
Sugar Hill	–	–	3	1	–	4
Surveyor Spring	–	–	–	–	1	1
Tucker Hill	–	–	–	2	–	2
Unknown 3	1	–	2	3	–	6
Variety 5	3	–	3	1	–	7
Wagontire	–	–	2	–	–	2
Yreka Butte	–	1	2	–	–	3
Total	**20**	**8**	**48**	**51**	**41**	**168**

Table G.2. Artifact provenance data table for the Connley Caves site (35-LK-50).

Specimen Number	Catalog Number	Unit	Depth	Class	Type	Length	Width	Thick	Shoulder Width	Neck Width	Base Width	Artifact Source/ Chemical Type
1	1-surf-2	1	surface	PPT	EE	3.6	1.8	0.5	1.8	1.1	1.7	Variety 5
2	1-4/1-3	1	level 4	PPT	ECN	3.1	1.5	0.5	1.5	0.8	1.0*	Silver Lake/Sycan Marsh
3	1-5/1-8	1	level 5	PPT	LSN	4.6	1.6	0.7	1.6	1.1	1.3*	Silver Lake/Sycan Marsh
4	1-6/1-5	1	level 6	PPT	ECN	3.3*	1.7	0.6	1.7	0.9	1.1	Variety 5
5	1-18/3-1	1	level 18	PPT	ECN	2.5*	3.3	0.6	3.3	1.3	NA*	Hager Mountain
6	1-9/1-2	1	level 9	PPT	ECN	3.6*	1.7	0.6	1.7	1.0	1.1*	Cougar Mountain
7	1-15/2-1	1	level 15	PPT	EE	3.3*	2.1	0.5	2.1	1.2	1.9	Unknown 1
8	1-5/1-14	1	level 5	PPT	CAS	3.1*	2.5	1.1	NA	NA	1.3	Newberry Volcano
9	1-5/1-1	1	level 5	BIF	NA	1.2*	1.1	0.2	NA	NA	NA	Silver Lake/Sycan Marsh
10	1-5/1-4	1	level 5	PPT	LSN	1.0*	1.5	0.4	NA	1.0	1.5	Silver Lake/Sycan Marsh
11	1-5/1-12	1	level 5	PPT	LSN	5.4*	1.8	0.7	1.8	1.4	1.7	Spodue Mountain
12	1-4/1-1	1	level 4	PPT	RGC	2.1	1.2	0.3	1.2*	0.6	0.7	Silver Lake/Sycan Marsh
13	1-5/1-11	1	level 5	BIF	NA	1.7*	1.1	0.3	NA	NA	NA	Silver Lake/Sycan Marsh
14	1-2/1-2	1	level 2	PPT	GCS	4.3*	2.5*	0.6	2.5*	1.6	1.7	Silver Lake/Sycan Marsh
15	1surf-1	1	surface	PPT	GCS	4.8*	2.0*	0.5	2.0*	1.0	0.8	Cougar Mountain
16	1-6/1-3	1	level 6	BIF	NA	3.3*	1.4	0.4	NA	NA	NA	Bald Butte
17	1-6/1-4	1	level 6	PPT	GCS	3.5*	1.3	0.5	1.3	0.8	0.6*	Variety 5
18	1-6/1-6	1	level 6	PPT	ECN	3.8*	1.9*	0.5	1.9*	1.2	1.3	Cougar Mountain
19	1-8/1-10	1	level 8	PPT	ECN	3.0*	2.1	0.4	2.1	1.0	NA*	Cougar Mountain
20	1-15/2-7	1	level 15	PPT	CAS	6.1	2.4	0.7	NA	NA	1.0	Cougar Mountain
21	3-5/1-1	3	level 5	PPT	CN	1.7*	1.4*	0.3	1.4*	0.6	NA*	Silver Lake/Sycan Marsh

Table G.2. Artifact provenance data table for the Connley Caves site (35-LK-50).

Specimen Number	Catalog Number	Unit	Depth	Class	Type	Length	Width	Thick	Shoulder Width	Neck Width	Base Width	Artifact Source/ Chemical Type
22	3-6/1-1	3	level 6	PPT	ECN	2.8*	1.6*	0.3	1.6*	0.6	0.6*	Silver Lake/Sycan Marsh
23	3-7/1-1	3	level 7	PPT	GCS	3.0*	1.8*	0.5	1.8*	0.9	0.7*	Spodue Mountain
24	3-fill-2	3	fill	PPT	CAS	4.3*	1.8*	0.7	NA	NA	NA	Massacre Lake/Guano Valley
25	3-23/3-2	3	level 23	PPT	ECN	2.3*	1.7	0.4	1.7	0.9	NA	Cougar Mountain
26	3-23/3-3	3	level 23	PPT	RSG	1.9*	1.1*	0.3	1.1*	0.5	NA	Big Obsidian Flow
27	3XT-2/1-8	3XT	level 2	PPT	CAS	3.9*	2.0	0.6	2.0	NA	1.5	Yreka Butte
28	4A-1/1-1	4A	level 1	PPT	RSG	1.6	1.1*	0.2	1.1*	0.4*	0.6	Silver Lake/Sycan Marsh
29	4A-10/1-2	4A	level 10	PPT	CAS	2.0*	1.8	0.8	NA	NA	1.2	Quartz Mountain
30	4A-12/1-6	4A	level 12	PPT	EE	5.4	1.2*	0.5	1.2*	1.3	1.6	Variety 5
31	4A-14/1-12	4A	level 14	PPT	CAS	3.5*	2.5*	0.8	NA	NA	0.8	Cougar Mountain
32	4A-16/2-12	4A	level 16	PPT	ECN	3.9*	2.2*	0.5	2.2	1.2	1.3*	Variety 5
33	4A-28/4-8	4A	level 28	BIF	NA	1.7*	1.6	0.5	NA	NA	NA	Cougar Mountain
34	4A-30/4-4	4A	level 30	BIF	NA	2.7*	1.5*	0.4	NA	NA	NA	Sugar Hill
35	4A-30/4-5	4A	level 30	PPT	CAS	8.2*	3.1	0.7	NA	NA	NA	Silver Lake/Sycan Marsh
36	4A-31/4-1	4A	level 31	PPT	CAS	6.5	2.7	1.0	NA	NA	1.5	Silver Lake/Sycan Marsh
37	4A-31/4-6	4B	level 31	PPT	CAS	2.0*	1.7	0.7	NA	NA	1.1	Big Stick
38	4A-32/4-11	4A	level 32	PPT	CAS	8.5*	3.2	1.0	NA	NA	1.2	Glass Buttes 3
39	4A-32/4-12	4A	level 32	PPT	CAS	2.8*	2.2	0.6	NA	NA	0.7	Cowhead Lake
40	4A-32/4-15	4A	level 32	PPT	CAS	6.9*	3.0	1.0	NA	NA	NA	Cougar Mountain?
41	4A-32/4-18	4A	level 32	BIF	NA	1.8*	1.5	0.6	NA	NA	NA	Wagontire
42	4A-34/4-8	4A	level 34	PPT	CAS	2.4*	2.2	0.7	NA	NA	1.7	Buck Mountain

Table G.2. Artifact provenance data table for the Connley Caves site (35-LK-50).

Specimen Number	Catalog Number	Unit	Depth	Class	Type	Length	Width	Thick	Shoulder Width	Neck Width	Base Width	Artifact Source/ Chemical Type
43	4A-33/4-12	4A	level 33	PPT	CAS	6.8	2.3	0.7	NA	NA	0.8	Cowhead Lake
44	4B-27/3-2	4B	level 27	BIF	NA	3.5*	2.2	0.6	NA	NA	NA	Yreka Butte
45	4B-27/3-4	4B	level 27	BIF	NA	4.3*	1.7	0.6	NA	NA	NA	Silver Lake/Sycan Marsh
46	4B-27/3-5	4B	level 27	BIF	NA	7.0*	3.1	0.8	NA	NA	NA	Cougar Mountain
47	4B-30/3-16	4B	level 30	PPT	GSS	3.4	1.6	0.5	1.6	0.6	0.7	Cougar Mountain
48	4B-31/4-1	4B	level 31	BIF	NA	4.1*	1.9	0.9	NA	NA	NA	Big Stick
49	4B-31/4-3	4B	level 31	PPT	CAS	2.7*	1.5	0.6	NA	NA	NA	Buck Mountain
50	4B-31/4-6	4B	level 31	PPT	CAS	2.6*	2.2	0.8	NA	NA	NA	Glass Buttes 2
51	4B-31/4-13	4B	level 31	BIF	NA	3.9*	2.4	0.5	NA	NA	NA	Horse Mountain
52	4B-31/4-14	4B	level 31	BIF	NA	2.8*	2.3	0.5	NA	NA	NA	Buck Mountain
53	4B-32/4-4	4B	level 32	BIF	NA	3.1*	2.1	0.7	NA	NA	NA	Horse Mountain
54	4B-32/4-8	4B	level 32	BIF	NA	5.1*	2.6	0.8	NA	NA	NA	Glass Buttes 2
55	4B-32/4-9	4B	level 32	BIF	NA	1.4*	1.5	0.5	NA	NA	NA	Cougar Mountain
56	4B-32/4-16	4B	level 32	PPT	CAS	11.6	2.7	0.8	NA	NA	0.4	Horse Mountain
57	4B-32/4-18	4B	level 32	BIF	NA	4.8*	2.4	0.7	NA	NA	NA	Unknown 2
58	4B-32/4-21	4B	level 32	PPT	CAS	5.3*	2.3	1.0	NA	NA	NA	Sugar Hill
59	4B-33/4-30	4B	level 33	PPT	CAS	4.0*	2.4	0.7	NA	NA	1.3	Yreka Butte
60	4B-33/4-31	4B	level 33	BIF	NA	4.6*	2.7	0.7	NA	NA	NA	Variety 5
61	4B-33/4-32	4B	level 33	PPT	CAS	4.2*	2.2	0.8	NA	NA	1.0	Spodue Mountain
62	4B-33/4-33	4B	level 33	BIF	NA	3.2*	2.2	0.7	NA	NA	NA	Buck Mountain
63	4B-33/4-34	4B	level 33	BIF	NA	1.5*	2.3	0.7	NA	NA	NA	Spodue Mountain

Table G.2. Artifact provenance data table for the Connley Caves site (35-LK-50).

Specimen Number	Catalog Number	Unit	Depth	Class	Type	Length	Width	Thick	Shoulder Width	Neck Width	Base Width	Artifact Source/ Chemical Type
64	4B-33/4-35	4B	level 33	BIF	NA	2.2*	1.3	0.5	NA	NA	NA	Sugar Hill
65	4B-33/4-40	4B	level 33	BIF	NA	2.4*	1.5	0.5	NA	NA	NA	Glass Buttes 3
66	4B-33/4-44	4B	level 33	BIF	NA	3.5*	2.9	1.0	NA	NA	NA	Big Stick
67	4B-35/4-17	4B	level 35	PPT	CAS	4.7*	2.2	0.8	NA	NA	1.2	Cougar Mountain
68	4B-38/4-6	4B	level 38	PPT	CAS	3.4*	1.9	0.6	NA	NA	NA	Glass Buttes 3
69	5-7/1-3	5	level 7	PPT	NA							Not Obsidian
70	5-8/1-2	5	level 8	PPT	LSN	2.5	1.6*	0.6	1.6*	0.9	1.3*	Coglan Buttes
71	5-8/1-3	5	level 8	PPT	RGC	1.6*	1.5*	0.3	1.6*	0.5	0.7	Glass Buttes 6
72	5-9/1-4	5	level 9	PPT	EE	1.0*	1.4*	0.3	NA	1.0	1.4	Cougar Mountain
73	5-9/1-5	5	level 9	PPT	GCS	4.9*	2.5	0.5	2.5	1.5	0.8	Cougar Mountain
74	5-10/1-1	5	level 10	BIF	NA	1.9*	1.5	0.5	NA	NA	NA	Cougar Mountain
75	5-10/1-3	5	level 10	BIF	NA	3.8*	1.3	0.4	NA	NA	NA	Silver Lake/Sycan Marsh
76	5-12/1-2	5	level 12	PPT	ECN	2.9*	1.6*	0.4	1.6*	0.8	0.7*	Variety 5
77	5-12/1-3	5	level 12	PPT	EE	3.2*	2.5*	0.5	2.5*	1.0	1.7	Cougar Mountain
78	5-16/1-1	5	level 16	PPT	GSS	2.5*	1.8*	0.6	1.8*	1.3	1.4*	McComb Butte
79	5-18/2-1	5	level 18	PPT	ECN	4.2	2.8*	0.6	2.8*	1.1	1.6	Cougar Mountain
80	5-22/2-2	5	level 22	BIF	NA	2.4*	1.6	0.5	NA	NA	NA	Mosquito Lake
81	5-22/2-3	5	level 22	PPT	ECN	3.2*	1.9	0.5	1.9	1.0	1.1	Cougar Mountain
82	5B-25/3-1	5B	level 25	PPT	CAS	4.9*	1.7*	0.8	NA	NA	1.2	Quartz Mountain
83	5B-26/3-1	5B	level 26	PPT	ECN	3.1*	2.8	0.5	2.8	1.4	2.1	Cougar Mountain?
84	5B-26/3-2	5B	level 26	PPT	LCB	3.0*	2.2	0.7	NA	NA	1.8	Buck Mountain

Table G.2. Artifact provenance data table for the Connley Caves site (35-LK-50).

Specimen Number	Catalog Number	Unit	Depth	Class	Type	Length	Width	Thick	Shoulder Width	Neck Width	Base Width	Artifact Source/ Chemical Type
85	5B-26/3-3	5B	level 26	PPT	ECN	3.8	1.9*	0.4	1.8*	1.0	1.2	Cougar Mountain
86	5B-26/3-7	5B	level 26	BIF	NA	2.9*	1.5	0.5	NA	NA	NA	Quartz Mountain
87	5B-27/3-1	5B	level 27	PPT	EE	3.5*	1.9*	0.5	1.9*	0.9	1.5	Tucker Hill
88	5B-27/3-2	5B	level 27	PPT	CAS	4.6*	3.6	0.9	NA	NA	1.5	Quartz Mountain
89	5B-27/3-4	5B	level 27	PPT	ECN	3.9*	2.7	0.7	2.7	1.1	0.5*	Cougar Mountain
90	5B-27/3-5	5B	level 27	BIF	NA	3.7*	1.9	0.7	NA	NA	NA	McKay Butte
91	5B-27/3-8	5B	level 27	PPT	EE	1.1*	1.6	0.5	NA	1.0	1.6	Quartz Mountain
92	5B-27/3-9	5B	level 27	PPT	EE	2.3*	1.4	0.4	1.4	0.9	1.2	Quartz Mountain
93	5B-28/3-1	5B	level 28	PPT	EE	3.4	1.7*	0.6	1.7*	0.9	1.4	Glass Buttes 1
94	5B-28/3-2	5B	level 28	BIF	NA	3.0*	2.0	0.7	NA	NA	NA	Spodue Mountain
95	5B-28/3-6	5B	level 28	BIF	NA	4.1*	2.7	1.0	NA	NA	NA	McKay Butte
96	5B-28/3-10	5B	level 28	PPT	CAS	1.7*	2.1	0.7	NA	NA	1.1	Silver Lake/Sycan Marsh
97	5B-29/3-1	5B	level 29	PPT	LCB	2.9*	2.5	0.5	NA	NA	1.9	Silver Lake/Sycan Marsh
98	5B-29/3-2	5B	level 29	BIF	NA	2.2*	1.4	0.6	NA	NA	NA	Massacre Lake/Guano Valley
99	5B-29/3-4	5B	level 29	BIF	NA	2.5*	1.7	0.5	NA	NA	NA	Unknown 3
100	5B-29/3-8	5B	level 29	BIF	NA	2.6*	1.9	0.7	NA	NA	NA	Unknown 4
101	5B-30/3-1	5B	level 30	PPT	CAS	5.2	1.4	0.6	1.3	0.9	0.6	Tucker Hill
102	5B-30/3-2	5B	level 30	BIF	NA	6.7*	2.4	0.6	NA	NA	NA	Glass Buttes 2
103	5B-30/3-10	5B	level 30	BIF	NA	2.6*	2.1	0.9	NA	NA	1.5	Unknown 4
104	5B-31/3-8	5B	level 31	BIF	NA	2.1*	1.7	0.7	NA	NA	NA	Silver Lake/Sycan Marsh
105	5B-31/3-9	5B	level 31	PPT	CAS	4.2*	2.4	0.7	NA	NA	1.4	Quartz Mountain

Table G.2. Artifact provenance data table for the Connley Caves site (35-LK-50).

Specimen Number	Catalog Number	Unit	Depth	Class	Type	Length	Width	Thick	Shoulder Width	Neck Width	Base Width	Artifact Source/ Chemical Type
106	5B-31/3-15	5B	level 31	PPT	CAS	11.6	3.2	0.9	NA	NA	1.3	Big Stick
107	5B-31/3-20	5B	level 31	PPT	CS	1.5*	1.1	0.4	NA	NA	NA	Spodue Mountain
108	5B-32/3-1	5B	level 32	BIF	NA	4.5*	1.6	0.5	NA	NA	NA	Hager Mountain
109	5B-32/3-5	5B	level 32	BIF	NA	2.0*	1.1	0.4	NA	NA	NA	Silver Lake/Sycan Marsh
110	5B-32/3-11	5B	level 32	BIF	NA	2.4*	2.3	0.6	NA	NA	NA	Quartz Mountain
111	5B-32/3-12	5B	level 32	PPT	CS	3.0*	2.0	0.8	NA	NA	NA	Horse Mountain
112	5B-33/3-1	5B	level 33	BIF	NA	3.2*	1.4	0.6	NA	NA	NA	Quartz Mountain
113	5B-33/3-9	5B	level 33	PPT	LCB	1.8*	2.1	0.5	NA	NA	1.9	Bald Butte
114	6-1/1-2	6	level 1	PPT	CN	1.7	1.5*	0.2	1.5*	0.7	0.7	Cougar Mountain
115	6-2/2-2	6	level 2	PPT	RSG	1.3*	1.5*	0.2	1.5*	0.4	NA	Cougar Mountain
116	6-2/2-3	6	level 2	BIF	NA	1.6*	1.3	0.4	NA	NA	NA	Quartz Mountain
117	6-2/2-10	6	level 2	PPT	CN	4.7*	3.6	0.6	3.6	1.4	NA	Obsidian Cliffs
118	6-2/2-13	6	level 2	PPT	ECN	4.0*	2.2*	0.6	2.2*	0.9	1.2	Cougar Mountain
119	6-3/2-1	6	level 3	BIF	NA	3.8*	1.5	0.4	NA	NA	NA	Hager Mountain
120	6-3/2-7	6	level 3	PPT	ECN	3.6*	1.7	0.5	1.7	1.1	1.3	Glass Buttes 1
121	6-5/2-1	6	level 5	BIF	NA	1.1*	1.4	0.5	NA	NA	NA	Silver Lake/Sycan Marsh
122	6-5/2-2	6	level 5	PPT	ECN	1.2*	1.6	0.5	1.6	0.7	1.2	Cougar Mountain
123	6-5/2-3	6	level 5	PPT	DSN	2.5*	1.3	0.6	1.1	0.7	1.3	Spodue Mountain
124	6-5/2-4	6	level 5	PPT	ECN	2.7*	1.4*	0.6	1.4	0.8	1.0	Silver Lake/Sycan Marsh
125	6-5/2-7	6	level 5	PPT	EE	3.9	1.4	0.6	NA	NA	NA	Silver Lake/Sycan Marsh
126	6-5/2-8	6	level 5	BIF	NA	3.2*	1.6	0.6	NA	NA	NA	Silver Lake/Sycan Marsh

Table G.2. Artifact provenance data table for the Connley Caves site (35-LK-50).

Specimen Number	Catalog Number	Unit	Depth	Class	Type	Length	Width	Thick	Shoulder Width	Neck Width	Base Width	Artifact Source/ Chemical Type
127	6-5/2-20	6	level 5	PPT	CN	2.8*	1.5*	0.5	1.1*	0.7*	1.5	Silver Lake/Sycan Marsh
128	6-6/2-1	6	level 6	BIF	NA	1.2*	1.3	0.2	NA	NA	NA	Hager Mountain
129	6-7/2-1	6	level 7	BIF	NA	1.6*	1.3	0.2	NA	NA	NA	Cougar Mountain
130	6-7/2-3	6	level 7	PPT	CAS	2.3*	1.5	0.6	NA	NA	0.5	Spodue Mountain
131	6-7/2-4	6	level 7	PPT	LSN	2.2*	1.2	0.5	1.2	0.7	0.7*	Drews Creek/Butcher Flat
132	6-7/2-5	6	level 7	PPT	EE	2.3*	2.4*	0.4	2.4*	1.1	1.8	Spodue Mountain
133	6-8/2-11	6	level 8	BIF	NA	3.2*	2.0*	0.8	NA	NA	NA	Cougar Mountain
134	6-10/2-6	6	level 10	PPT	GSS	4.9	1.7	0.5	1.7	1.2	0.8	Cougar Mountain
135	6-10/2-11	6	level 10	PPT	CAS	3.3*	1.7*	0.8	NA	NA	1.0	Cougar Mountain
136	6-12/2-4	6	level 12	PPT	CAS	4.5	1.8	0.6	NA	NA	1.2	Horse Mountain
137	6-13/2-1	6	level 13	BIF	NA	1.3*	1.5	0.5	NA	NA	NA	Silver Lake/Sycan Marsh
138	6-13/2-4	6	level 13	PPT	GSS	2.9*	1.5	0.5	1.5	0.8	0.9	Coglan Buttes
139	6-14/2-1	6	level 14	PPT	LSN	1.8	1.1	0.4	1.0	0.8	1.1	Silver Lake/Sycan Marsh
140	6-17/2-2	6	level 17	BIF	NA	1.4*	1.5	0.3	NA	NA	NA	Hager Mountain
141	6-17/2-5	6	level 17	PPT	CAS	3.9*	1.7	0.5	NA	NA	NA	Glass Buttes 7
142	6-19/2-1	6	level 19	PPT	LCB	1.6*	1.3	0.4	NA	NA	1.0	Surveyor Spring
143	6-19/2-3	6	level 19	BIF	NA	2.7*	1.3*	0.4	NA	NA	NA	Big Obsidian Flow?
144	6-19/2-10	6	level 19	BIF	NA	2.8*	1.6	0.7	NA	NA	NA	Quartz Mountain
145	6-19/2-23	6	level 19	PPT	CAS	4.7*	2.0*	0.8	NA	NA	NA	Quartz Mountain
146	6-19/4-8	6	level 19	BIF	NA	3.2*	2.1	0.7	NA	NA	NA	Spodue Mountain
147	6-19/4-9	6	level 19	PPT	GCS	3.1*	2.7	0.6	2.7	1.2	0.9*	Spodue Mountain

Table G.2. Artifact provenance data table for the Connley Caves site (35-LK-50).

Specimen Number	Catalog Number	Unit	Depth	Class	Type	Length	Width	Thick	Shoulder Width	Neck Width	Base Width	Artifact Source/ Chemical Type
148	6-19/4-26	6	level 19	BIF	NA	2.3*	2.0	0.6	NA	NA	NA	Obsidian Cliffs
149	6-21/4-4	6	level 21	BIF	NA	4.6*	2.1	0.7	NA	NA	NA	McKay Butte
150	6-22/4-4	6	level 22	BIF	NA	4.1*	2.4	0.8	NA	NA	NA	Glass Buttes 2
151	6-22/4-6	6	level 22	BIF	NA	2.7*	1.8	0.6	NA	NA	NA	Glass Buttes 3
152	6-22/4-7	6	level 22	PPT	CAS	7.3	2.0	0.8	NA	NA	1.1	Silver Lake/Sycan Marsh
153	6-22/4-19	6	level 22	PPT	CAS	3.1*	1.6	0.6	NA	NA	1.0	Glass Buttes 3
154	6-22/4-3	6	level 22	PPT	EE	2.5*	2.1*	0.6	2.1*	1.2	1.5	Glass Buttes 3
155	4A-2/1-1	4A	level 2	PPT	NA	1.3*	1.0*	0.3	NA	NA	NA	Silver Lake/Sycan Marsh
156	4A-12/1-2	4A	level 12	PPT	ECN	0.5*	1.5	0.3	NA	NA	1.5	Hager Mountain
157	4A-26/3-6	4A	level 26	BIF	NA	1.8*	2.1	0.5	NA	NA	NA	Cougar Mountain
158	4A-30/4-3	4A	level 30	BIF	NA	2.6*	2.4	0.7	NA	NA	NA	Horse Mountain
159	4A-30/4-6	4A	level 30	PPT	NA	1.0*	1.2*	0.3	1.2*	NA	NA	Cougar Mountain
160	4A-32/4-13	4A	level 32	BIF	NA	3.2*	1.8	0.6	NA	NA	NA	Wagontire
161	5-6/1-1	5	level 6	BIF	NA	1.9*	1.0	0.5	NA	NA	NA	Glass Buttes 3
162	5-27/3-1	5	level 27	BIF	NA	2.1*	1.8	0.6	NA	NA	NA	Cougar Mountain
163	5-27/3-2	5	level 27	BIF	NA	1.8*	1.5*	0.8	NA	NA	NA	Silver Lake/Sycan Marsh
164	5-27/3-3	5	level 27	PPT	CAS	2.1*	2.3	0.6	NA	NA	1.8*	Sugar Hill
165	5B-31/3-3	5B	level 31	BIF	NA	6.3*	2.4*	0.9	NA	NA	NA	Glass Buttes 2
166	3-5/1-2	3	level 5	PPT	DSN	0.9*	1.0	0.2	0.8	0.6	1.0	Spodue Mountain
167	4B-30/4-6	4B	level 30	PPT	CAS	8.8	3.2	0.7	NA	NA	NA	Unknown 5
168	5B-12/1-7	5	level 12	PPT	ECN	2.6*	2.6*	0.4	NA*	NA*	2.3	Cougar Mountain

Table G.3. Lithic tool classification code key

Tool Class	
PPT	projectile point
BIF	biface
Projectile Point Type	
CAS	Cascade
CN	Corner Notched
CS	Contracting Stem
DSN	Desert Side Notched
ECN	Elko Corner Notched
EE	Elko Eared
GCS	Gatecliff Contracting Stem
GSS	Gatecliff Split Stem
LCB	Lanceolate Concave Base
LSN	Large Side Notched
RGC	Rosegate C (stemmed, no side notching, narrow-necked, diverging stem)
RSG	Rosegate

All measurements listed in Table G.2 are recorded in centimeters. An asterisk (*) denotes a fragment or broken edge along the measured axis. The tool classification is based on types described by Pettigrew (1985).

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
35-LK-50	1	1-surf-2	61	21	119	38	42	189	9	375	316	1113	0.94	31.2	80.5	Variety 5
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	2	1-4/1-3	101	28	131	8	53	360	20	522	404	859	1.19	29.4	73.2	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	3	1-5/1-8	121	26	127	12	58	351	14	622	423	885	1.15	27.0	59.8	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	4	1-6/1-5	66	28	129	42	40	196	9	426	320	1229	0.93	30.6	71.1	Variety 5
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	5	1-18/3-1	73	22	111	59	33	150	13	337	715	869	1.37	18.0	127.1	Hager Mountain
			± 7	2	3	7	3	7	1	96	48	13	0.11			
35-LK-50	6	1-9/1-2	71	25	97	40	59	139	14	196	251	1328	0.84	37.2	133.5	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	7	1-15/2-1	53	15	87	119	31	157	5	1070	322	1280	1.29	41.1	39.4	Unknown 1
			± 7	3	3	7	3	7	2	97	47	15	0.11			
35-LK-50	8	1-5/1-14	53	20	147	67	41	293	20	1120	321	930	1.60	50.5	46.0	Newberry Volcano
			± 7	3	3	7	3	7	2	97	47	13	0.11			
35-LK-50	9	1-5/1-1	101	23	125	9	55	334	15	385	294	812	0.82	30.0	69.7	Silver Lake/Sycan Marsh
			± 8	3	4	7	3	7	2	95	47	17	0.11			
35-LK-50	10	1-5/1-4	127	21	99	5	43	284	19	352	282	825	0.67	26.3	63.2	Silver Lake/Sycan Marsh
			± 9	4	3	8	3	7	2	95	47	15	0.11			
35-LK-50	11	1-5/1-12	48	18	113	48	26	126	20	468	484	870	0.59	12.8	43.2	Spodue Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	12	1-4/1-1	100	27	133	7	55	356	19	515	385	818	1.14	29.7	71.1	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	13	1-5/1-11	75	27	118	6	54	325	18	358	298	796	0.72	26.3	66.4	Silver Lake/Sycan Marsh
			± 8	3	4	7	3	7	2	95	47	17	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.	Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
35-LK-50	14	1-2/1-2	91	23	126	8	48	345	18	852	557	789	1.78	30.2	66.6	Silver Lake/Sycan Marsh
			± 7	2	3	7	3	7	2	96	48	13	0.11			
35-LK-50	15	1surf-1	83	18	105	41	57	136	18	305	269	1286	0.96	38.4	99.9	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	16	1-6/1-3	111	29	117	57	44	284	17	401	289	1312	0.90	33.4	72.9	Bald Butte
			± 8	3	4	7	3	7	2	96	47	17	0.11			
35-LK-50	17	1-6/1-4	63	23	123	40	38	193	11	544	285	1211	0.89	33.7	54.1	Variety 5
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	18	1-6/1-6	68	20	102	40	56	140	13	277	269	1311	0.94	37.6	107.2	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	19	1-8/1-10	90	20	103	41	54	136	13	320	350	1341	1.04	30.6	103.3	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	20	1-15/2-7	80	18	106	41	55	136	12	291	386	1283	1.02	26.8	110.7	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	21	3-5/1-1	80	24	130	9	54	350	21	638	420	805	1.33	31.1	66.7	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	22	3-6/1-1	83	28	127	7	57	355	19	454	339	831	1.02	31.1	72.6	Silver Lake/Sycan Marsh
			± 7	3	4	7	3	7	2	95	47	15	0.11			
35-LK-50	23	3-7/1-1	49	21	112	51	24	133	16	499	493	911	0.63	13.3	43.3	Spodue Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	24	3-fill-2	141	35	222	ND	92	576	28	1197	791	9	1.60	18.7	43.1	Massacre Lake/ Guano Valley
			± 7	3	4	ND	3	7	2	96	48	24	0.11			
35-LK-50	25	3-23/3-2	76	17	96	40	50	126	11	289	327	1307	0.85	27.5	94.5	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	26	3-23/3-3	60	16	121	55	48	347	21	579	232	824	0.94	45.3	53.3	Big Obsidian Flow
			± 8	3	4	7	3	7	2	96	47	16	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
				Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
35-LK-50	27	3XT-2/1-8		89	26	96	83	73	402	16	1258	470	1289	1.94	39.4	49.3	Yreka Butte
			±	7	3	3	7	3	7	2	97	48	14	0.11			
35-LK-50	28	4A-1/1-1		107	23	137	13	56	348	15	364	255	931	0.65	29.2	60.0	Silver Lake/Sycan Marsh
			±	8	3	4	7	3	7	2	95	47	18	0.11			
35-LK-50	29	4A-10/1-2		68	26	138	66	47	190	11	493	249	953	1.22	53.0	79.4	Quartz Mountain
			±	7	3	3	7	3	7	2	96	47	13	0.11			
35-LK-50	30	4A-12/1-6		68	27	124	40	36	191	10	458	320	1238	0.99	32.4	70.2	Variety 5
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	31	4A-14/1-12		79	21	103	42	56	135	12	282	290	1219	0.98	35.9	110.1	Cougar Mountain
			±	7	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	32	4A-16/2-12		66	26	117	40	35	186	10	451	364	1213	1.18	32.8	83.7	Variety 5
			±	6	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	33	4A-28/4-8		84	20	100	41	58	131	11	218	217	1322	0.66	35.8	97.7	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	16	0.11			
35-LK-50	34	4A-30/4-4		42	26	149	56	24	128	21	427	211	701	0.48	28.1	39.7	Sugar Hill
			±	7	3	4	7	3	7	2	95	47	15	0.11			
35-LK-50	35	4A-30/4-5		81	28	123	7	55	353	18	768	529	803	1.70	30.6	70.5	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	48	13	0.11			
35-LK-50	36	4A-31/4-1		84	27	124	20	56	360	20	963	552	867	1.68	28.7	55.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
35-LK-50	37	4A-31/4-6		54	34	109	62	43	189	19	697	316	1609	0.98	32.3	46.1	Big Stick
			±	7	2	3	7	3	7	2	96	47	15	0.11			
35-LK-50	38	4A-32/4-11		38	23	107	74	25	110	10	730	286	1230	0.79	30.0	36.4	Glass Buttes 3
			±	6	2	3	7	3	7	2	97	47	14	0.11			
35-LK-50	39	4A-32/4-12		60	23	136	7	34	87	21	157	679	36	0.56	8.4	113.7	Cowhead Lake
			±	7	2	3	7	3	7	2	95	48	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
35-LK-50	40	4A-32/4-15		73	19	111	53	32	134	13	342	630	792	1.34	20.2	122.4	Cougar Mountain?
			±	6	2	3	7	3	7	1	96	48	13	0.11			
35-LK-50	41	4A-32/4-18		79	32	107	41	59	326	20	807	355	1655	1.39	39.2	55.5	Wagontire
			±	7	3	3	7	3	7	2	97	47	16	0.11			
35-LK-50	42	4A-34/4-8		45	21	108	83	21	106	12	690	390	749	0.89	23.5	43.0	Buck Mountain
			±	6	2	3	7	3	7	1	96	47	13	0.11			
35-LK-50	43	4A-33/4-12		50	17	129	11	34	90	16	181	659	56	0.64	9.8	112.7	Cowhead Lake
			±	6	3	3	7	3	7	2	95	48	12	0.11			
35-LK-50	44	4B-27/3-2		95	30	91	79	75	391	19	1285	486	1290	2.05	39.9	50.7	Yreka Butte
			±	7	2	3	7	3	7	2	97	48	14	0.11			
35-LK-50	45	4B-27/3-4		97	32	137	8	57	365	19	683	494	827	1.48	28.9	69.3	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	46	4B-27/3-5		72	20	102	43	59	138	10	263	278	1224	0.98	37.9	117.2	Cougar Mountain
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	47	4B-30/3-16		71	23	100	42	59	137	10	240	237	1403	0.81	38.3	107.1	Cougar Mountain
			±	7	2	3	7	3	7	2	96	47	15	0.11			
35-LK-50	48	4B-31/4-1		63	34	111	59	43	195	17	743	346	1644	1.06	31.6	47.0	Big Stick
			±	6	2	3	7	3	7	2	97	47	14	0.11			
35-LK-50	49	4B-31/4-3		38	26	118	75	22	106	14	356	275	759	0.44	19.2	44.2	Buck Mountain
			±	7	3	3	7	3	7	2	95	47	14	0.11			
35-LK-50	50	4B-31/4-6		41	12	76	56	48	126	10	552	269	1413	0.82	33.4	49.5	Glass Buttes 2
			±	6	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	51	4B-31/4-13		183	36	140	4	111	664	33	887	462	50	2.57	52.5	91.0	Horse Mountain
			±	7	3	3	8	3	7	2	96	48	13	0.11			
35-LK-50	52	4B-31/4-14		35	23	117	71	17	105	11	451	318	731	0.58	20.3	44.5	Buck Mountain
			±	7	3	3	7	3	7	2	96	47	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
35-LK-50	53	4B-32/4-4		195	42	142	6	114	655	38	926	466	60	2.69	54.4	91.0	Horse Mountain
			±	7	3	3	7	3	7	2	96	48	13	0.11			
35-LK-50	54	4B-32/4-8		35	13	70	56	48	125	10	547	276	1385	0.81	32.1	49.3	Glass Buttes 2
			±	7	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	55	4B-32/4-9		77	22	98	37	57	138	15	194	219	1336	0.74	39.3	120.0	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	15	0.11			
35-LK-50	56	4B-32/4-16		166	29	118	4	97	566	31	1077	486	322	2.47	47.8	72.3	Horse Mountain
			±	7	3	3	8	3	7	2	96	48	13	0.11			
35-LK-50	57	4B-32/4-18		87	24	102	131	41	271	15	468	615	1137	1.78	27.0	118.5	Unknown
			±	7	3	3	7	3	7	2	96	48	14	0.11			
35-LK-50	58	4B-32/4-21		47	18	140	58	26	126	15	542	302	651	0.71	25.8	44.4	Sugar Hill
			±	6	3	3	7	3	7	2	96	47	13	0.11			
35-LK-50	59	4B-33/4-30		100	32	93	81	73	398	24	1365	502	1304	2.12	39.9	49.5	Yreka Butte
			±	7	2	3	7	3	7	2	97	48	14	0.11			
35-LK-50	60	4B-33/4-31		64	21	113	37	37	178	9	464	398	1111	1.27	31.7	86.9	Variety 5
			±	6	2	3	7	3	7	2	96	47	13	0.11			
35-LK-50	61	4B-33/4-32		55	17	111	48	21	129	16	550	621	887	0.78	12.4	47.2	Spodue Mountain
			±	6	3	3	7	3	7	2	96	48	13	0.11			
35-LK-50	62	4B-33/4-33		36	30	122	68	19	102	14	376	297	612	0.48	18.7	45.0	Buck Mountain
			±	6	3	3	7	3	7	2	95	47	13	0.11			
35-LK-50	63	4B-33/4-34		151	16	101	47	24	123	16	485	536	954	0.69	13.1	48.0	Spodue Mountain
			±	7	2	3	7	3	7	2	96	47	13	0.11			
35-LK-50	64	4B-33/4-35		35	20	136	55	24	121	12	434	229	676	0.53	27.5	42.3	Sugar Hill
			±	7	3	3	7	3	7	2	95	47	14	0.11			
35-LK-50	65	4B-33/4-40		26	15	108	75	31	112	5	365	219	1505	0.51	28.7	48.9	Glass Buttes 3
			±	7	3	3	7	3	7	2	96	47	16	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.	Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
			Trace Element Concentrations											Ratios		
35-LK-50	66	4B-33/4-44	66	39	115	60	46	197	15	713	332	1529	1.01	31.6	46.7	Big Stick
			± 7	2	3	7	3	7	2	97	47	14	0.11			
35-LK-50	67	4B-35/4-17	78	22	106	40	59	138	14	252	318	1323	1.05	34.3	129.8	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	68	4B-38/4-6	31	14	107	74	31	111	6	510	309	1326	0.77	27.0	50.6	Glass Buttes 3
			± 6	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	69	5-7/1-3	16	5	ND	7	3	ND	4	51	1662	763	0.00	0.4	30.2	Not Obsidian
			± 7	3	ND	7	3	ND	2	95	48	13	0.11			
35-LK-50	70	5-8/1-2	48	23	105	71	25	102	14	213	347	841	0.48	15.6	76.1	Coglan Buttes
			± 7	3	3	7	3	7	2	95	47	14	0.11			
35-LK-50	71	5-8/1-3	34	19	115	62	30	105	11	388	289	1115	0.59	23.0	51.7	Glass Buttes 6
			± 6	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	72	5-9/1-4	74	23	100	43	61	135	14	119	188	1281	0.53	35.8	139.2	Cougar Mountain
			± 7	3	3	7	3	7	2	95	47	17	0.11			
35-LK-50	73	5-9/1-5	73	17	99	38	55	139	11	273	303	1250	1.04	36.1	119.8	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	74	5-10/1-1	78	19	96	39	53	133	12	204	234	1294	0.81	39.1	124.7	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	75	5-10/1-3	100	29	133	8	58	357	21	597	389	793	1.17	30.2	63.4	Silver Lake/Sycan Marsh
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	76	5-12/1-2	71	23	126	38	40	195	11	346	314	1239	0.92	31.0	85.8	Variety 5
			± 7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	77	5-12/1-3	71	17	101	41	57	137	16	262	296	1238	1.01	36.1	120.8	Cougar Mountain
			± 7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	78	5-16/1-1	45	26	102	76	24	71	8	219	386	363	0.38	11.4	61.0	McComb Butte
			± 6	3	3	7	3	7	2	95	47	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
				Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
35-LK-50	79	5-18/2-1		80	22	100	41	58	135	12	268	327	1341	1.08	34.3	126.3	Cougar Mountain
			±	7	2	3	7	3	7	1	96	47	14	0.11			
35-LK-50	80	5-22/2-2		83	27	145	28	45	200	36	268	225	248	0.61	32.2	76.1	Mosquito Lake
			±	7	3	4	7	3	7	2	95	47	14	0.11			
35-LK-50	81	5-22/2-3		84	19	105	40	58	139	14	264	297	1311	1.03	36.5	122.2	Cougar Mountain
			±	6	2	3	7	3	7	2	96	47	15	0.11			
35-LK-50	82	5B-25/3-1		81	29	131	67	43	191	11	288	230	962	0.99	47.7	108.5	Quartz Mountain
			±	7	2	3	7	3	7	2	95	47	14	0.11			
35-LK-50	83	5B-26/3-1		70	19	109	51	34	135	13	311	672	865	1.43	19.9	141.8	Cougar Mountain?
			±	6	2	3	7	3	7	1	96	48	13	0.11			
35-LK-50	84	5B-26/3-2		39	28	119	73	20	109	8	495	348	709	0.61	19.1	42.3	Buck Mountain
			±	6	3	3	7	3	7	2	96	47	13	0.11			
35-LK-50	85	5B-26/3-3		72	19	106	40	61	137	14	253	282	1334	0.93	35.5	116.0	Cougar Mountain
			±	7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	86	5B-26/3-7		70	27	146	66	46	194	7	482	225	981	1.18	58.0	78.5	Quartz Mountain
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	87	5B-27/3-1		42	25	107	52	26	76	10	173	402	256	0.45	12.4	86.1	Tucker Hill
			±	6	3	3	7	3	7	2	95	47	13	0.11			
35-LK-50	88	5B-27/3-2		77	23	142	66	44	191	6	646	304	879	1.64	54.8	80.3	Quartz Mountain
			±	7	3	3	7	3	7	2	96	47	13	0.11			
35-LK-50	89	5B-27/3-4		79	22	98	39	58	136	11	303	286	1297	1.08	39.7	111.8	Cougar Mountain
			±	7	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	90	5B-27/3-5		44	22	134	62	41	207	13	913	260	1086	1.41	57.3	49.9	McKay Butte
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	91	5B-27/3-8		79	29	139	65	45	182	8	256	140	932	0.57	57.2	74.8	Quartz Mountain
			±	8	3	4	7	3	7	2	95	47	16	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
				Trace Element Concentrations											Ratios		
35-LK-50	92	5B-27/3-9		63	28	137	63	44	187	11	396	223	964	1.11	55.3	89.4	Quartz Mountain
			±	7	2	3	7	3	7	2	96	47	15	0.11			
35-LK-50	93	5B-28/3-1		45	16	91	28	52	97	14	266	249	1247	0.55	25.7	69.3	Glass Buttes 1
			±	6	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	94	5B-28/3-2		45	22	112	48	24	126	20	526	550	904	0.71	13.1	45.4	Spodue Mountain
			±	6	3	3	7	3	7	2	96	48	14	0.11			
35-LK-50	95	5B-28/3-6		44	25	138	62	37	206	11	1007	277	1076	1.50	56.5	48.1	McKay Butte
			±	7	2	3	7	3	7	2	97	47	13	0.11			
35-LK-50	96	5B-28/3-10		88	26	131	8	57	358	24	725	491	893	1.55	30.2	68.1	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	14	0.11			
35-LK-50	97	5B-29/3-1		78	23	125	6	54	350	21	961	582	783	1.98	31.7	65.3	Silver Lake/Sycan Marsh
			±	7	2	3	7	3	7	1	97	48	13	0.11			
35-LK-50	98	5B-29/3-2		148	37	220	4	88	578	37	1040	551	32	1.34	23.3	41.8	Massacre Lake/ Guano Valley
			±	7	3	4	8	3	7	2	96	48	13	0.11			
35-LK-50	99	5B-29/3-4		70	23	125	35	58	326	16	820	284	932	1.32	48.4	52.0	Unknown
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	100	5B-29/3-8		66	24	117	185	29	108	13	523	452	1067	0.96	21.3	59.8	Unknown
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	101	5B-30/3-1		44	30	115	56	26	79	16	145	332	303	0.31	11.5	75.5	Tucker Hill
			±	7	3	3	7	3	7	2	95	47	13	0.11			
35-LK-50	102	5B-30/3-2		41	18	72	55	46	121	13	531	308	1314	0.90	31.1	55.9	Glass Buttes 2
			±	6	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	103	5B-30/3-10		66	21	107	164	29	100	16	438	530	1003	0.93	17.4	69.0	Unknown 2
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	104	5B-31/3-8		82	24	126	13	54	345	15	714	477	921	1.43	29.1	64.3	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	14	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Ratios Fe:Mn	Fe:Ti	Artifact Source/ Chemical Type
35-LK-50	105	5B-31/3-9		68	30	142	66	45	190	6	488	262	931	1.31	52.9	85.2	Quartz Mountain
			±	7	2	3	7	3	7	2	96	47	13	0.11			
35-LK-50	106	5B-31/3-15		60	38	115	63	48	200	18	801	348	1480	1.06	31.2	43.4	Big Stick
			±	7	2	3	7	3	7	2	97	47	14	0.11			
35-LK-50	107	5B-31/3-20		43	17	114	49	25	120	16	322	358	828	0.40	12.9	44.6	Spodue Mountain
			±	7	3	3	7	3	7	2	95	47	15	0.11			
35-LK-50	108	5B-32/3-1		71	17	110	57	33	146	11	218	529	870	1.05	19.4	148.2	Hager Mountain
			±	6	3	3	7	3	7	2	95	48	14	0.11			
35-LK-50	109	5B-32/3-5		104	24	125	12	54	346	20	492	300	813	0.84	30.1	56.6	Silver Lake/Sycan Marsh
			±	7	3	4	7	3	7	2	95	47	15	0.11			
35-LK-50	110	5B-32/3-11		63	27	142	68	42	187	6	494	266	939	1.40	55.3	89.6	Quartz Mountain
			±	7	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	111	5B-32/3-12		237	38	134	4	107	653	36	839	418	46	2.34	53.7	87.7	Horse Mountain
			±	8	3	3	8	3	7	2	96	48	13	0.11			
35-LK-50	112	5B-33/3-1		65	31	143	70	39	187	9	325	177	993	0.82	56.6	82.2	Quartz Mountain
			±	7	3	4	7	3	7	2	95	47	15	0.11			
35-LK-50	113	5B-33/3-9		80	20	111	55	46	270	10	657	320	1325	1.28	41.0	62.8	Bald Butte
			±	7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	114	6-1/1-2		74	20	100	39	57	135	9	252	251	1317	0.86	37.8	108.0	Cougar Mountain
			±	7	3	3	7	3	7	2	96	47	16	0.11			
35-LK-50	115	6-2/2-2		75	23	100	36	57	133	16	179	184	1151	0.60	41.0	108.0	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	17	0.11			
35-LK-50	116	6-2/2-3		79	31	144	68	40	189	8	434	210	964	1.05	56.4	77.6	Quartz Mountain
			±	7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	117	6-2/2-10		39	13	80	113	18	100	7	569	308	890	1.05	35.8	60.3	Obsidian Cliffs
			±	6	2	3	7	3	7	2	96	47	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

				Trace Element Concentrations											Ratios		Artifact Source/
Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Chemical Type
35-LK-50	118	6-2/2-13		72	23	98	40	57	137	12	262	290	1302	0.98	35.7	117.0	Cougar Mountain
			±	7	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	119	6-3/2-1		75	28	114	58	34	137	10	180	460	881	0.89	19.4	151.8	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	14	0.11			
35-LK-50	120	6-3/2-7		31	18	95	28	54	101	7	293	276	1233	0.57	23.6	65.8	Glass Buttes 1
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	121	6-5/2-1		128	25	125	12	57	351	16	438	323	914	0.88	28.7	65.8	Silver Lake/Sycan Marsh
			±	8	3	4	7	3	7	2	95	47	16	0.11			
35-LK-50	122	6-5/2-2		89	20	101	39	57	138	16	173	187	1353	0.61	40.3	112.4	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	16	0.11			
35-LK-50	123	6-5/2-3		50	16	104	46	26	123	18	290	286	933	0.30	13.3	39.1	Spodue Mountain
			±	7	3	3	7	3	7	2	95	47	15	0.11			
35-LK-50	124	6-5/2-4		108	30	125	17	58	363	15	379	276	943	0.71	28.4	61.9	Silver Lake/Sycan Marsh
			±	8	3	4	7	3	7	2	95	47	15	0.11			
35-LK-50	125	6-5/2-7		122	24	121	9	53	343	16	543	409	825	1.21	29.3	71.4	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	126	6-5/2-8		85	33	129	6	57	358	17	565	409	845	1.26	30.6	71.8	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	127	6-5/2-20		112	18	114	10	53	332	14	336	215	873	0.56	31.4	56.6	Silver Lake/Sycan Marsh
			±	8	3	4	7	3	7	2	95	47	15	0.11			
35-LK-50	128	6-6/2-1		74	18	105	56	31	146	9	150	289	867	0.47	18.9	101.8	Hager Mountain
			±	8	3	4	7	3	7	2	95	47	16	0.11			
35-LK-50	129	6-7/2-1		76	23	102	40	55	138	14	185	203	1268	0.65	38.5	112.1	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	17	0.11			
35-LK-50	130	6-7/2-3		59	17	108	46	26	134	14	407	452	855	0.56	13.2	47.5	Spodue Mountain
			±	7	3	3	7	3	7	2	96	47	14	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
				Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
35-LK-50	144	6-19/2-10		64	26	139	63	44	189	8	463	225	969	1.15	56.4	79.5	Quartz Mountain
			±	7	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	145	6-19/2-23		77	25	142	64	44	189	8	548	272	958	1.41	54.2	81.8	Quartz Mountain
			±	6	2	3	7	3	7	2	96	47	13	0.11			
35-LK-50	146	6-19/4-8		55	17	109	49	26	126	14	681	586	814	0.77	13.1	38.1	Spodue Mountain
			±	7	3	3	7	3	7	2	96	48	13	0.11			
35-LK-50	147	6-19/4-9		60	15	108	50	20	121	18	551	569	866	0.74	13.0	45.0	Spodue Mountain
			±	6	3	3	7	3	7	1	96	48	13	0.11			
35-LK-50	148	6-19/4-26		55	17	87	116	19	106	12	416	241	960	0.66	31.7	53.8	Obsidian Cliffs
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	149	6-21/4-4		62	23	138	65	38	209	13	893	267	1037	1.41	55.3	50.8	McKay Butte
			±	7	3	3	7	3	7	2	97	47	14	0.11			
35-LK-50	150	6-22/4-4		44	15	75	49	52	123	12	503	295	1299	0.80	29.3	52.8	Glass Buttes 2
			±	6	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	151	6-22/4-6		49	19	107	73	28	109	6	371	238	1402	0.52	25.9	48.3	Glass Buttes 3
			±	7	3	3	7	3	7	2	96	47	15	0.11			
35-LK-50	152	6-22/4-7		78	29	136	7	60	365	18	676	475	816	1.51	30.7	71.3	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
35-LK-50	153	6-22/4-19		34	17	102	72	28	108	12	518	267	1404	0.69	28.9	44.9	Glass Buttes 3
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	154	6-23/4-3		38	23	102	72	28	108	7	538	300	1388	0.79	28.3	48.8	Glass Buttes 3
			±	6	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	155	4A-2/1-1		95	31	121	13	52	335	17	465	283	846	0.74	28.7	53.1	Silver Lake/Sycan Marsh
			±	8	3	4	7	3	7	2	95	47	16	0.11			
35-LK-50	156	4A-12/1-2		78	15	97	50	32	131	12	67	229	929	0.34	19.0	151.6	Hager Mountain
			±	9	4	4	7	3	7	2	95	47	19	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

				Trace Element Concentrations											Ratios		Artifact Source/
Site	Specimen No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Chemical Type
35-LK-50	131	6-7/2-4		40	21	131	13	31	91	17	187	308	40	0.35	13.9	66.3	Drews Creek/ Butcher Flat
			±	7	3	3	7	3	7	2	95	47	13	0.11			
35-LK-50	132	6-7/2-5		75	22	106	52	25	130	17	494	491	849	0.62	13.1	42.6	Spodue Mountain
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	133	6-8/2-11		92	24	99	40	56	136	13	556	267	1317	1.06	42.5	62.0	Cougar Mountain
			±	7	2	3	7	3	7	2	96	47	14	0.11			
35-LK-50	134	6-10/2-6		74	19	103	39	55	134	18	191	239	1384	0.75	35.7	124.3	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	16	0.11			
35-LK-50	135	6-10/2-11		89	16	94	37	53	135	12	243	260	1290	0.93	38.9	119.7	Cougar Mountain
			±	6	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	136	6-12/2-4		204	41	137	5	106	640	34	826	424	48	2.29	51.6	87.1	Horse Mountain
			±	7	3	3	7	3	7	2	96	48	13	0.11			
35-LK-50	137	6-13/2-1		89	17	123	8	50	337	18	491	366	819	1.13	31.2	73.7	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	138	6-13/2-4		34	26	102	65	27	100	13	202	344	853	0.46	15.2	77.1	Coglan Buttes
			±	7	3	3	7	3	7	2	95	47	14	0.11			
35-LK-50	139	6-14/2-1		84	25	122	15	53	340	20	512	344	872	0.94	28.4	60.2	Silver Lake/Sycan Marsh
			±	7	3	4	7	3	7	2	96	47	15	0.11			
35-LK-50	140	6-17/2-2		60	18	109	52	29	130	10	120	348	886	0.62	19.3	156.6	Hager Mountain
			±	7	3	3	7	3	7	2	95	47	16	0.11			
35-LK-50	141	6-17/2-5		47	16	92	109	27	142	8	1002	340	1280	1.29	38.6	42.0	Glass Buttes 7
			±	6	2	3	7	3	7	2	97	47	14	0.11			
35-LK-50	142	6-19/2-1		28	28	160	36	26	136	14	498	205	319	0.62	36.3	42.5	Surveyor Spring
			±	7	2	4	7	3	7	2	95	47	13	0.11			
35-LK-50	143	6-19/2-3		81	20	115	49	58	372	19	521	214	954	0.91	48.3	57.2	Big Obsidian Flow?
			±	8	3	4	7	3	7	2	96	47	17	0.11			

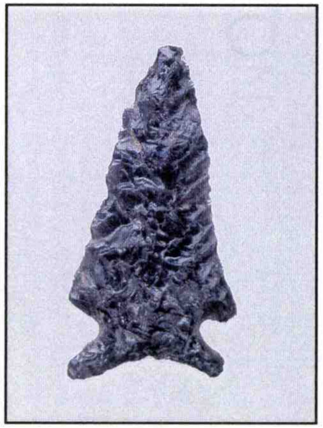
All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table G.4. Results of XRF studies: artifacts from the Connley Caves site (35-LK-50), Fort Rock Basin, Oregon.

Site	Specimen No.	Catalog No.		Trace Element Concentrations											Ratios		Artifact Source/ Chemical Type
				Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
35-LK-50	157	4A-26/3-6		72	18	95	39	54	130	12	217	224	1389	0.77	39.3	112.3	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	15	0.11			
35-LK-50	158	4A-30/4-3		191	36	137	4	105	640	38	1016	530	49	2.97	51.9	91.5	Horse Mountain
			±	7	3	3	7	3	7	2	96	48	12	0.11			
35-LK-50	159	4A-30/4-6		62	20	93	41	54	129	19	152	172	1245	0.49	37.3	104.6	Cougar Mountain
			±	7	3	3	7	3	7	2	95	47	17	0.11			
35-LK-50	160	4A-32/4-13		66	34	103	41	56	329	22	828	394	1604	1.52	37.9	58.7	Wagontire
			±	7	2	3	7	3	7	2	97	47	15	0.11			
35-LK-50	161	5-6/1-1		26	18	102	73	29	110	7	445	229	1348	0.52	27.4	41.0	Glass Buttes 3
			±	8	3	3	7	3	7	2	96	47	16	0.11			
35-LK-50	162	5-27/3-1		74	15	90	37	48	123	11	256	277	1336	1.02	39.3	124.4	Cougar Mountain
			±	7	3	3	7	3	7	2	96	47	14	0.11			
35-LK-50	163	5-27/3-2		95	24	122	9	50	335	19	708	531	802	1.63	29.2	73.2	Silver Lake/Sycan Marsh
			±	7	3	3	7	3	7	2	96	48	13	0.11			
35-LK-50	164	5-27/3-4		28	21	140	57	21	123	14	755	371	644	0.97	26.9	42.6	Sugar Hill
			±	6	2	3	7	3	7	1	96	47	13	0.11			
35-LK-50	165	5B-31/3-6		43	12	72	48	50	116	11	528	340	1307	0.89	27.3	55.5	Glass Buttes 2
			±	6	3	3	7	3	7	1	96	47	14	0.11			
35-LK-50	166	3-5/1-2		58	17	109	49	27	123	17	259	277	828	0.28	13.1	41.3	Spodue Mountain
			±	7	4	4	7	3	7	2	95	47	18	0.11			
35-LK-50	167	4B-30/4-6		53	21	123	81	40	259	13	1183	314	980	1.86	59.5	50.2	Unknown 3
			±	7	2	3	7	3	7	2	97	47	13	0.11			
35-LK-50	168	5B-12/1-7		83	18	100	42	58	137	14	304	285	1355	1.02	38.2	106.6	Cougar Mountain
			±	7	2	3	7	3	7	2	96	47	15	0.11			
NA	RGM-1	RGM-1		34	27	156	111	27	228	8	1629	277	776	1.90	70.3	37.3	RGM-1 Reference Standard
			±	6	2	3	7	3	7	2	97	47	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Digital Images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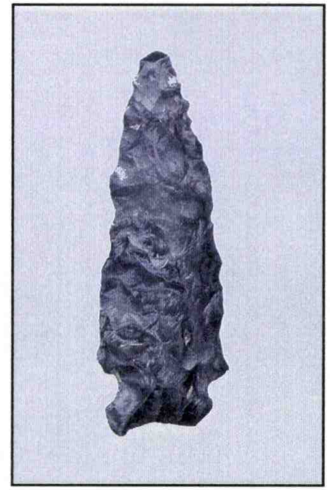
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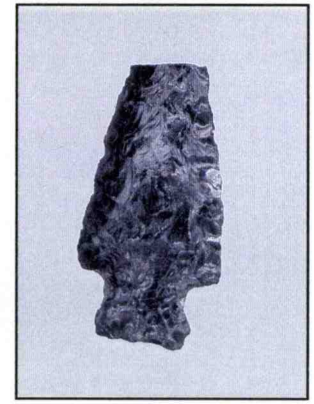
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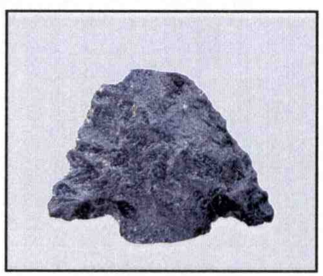
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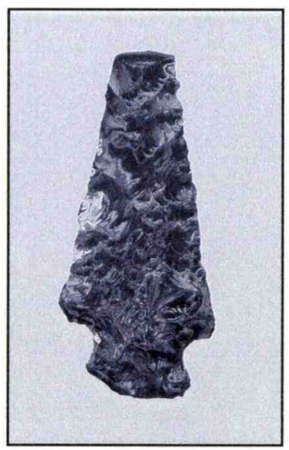
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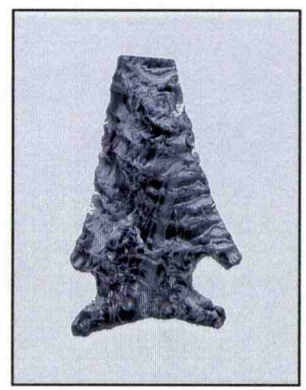
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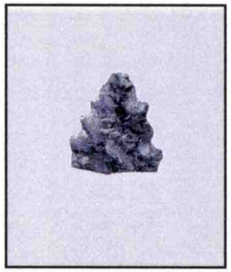
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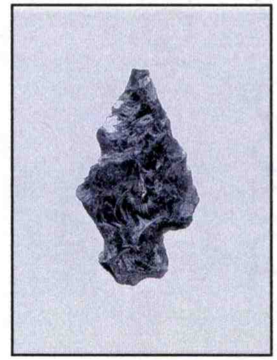
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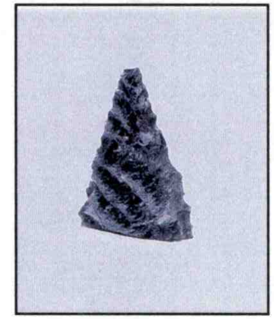
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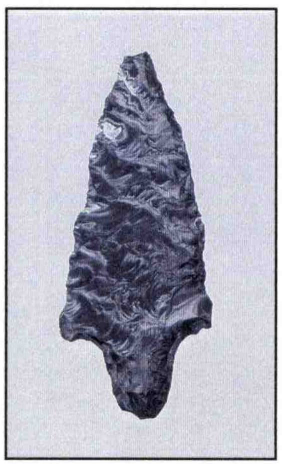
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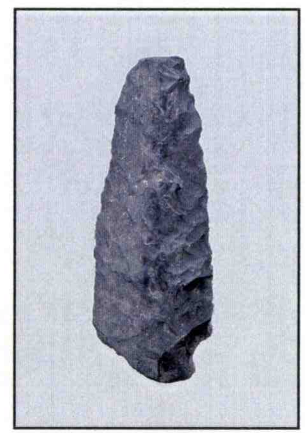
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98-93-22 (3-6/1-1)

98-93-23 (3-7/1-1)

98-93-24 (3-fill-2)

98-93-25 (3-23/3-2)

98-93-26 (3-23/3-3)

98-93-27 (3XT-2/1-8)


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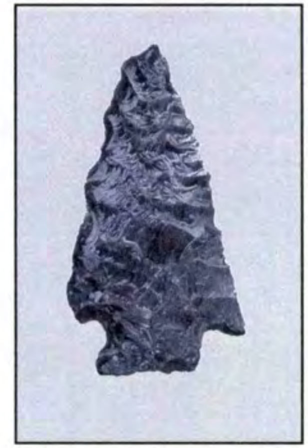
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98-93-43 (4A-33/4-12)


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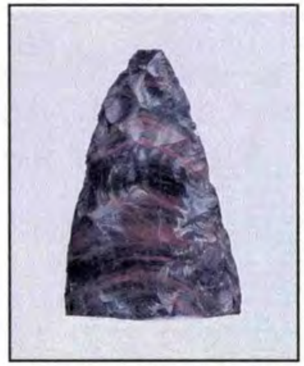

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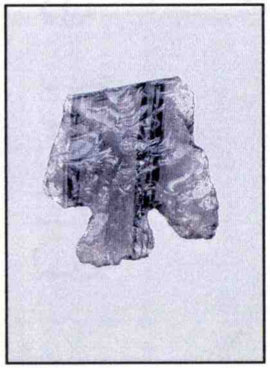
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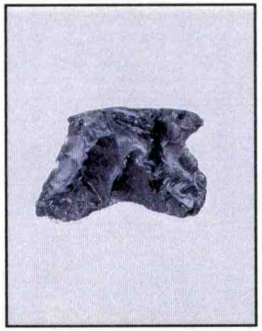
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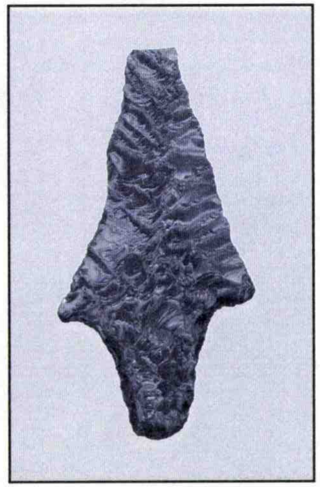
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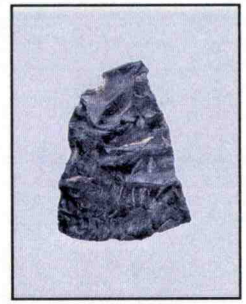
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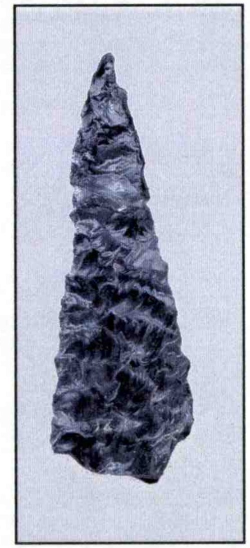
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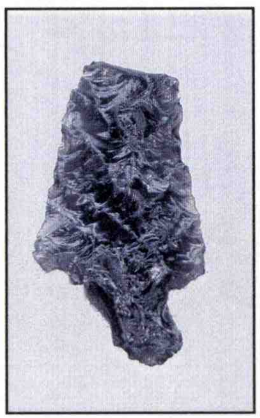
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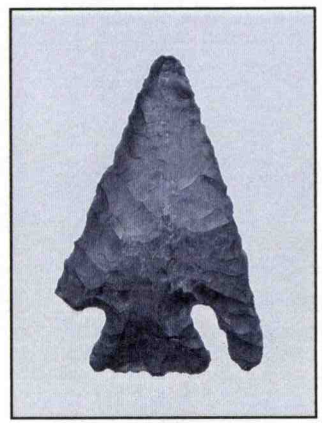
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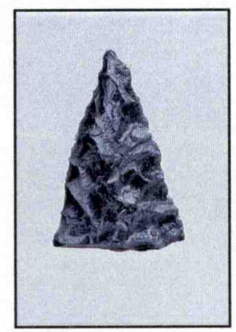
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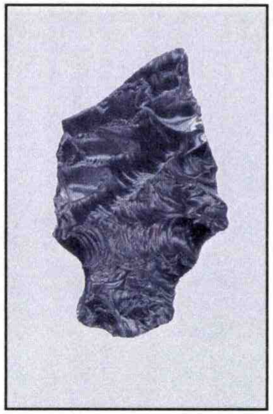

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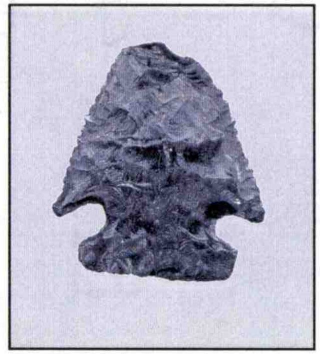

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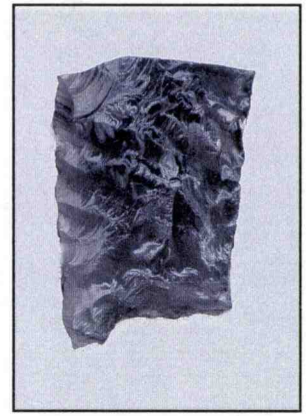

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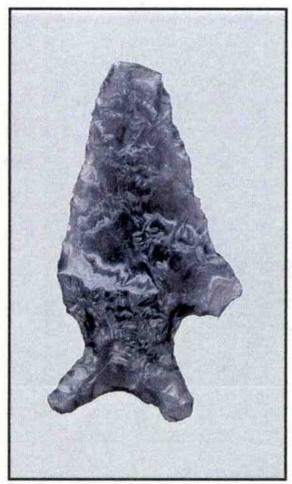

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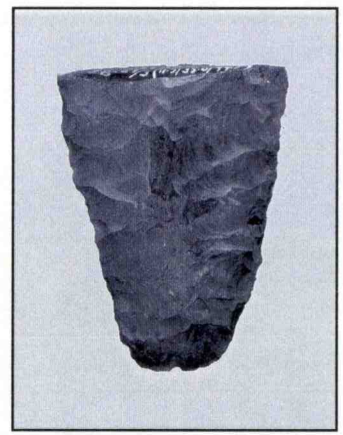

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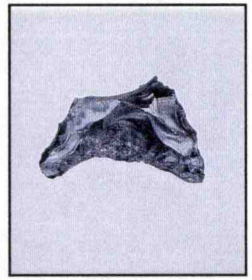
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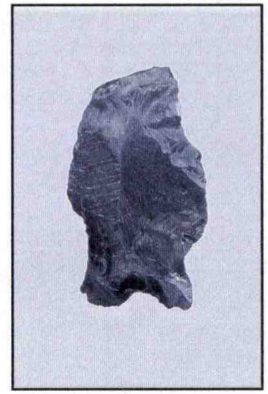
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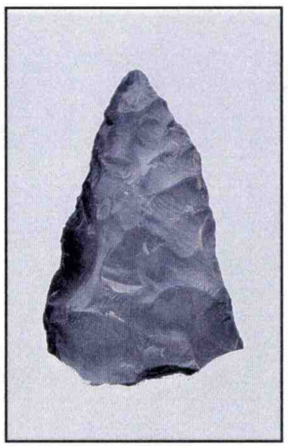
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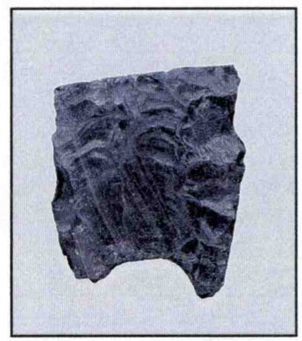
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98-93-102 (5B-30/3-2)

98-93-102 (5B-30/3-2)

98-93-103 (5B-30/3-10)

98-93-104 (5B-31/3-8)

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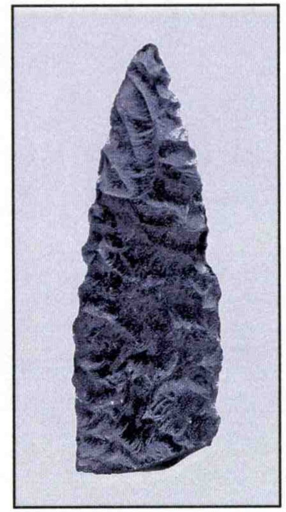

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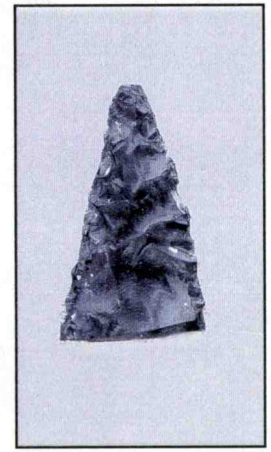

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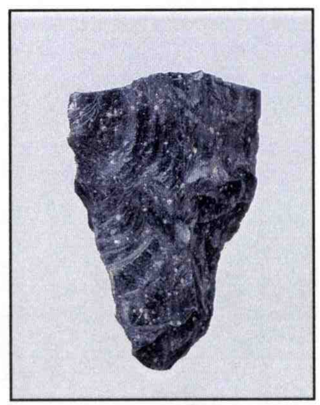

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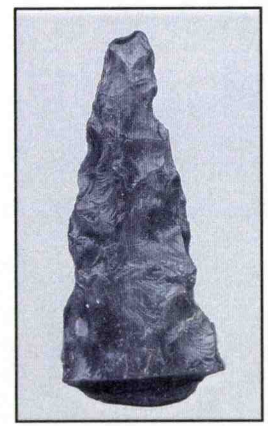

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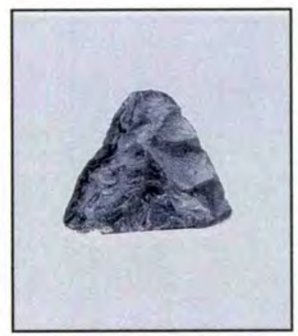

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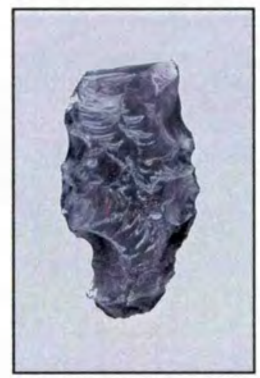
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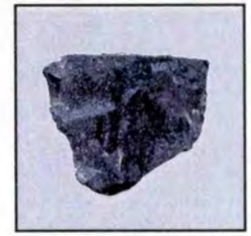
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98-93-145 (6-19/2-23)

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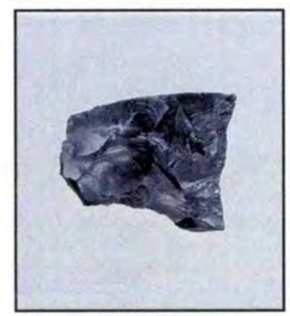
98-93-157 (4A-26/3-6)

98-93-158 (4A-30/4-3)



98-93-159 (4A-30/4-6)

98-93-160 (4A-32/4-13)

98-93-161 (5-6/1-1)

98-93-162 (5-27/3-1)

98-93-163 (5-27/3-2)

98-93-164 (5-27/3-3)

98-93-165
(5B-31/3-3)

dorsal (left)
ventral (right)

98-93-166 (3-5/1-2)

98-93-167 (4B-30/4-6)

98-93-168 ( )