The Biderbost Site: Exploring Migration and Trade on the Social Landscape of the Pacific Northwest

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The Biderbost site of Duvall, Washington presents an interesting archaeological case for investigating trade and migration. The extensive lithic remains contain several stylistic traits of regional groups, but incomplete excavation records hinder most traditional archaeological analyses. Instead, an analysis of tool style suggested particular tools at the Biderbost were remnants of regional trade. Additionally, a portable X-Ray Fluorescence Spectrometry study was able to accurately identify the source of several pieces of Biderbost obsidian. The results of these two analyses provided potentially conflicting conclusions regarding trade and migration in the Pacific Northwest. Ultimately, patterns in the site's stratigraphy indicating periods of abandonment may resolve these conflicting results through the possibility of multiple site occupations. The results from this analysis hold a variety of implications for the region and emphasize the importance of combing traditional archaeological methods and archaeometric methods.

Table of Contents:

List of Tables:

List of Figures:

Acknowledgements:

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Introduction:

One of the most striking questions in archaeology looks outside settlements and daily life, and questions how populations interacted with their social landscape. This approach often refers back to communities and their migration, and/or involvement in regional trade. Traditionally, archaeologists have examined the lithic assemblages of populations, identifying patterns suggesting how they interacted on a large-scale. New archaeometric tools have expanded the potential for archaeologists to study the lithic remains of populations; in particular, portable X-Ray Florescence analyses of lithics have been used to study regional trading and group mobility. This research will rely upon traditional lithic analysis and newer archaeometric methods to explore the mobility and trade of populations from the Biderbost site in western Washington State.

Several reports published on the Biderbost site shortly after excavation made preliminary claims about the occupants of the site and their relationship with regional cultural groups (Nelson 1962, Nelson 1976). However, these claims were based upon brief examinations and predictions from the first two seasons of archaeological excavation. Little research on the site has been conducted since these initial reports, and this early research has been left untested.

This paper will use a multi-scalar approach, combining traditional and new archaeological methods, to identify the relative mobility of the occupants from the Biderbost site, and explore their relationship with regional groups. First, a traditional lithic analysis will identify tool styles, and explore the potential regional influences at the Biderbost. Second, a portable X-Ray Florescence analysis identifies the geologic source of obsidian excavated from the site, in an attempt to understand whether this raw material arrived through direct procurement or trade.

These methods build upon earlier site reports, and explore the role played by the occupants of the Biderbost site in the social landscape of the Pacific Northwest.

This paper will argue that the Biderbost site was likely occupied intermittently over several millennia. Evidence exists indicating that the site functioned as a semi-permanent settlement for sedentary groups involved in regional trading, and potentially as a temporary stop for highly mobile populations over time.

Objectives:

This research began in the Summer of 2014, facilitated by the Burke Museum and the University of Washington. Though excavation on the Biderbost site concluded in the mid-1970s, little is known about the occupants of the site. This project sought to better understand the occupants of the Biderbost site. More specifically, I hoped to identify the mobility of the population or populations from the Biderbost site. A number of regional, cultural influences were evident from the excavated material, and through understanding the mobility of the populations at the Biderbost, I could better identify whether these cultural influences were catalyzed by migrating or trading populations. Ultimately, this research would explore the prehistoric social landscape of the Pacific Northwest.

Research Questions:

1. How mobile were the occupants of the Biderbost site?

2. Why were these regional cultural influences present at the Biderbost site? Were the occupants of the site migrating from outlying regions, or was there involvement in regional trading networks?

Background

The Biderbost site (45SN100), dating to around 2000 B.P.[1], is located near the town of Duvall, Washington, in the Western foothills of the Cascade Mountains (Figure 1). This site lies along the Snoqualmie River and well within its floodplain. The region is dominated by the Cascade Mountains to the east and the Puget Sound to the west. Lithic raw material in the Pacific Northwest is primarily composed of chert, petrified wood, slate, basalt, granite, and obsidian (Livingston 1969).

[1] The period the Biderbost was settled remains unclear, though a portion of the site has been dated to 2000 B.P. I will elaborate on this topic later.

Figure 1: Map of the Pacific Northwest illustrating the position of the Biderbost Site (45SN100, in red). Adapted from Sanger (1968).

Prior to 4500 B.P., the peoples of the Pacific Northwest were highly mobile-hunter gatherers (Barnett 1955; Hayden 1995). Populations by the coastline were generally more mobile (Hayden 1995, Matson 1992) while those occupying the Columbia Plateau to the east had the earliest forms of sedentary societies in the region (Matson and Magnee 2007:17). From around 4500 B.P. onwards, groups in the Pacific Northwest began to settle into more socially-complex, sedentary societies. Semi-permanent houses in small villages developed by 3500 B.P., particularly in the Columbia Plateau region, and peoples shifted from broad-scale foraging to more local collection strategies. Social complexity grew and spread in the region from 2500 B.P. onwards, stimulating the large-scale trade of prestige items (Ames 1995).

The Biderbost site lies within the historic home of the Snoqualmie people (Tollefson, 1987: 121). A number of regional cultural influences are present in the cultural material from the Biderbost site, including the late Archaic Columbia in Washington's western plateau, and the Fraser River Valley peoples from British Columbia (Nelson, 1976: 2). Unfortunately, there is no consensus to the cultural identity of the population from the Biderbost site.

The Biderbost Site:

The borders of the site are bounded by a stream along the western edge running north to south and the Snoqualmie River along the southern edge, running east to west (Figure 2). As the Snoqualmie River has shifted, the "toe" of the site (sandy outcrop reaching into the water) has covered and preserved numerous plant remains and fragile artifacts (Nelson 1976: 2). Midden depths extend up to around 15'6", with a fairly gradual and progressive burial over time.

The site has a slight elevation, around 115 feet above sea level at the riverbank, moving north, up to 122 feet above sea level. As the floodplain has spread over time, stratified layers of sterile silts have covered the base of the site, creating ideal conditions for the preservation of material culture at the site (Nelson, 1976: 2).

Sterile silts and sands are accumulated upon the cultural layers of the Biderbost site, and alluvial deposition appears to have been gradual and progressive (Nelson 1962). Soil composition change occurs around every 6 inches, although much of the deepest layers are silt loam with varying pH levels and porosity (Goldin 1994).

Figure 2: Map of the Biderbost Site; Black squares illustrate units from the 1960 field season; Blue marks riverbank; Red outlines speculative locations of site units from the 1970s excavations. Adapted from Nelson (1976).

The Biderbost is one of the many wet-sites of Washington. Unfortunately, while these wet-sites are known for their good preservation, their excavation is often arduous. Between 1960 and 1965, the Washington Archaeological Society conducted a series of test excavations, primarily focused upon a "submerged midden rich in basketry and other perishable artifacts" (Nelson, 1976: 1). Several excavation units lay below the water line of the Snoqualmie Riverbank, requiring significant water-bailing. The 1960 and 1961 field seasons were hindered by these drainage issues, limiting the amount excavated; fewer than 250 cubic feet of midden were removed during these seasons from a few excavation units. Excavation continued again in the early-1970s over several more seasons.

The Collection:

The Biderbost collection currently resides in the Burke Museum, affiliated with the University of Washington. The most notable objects within this collection are the Biderbost's basketry, fish hooks, and weir fragments, all well-preserved in the saturated environment (Nelson 1962: 2). Several seasons of excavation recovered 1200 lithic remains: tools, cores, cobble, refuse, flakes, and microliths. Only an early report on the 1961 field season analyzed the lithic assemblage from the Biderbost site.

While all material culture was well preserved, the literature on site excavation is difficult to discern and largely incomplete. For example, information regarding artifact context during excavation is vague or wholly missing. The exact locations of units are omitted from most excavation records; the best evidence for their placement comes from an original sketch of the site after excavation in the 1960s. Unfortunately, this 1960s map omits later excavated units from the 1970s, and their locations are speculative.

The artifact depth measurements from all available units were taken in inches, and this large unit of measurement creates ambiguity in the available records. Unit levels were taken in 6 inch increments, beginning with “0-6 inches” and moving up into “66-72 inches” in some of the deeper units. Some unit levels were taken in measurements greater than 6 inches, and other units simply did not follow this pattern of measurement. The slight majority of these measurements were taken from the ground surface, down to the location of the artifact, and the base of the unit level. A number of others from excavation in the 1970s recorded the “Depth from Datum” in inches, although the exact location of the site’s datum and how this related to surface depth was unknown. Several hundred artifacts are missing any provenience data.

Traditional archaeological analyses concentrate upon the analysis of artifacts contextually. The exact placement of an artifact allows archaeologists to identify its age, origins, and functionality, illuminating patterns of daily life. The lack of artifact recording at the Biderbost site complicates traditional archaeological analysis, leaving the lithic collection mostly untouched after the publication of early excavation reports.

Early Site Reports and Analyses: After the 1960s excavations at the Biderbost site, preliminary reports (Nelson 1962, 1976) on its excavation and assemblage attempted to understand the population or populations that occupied the site. While these brief analyses were unable to pose definitive conclusions about the site, Nelson (1962, 1976) created a foundation for future study.

Radiocarbon Age Study of the Biderbost Site: In 1976, Nelson tested the radiocarbon age of the Biderbost site, publishing the results in "The Washington Archaeologist". During excavation, several charcoal remains, C-14 samples, were collected from an upslope unit at the site. Originating in the midden feature from Square 10CL (Figure 3), the sample was then sent to the Rikagak Kenkyusho Institute of Physical and Chemical research in Sitama, Japan. Using a half-life of 5,730 years, this charcoal sample has a calibrated date of 2000 B.P. (50±80 BC) (Nelson 1976: 4).

Figure 3: Adapted from Nelson 1976, a figure showing where the C-14 sample was excavated.

Unfortunately, there are a number of red flags in the report's radiocarbon dating analysis. The biggest issue here is not with the sample—it was well preserved and likely uncontaminated—but with the single sample's ability to represent the entirety of the site. These results more likely represent a fraction of the site's history. The exact location of where the sample was collected is unknown as its excavated depth and context went unreported.

The amount of fluvial deposition at a site is dependent upon proximity to the riverbank. From a site this close to a major river, one sample is insufficient. Multiple samples from across the site at varying depths should be taken for evaluation. This would indicate how sediment deposited over long periods of time, and better understand the strength of flooding at different elevations; it is likely a sample taken from a depth of 30 inches at the riverbank would yield a different date from a similar sample taken from a depth of 30 inches upslope.

Differential deposition across the floodplain is likely, meaning few artifacts can be associated with this date. The Biderbost site was likely occupied around 2000 B.P. as suggested by Nelson (1976), although the extent of its occupation remains unknown. The sheer volume of accumulation and material culture suggests a longer period of occupation.

As reported by Nelson (1976) the interbedding of occupational layers with sterile soil at the Biderbost site suggests periods of abandonment. As previously mentioned, the "toe" of the site was eventually covered by the Snoqualmie River and Nelson suggests this fluvial shift occurred around one of the more lengthy periods of abandonment. Excavation from this area of the riverbank uncovered evidence for fishing in net weights, weir fragments, fish hooks, and calcined fish bones. This deposit by the water was evidently once a useful fishing site. As suggested by Nelson, flooding and fluvial deposition "destroyed the usefulness of the site as a fishing station" (Nelson 1976: 4), terminating the seasonal utilization of the Biderbost site.

First Report on Lithics of the Biderbost Site: After the second season of excavation, Charles M. Nelson published a report in 1962 on "Stone Artifacts from SN100"(the Biderbost site), commenting on the lithic assemblage. At this point in the project, excavation had uncovered 431 stone tools, then comprising 63% of the site's total catalogue.

After these first field seasons, 94% of the lithic raw material at the site were cryptocrystallines, including agate, jasper, chert, chalcedony, and petrified wood. Commenting on their use, Nelson suggested "though no formal count has been made, it is estimated that for every worked piece of cryptocrystalline material about three unworked flakes have been found…these include many minute specimens" (1962: 38). Nelson saw no evidence for the conservation of this raw material. In the discussion of obsidian at the site, he noted that of the 34 pieces, at least one was the double flow variety. Nelson estimated one piece of debitage per obsidian tool, indicating the material was not readily accessible (Nelson 1962: 38).

Similarities between Regional Lithic Industries: Substantial evidence dating back to the Biderbost's earliest excavations indicates parallels between the lithics of the Biderbost site and regional lithic industries. Exactly how the Biderbost site fits in with these contemporary groups is unknown. Nelson suggested several theories regarding the origins of Biderbost populations or trading partners in the Pacific Northwest. Ultimately, my study will shed light on these questions through modern methods, but it is helpful to initially understand the background for my research questions. Below, I address the three regions of significance for the Biderbost site. Similarities in cultural material or raw material are evident between groups in these regions and the Biderbost site.

Columbia Plateau, Eastern Washington: For Nelson, the variety and appearance of cryptocrystalline materials from the Biderbost site brought "to mind the agates and petrified woods found and used along the Columbia River" (Nelson 1962: 22). As further suggested by Nelson: "it is safe to conclude that more than 90% of the cryptocrystallines utilized at SN100 did not come from the Snoqualmie, Skirkomish, Stillaguamish, or Skagit river basins…points north, at least for material origin, are eliminated" (1962: 38).

Nelson further suggests that several points in southern Washington were potentially the original source of these cryptocrystallines, which were either procured directly or traded in. However, as these materials were not available in southern Washington as bountifully as in eastern Washington (Nelson 1962: 22), the Columbia Plateau may be a legitimate source for this cryptocrystalline (Figure 4).

While a number of tool styles at the Biderbost site have varying origins, the Columbia Plateau is most apparent. The Biderbost radiocarbon date of 2000 B.P. coincides with particular styles of Columbia Plateau lithic industry, some of which were found at the Biderbost site as well. The presence of projectile point styles from the Columbia Plateau will be discussed in depth later.

Figure 4: Map of the Pacific Northwest with the Columbia Plateau highlighted in yellow and Biderbost site in red. Adapted from *Plateau Archaeological Investigations, LLC*.

Vancouver Island and Southern British Columbia, Canada: Several pieces of excavated basalt were compared with a variety of pieces found at other Pacific Northwest sites in Nelson's report. Ultimately, several pieces of basalt resembled a type commonly found on Vancouver Island, and others resembled basalt from Whidbey Island, and the Fraser River Delta. From this, Nelson claimed trade relations existed with Washington's inland islands, the Fraser River Delta, and the Biderbost site.

Oregon: Obsidian is another non-local raw material found in surprising quantity at the site. Nelson states that the double flow obsidian's origin is "unquestionably Oregon" (Nelson 1962: 20), and likely represents an article of trade. That one piece of unworked obsidian exists per manufactured tool suggests that while the raw material was in relatively high demand, "it was never too scarce" (Nelson 1962: 20).

Research Questions:

Three research questions formed the basis of this study, each building upon earlier knowledge about the occupants of the Biderbost in the hopes of better understanding daily life and regional interaction.

1. How mobile were the occupants of the Biderbost site? Highly mobile, traversing hundreds of kilometers? Fairly mobile, with a temporary settlement? Permanently settled in the Pacific Northwest?

2. Why were these regional cultural influences present at the Biderbost site? Were the occupants of the site migrating from these regions, or were these occupants involved in the trade and exchange of goods?

Unfortunately, a quantitative lithic analysis identifying site function, tool-use change over time, and the daily life of these occupants is difficult due to the poor excavation records from the site. Without an understanding of site chronology and the possibility for multiple settlements (Nelson, 1976: 3), pieces of evidence from different periods of time may accidentally be lumped together. Tools from hundreds of years apart may appear contemporaneous, rendering any subsequent interpretations incorrect.

Instead, a qualitative analysis of tool styles will identify potential items of trade and pinpoint the regional lithic industries present at the Biderbost site. These results will be compared to similar studies in the Pacific Northwest identifying traded goods and trade routes between regions.

To expand this initial framework, I additionally sourced the obsidian excavated from the Biderbost site using portable X-Ray Florescence Spectrometry. The results from that analysis and will help identify whether this raw material provided evidence for high-mobility procurement or regional trading

Methods for Lithic Tool Analysis:

This analysis analyzed all excavated tools from the Biderbost site. I determined the utility of these tools, and made note of highly unique styles. I paid particular attention to the method of manufacture for these tools to identify which styles or forms required the greatest time and effort. Tool shape was particularly important to identify which objects were the most unique in the assemblage. I additionally recorded tool raw material, notable traits, and all available provenance data.

To compare the possibilities of direct procurement through high mobility or trade within a settlement system, I adapt a model used by Barbara Roth (1999), Stephen Shackley (1990, 1996), Binford (1979), and Morrow & Jeffries (1989), which uses lithic remains to identify the mobility or trade network of a population. This model is explored later in this analysis.

Results from Lithic Tool Analysis:

I analyzed 854 lithic tools from the Biderbost site. This included 72 ground stone tools, comprising around 9% of the assemblage. These were primarily composed of cooking stones, abraders, and adze blades. The raw material of these tools included granite, sandstone, basalt, nephrite, and serpentine. The remainder of the lithic assemblage was composed of 782 chipped stone tools, around 91% of the total. These tools were primarily scrapers, bifaces, and projectile points, manufactured from cryptocrystallines, and basalt.

There were twelve types of raw material at the site, consisting of sedimentary, metamorphic, and igneous stone. The largest group of stone materials were cryptocrystallines, composing over 63% of the assemblage.

Basalt	27%
Chert[2]	26%
Chalcedony	16%
Jasper	12%
Agate	8%
Obsidian	3%
Granite	2%
Sandstone	2%
Slate	1%
Nephrite	<1%
Serpentine	<1%

Table 1: Raw materials found at the Biderbost site, organized from most to least prevalent.

Results from Lithic Tool Analysis: Projectile points

Projectile points are the most stylized form of lithic tool; phases within tool cultures are identifiable by projectile point traits, and trade and migration has been traced through their geographic spread (Sanger 1967; Galm 1994; Bettinger & Eerkens 1999; Mesoudi 2008). Although 13% of these lithic tools consisted of projectile points (Figure 5), not all point types and styles could be identified during my limited stay. I estimate around a half-dozen tool styles were represented at the Biderbost site.

[2] Where the nature of the chert was not further distinguishable as "Chalcedony", "Jasper", or "Agate", the object was labelled as "Chert".

Points which were identifiable were similar to the style of Columbia Plateau projectile points. These included Quilomene Bar Basal-Notched and Columbia Corner-Notched points. There were potentially Columbia Stemmed points as well. The remainder of the projectile points were of an unknown style, and may further represent influential cultural traits from across the Pacific Northwest.

Figure 5: Projectile points excavated after the 1960 field season demonstrating the variability in style present. Adapted from image taken by Washington Archaeological Society.

Discussion of Lithic Analysis Results: Projectile Points

These projectile points were highly diverse, and likely represent a number of different lithic tool industries. Of those excavated from the Biderbost site, several were of styles found in the Columbia Plateau. These included the Quilomene Bar Basal-Notched (Figure 6) and Columbia Corner-Notched points (Figure 7), both known to originate in the Columbia Plateau. The Quilomene Bar Basal-Notched point style dates to between 2200 B.P. and 1850 B.P. (Chatters 1995; 2009), a period when the Biderbost site was almost certainly occupied (Nelson 1976). The Columbia Corner-Notched point style dates to between 5000 B.P. and 2000 B.P. (Lohse and Sammons 1994), just before the Biderbost site is currently known to have been occupied. This may indicate the Biderbost site occupation began earlier than 2000 B.P.

Figure 6: Image of a diverse set of Quilomene Bar Basal-Notched points from the Biderbost site. Adapted from image taken by Washington Archaeological Society.

Figure 7: Image of a Columbia Corner-Notched point from the Biderbost site. Adapted from image taken by Washington Archaeological Society.

The spread of projectile points, similar to most goods, is indicative of either movement of peoples, or trade and exchange. To better identify how this style of lithic tool arrived at the Biderbost site, I examined the cultural dynamics of the Columbia Plateau. Semi-sedentary from 10,000 B.P. onwards (Sobel 2012; Ames & Maschner 1999), these groups were known to have migrated little, and traded often (Stern 1998; Walker 1997; Ames & Maschner 1999). The Columbia River area, especially in Southern Washington, is thought to have been an interregional exchange center for millennia (Stern 1998; Sobel 2006, 2012; Stapp 1984). The presence of these projectile point styles at the Biderbost site suggests regional contact, likely through trade, with groups in the Columbia Plateau.

Results from Lithic Tool Analysis: Adze blades

Thirteen portions of adze blades and at least one chisel were recovered from the site, composing just over 1% of the total lithic assemblage. Expertly manufactured, several of these adzes were in sharp contrast to the smaller, chipped stone tools in the assemblage. These adzes were ground-stone tools, and their blades likely required an enormous amount of skill and time commitment to manufacture.

The majority of these adzes were broken, with chipped edges or the blade split in two. Nearly all adzes, especially the heavily damaged ones, were excavated within midden features, suggesting their usefulness only declined after significant breakage. Because of this heavy utilization, these adzes were likely of great value to the occupants of the Biderbost site.

Five adzes were of ground-stone nephrite; no other tools from the Biderbost site were manufactured from this raw material. Nephrite is found primarily in British Columbia, with a few sources in Washington State. A single chisel made from serpentine was recovered as well, and is the only instance of serpentine at the site. As noted by Nelson (1962) and supported in this analysis, there was no evidence for a nephrite saw with which to manufacture these adzes.

OID	Object	Raw Material	Unit	Surface Depth	Excavated Layer (in inches)	Layer Information
3511	Adze Blade	Nephrite	F20 R15			
4094	Adze Blade	Nephrite	F21 R15	21	18-24	Midden
4169	Adze Blade	Nephrite	F21 R15	29	24-30	Midden
4383	Adze Blade	Nephrite	F19 R15	39	36-42	Midden
67	Adze Blade	Nephrite	10.5R3	48	48-54	
174	Chisel	Serpentine	8R1	49	48-54	Beach

Table 2: Adze Blades and Chisel information available.

Discussion of Lithic Analysis Results: Adze Blades

Nephrite only appears at the Biderbost site with a few adze blades. These nephrite adzes excavated from the Biderbost were part of the site's few ground-stone tools, and Nelson (1962) estimated these tools required an immense amount of skill and time to manufacture.

Nephrite is a beautiful raw material, well suited for ground-stone tool production (Kostov 2005). Due to the amount of skill required and aesthetically pleasing quality of nephrite adzes, these tools were a common trade good in the Pacific Northwest. Around this area in particular, high-quality nephrite stone is found along the gravel bars of the Fraser River (Binford 1965, Hayden and Schulting 1997). Their manufacture required an enormous amount of skill, and potentially functioned more as prestige rather than practical technologies (Hayden 1998; Prentiss et al. 2007). In a region of fairly high-quality raw materials, the manufacture of nephrite adzes were for personal, economic gain (Rousseau 2004: 18).

Nephrite adzes were frequently traded across the Pacific Northwest, especially around 2000 B.P., and played a major role in the interaction sphere of the region (Binford 1965, Hayden and Schulting 1997). The manufacture of these adzes may have required a complex settlement system which allowed over 100 hours to be dedicated to their production (McIlwraith 1992, Hayden and Schulting 1997: 71). However, there is no evidence for their production at this site and no nephrite saws were excavated.

Instead, these nephrite adzes and single serpentine chisel were likely traded into the site. Especially later in prehistory—potentially 2000 B.P. when the Biderbost site was known to have been settled—trade centers existed in the Pacific Northwest, including the Fraser River region where high-quality nephrite was plentiful. These nephrite adzes and serpentine chisel may have been part of the lithic industry of later occupations at the Biderbost site. There is evidence that these tools were trade into the site rather than manufactured there, potentially indicating a later-period complex settlement capable of large-scale interaction, with social stratification.

A number of lines of evidence suggest that the occupants of the Biderbost site were involved with regional populations. The highly unique and variable tool styles suggests a variety of cultural influences on the lithic industry present at the Biderbost site, particularly in the projectile points, nephrite adze, and serpentine chisel.

Introduction to PXRF Project:

To expand upon this research and explore the likelihood of trade, I sourced the Biderbost obsidian using an elemental composition analysis. Although geochemical sourcing alone cannot give direct evidence for trade and/or migration in the Pacific Northwest, used in combination with an analysis of obsidian tools, it may help unravel how obsidian arrived at the Biderbost site. Additionally, the region of origin for this raw material may further relate the occupants of the Biderbost to particular regional groups.

Portable X-Ray Florescence:

Portable X-Ray Florescence is a non-destructive method to analyze elemental composition, making it popular among archaeologists. Samples require minimal preparation and measurements are taken quickly and accurately. The procedure is cost-effective, and the machine is highly portable, transforming any space into a laboratory. PXRF was initially met with skepticism, and archaeologists were largely unsure of its abilities to analyze and source obsidian, though further testing proved it was sufficient (Speakman 2012; Shackley 2012; Craig 2007).

PXRF has found its way into a variety of fields in archeology and has assisted in the analysis of the elemental compositions of ceramics, soil, basalt, and obsidian. With ceramics, archaeologists have analyzed the chemical compositions of sherds to determine the similarity in composition (Bennett and Oliver 1992; Papadopoulou et al. 2006; Speakman et al. 2011; Forster et al. 2011). PXRF also assists in analyzing soil compositions, and archaeologists have had great success identifying areas of ancient mining and activity areas (Jang 2010; Sandu et al. 2012). Attempts have been made to source basalt artifacts using PXRF (Latham et al. 1992; April and

Keller 1992; Piazza and Pearthree 2001), although no raw materials are as effectively analyzed as obsidian (Craig et al. 2007; Phillips and Speakman 2009). PXRF analysis and identification of obsidian sources have helped identify trade routes, migration patterns, and raw material use change over time (Nazaroff et al. 2010; Tykot 2010; Forster and Grave 2012).

PXRF samples rarely require extensive preparation, and must meet simple parameters. Samples must be taken on a section of the object free of obvious contaminants (i.e. paint, dirt). For an accurate reading, samples must be at least 100µ thick (Malainey 2010: 483).

X-Ray Florescence Spectrometry uses X-Rays to excite specific atoms. Primary X-Rays from the machine cause the release of secondary X-Rays which are analyzed and measured. When X-Rays reach and penetrate the atoms of particular elements, the inner shell electrons absorb the primary X-Rays and are ejected. This instability causes the outer shell electrons to fill these inner shell vacancies. Those falling electrons then emit energy in the form of secondary X-Rays. This energy from the secondary X-Rays corresponds directly to the energy difference between the outer and inner shell electrons (Malainey 2010: 481-483)..

These secondary X-Rays have varying wavelengths, meaning multiple peaks can appear in the data. The intensity of these secondary rays relates to the amount of the element in the sample. Results for PXRF analyses will illustrate the intensity of elemental composition as a peak in the data. PXRF software will display these peaks along a Y-Axis, and the energy and wavelength of the secondary X-Rays are along the X-Axis. Quantification of this elemental data often requires calibrations and corrections for proper analysis (Malainey 2010: 481-483).

Compton Scatter: Also referred to as inelastic or incoherent scattering, Compton Scatter can create peaks in the data unrelated to density of elemental composition. When an X-

Ray photon collides with a loosely bound outer electron, a small portion of the primary photon's energy is deflected. This creates a wavelength detected by the PXRF machine and software. This wavelength only indirectly illustrates elemental concentrations. With Compton Peaks, there is a fixed wavelength difference between the elemental peak and the Compton Peak. The amount of element present will be reflected in its corresponding Compton Peak. In this PXRF machine in particular, the Compton peak is produced by Rhodium. The amount of Compton Scatter varies with time, meaning normalizing data to a Compton Scatter is the same as normalizing data to their length of time samples were analyzed for (Shackley 2011: 23). This project utilized the Compton Scatter of samples to normalize for time, making them comparable to one another.

PXRF and Obsidian: Obsidian, an igneous rock often referred to as "volcanic glass", is a highly homogenous substance that forms under high heat. Due to its homogeneity and use in Hunter-Gatherer societies, obsidian is ideally suited for PXRF analysis. Elements are present in consistent and reliable amounts across geographic regions. Obsidian's composition is unique to regions and volcanic sources—similar to a geographic fingerprint. The elements most commonly used to source obsidian in PXRF analyses include Rubidium (Rb), Strontium (Sr), Zirconium (Zr), Yttrium (Y), Niobium (Nb), Iron (Fe), Copper (Cu), and Zinc (Zn) (Malainey 2010; Shackley 2011).

Closest Obsidian Source to the Biderbost Site: A number of obsidian sources exist throughout Washington State, Oregon, British Columbia, and surrounding provinces, however no sources exist within 100 kilometers of the site. Nearly all Washington obsidian is thought to be low quality, and largely unused for tool manufacture. The closest source, at around 110 kilometers is Agnes Creek, is not only lacking in quality, it would also require travelling through, or around the Cascade Mountains (Figure 8).

Figure 8: Map of the Washington State obsidian sources with Biderbost Site (red). Adapted from the Northwest Research Obsidian Studies Laboratory.

Methods for PXRF Analysis:

This project analyzed four pieces of obsidian from the Biderbost site (Table 3). While the site had a number of microblades and smaller tools made from obsidian, only four pieces met the necessary size qualifications for a PXRF analysis. These four pieces were thick enough for the study, and their on-object ID label was located far enough away from the machine's reader to ensure the Tracer only analyzed the composition of the obsidian.

Object ID	**Tool Type**	**Unit**	**Surface Depth**	**Excavated Layer (in inches)**	**Layer Information**
425	Scraper	9R1		0-12	
883	Biface	N15E20[3]	49	48-54	
3082	Projectile Point	F24R8		43-49	
4273	Blade	F16R15	22	18-24	Midden

Table 3: Biderbost obsidian analyzed and their excavated location.

These four tools were found at various depths across the site. Unfortunately, due to the incomplete site records and inability to identify provenance of objects, there is no discernable temporal relationship between these tools. No obsidian tool had evidence of extensive wear, although *Object ID: 4273* was found in a midden deposit. When tools are discarded prior to their exhaustion, this often suggests the raw material and/or tool is not of great value to the group.

[3] Unit not recorded; North and East coordinates provided instead

These four obsidian tools were analyzed using a Bruker Tracer IV Portable X-Ray Florescence Machine in the Archaeology Lab at the University of Pittsburgh. Each sample was measured for 90 seconds, using a green filter with a voltage of 40 kV and current of 35µA. This allows the Tracer to perform a trace element analysis as appropriate for obsidian. The measured spectra were uploaded into the Bruker Artax software to identify and compare their elemental composition (Figure 9).

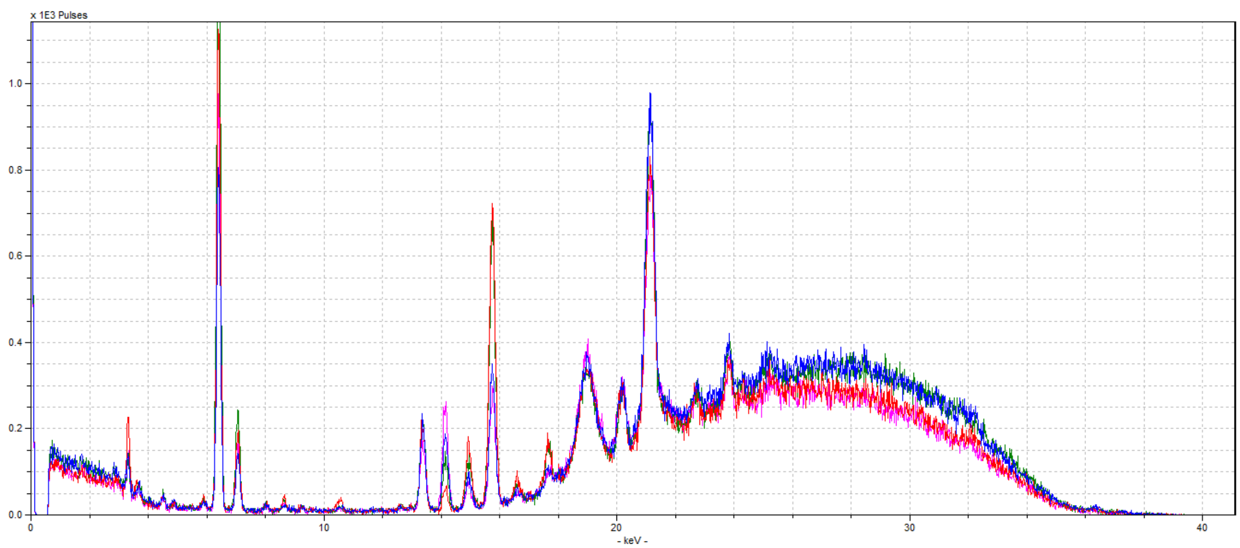

Figure 9: Biderbost spectra displayed in Artax software;

Object ID: 425: red, *Object ID: 883*: green, *Object ID: 3082:* blue, *Object ID: 4273:* pink.

This analysis followed the parameters suggested by Bruker instruments; for comparing samples to potential obsidian sources, I relied upon the raw net amounts of elements as designed by their photon counts. Biderbost obsidian was compared to thirteen samples of popular obsidian sources from the Pacific Northwest as measured by Bruker (Table 4).

The majority of these sources are in Oregon, the region Nelson suggested as the origin of Biderbost obsidian (Nelson 1962). Several sources in Idaho were included as well to identify any potential relationships between the Biderbost site and populations to the east—the area of the Columbia Plateau. If Biderbost obsidian originated at any of these popular Idaho sources, this may further support the site's connection to groups in the Columbia Plateau. No Washington obsidian samples were included in this analysis due to the low quality of the state's obsidian sources. Washington obsidian was rarely used by hunter-gatherer societies, and as described by the Northwest Research Obsidian Studies Laboratory, "Washington suffers from a shortage of artifact-quality obsidian sources and it's no surprise that four of the five top sources represented among Washington artifacts are located in Oregon" (Skinner 2010). Frankly, Washington state obsidian is so unpopular that few standards exist for its sources.

Two additional sources from far outside the Pacific Northwest were included in the analysis for validation (Table 5). These samples were analyzed using a Bruker tracer and the same parameters of my study, eliminating any outside sources of error.

Big Southern Butte, Idaho
Burns Green, Oregon
Cannonball, Idaho
Chickahominy, Oregon
Cougar Mountain, Oregon
Glass Buttes, Oregon
Gregory Creek, Oregon
Inman Creek, Oregon
Obsidian Cliffs, Oregon
Timer Butte, Idaho
Tucker Hill, Oregon
Whitewater Ridge, Oregon
Witham Creek, Oregon

Table 4: Bruker samples of popular obsidian sources from the Pacific Northwest

El Paraiso, Mexico
Zacualtipan, Mexico

Table 5: Bruker samples of obsidian sources from outside the Pacific Northwest used to test for error.

Normalization: These fifteen samples provided by Bruker were each analyzed for 1205 seconds, significantly longer than the 90 seconds for the Biderbost obsidian. Because of this, the elemental raw data of these Bruker samples were represented in higher concentrations (Figure 10).

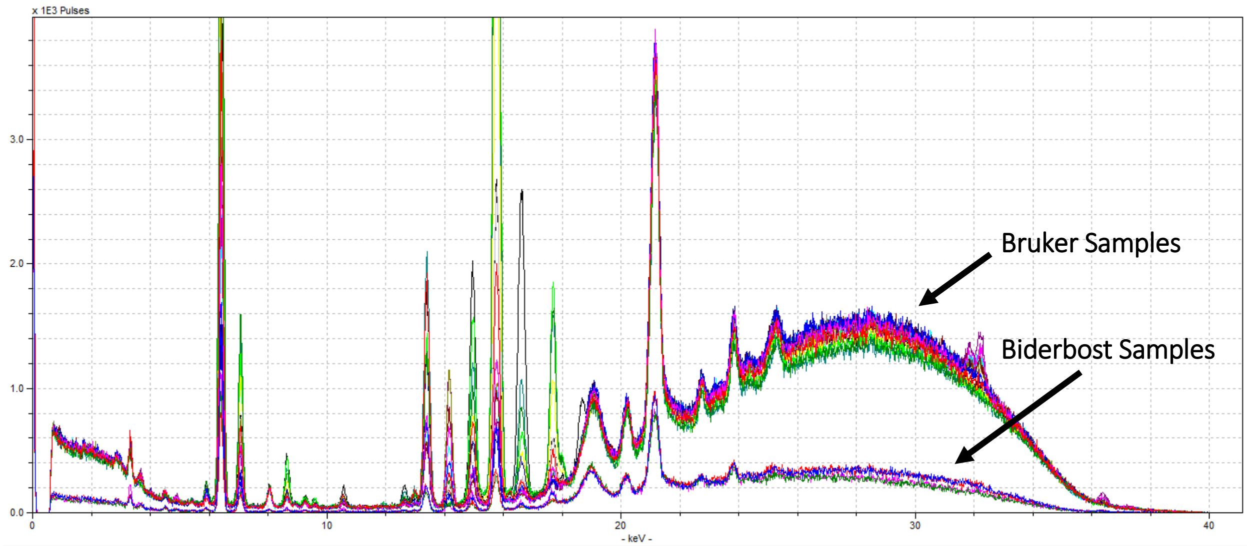

Figure 10: Spectra from Bruker and Biderbost samples before normalization, indicating the higher concentrations of elements in Bruker samples taken over a longer period of time.

To make the Biderbost data and Bruker data comparable, all samples had to be normalized to a common factor (Figures 11 & 12). The normalization process involves matching one specific peak on each spectra. For greatest accuracy, every sample was normalized on the same scale. Two separate methods for normalization are recommended by Bruker (Lee, *XRF Guru)*; both were performed to ensure obsidian was sourced properly. Two specific points in the spectra were chosen and equalized.

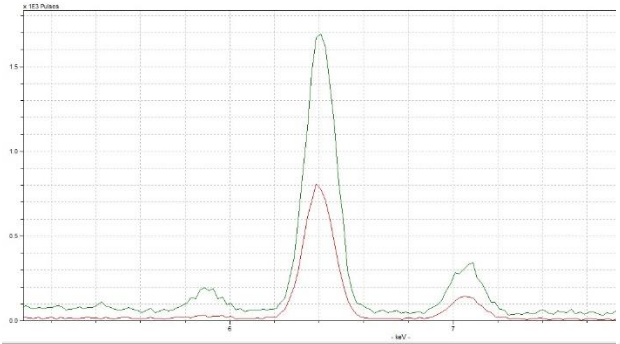

Figure 11: Two spectra before normalization

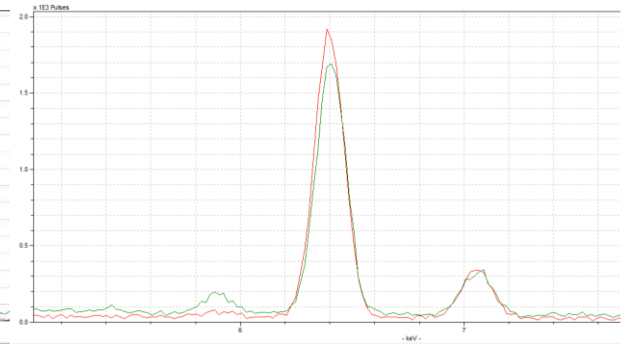

Figure 12: Two spectra after normalization with matching Fe peak

This is an example of how normalization equalizes to peaks to one another as determined by a particular element of wavelength. This example normalized to the Iron peak as it is a particularly obvious change; my analysis in particular normalized to the Rhodium and Compton Peaks.

1. Compton Peak (Figure 13): For most PXRF analyses, the Compton peak is found at 18.5 keV. As described earlier, the Compton peak is a false peak, caused by the elastic scatter of Rhodium. The amount of this scatter is determined by the length of time these samples were analyzed (Lee, *XRF Guru*). Because the Compton peak is an indicator for time and does not directly impact the elements needed for obsidian analyses, it can serve as a reference across all samples.

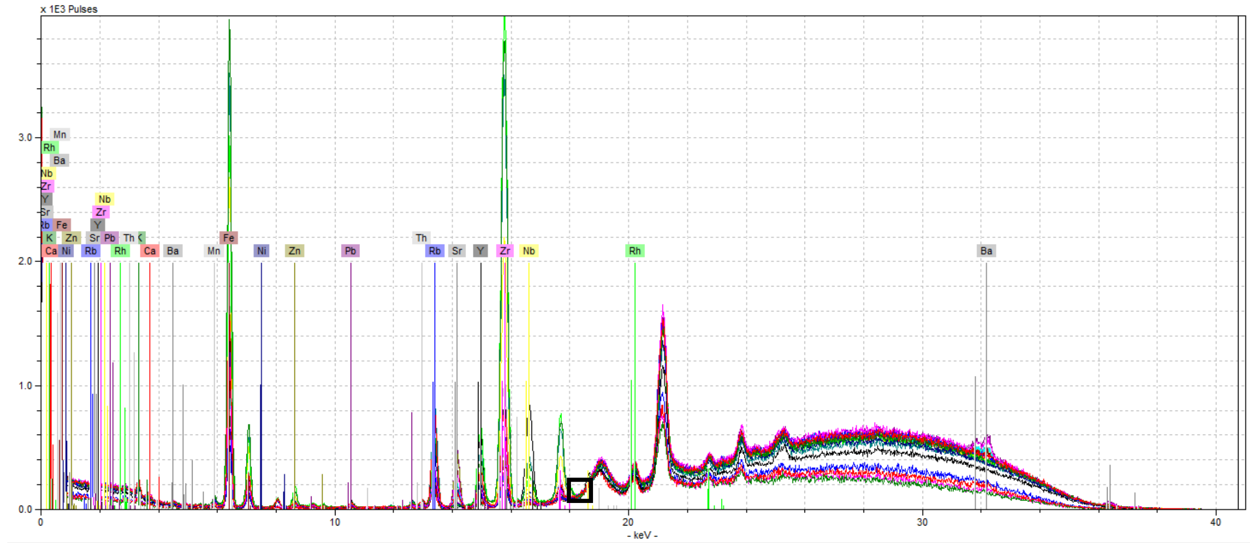

Figure 13: All Bruker and Biderbost spectra after normalizing to the Compton Peak (area indicated)

2. Rhodium (Figure 14): Rhodium is not present in these obsidian samples, but appears in the spectra since Rhodium is present within the Tracer and is read by the machine's software. Because the Rhodium measured is from the Tracer rather than the sample, the amount of Rhodium measured is roughly equivalent to the length of time samples were analyzed. Normalizing to Rhodium creates a way to compare all samples regardless of their length of time analyzed.

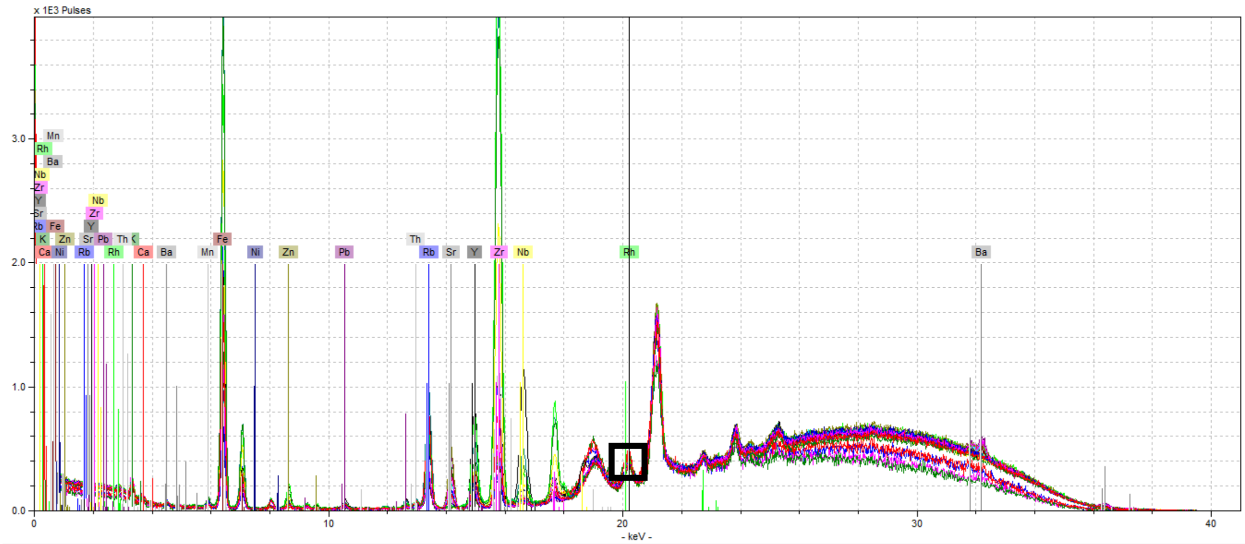

Figure 14: All Bruker and Biderbost spectra after normalizing to the Rhodium peak (area indicated)

The intersection point for each peak described above was made equal to one another. This process of normalization made all samples comparable (Lee, *XRF Guru*).

Elemental Composition:

This research utilized a strictly quantitative method for comparing this obsidian due to the small sample size; this approach allows for a close examination of the similarities between obsidian. We can represent each piece of obsidian as a vector of representative features computed from the raw element amounts. In line with prior research (Kobayashi et al., 2016: 179; Richardson et al. 1976: 111), we choose the following features, which are typically used for obsidian analyses due to their prevalence in obsidian and their variation in geographic origin:

A. $RbRatio = \frac{Rb \times 100}{Rb+Sr+Y+Zr}$

B. $SrRatio = \frac{Sr \times 100}{Rb+Sr+Y+Zr}$

C. $Mn/Fe = \frac{Mn \times 100}{Fe}$

To identify the most likely source for each sample, we use a distance functions to compute the distance between the sample vector and each source vector. Then, we choose the source with the lowest distance (most similar) as the most likely. We compute the distance using two standard distance functions: Euclidean Distance and Mean Absolute Error.

Euclidean Distance:

$$d(sample, source) = \sqrt{\sum_{i=1}^{n}(sample_i - source_i)^2}$$

$$d(sample, source) = \sqrt{\left(RbRatio_{sample} - RbRatio_{source}\right)^2 + \left(SrRatio_{sample} - SrRatio_{source}\right)^2 + \left(Mn/Fe_{sample} - Mn/Fe_{source}\right)^2}$$

Mean Absolute Error:

$$d(sample, source) = \frac{1}{n}\sum_{i=1}^{n}|q_i - p_i|$$

$$d(sample, source) = \frac{1}{3}\left(\left|RbRatio_{sample} - RbRatio_{source}\right| + \left|SrRatio_{sample} - SrRatio_{source}\right| + \left|\left(Mn/Fe_{sample} - Mn/Fe_{source}\right)\right|\right)$$

These measures of similarity were used to identify the most likely source of the Biderbost obsidian.

Results of pXRF Analysis:

Below are the results of the formulated net elements after calculating their Euclidean Distance and Mean Average Error. The smaller the differential, the more similar the elemental composition and the higher the chance that the Biderbost obsidian originated from the particular source.

The highlighted sources are those with the smallest differential in elemental net composition between the Biderbost obsidian and Bruker obsidian samples.

Computed Euclidean Distance

Biderbost Obsidian	Big Southern Butte	Burns Green	Cannonball	Chickahominy	Cougar Mountain	El Paraiso	Glass Buttes	Gregory Creek
OID: 425	10.658	10.926	5.208	**2.287**	9.253	9.866	22.193	46.646
OID: 883	14.512	14.844	11.294	7.254	**6.514**	14.117	16.732	40.221
OID: 3082	26.443	32.796	29.062	25.264	15.802	32.149	3.081	25.737
OID: 4273	38.788	41.246	39.272	35.169	27.631	40.943	15.599	13.123

	Inman Creek	Obsidian Cliffs	Timber Butte	Tucker Hill	Whitewater Ridge	Witham Creek	Zacualtipan
OID: 425	39.604	33.724	40.851	27.462	22.898	9.602	23.567
OID: 883	33.135	27.294	41.345	24.090	17.115	13.954	23.914
OID: 3082	19.347	12.562	38.763	14.111	**1.179**	32.025	24.838
OID: 4273	6.572	**0.878**	49.653	24.510	13.804	40.852	37.477

Table 6: Computed Euclidean Distance of results from samples normalized by the Compton Peak following PXRF analysis; smallest distance highlighted, representing likely source for obsidian sample

Computed Mean Absolute Error

Biderbost Obsidian	Big Southern Butte	Burns Green	Cannonball	Chickahominy	Cougar Mountain	El Paraiso	Glass Buttes	Gregory Creek
OID: 425	4.963	4.914	2.643	**0.880**	4.419	4.874	10.406	17.672
OID: 883	6.979	7.028	4.756	3.169	**2.335**	6.988	8.293	15.559
OID: 3082	8.973	15.318	13.046	11.490	6.324	15.278	1.669	11.837
OID: 4273	14.670	18.039	15.767	14.004	9.717	17.999	6.996	6.140

	Inman Creek	Obsidian Cliffs	Timber Butte	Tucker Hill	Whitewater Ridge	Witham Creek	Zacualtipan
OID: 425	14.117	12.740	16.520	14.207	10.130	4.463	8.710
OID: 883	12.004	10.627	18.729	12.094	8.017	6.576	9.797
OID: 3082	8.986	5.732	20.754	7.519	**0.582**	14.866	11.792
OID: 4273	3.290	**0.440**	26.082	12.847	5.823	17.587	17.488

Table 7: Computed Mean Absolute Error of results from samples normalized by the Compton Peak following PXRF analysis; Smallest error highlighted, representing likely source for obsidian sample

Computed Euclidean Distance Biderbost Obsidian	Big Southern Butte	Burns Green	Cannonball	Chickahominy	Cougar Mountain	El Paraiso	Glass Buttes	Gregory Creek
OID: 425	10.57946806	10.96477186	5.076558397	**2.291092715**	9.249215199	9.815846304	22.51661955	47.35370031
OID: 883	14.40556673	14.85415911	11.15579262	7.281300204	**6.643797433**	14.01328295	17.12124863	40.91735154
OID: 3082	26.52099628	33.09798765	29.20847446	25.57598595	16.15662419	32.33024454	3.216161466	26.18933991
OID: 4273	39.08329224	41.72170857	39.60818714	35.67987177	28.22022901	41.29555332	16.06548496	13.3046036

Computed Euclidean Distance Biderbost Obsidian	Inman Creek	Obsidian Cliffs	Timber Butte	Tucker Hill	Whitewater Ridge	Witham Creek	Zacualtipan
OID: 425	41.48413822	35.15968165	41.48259852	27.59259798	23.25351298	9.562209289	23.61805193
OID: 883	35.01224422	28.7396796	42.00938999	24.13685831	17.50061765	13.85501976	23.98959069
OID: 3082	20.63245583	13.39551108	39.36327212	13.7130562	**1.096300748**	32.21450295	24.96751662
OID: 4273	7.522795098	**0.305539814**	50.46977271	24.35598453	14.08676367	41.20816607	37.85764155

Table 8: Computed Euclidean Distance of results from samples normalized by the Rhodium Peak following PXRF analysis; smallest distance highlighted, representing likely source for obsidian sample

Computed Mean Absolute Error Biderbost Obsidian	Big Southern Butte	Burns Green	Cannonball	Chickahominy	Cougar Mountain	El Paraiso	Glass Buttes	Gregory Creek
OID: 425	4.920686424	4.927214557	2.582170547	**0.903164407**	4.358673736	4.831517876	10.52674501	17.88280259
OID: 883	6.953598516	7.046086437	4.701042427	3.152886993	**2.357692822**	6.950389756	8.407873128	15.76393071
OID: 3082	9.041655002	15.45759094	13.11254694	11.6337045	6.414241803	15.36189426	1.748973417	11.94401197
OID: 4273	14.7340705	18.2541068	15.90906279	14.23005665	9.967398531	18.15841012	7.159581479	6.141700681

Computed Mean Absolute Error Biderbost Obsidian	Inman Creek	Obsidian Cliffs	Timber Butte	Tucker Hill	Whitewater Ridge	Witham Creek	Zacualtipan
OID: 425	14.95630071	13.37041903	16.73720358	14.19463021	10.30150264	4.419341049	8.743926171
OID: 883	12.83742883	11.25154715	18.94334181	12.07575833	8.142758644	6.538212929	9.866123598
OID: 3082	9.33110703	5.870328675	20.99081551	7.265226792	**0.471412897**	14.94971744	11.84428429
OID: 4273	3.52879574	**0.143907903**	26.40142358	12.67583485	6.032018098	17.74623329	17.64659558

Table 9: Computed Mean Absolute Error of results from samples normalized by the Rhodium Peak following PXRF analysis; Smallest error highlighted, representing likely source for obsidian sample

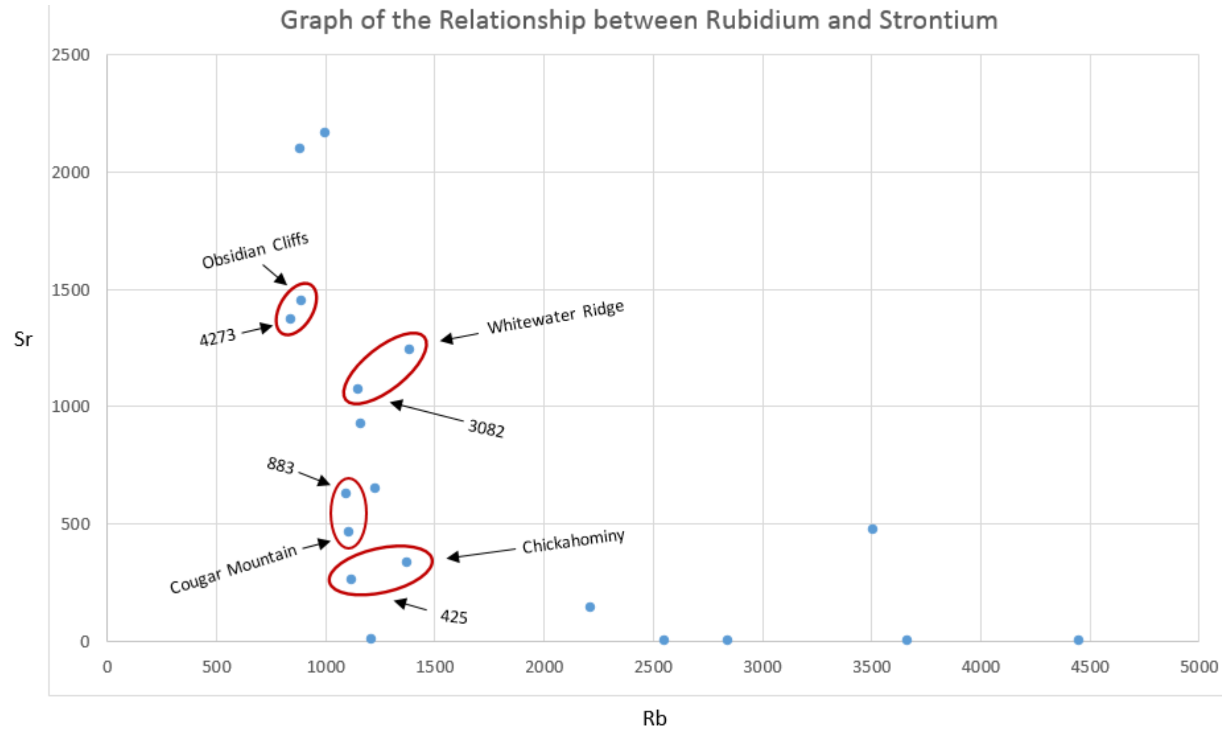

Figure 15: Graph illustrating the direct relationship between Rubidium and Strontium photon counts per sample; those samples with similar ratios of Rubidium to Strontium are indicated by the red circle grouping them; these results support the data in the tables shown above (Table 1&2).

While the exact data varied between the two normalization methods (Figures 13 & 14), their overall results were the same (Tables 6, 7, 8, 9). As expected, the results from both normalization methods of El Paraiso and Zacultipan were very different from the other Pacific Northwest sources.

The quantitative results in Tables 1 and 2 are further supported by the graphic representation in Figure 15. Often, archaeologists have relied upon such scatterplots to identify similarities between large numbers of samples; representing relationships in this way makes large quantities of data more manageable. This analysis had relatively few samples from obsidian sources. This could potentially become an issue if samples were not exemplary of their sources. However, using such few samples allows relationships to be studied in greater depth. Computing the Euclidean Distance and Mean Average Error directly compares the net elemental results from each sample to each source, quantifying their similarity. The origins of the Biderbost obsidian are suggested by this analysis.

Origins: All four Biderbost samples appear to have originated in Oregon (Figure 16), ranging from a distance of 400-515 kilometers away (Table 10).

Object ID: 425 (OID: 425): The source with the closest net elemental results to *OID: 425* is Chickahominy, Oregon. The Chickahominy reservoir, in Harney County, is located in a region of many obsidian sources, around 515 kilometers southeast of the Biderbost site. Travelling this distance requires crossing the Cascade Mountain range and passing through portions of Oregon's Blue Mountains.

Object ID: 883 (OID 883): The source from these examples with the closest net elemental results to *OID: 883* is Cougar Mountain, Oregon. Cougar Mountain, in Lake County, is just over 480 kilometers southeast of the Biderbost site, a distance that additionally requires crossing the Cascade Mountain range.

Object ID: 3082 (OID: 3082): The source with the closest net elemental results to *OID: 3082* is Whitewater Ridge, Oregon. Both tests conclusively showed strong similarities in the elemental composition of the Whitewater Ridge sample and *OID: 3082*. Whitewater Ridge is located in Grant County, Oregon, just under 490 kilometers southeast of the Biderbost site. Travelling this distance requires crossing the Cascade Mountain range and passing through portions of Oregon's Blue Mountains.

Object ID: 4273 (OID: 4273): The source with the closest net elements results to *OID: 4273* is Obsidian Cliffs, Oregon. The results from the Biderbost obsidian sample and Obsidian Cliffs' sample were strikingly similar in both tests. Obsidian Cliffs, in Lane County, lies along the eastern portion of the Cascade Mountain, around 400 kilometers south of the Biderbost site.

Biderbost Obsidian	Source	Location	Distance from Biderbost Site
OID: 425	Chickahominy	Harney County, Oregon	515 kilometers
OID: 883	Cougar Mountain	Lake County, Oregon	480 kilometers
OID: 3082	Whitewater Ridge	Grant County, Oregon	490 kilometers
OID: 4273	Obsidian Cliffs	Lane County, Oregon	400 kilometers

Table 10: Biderbost Obsidian Sources.

Figure 16: Sources of Biderbost Obsidian: *OID: 425* (yellow), *OID: 883* (green), *OID: 3082 (blue), OID: 4273* (red). Adapted from the Northwest Research Obsidian Studies Laboratory.

Obsidian Procurement:

These results suggest that the Biderbost obsidian originated several hundred kilometers away. Interestingly enough, this data does not further relate the Biderbost site occupants to previously identified groups. No lithic traditions present at the Biderbost site were related to any groups to the South, where this obsidian appears to have originated from. These four potential sources in central Oregon are the first piece of evidence relating the Biderbost site to this region.

The original research question regarding the mobility of the site's occupants is explored through this PXRF analysis. A large amount of research exists regarding obsidian sourcing through PXRF and how to identify obsidian procurement strategies through the results (Chia 2014; Eerkens 2008; Gratuze 1999). Certain qualifications must be met to identify whether a group obtained obsidian directly, or through trade and exchange. Obtaining obsidian directly from these potential sources in Oregon would require high mobility, while trade of this raw material would indicate a complex settlement system, capable of trading over hundreds of kilometers.

The following models below were synthesized by Roth (2000), as based upon the archaeological studies of Shackley (1990, 1996), Morrow & Jeffries (1989), and Mitchell & Shackley (1995). Shackley (1990, 1996), and Morrow & Jeffries (1989) analyzed the mobility patterns of peoples in the American Southwest, comparing obsidian tool use with obsidian origin, to identify how the raw material arrived at each site. The ideas presented below are additionally based upon the lithic-use in settlement systems ideas of Binford (1979), Bamforth (1986), Parry & Kelly (1987), and Shott (1986). This is simplified below in Figure 17.

> *Nearby Procurement:* The distance from site to source has obvious implications for how mobile a population is. In settlements close to obsidian sources, direct procurement is evident through a large amount of obsidian cores, cortex, and pieces exhibiting early-stage reduction. In these cases, obsidian is easy to obtain and present in large quantities at these sites. Travelling over shorter distances means obsidian cores can remain large and bulky—

something which would be a great hindrance over many kilometers. Since obsidian is easy to obtain, there is less pressure to conserve its use, and cores, preform tools, and cortex are commonly seen.

Specialized Procurement: Through Specialized Procurement, groups target far-away obsidian sources specifically to harvest the raw material. Obtaining obsidian directly over greater distances is evidenced by reduced cores or bifaces to facilitate transport. Small debitage is common at settlements as tools are retouched—rather than replaced—to conserve obsidian use. The distance from site to source largely determines the value of this raw material within a group. The value of obsidian is generally identified through its use-patterns; which tools are made from obsidian is the clearest indicator of value. If all tools are made using a variety of raw materials—including obsidian, then there is little preference given to this lithic material.

Embedded Procurement: A more complex model is when obsidian procurement is embedded in the procurement of other resources (Binford 1996). As an example, Shackley (1990, 1996) related the presence of obsidian at Archaic sites in the Southwest to the hunting of game and gathering pinon in the fall. If this is the case, obsidian procurement was of secondary importance to the population's hunting and gathering needs, with sources visited as a mere stop along the way. Embedded Procurement obsidian tools take the form of reduced cores and bifaces, as the process often involves significant mobility. There is little evidence for specialized tool use with obsidian obtained through Embedded Procurement patterns; through Embedded Procurement, obsidian has not been the only resource obtained, and populations often reflect this in their manufacture and use of tools. Obsidian is used for a variety of tool types, and there is no significant recycling of raw material.

Procurement by Trade: Obsidian is often traded as finished products or preforms. At sites with traded obsidian, there is little evidence for tool production and the small amount of debitage reflects re-sharpening. Traded tools are highly valued, with specialized use. Recycling traded tools and raw materials is common and tools are only discarded once they are fully exhausted. The more complex or long-distance the trade network, the more these characteristics appear in the archaeological record.

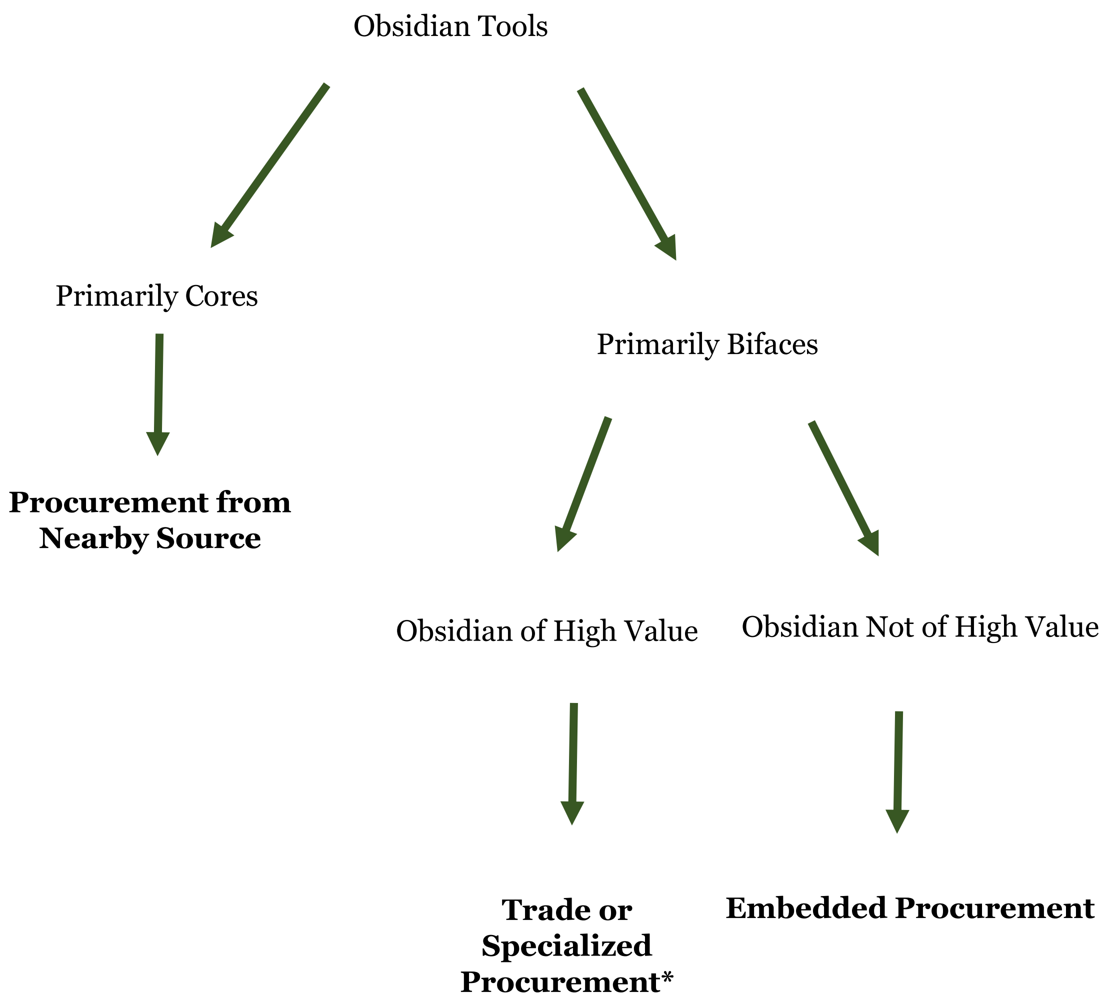

Figure 17: Obsidian Tools and Tool Use for Identifying Procurement Strategies

*Outside factors other than Obsidian Use would further identify Trade or Specialized Procurement

Discussion of All Results:

Nephrite Adzes: Nephrite adzes, and their intensive methods of manufacture, stimulated social complexity in the Pacific Northwest (Ames 1995, Morin 2012; Rousseau 2004). Regional trade centers developed in later prehistory, and the possession of these goods became a form of wealth (McIlwraits 1992). Their presence at the Biderbost site and lack of evidence for manufacture there suggests that the occupants of the site traded for these goods (Figure 18).

If the occupants of the Biderbost were involved in trade, this would require them to have been socially complex and stable enough to acquire goods for prestige rather than functionality (Hayden 1998). Populations involved in this socially-complex network of adze trade generally practiced residential mobility. These settlements tended to be more permanent, and populations relied on more local subsistence strategies, rather than embarking on long-distance procurement of resources.

Projectile Points: The Columbia Plateau-style projectile points from the Biderbost site may additionally indicate trade between these groups. The peoples of the Columbia Plateau were well known to have been sedentary and involved in regional trading in the millennia before these styles of lithic industry appeared (Ames & Maschner 1999; Sobel 2012). While these types of projectile points may not have been as prestigious trade goods at nephrite adzes, the trade network of the Columbia Plateau suggests interaction through exchange between these groups and the occupants of the Biderbost site.

Obsidian: No obsidian cores were excavated at the Biderbost site; all obsidian was manufactured into a variety of handheld tools, and the few obsidian flakes recovered suggests tools were not manufactured at the Biderbost site. This supports the PXRF results that these obsidian sources originated a long distance away from the site. The obsidian from the Biderbost site, both tested and untested tools, were present in a variety of forms. Aside from the microblades—which are difficult to manufacture in other raw materials—no tool type was more partial to obsidian than others. Unfortunately, it is not especially clear whether obsidian arrived at the Biderbost site through direct procurement or trade. Evidence exists for both potential scenarios, and possible solutions are addressed below.

Figure 18: Map of all areas related to the lithic industry of the Biderbost Site. Fraser river region of adze manufacture and trade highlighted in green. Columbia Plateau highlighted in orange. Biderbost site indicated by yellow star and all obsidian sources indicated by colored triangles.

Embedded Procurement and Logistical Mobility: While Nelson (1962) had believed that this obsidian was traded into the Biderbost site, possibly from a source in Oregon, a further analysis of Biderbost obsidian origins and use patterns do not solely support this possibility. The value given to obsidian by the occupants of the Biderbost site is not entirely known, and evidence exists for it having been highly valued, and not highly valued. Tools were discarded before their potential was fully exercised and there was little recycling of tools at the Biderbost site. Additionally, biface *OID: 883* was the largest obsidian tool at nearly 4 inches in length, and largely intact. If this tool had been traded into the Biderbost site, I would expect it to have been highly valued, and not to have been left behind. Those obsidian tools found in middens at the site had little evidence for wear, and no tools were entirely exhausted.

Four independent sources are represented within the Biderbost assemblage, and the distance between site and source suggests that directly obtaining this resource was a large commitment. If this raw material was traded into the site, this could require up to four independent trade routes, meaning the Biderbost site was an immensely complex settlement.

These four sources and potential evidence for obsidian's low value support the possibility that obsidian was procured by the occupants of the Biderbost, rather than traded into the region. It is possible that procurement was embedded within other activities which required mobility, meaning the occupants of the Biderbost practiced more logistical mobility. These populations may have migrated across the region, following game or in search of particular resources, and temporarily settled at the Biderbost site, leaving behind occasional obsidian remains.

Trade and Residential Mobility: Obsidian is the highest quality raw material across the Pacific Northwest and at the Biderbost site. Frequently known as an article of trade (Gratuze 1999; Cobean 1971; Furukawa 2013), obsidian has crossed thousands of kilometers in prehistory, passing through the hands of communities. At the Biderbost site, obsidian comprises only 3% of all raw material tools, indicating it was not an easily acquired substance. The high-quality of obsidian and little remains found at the site indicate it was a highly-valued resources. No cores and few flakes were excavated, suggesting that finished tools arrived at the Biderbost.

This obsidian appears to have originated a few hundred kilometers to the south in Oregon. Three sources, Chickahominy, Cougar Mountain, and Whitewater Ridge are located within the Columbia Plateau region. As discussed earlier, several projectile points from the Biderbost site are similar to a style found in the Columbia Plateau region of Washington State, suggesting a relationship existed between these cultural groups. Perhaps the obsidian from this Columbia Plateau region of Oregon indicates trade between the Biderbost site and Oregon Columbia Plateau populations as well. Evidence for trade here may further suggest the occupants of the Biderbost site practiced residential mobility and had their goods come to them.

Conclusions:

An analysis of the Biderbost tools and the PXRF sourcing of obsidian expounds upon what function the Biderbost site served in the Pacific Northwest to understand more about the populations which settled there. The results of the stylistic analysis, focusing on the nephrite adzes and Columbia Plateau projectile points, suggest that the Biderbost site occupants were involved in regional trading. Biderbost obsidian tools may have arrived at the site in a similar way, indicating further trade relations with southern regions, or this obsidian may have been procured by the highly-mobile occupants of the site.

There are two conflicting lines of evidence here regarding the Biderbost obsidian: one solely suggesting a socially complex population with residential mobility, involved in regional trading, and another additionally implicating a highly mobile population procuring obsidian themselves. If the Biderbost obsidian was traded to the occupants of the site, this would expand upon the trade network of this population. Not only were populations within British Columbia and the Washington State Columbia Plateau interacting with this group, but populations with access to this Oregon obsidian were as well. This would indicate the Biderbost peoples had an enormously wide-ranging sphere of influence, or had multiple periods of occupation involving trade with different regions.

If the obsidian arrived at the Biderbost site through their own procurement, this may suggest a population with logistical mobility, travelling to obtain the necessary goods themselves. This then contradicts the evidence which indicates the presence of a socially-complex population with residential mobility involved in regional trade. There is additionally the potential that some of these obsidian tools were articles of trade, and others were procured directly.

Regardless, an analysis of the site's stratigraphy may bridge these models for Biderbost occupation. Nelson (1962) suggested that the strata of sterile silt between occupational layers at the Biderbost indicate periods of abandonment. If periods of abandonment occurred, this may reconcile the conflicting ideas presented above. Periods of abandonment would allow for multiple groups to have settled this site at different points in time. Mobile peoples may have migrated into the region, bringing obsidian from the south. Using the Biderbost site seasonally or temporarily, these populations may have left behind evidence for a number of cultural lithic styles and projectile points, before abandoning the site once again.

After periods of abandonment, another group may have been attracted to this fishing site, and settled more permanently. Perhaps over time this population became involved in regional trading, procuring or copying projectile point styles from the Columbia Plateau region, and trading for nephrite adzes from the north. These conflicting lines of evidence and evident periods of site abandonment present the possibility for multiple, individual populations having occupied the Biderbost site at various points in prehistory.

The populations settled at the Biderbost site were likely involved in large-scale regional trading with British Columbia, collecting nephrite adzes for social influence. This indicates Biderbost occupants were fairly socially-complex and interacting with groups across hundreds of kilometers. While the obsidian excavated by the Biderbost site originated in Oregon, whether it was procured directly or through further trade is unclear. Four independent sources were utilized, complicating the theory of trade and exchange, and potentially supporting the possibility that this obsidian was procured directly. These conflicting ideas of a highly-mobile population and a stable, socially-complex settlement existing at the Biderbost site is potentially ramified by the evidence for periods of abandonment in the soil.

The Biderbost site was evidently located within a great fishing area. A number of fishing weirs and hooks were excavated and the "toe" of the site was once a great place to catch fish and other estuarine life. There is the additional possibility that the Biderbost site was settled very briefly by populations. Rather than the site itself having functioned as a logistical or residential settlement, it may have been a base camp, or fishing camp for people in the area.

As populations in British Columbia and the Columbia Plateau were largely sedentary (Sobel 2012; Ames & Maschner 1999), a separate local population involved in trade with these groups may have utilized the Biderbost site for fishing, leaving remnants of their stay behind. The case is similar for populations involved in trade with Oregon or having migrated from the South who fished in the Snoqualmie River, and deposited obsidian tools there.

While there are a number of possibilities for how the Biderbost site was settled, and several of these were likely occurred at different points in time, the site itself evidently played a significant role on the social landscape of the Pacific Northwest. There is evidence for trade-goods likely originating in British Columbia and the Columbia Plateau, as well as new evidence linking the Biderbost populations to separate points in Oregon. The site may have been settled at different periods of time, intermittently, by settlements practicing residential and logistical mobility, and either trading for or self-procuring their resources. Additionally, the site may have functioned as a fishing camp, where regional groups utilized the embankment along the Snoqualmie River, leaving remnants of their material culture behind. The Biderbost site illustrates the variety of settlement strategies present in the Pacific Northwest, and provides an example of a well-trafficked area, full of vibrant and eclectic regional material culture.

Final Remarks:

This paper provides evidence for the success of relying upon a multi-scalar approach in archaeology. Early reports on the site and its excavation used in combination with a holistic lithics and PXRF analysis have pieced together the prehistory of the Biderbost site. Without using multiple methods of analysis, the issues arising from a lack of archaeological records have limited these results and conclusions.

While this research has illuminated more about the function of the Biderbost site and the mobility of its populations, much is still unknown. Another few seasons of excavation at the site could provide better data and clearer conclusions, and further work on the current assemblage will better explore the site. More accurate and holistic radiocarbon dating from separate portions of the site may provide a chronology and identify a timeline of events. Additionally, a more intensive qualitative analysis of projectile points may identify other cultural groups which once resided at the site. The Biderbost site has an immense amount of material culture, and further analyses can highlight the impact this site had on the populations of the Pacific Northwest.

References Cited:

Ames, Kenneth M.

1995 Chiefly power and household production on the Northwest Coast. In Foundations of social inequality. T. Douglas Price and Gary M. Feinman, eds. Pp. 155-187. New York: Springer US.

Ames, Kenneth M., and Herbert GD Maschner

1999 Peoples of the Northwest Coast: Their Archaeology and Prehistory. London: Thames and Hudson.

April, Richard H., and Dianne M. Keller

1992 Saponite and vermiculite in amygdales of the Granby basaltic tuff, Connecticut Valley. Clays and Clay Minerals 40(1): 22-31.

Bamforth, Douglas B.

1986 Technological efficiency and Tool Curation. American Antiquity 50(1): 38-50.

Barnett, Homer Garner

1955 The Coast Salish of British Columbia. Eugene: University of Oregon.

Bennett, Harry, and Graham J. Oliver

1992 XRF Analysis of Ceramics, Minerals and Allied Materials. Hoboken: Wiley.

Binford, Lewis R

1965 Archaeological Systematics and the Study of Culture Process. American Antiquity 31(2): 203-210.

Binford, Lewis R.

1979 Organization and Formation Processes: Looking at Curated Technologies. Journal of Anthropological Research 35(3): 255-273.

1980 Willow Smoke and Dog's Tails: Hunter-Gatherer Settlement System and Archaeological Site Formation. American Antiquity 45(1): 39-78.

Bettinger, Robert L., and Jelmer Eerkens

1999 Point Typologies, Cultural Transmission, and the Spread of Bow-and-Arrow Technology in the Prehistoric Great Basin. American Antiquity 64(2): 231-242.

Chatters, James C., Sarah K. Campbell, Grant D. Smith, and Phillip E. Minthorn Jr.

1995 Bison Procurement in the Far West: A 2,100-year-old Kill Site on the Columbia Plateau. American Antiquity 60(4): 751-763.

Chatters, James C.

2009 A Macroevolutionary Perspective on the Archaeological Record of North America. In Macroevolution in Human Prehistory. Prentiss, Anna, Ian Kuijt, James C. Chatters eds. Pp. 213-234 New York: Springer.

Chia, Stephen, Lee Anthony M. Neri, and Amalia De La Torre

2014 Obsidian Sourcing at Ulilang Bundok Site and its Implications for Mobility, Exchange, and Social Contexts in the Philippine Metal Age. Asian Perspectives 53(1): 97-115.

Cobean, Robert H.

1971 Obsidian trade at San Lorenzo Tenochtitlan, Mexico. Science 174(4014): 666-671.

Craig, Nathan, Robert J. Speakman, Rachel S. Popelka-Filcoff, Michael D. Glascock, J. David Robertson, M. Steven Shackley, and Mark S. Aldenderfer

2007 Comparison of XRF and PXRF for Analysis of Archaeological Obsidian from Southern Peru. Journal of Archaeological Science 34(12): 2012-2024.

Darwent, John

1996 The Prehistoric Use of Nephrite on the British Columbia Plateau. Dissertation Theses of Dept. of Archaeology, Simon Fraser University.

Eerkens, Jelmer W., Amy M. Spurling, and Michelle A. Gras

2008 Measuring Prehistoric Mobility Strategies Based on Obsidian Geochemical and Technological Signatures in the Owens Valley, California." Journal of Archaeological Science 35(3): 668-680.

Forster, Nicola, Peter Grave, Nancy Vickery, and Lisa Kealhofer

2011 Non-destructive Analysis using PXRF: Methodology and Application to Archaeological Ceramics. X-Ray Spectrometry 40(5): 389-398.

Forster, Nicola, and Peter Grave

2012 Non-destructive PXRF Analysis of Museum-Curated Obsidian from the Near East. Journal of Archaeological Science 39(3): 728-736.

Furukawa, Takumi

2013 Jomon Water Transportation of Obsidian and Volcanic Activity: Excavation and Analyses of the Yokoo Coastal Wetland Site, Japan. Journal of Wetland Archaeology 13(1): 71-90.

Galm, Jerry R.

1994 Prehistoric Trade and Exchange in the Interior Plateau of Northwestern North America. In Prehistoric Exchange Systems in North America. Baugh, Timothy G., Jonathon E. Ericson eds. Pp. 275-305.New York: Springer US.

Goldin, Alan, and James A. Mitchell

1992 Soil survey of Snoqualmie Pass area, parts of King and Pierce counties, Washington. Washington D.C.: Soil Conservation Service.

Gratuze, Bernard

1999 Obsidian Characterization by Laser Ablation ICP-MS and its Application to Prehistoric Trade in the Mediterranean and the Near East: Sources and Distribution of Obsidian within the Aegean and Anatolia." Journal of Archaeological Science 26(8): 869-881.

Hayden, Brian

1995 Pathways to Power. In Foundations of Social Inequality. T. Douglas Price and Gary M. Feinman, eds. Pp. 15-86. New York: Springer US.

1998 Practical and Prestige Technologies: The Evolution of Material Systems. Journal of Archaeological Method and Theory 5(1): 1-55.

Hayden, Brian, and Rick Schulting

1997 The Plateau Interaction Sphere and Late Prehistoric Cultural Complexity. American Antiquity. 62(1): 51-85.

Jang, Min

2010 Application of Portable X-Ray Fluorescence (pXRF) for Heavy Metal Analysis of Soils in Crop Fields Near Abandoned Mine Sites. Environmental Geochemistry and Health 32(3): 207-216.

Kobayashi, Katsuji, and Akihiko Mochizuki

Source Identification of Obsidian Projectile Points from Kaman-Kalehöyük. AAS XVI

Kostov, Ruslan I.

2005 Gemmological Significance of the Prehistoric Balkan “Nephrite Culture” (Cases from Bulgaria). Annual of the University of Mining and Geology 48(1): 91-94.

Latham, Thomas S., Paula A. Sutton, and Kenneth L. Verosub

1992 Non-destructive XRF Characterization of Basaltic Artifacts from Truckee, California. Geoarchaeology 7(2): 81-101.

Livingston Jr, V. E.

1969 Geologic History and Rocks and Minerals of Washington. Olympia: Department of Natural Resources.

Lohse, E. S., and D. Sammons

1994 Southeastern Idaho Prehistory: Status and Stasis. Idaho Archaeologist 17(2): 35-46.

Malainey, Mary E.

2010 A Consumer's Guide to Archaeological Science: Analytical Techniques. New York: Springer Science & Business Media.

Matson, Richard G.

1992 The Evolution of Northwest Coast Subsistence. In Long-Term Subsistence Change in Prehistoric North America. Research in Economic Anthropology Supplement:6. D.R. Croes, R.A. Hawkins, and B.L. Isaac, eds. Pp. 367-428. Greenwich: Jai Press.

Matson, Richard Ghia and Martin Paul Robert Magne

2007 Athapaskan Migrations: The Archaeology of Eagle Lake, British Columbia. Tucson: University of Arizona Press.

McIlwraith, Thomas Forsyth

1992 The Bella Coola Indians. Vol. 1. Toronto: University of Toronto Press.

Mesoudi, Alex, and Michael J. O'Brien

2008 The Cultural Transmission of Great Basin Projectile-Point Technology I: An Experimental Simulation. American Antiquity 73(1): 3-28.

Mitchell, Douglas R. and M. Steven Shackley.

1995 Classic Period Hohokam Obsidian Studies in Southern Arizona. Journal of Field Archaeology 22(3): 291-304.

Morin, Jesse

2008 The Political Economy of Stone Celt Exchange in Pre-Contact British Columbia: the Salish Nephrite/Jade Industry. Electronic Theses and Dissertations: University of British Columbia.

2015 Near-Infrared Spectrometry of Stone Celts in Pre-Contact British Columbia, Canada. American Antiquity 80(3): 530-547.

Morrow, Carol A. and Richard W. Jefferies

1989 Trade or Embedded Procurement? A Test Case from Southern Illinois. In Time, Energy, and Stone Tools. Robin Torrence ed. Pp. 27-33. Cambridge: University of Cambridge Press.

Nazaroff, Adam J., Keith M. Prufer, and Brandon L. Drake.

2010 Assessing the Applicability of Portable X-Ray Fluorescence Spectrometry for Obsidian Provenance Research in the Maya Lowlands. Journal of Archaeological Science 37(4): 885-895.

Nelson, Charles M.

1962 Stone Artifacts from SN100. The Washington Archaeologist 7(4): 2-41.

1976 The Radiocarbon Age of the Biderbost Site (45SN100) and its Interpretive Significance for the Prehistory of the Puget Sound Basin. The Washington Archaeologist 20(1): 1-17.

Papadopoulou, D. N., G.A. Zachariadis, A.N. Anthemidis, N.C. Tsirliganis, J.A. Stratis

2006 Development and Optimisation of a Portable Micro-XRF Method for in-situ Multi-Element Analysis of Ancient Ceramics. Talanta 68(5): 1692-1699.

Parry, William J., and Robert L. Kelly

1987 Expedient Core Technology and Sedentism. In The Organization of Core Technology. J.K. Johnson and C.A. Morrow ed. Pp. 285-304. Boulder: Westview Press.

Phillips, S. Colby, and Robert J. Speakman

2009 Initial Source Evaluation of Archaeological Obsidian from the Kuril Islands of the Russian Far East using Portable XRF. Journal of Archaeological Science 36(6): 1256-1263.

Piazza, Anne Di, and Erik Pearthree

2001 Voyaging and Basalt Exchange in the Phoenix and Line Archipelagoes: the Viewpoint from Three Mystery Islands. Archaeology in Oceania 36(3): 146-152.

Prentiss, Anna Marie

2009 The Emergence of New Socioeconomic Strategies in the Middle and Late Holocene Pacific Northwest Region of North America. In Macroevolution in Human Prehistory. Anna Prentiss, Ian Kuijt, James C. Chatters eds. Pp. 111-131. New York: Springer New York.

Prentiss, Anna Marie, Natasha Lyons, Lucille E. Harris, Melisse R.P. Burns, Terrence M. Godin

2007 The Emergence of Status Inequality in Intermediate Scale Societies: A Demographic and Socio-Economic History of the Keatley Creek Site, British Columbia. Journal of Anthropological Archaeology 26(2): 299-327.

Richardson, Darlene, and Dragoslav Ninkovich

1976 Use of K2O, Rb, Zr, and Y versus SiO2 in Volcanic Ash Layers of the Eastern Mediterranean to trace their Source. Geological Society of America Bulletin 87(1): 110-116.

Roth, Barbara J.

2000 Obsidian Source Characterization and Hunter–Gatherer Mobility: an Example from the Tucson Basin. Journal of Archaeological Science 27(4): 305-314.

Rousseau, Mike K.

2004 A Culture Historic Synthesis and Changes in Human Mobility, Sedentism, Subsistence, Settlement, and Population on the Canadian Plateau, 7000-200 BP. In Complex Hunter-Gatherers: Evolution and Organization of Prehistoric Communities on the Plateau of Northwestern North America. W.C. Prentiss and Ian Kuijt ed. Pp. 3-22. Salt Lake City: University of Utah Press.

Sandu, I.G., O. Mircea, V. Vasilache, I. Sandu

2012 Influence of Archaeological Environment Factors in Alteration Processes of Copper Alloy Artifacts. Microscopy Research and Technique 75(12): 1646-1652.

Sanger, David

1967 Prehistory of the Pacific Northwest Plateau as seen from the Interior of British Columbia. American Antiquity 32(2): 186-197.

1968 Prepared Core and Blade Traditions in the Pacific Northwest. Arctic Anthropology 5(1): 92-120.

Shackley, Michael Steven

1990 Early Hunter-Gatherer Procurement Ranges in the Southwest: Evidence from Obsidian Geochemistry and Lithic Technology. Diss. Tucson: Arizona State University.

2011 An Introduction to X-ray Fluorescence (XRF) Analysis in Archaeology. New York: Springer New York.

2012 X-Ray Fluorescence Spectrometry (pXRF): the Good, the Bad, and the Ugly. Archaeology Southwest Magazine 26(2): 8.

Shackley, M. Steven, Justin R. Hyland, and Maria de la Luz Gutierrez M.

1996 Mass Production and Procurement at Valle del Azufre: a Unique Archaeological Obsidian Source in Baja California Sur. American Antiquity 61(4): 718-731.

Shott, Michael

1986 Technological Organization and Settlement Mobility: an Ethnographic Examination. Journal of Anthropological Research 42(1): 15-51.

Skinner, Craig E.

"Northwest Research Obsidian Studies Lab. "Northwest Research Obsidian Studies Lab. N.p., 16 June 2010. Web.

Sobel, Elizabeth A.

2006 Household Prestige and Exchange on the Northwest Coast: A Case Study of the Lower Columbia River Valley. In Household Archaeology on the Northwest Coast. Elizabeth Sobel, D. Anne Trieu Gahr and Kenneth M. Ames ed. Pp. 159-199. Oxford: Oxbow Books; International Monographs in Prehistory.

2012 An Archaeological Test of the “Exchange Expansion Model” of Contact Era Change on the Northwest Coast. Journal of Anthropological Archaeology 31(1): 1-21.

Speakman, Robert J.

2012 Evaluation of Bruker’s Tracer Family Factory Obsidian Calibration for Handheld Portable XRF Studies of Obsidian. Report prepared for Bruker AXS, Kennewick, WA. Available on-line: http://www. bruker-axs. com/fileadmin/user_upload/PDFse/handhelds/Bruker_Obsidian_Report. Pdf.

Speakman, Robert J., Nicole C. Little, Darrell Creel, Myles R. Miller, Javier G. Inanez

2011 Sourcing Ceramics with Portable XRF Spectrometers? A Comparison with INAA using Mimbres Pottery from the American Southwest. Journal of Archaeological Science 38(12): 3483-3496.

Stapp, Darby Campbell

1984 Late Protohistoric Burials with Copper Artifacts in the Pacific Northwest. Thesis. Moscow: University of Idaho.

Stern, Theodore

1998 Columbia River Trade Network. Handbook of North American Indians 12. Walker, Jr. Deward E., William C. Sturtevant eds. Pp. 641-652. Washington D.C.: Smithsonian Institution.

Tollefson, Kenneth D.

1987 The Snoqualmie: A Puget Sound Chiefdom. Ethnology 26(2): 121-136.

Tykot, Robert H.

2010 Sourcing of Sardinian Obsidian Collections in the Museo Preistorico-Etnografico “Luigi Pigorini” using Non-destructive portable XRF.L’ossidiana del Monte Arci nel Mediterraneo. Nuovi apporti sulla diffusione, sui sistemi di produzione e sulla loro cronologia. C. Luglie ed. Pp. 85-97. Pau, Italia: NUR.

Walker, D. E.

1997 The Yakama System of Trade and Exchange. Northwest Anthropological Research Notes 31(1-2): 71-95.