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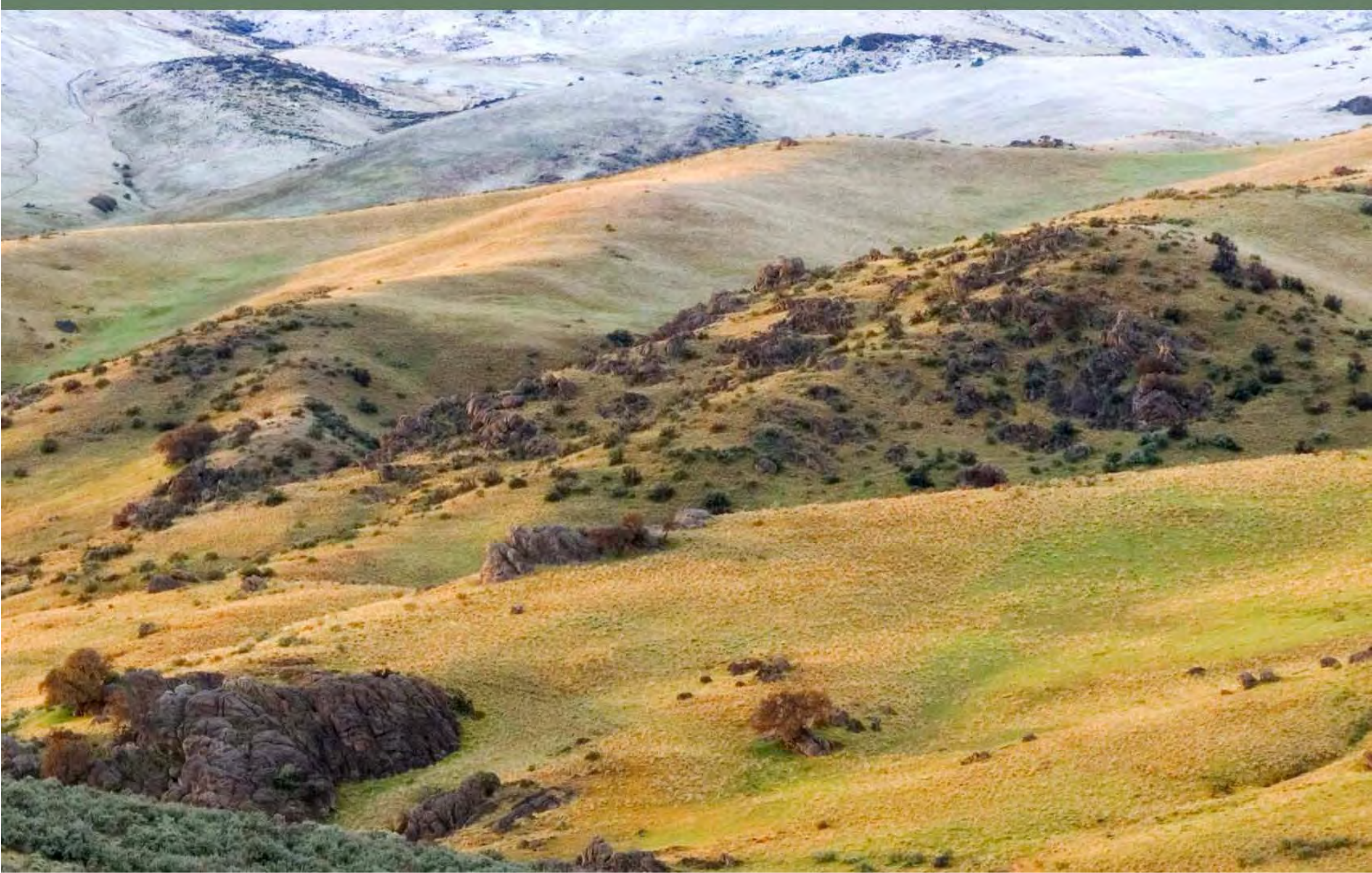

THE IDAHO ARCHAEOLOGIST

Scope

The *Idaho Archaeologist* publishes peer reviewed articles, reports, and book reviews. Though the journal's primary focus is the archeology of Idaho, technical and more theoretical papers having relevance to issues in Idaho and surrounding areas will be considered. The *Idaho Archaeologist* is published semi-annually in cooperation with the College of Arts and Sciences, Boise State University as the journal of the Idaho Archaeological Society.

Submissions

Articles should be submitted online to the Editor at mplew@boisestate.edu. Upon review and acceptance authors are required to electronically submit their manuscripts in Microsoft Word. It is the responsibility of authors to insert illustrative materials and tables into texts**.** Titles and headings should be formatted in Calibri, Bold, 12 pt. The body of the text should be Cambria, 11 pt.

Style Sheet

The *Idaho Archaeologist* generally conforms to the style sheet of *Plains Anthropologist.*

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Editor's Note

MARK PLEW

This issue of the *Idaho Archaeologist* is marked by a number of significant changes, most notably the now online publication of the journal. Owing to increasing publication costs and a desire to increase the circulation of the journal the Board of Directors of the Idaho Archaeological Society have elected to end hard copy production. The journal follows a growing national trend in moving to online publication.

In addition to going online, a number of format changes are being initiated. The journal will now publish articles, reports, comments, and book reviews. Articles will continue to consist of longer synthetic papers while reports will replace the Short Contributions section of the journal. Material culture notes, short field reports, and comments will be included in the reports section. Readers will also note changes in the layout and design of the journal.

The journal will continue its practice of peer review of articles and reports. Comments and book reviews are reviewed by the editorial staff. The journal will continue to focus on publication of papers dealing with Idaho archaeology but will also continue to publish technical and more theoretical or methodological papers having relevance to issues and debates in Idaho archaeology.

The journal remains committed to the ideals and objectives of the Idaho Archaeological Society which are to protect and preserve the remnants of the past and to foster an understanding of the prehistory of Idaho.

ARTICLE

GIS Modeling of the Owyhee Country of the Snake River Plain, Idaho: Creative Approaches to Section 106 Compliance

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Abstract

The Bureau of Land Management (BLM) worked with Gnomon, Inc. to complete GIS modeling of the proposed Owyhee Land Exchange with the Idaho Department of Lands (IDL), comprising the exchange of 34,000 acres of BLM for 38,000 acres of state lands. The model facilitated a Class II inventory strategy to allow BLM to fulfill responsibilities pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended (NHPA). The model utilizes variables to model high, moderate, and low probability areas/zones for the occurrence of archaeological sites, with an emphasis on locating sites eligible or potentially eligible for listing on the National Register of Historic Places (NRHP). This paper provides a brief overview of the model's parameters and variables, the initial application to existing site and survey data to "train" the model, field testing, verification, and final application for planning and decision making for the exchange. While both historic and prehistoric resources were modeled, this paper focuses on the results and evaluation of the model for predicting prehistoric/Native American sites.

KEYWORDS: Modeling, Section 106, National Historic Preservation Act, Land Exchange, Prehistory Archaeology, Historic Archaeology

Introduction

Over the years the use of modeling as a tool for archaeological investigations by cultural resource managers has often been viewed with a suspicious eye, misrepresented and misunderstood. But since the publication, by the BLM, of "Quantifying the Present and Predicting the Past" (Judge and Sebastian 1988) more sophisticated yet user friendly applications, such as GIS, have made modeling a more viable tool (Heilen et al. 2013; Kvamme 1985, 1990; Warren 1990; Wescott and Brandon 2000). In this paper we briefly present the results of the application of modeling for compliance with Section 106 of the NHPA for the proposed Owyhee Land Exchange. Modeling is necessarily an iterative process and our efforts are informed by and build on many previous modeling efforts in the region (Drews et al. 2004; Halford and Aiello 2012; King and Young 2006; Plager et al. 2004; Ringe 1995).

The Owyhee Land Exchange model universe encompasses all of Owyhee County in the southwest corner of Idaho, including 4,926,060 acres and three identified ecoregions or topographic zones: Northern Basin & Range, Snake River Plain and Owyhee Uplands. Approximately 34,000 acres, within 15 separate parcels of BLM lands, are proposed to be exchanged for 38,000 acres of IDL Lands (Figure 1). The overall goal of the project was to create a cultural resource planning model that will facilitate management decisions for the land exchange. The need for a model in this study is driven by NHPA Section 106 compliance. Section 106 directs that Federal Agencies "…take into the account the effects…" of its undertakings "…on historic properties eligible or potentially eligible to the National Register of Historic Places." The implementing regulations, found at 36 CFR § 800.4(b)(1), go on to state that, "The agency official shall make a reasonable and good faith effort (emphasis ours) to carry out appropriate identification efforts…may include… background research, consultation, oral history, sample field investigation, field survey." For this project, sample field or Class II investigation is being accomplished to fulfill Section 106 compliance.

The planning model is relatively coarse-grained with layer scales that range from 1:100,000 to 1:24,000. Therefore, accuracy can only be expected at the 1:100,000 scale. Best predictors of site location are determined to be those environmental variables or evidential layers that correlate best with known site locations. Archaeological landscape models are based on a set of techniques for characterizing and anticipating trends in the data used. These models operate from the assumption that people in the past oriented themselves within their environment in predictable, non-random ways in order to maximize the efficiency in which resources were procured and utilized. In order to exploit valuable resources such as fresh water, game, lithic raw material, and particular vegetation communities, people tend to locate or station themselves within a definable proximity to these resources. It is assumed that archaeological site locations should occupy only a limited portion of the total variation present in the environment. Basic principles of the model-building process are:

- Environmental data provides a landscape baseline
- Existing cultural resource data can be used to "train" the model
- Inventoried space is important as a means to identify where sites are, and just as important, where sites are not
- The outcome should characterize probable density, diversity, and distribution of cultural properties within sensitivity zones

One way to ensure that a model never gets used or is used improperly is to make it so complex or so statistically complicated that users do not understand the interim data or even how to interpret the final output. We feel that it is of utmost importance to make models simple enough to be replicated, sophisticated enough to allow for robust interpretation, and statistically defensible. Modeling objectives and expectations need to be realistically based on the available data. Some course-grained expectations about site location are safe to state, including the overwhelming fact that sites are generally located close to water and on flat ground. However, all sensitivity models are not created equal and therefore, steps should always be taken to sample the environmental variability within a given study area. Modeling objectives, which are inextricably linked to the expectations, need to be framed in a similar manner. Ultimately, the primary objective of model use is to forecast sites within a set of environmental parameters much better than chance alone.

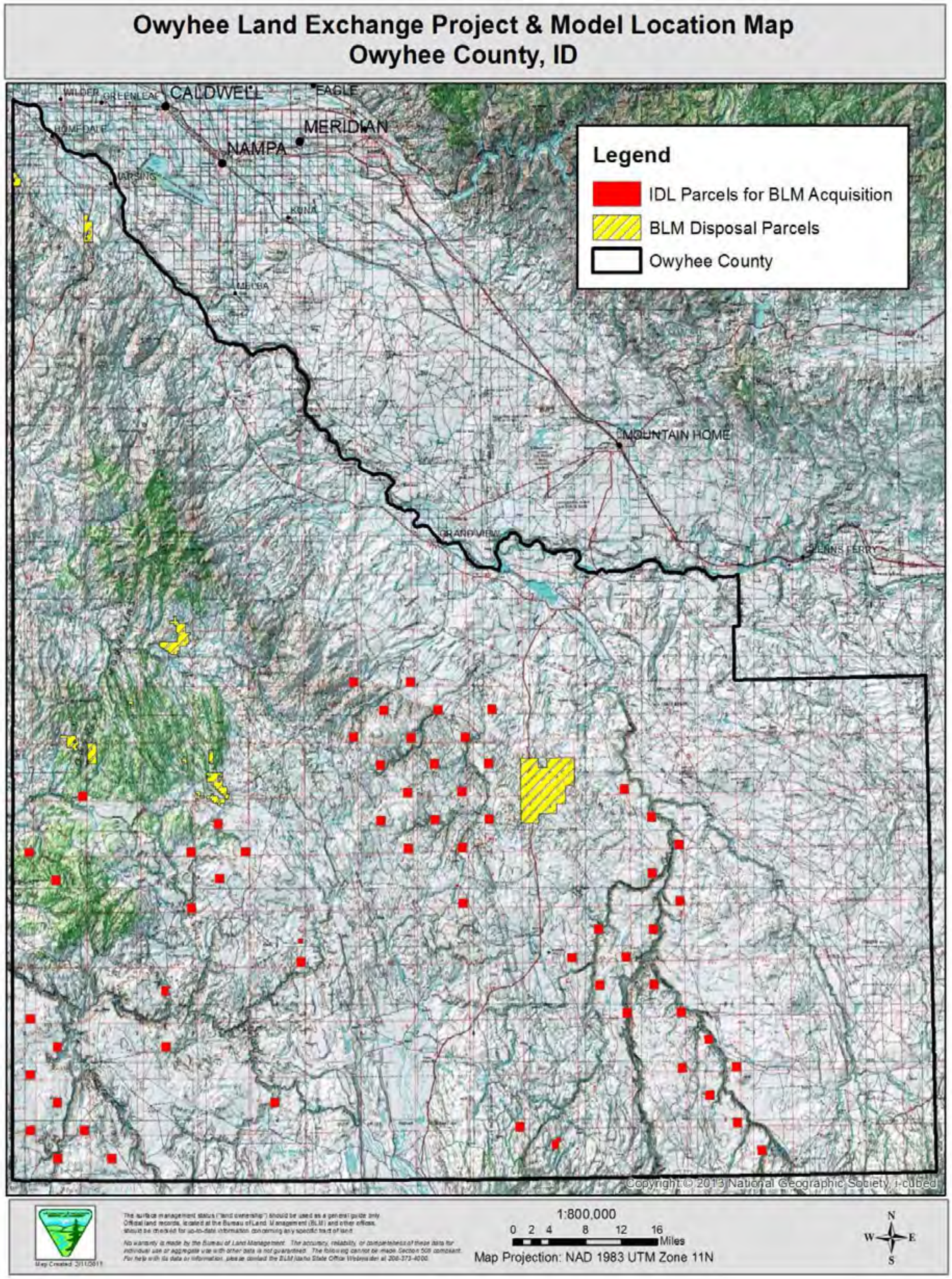

Figure 1. BLM and State Exchange Parcels.

Data Acquisition and Model Parameters

Most of the data was derived from data maintained at the Idaho BLM State Office. Several of these datasets are also available from the governmental agencies that created them or were used as part of a first pass model conducted by Halford and Aiello (2012). Environmental landscape data include slope, aspect, edge, distance to various water sources, distance to and viewshed from buttes, vegetation and lithic sources. Site and inventory data was provided by the Idaho BLM State Office from 2011 GIS datasets. Environmental datasets include:

- Slope—Digital Elevation Model (DEM)
- Aspect—DEM
- Vegetation—USGS National Gap Analysis Program (GAP)
- Distance to Buttes—Geographic Names Information System (GNIS)
- Viewshed from Buttes —GNIS
- Distance to Lithic Source—Northwest Obsidian Studies Lab - Cultural Resource overviews
- Distance to Major River—USGS Hydrologic dataset
- Distance to Secondary River—USGS Hydrologic dataset
- Distance to Intermittent Drainage—USGS Hydrologic dataset
- Distance to Major Confluence—USGS Hydrologic dataset
- Distance to Wetland, Lake or Playa—USGS Digital Line Graph, National Wetlands Inventory, EPA, Idaho Fish and Game, USGS Hydrologic dataset
- Distance to Spring—Idaho BLM State Office

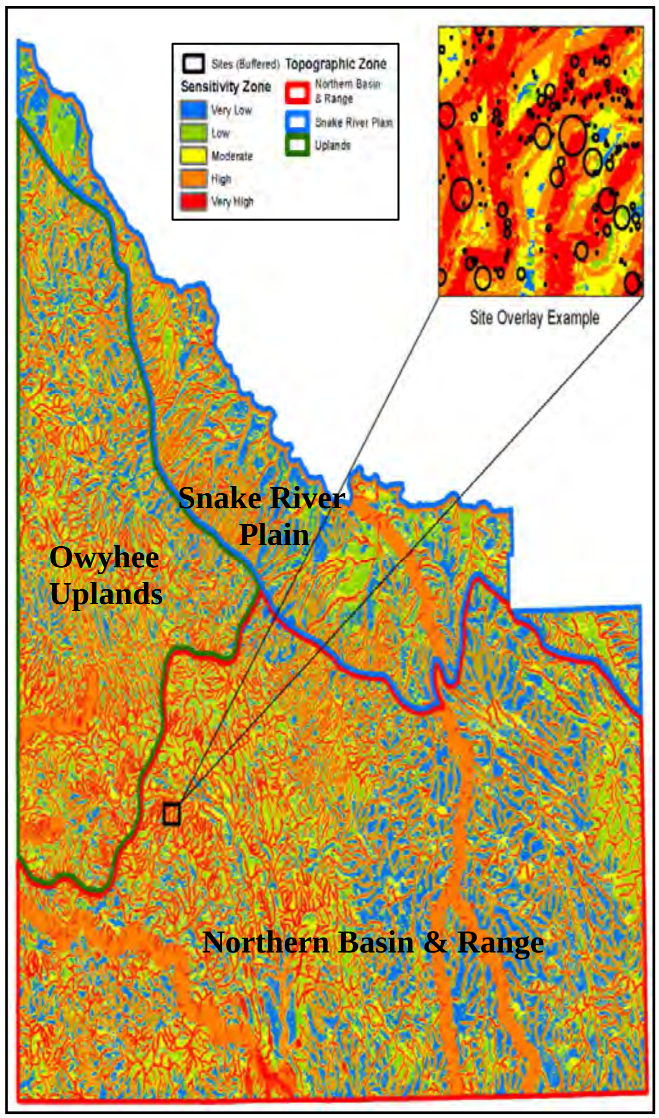

Figure 2. Ecological/Topographic Zones, Buffered Sites and Sensitivity Zones.

Inventory and Site Data Issues

Inventoried space is a critical component of model formation because in order for statistical calculations to be substantive, knowledge regarding site presence is just as important as knowledge about site absence (i.e., inventoried space that excludes site area). Unfortunately, due to the inordinate amount of missing inventory data, especially in the Snake River Plain, modeling results for this topographic zone need to be interpreted with caution. While numerous sites are recorded on the Snake River Plain ecological zone, particularly along the

Snake River, very few inventories have been documented in a GIS. Given the unfavorable limitation of skewed inventories between topographic zones, careful selection of quality data within the existing dataset was determined paramount in order to proceed. Traditionally, when inventory datasets can account for the majority of sites, modeling proceeds by creating a random sample of inventories and sites from which to "train" the model. It was determined to select all inventories greater than 500 acres and use all sites within for model training.

Site data was only available as points which present significant analytical limitations and if used, evidential layer correlation with site location would become drastically skewed, effectively treating all sites as equal. For instance a small lithic scatter of less than 30 m square should only extract one 30 x 30 meter cell value from a given evidential layer. However, a large habitation site may cover several cell values from that same evidential theme. By only using a single point to represent the large habitation site, environmental correlation is incomplete.

We first attempted to buffer the points by its area provided in the site database, but this creates its own problems because a site might be long and linear and the buffer creates a large circle. This potentially skews environmental correlation in a different way – by capturing variability that should not be present within the actual site boundary. The compromise to work around this issue was to construct raster size categories of small, medium, and large.

The model environment comprises a continuous grid of 30x30 meter cells across the research domain. By depicting a site as a point, only a single 30x30 meter cell will be assigned that site's attributes. A site depicted as a polygon contains a series of grid cells. The single point could assign a site to a moderate sensitivity zone, while a gridded polygon would characterize most of the site area within high sensitivity. In an attempt to better characterize site extent, sites were characterized as small, moderate or large in size based upon listed areal extent then buffered to a single cell, 3x3 cells or 5x5 cell areas.

The site rasters were built only for the site sample within the 33 inventories within the sample universe over 500 acres. A natural breaks classification of buffer size, derived from the area available in the provided site database, was used to construct the small, medium, and large site rasters. Small sites range from a buffer distance of 15-37 m and are represented by a single 30x30 m cell or 900 sq. m (see Figure 2). Medium sites range from 37-97 m and are represented by a 3x3 cell grid (8,100 sq. m). Large sites range from 98-424 m and are represented by a 5x5 cell grid (22,500 sq. m). In several cases, the site buffer accurately depicts the site as mapped which is important to correctly extract the type and quantity of a particular evidential theme. In other cases, the site buffer overlaps model strata that are not present according to the mapped site, incorrectly skewing the association between site location and environmental features. Although imperfect, we feel this compromise avoids drastically over or under representing environmental variability given site size.

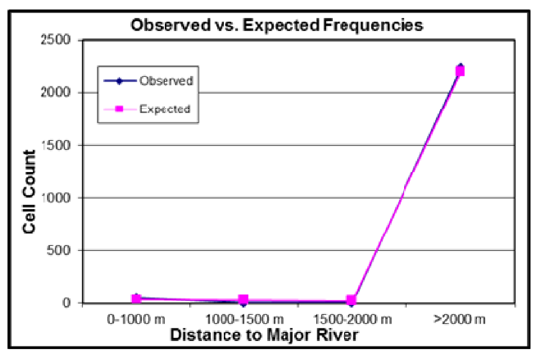

Figure 3. Distance to Major River.

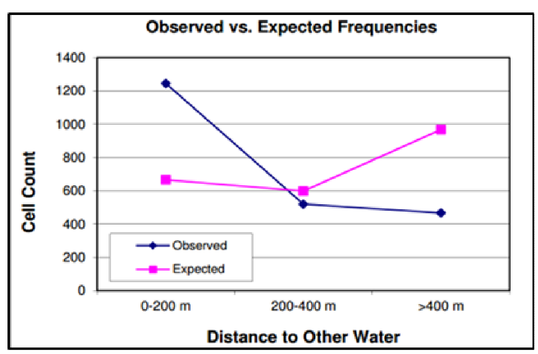

Figure 4. Positive Correlation of Site Cell Count and Distance to Water.

Model Process Overview

The modeling process consisted of a series of statistical evaluations designed to test the adequacy of environmental layer coverage, then to overlay cultural resource layers to assess which environmental themes or groups of themes strongly suggest a non-random distribution of sites. In short, we evaluate which environmental themes (e.g., 0-100 meters to water) have predictive potential. We checked for sampling bias within selected inventory areas—whether the environmental theme is under or over represented and checked for spatial autocorrelation—whether one environmental theme directly correlates with another. We then identify layers or evidential themes within each environmental variable that predict site location and assign weights for each theme if required. Then we evaluated how well the model performs in identifying site location better than chance alone.

Observed and expected frequencies are identical for distance to a major river (Figure 3). Layer classes with observed frequencies that exceed expected frequencies are positively associated with site location (0-200 m to intermittent water; Figure 4), classes with observed frequencies that are less than expected frequencies are negatively associated (>400 meters from intermittent water) and neutral associations are denoted by somewhat equal observed and expected values (200-400 m from intermittent water).

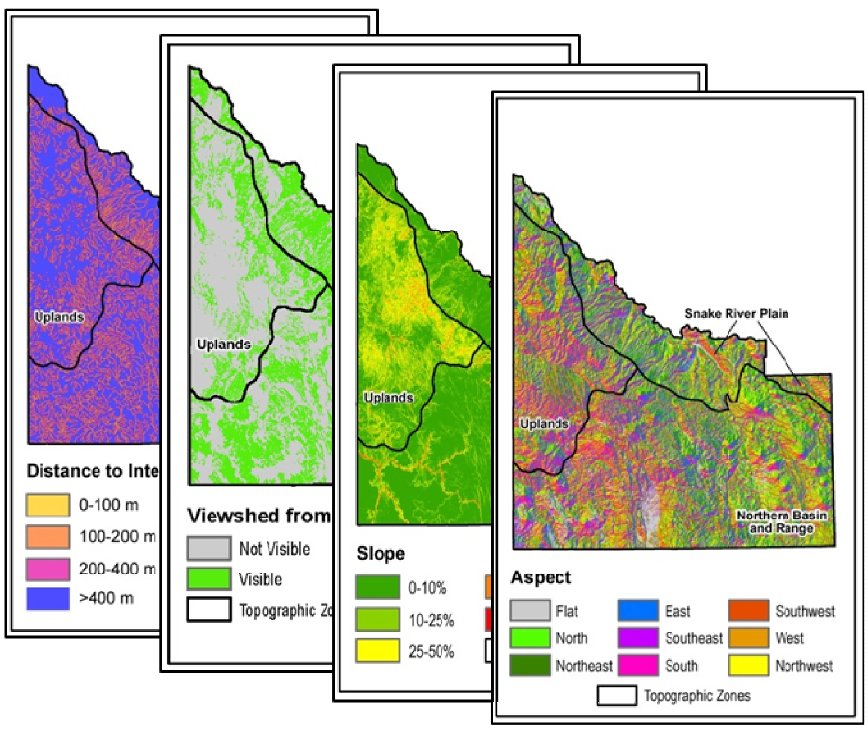

Figure 5. Modeled Evidential Themes.

The chi-square statistic provides a fairly straight-forward method to measure the ability of an evidential theme to predict site location. In its simplest form, a normal distribution of sites across an environmental landscape should produce a frequency curve similar to that environmental landscape. After chi-square analysis four evidential themes were determined to be the best predictors for sites: South aspect, 0-10% slope, not visible from buttes, and within 200 meters of water (Figure 5).

Determining variable weights is a crucial step in predictive modeling because people tend to favor certain environmental factors over others regarding site location. Proximity to water is always important, but depending on the time of year, maximizing exposure to sunshine may be more important. Two different methods of variable weighting were employed and evaluated. One method utilized the adjusted standard residuals (ASR) derived from the chi-square test and another used the calculated percent site area (percent site) within each layer class. These values are applied as coefficients (i.e., multipliers) using map algebra to develop the initial sensitivity rasters. Map algebra adds weighted predictive layers together to generate sensitivity. Re-classifying values using natural breaks creates a color coded sensitivity map. Figure 5, shows the modeled evidential themes. Upon comparing ASR and Percent Site composite weightings, it was determined that application of ASR performed most effectively.

As shown in Figure 6, very high and high sensitivity zones comprise 37.5% of the model area but predict 66.4% of the prehistoric sites within the 500 acre inventory sample. Conversely, while covering 38.3% of the model area, low and very Low sensitivity zones contain just 12.9% of prehistoric sites within the 500 acre inventory sample.

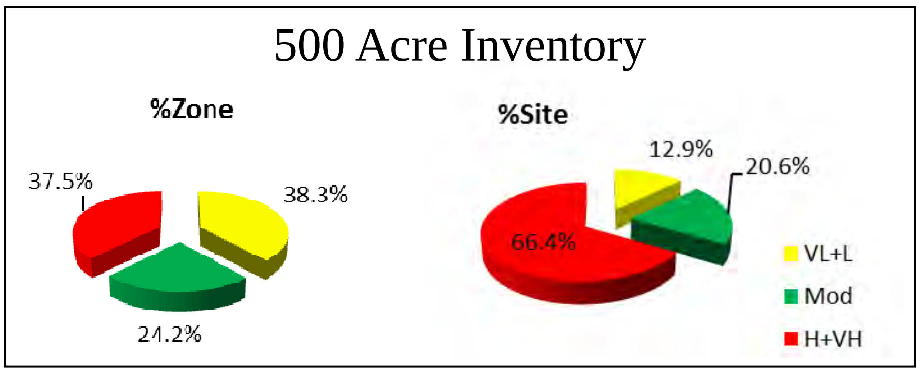

Figure 6. Percent Sensitivity Zone and Site Occurrence within Zones.

As detailed in Hall et al. (2013), evaluations of site cell and site centroid results suggest that for analytical purposes, site centroids provide an adequate means of quantifying sites within sensitivity zones. County-wide, over 4,100 sites were identified with more than half within the Northern Great Basin and Range topographic zone. The remainder is evenly distributed between the Uplands and Snake River Plain. When sites within Owyhee County topographic zones are evaluated against the sensitivity model, the model is more accurate. Countywide, 64% of the all sites occur within high sensitivity zones while the lowest site proportions (17%) are associated with predicted low sensitivity areas.

In all cases, the frequency of sites in high sensitivity zones greatly exceeds the proportional coverage of that model area by topographic zone. Forty percent of the Uplands are considered a high sensitivity area, while 64% of Upland sites occur in that area. The greatest variation is seen in the Snake River Plain. Here, 74% of the sites are found within high sensitivity zones that compose 34% of the topographic zone. The Northern Great Basin and Range topographic zone is similar to the Uplands with a 25% disparity between site frequencies and areal extent of high sensitivity areas. Conversely, frequencies of sites within low sensitivity zones fall below the proportion of the topographic zone covered by low sensitivity areas. Low sensitivity zones cover between 30% and 46% of the topographic zones in Owyhee County, but only 18% or fewer sites are located in those model areas. The contrast is most striking within the Snake River Plain, where 46% of the area is characterized by low sensitivity, and only 14% of sites fall within that zone.

Site Typologies

To further refine our evaluation, site types were assigned according to artifact types listed within the GIS attributes from the SHPO database provided by BLM. The goal here is to assess the model for applicability to predicting sites containing National Register qualities, further enhancing the model's utility for Section 106 compliance. Nine site types are defined in the Research Design (see Hall et al. 2013) ranging from Specialty Sites (Rock Art, Stacked Rock, Mortuary) to Temporary Base Camps and Residential Bases. All of the site types are present within Owyhee County; however, known Mortuary sites are relatively infrequent. Seven primary site types were retained for analysis as summarized below.

- Residential Sites: Exhibit residential and long-term use through density and diversity of artifact classes, including flaked stone debris, formal tools (edge modified flakes, scrapers, drills, bifaces [generally later stage]), projectile points, milling tools, pottery, and features such as midden deposits, hearths, house pits and rings. Sites contain 3 or more artifact classes and a diversity of formal tools.
- Temporary Base Camp: Logistical or embedded procurement camps similar to residential bases, but used for short-term, task specific hunting, gathering or tool stone procurement. The density and diversity of artifacts decreases with these types of occupations exhibiting the functional traits of the type of resource procurement being conducted. Sites may lack evidence of living floors or structures.
- Hunting/Processing: These are sites that contain tools related to a single subsistence related activity. For instance, hunting related sites should contain projectile points, bifaces, unifaces, formed flake tools and maintenance related debitage.
- Lithic Reduction: This site class is limited to scatters of lithic debitage related to tool maintenance or manufacture of expedient tools.
- Task Specific: These locales will exhibit very specific short term activities and will lack density and diversity of artifacts.
- Specialty Sites: These sites will lack diversity of artifact or feature types but include very specialized sites such as rock art, burial areas, vision quest sites, caches, cairns, hunting blinds, trails, etc.
- Isolate Finds: Locations exhibiting brief episodes of activity with 10 or less artifacts. Isolates are marked by a lack of artifact density and diversity of artifact classes.

Within Owyhee County, high sensitivity zones are very predictive for most site types. Low site counts for mortuary sites, quarries, and residential bases may bias predictive trends. Countywide, high sensitivity zones are only mildly predictive for quarry and mortuary sites. Rock shelters, rock art sites, and temporary base camps are very well predicted by the model, with more than 80% of those site types falling within high sensitivity zones.

Similar trends are seen by topographic zone. Site numbers are relatively low for mortuary and quarry sites so predictive trends may not be reliable. In general, high sensitivity zones appear to account for the greatest site frequencies across all topographic zones. Within the Uplands, high sensitivity zones are most predictive for hunting/processing sites, lithic scatter/single reduction sites, rock shelters, and temporary base camps sites. Frequencies within high sensitivity zones range from 68.3 % for lithic scatter/single reduction sites, to 83.3% for temporary base camps. Forty-five percent of the Uplands are considered as high

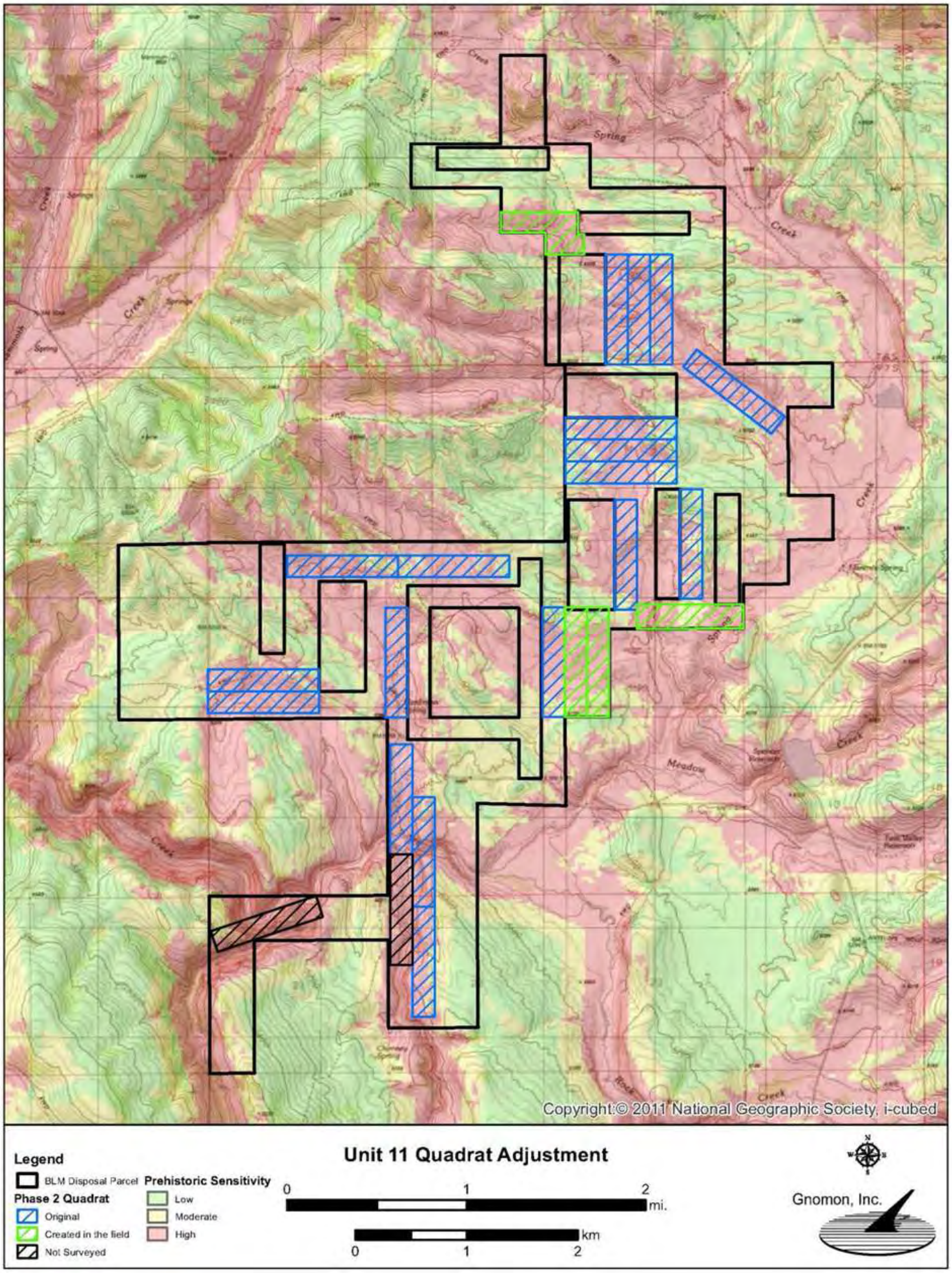

Figure 7. Owyhee Uplands Unit 11 Surveyed Quadrats during Phase 1 and 2.

sensitivity. A considerable number of stacked rock specialty sites were identified in the Uplands, but sensitivity zones do not appear to account for their occurrence.

Lithic scatter/single reduction sites, rock shelters, and temporary base camps produce the highest relative frequencies within the Snake River Plain. Nearly 90% of those site types fall within the high sensitivity zone while only 41.6% of the Snake River Plain is characterized by high sensitivity zone. Greater numbers of specialty sites suggests a positive association with high sensitivity zones in the Snake River Plain. Quarry sites are not well predicted by prehistoric sensitivity zones. Slightly more than 40% of the Snake River Plain is characterized by low prehistoric sensitivity. Hunting/processing sites occur most frequently within the low sensitivity zone, but still only account for 20.5% of that site type. When the model is evaluated based on site type, all site types except lithic reduction sites are identified exceptionally well (within the 60th and 70th percentile) in the high and very high sensitivity zones. Task specific sites exhibit the poorest correlation, while residential bases correlate the best.

The initial steps in building the model as discussed above indicate that the model provides a reliable indicator for predicting cultural resources on a landscape level. It is not an optimal foraging or explanatory model, but identifies landscape elements as a potential probability surface. Most landscape components are observable at the field level, such as distance to water, slope, and landform, facilitating field application.

Field Testing the Model

In the next step we tested the model by conducting field sampling within each probability zone using a 10% sample of the BLM exchange parcels distributed roughly equally between probability zones. A total of 3,050 acres was surveyed, dispersed across 61 quadrats in three inventory parcels. Idaho SHPO and BLM Class III standards were followed applying 30 m or less transect spacing. Each quadrat measured 200 meters by 1,000 meters (50 acres). Thirty seven sites and 54 isolated finds were recorded. The results were remarkably consistent with the model development percentages of sites recorded in each sensitivity zone. The model worked best within the Owyhee Uplands (Unit 11: Figure 7, from Hall et al. 2014), correctly forecasting over 70% of sites within the high sensitivity zones. In the other parcels, the model results are equivocal, due to low site numbers and site types not originally accounted for by model parameters (see Hall et al. 2013: Chapter 12). In all cases, however the model predicts sites to occur roughly 70% of the time in the high probability/sensitivity zone.

Section 106 Application of Modeling Results

Due to the models performance it was agreed to complete final inventory of 4,000 acres of high probability zone. In June 2014, the final inventory was conducted on BLM land within the high probability zone (Hall et al. 2014). As a result of the 7,050 acres of sample inventory that was completed during the two phases of field investigation, 79 sites and 138 isolated finds were recorded. Approximately 5,350 of the inventoried acres fall within the high probability zone. The majority of sites are prehistoric lithic scatters/lithic reduction and historic can dumps.

The highest site densities are found in the Owyhee Uplands with lower site densities on the Bruneau parcels. The sites generally represent task specific sites (e.g., can dumps, lithic

TABLE 1. Predicted Acres to be Transferred by Probability Zones

Probability Zone	BLM to State (Acres)	State to BLM (Acres)
Low	12,018	11,127
Medium	7,855	7,299
High	14,234	20,041
Total Acres	**34,107**	**38,467**

TABLE 2. Prediction of Sites to be Transferred between BLM and IDL

Probability Zone	BLM to State (sites)	State to BLM (sites)
All Zones (1 site/89 acres)	383	432
High (1 site/97 acres)	147	207
Eligible Sites (1 site/764 acres)	19	26

reduction) or temporary camps seasonally used to exploit available resources. Of the 79 sites recorded, nine prehistoric sites were recommended eligible or potentially eligible for listing on the National Register of Historic Places (NRHP), seven of which were in the high and two were in the moderate probability zones. The two sites in the moderate probability zone are small rock shelters with no cultural material. However, due to smoke staining, and in one case rock stacking, it was recommended that subsurface testing be conducted to determine if cultural material is extant and to determine final eligibility.

For purposes of providing reliable information to BLM managers for decision making we believe the model allows a comparison on lands to be exchanged (Table 1) for both consideration in the environmental assessments and Section 106 compliance. Due to the unique nature of the proposed exchange, and the fact that it would provide a net gain of acres coming into BLM administration versus those being transferred to IDL, it was determined that application of the model to the lands to be acquired from IDL would assist in decision making and ultimately the effect determination to be rendered for the proposed undertaking. Table 1 shows the comparative statistics of BLM versus IDL lands as distributed by probability zone.

As shown in the table, the exchange will result in a net gain of approximately 4,000 acres coming into BLM administration. When analyzing by probability zone, low and medium are relatively similar, but there will be a net increase of nearly 6,000 acres of high probability lands coming under BLM administration. Based on these data, and calculating the ratio of sites recorded per acre within the high probability zone, it is predicted that BLM would gain 60 more sites than would be transferred to IDL regardless of eligibility (Table 2). It can be predicted that BLM would also see a net gain of eligible properties. As a result of the various phases of testing and field application, we believe the model provides a viable tool for informed decision making and in assessing the effects of the proposed undertaking on resources. Modeling allows for pragmatic, creative and research oriented solutions for addressing Section 106 compliance, taking into account what we understand about the archaeological record and past human behavior after nearly 100 years of archaeological investigation in the region.

Conclusions and Discussion

The Owyhee Land Exchange study had many goals; model development and testing, determining characteristics of sites within different settings in Owyhee County; evaluating the probable effect of the proposed BLM and IDL land exchange. We feel the study achieved its goals. Above, we discussed whether the model-based approach was "accurate" within the study area in southern Idaho. We concluded that within the landscape settings that we examined, the model accurately forecasts the occurrence of sites eligible and potentially eligible to the NRHP. It also forecasts the density of other kinds of sites within reasonable certainty too – but these are types of sites that are not often eligible to the National Register (e.g., small lithic scatters; historic trash scatters).

Can and should the model be improved? The answer to this question must always be "yes", not only for the present study but for every study that uses a model-based approach. As previously discussed, modeling is an iterative process that requires continued use and reconstruction as new results and information come to bear, building on previous efforts (cf. Drews et al. 2004; Halford and Aiello 2012; King and Young 2006; Plager et al. 2004; Ringe 1995). No model is perfect (or even close to perfect) in its formulation. Whether this is due to the assumptions and constructs in the model, or the data it relies upon, every model can be improved through a process of re-evaluation. The ideal, of course, is to re-evaluate and improve a model on a regular basis. One should compare the results of other fieldwork in the model's area, re-formulate the model with new information, and always re-assess its accuracy and the effectiveness of parameters employed. One of the reasons we provide so much detail on model formulation methods and data sources used in the study (Hall et al. 2013; Hall and Ingbar 2014) is in the hope that the model's forecasts will be improved over time by other users.

We determined that our current effort could be refined to provide more robust predictive power by modeling the three separate environmental zones (see Figure 2) independently to capture the unique variables and qualities of each habitat. Refining and improving upon stream, spring, playa data would further increase model predictive effectiveness in all environmental zones. Application of standard deviation of slope using a finer grained DEM would help define low lying rock out crops where shelters may occur as well as steep cliff faces along river corridors.

The only way to ensure that models get improved is to use them. Too often, models are constructed at great expense and effort, used once (e.g., for a land exchange proposal) and then pushed aside in the day-to-day routine of inventory, identification, and evaluation of "standard Section 106" cultural resource management. In fact, models can help the day-to-day actions of cultural resource management in many ways. At a planning or pre-project phase, models can help guide land uses, so as to avoid or minimize conflicts with cultural resources. As a model gains credibility, it can be used to tailor survey strategies – focusing field time on areas likely to contain resources and on settings where significant resources are likely to occur. As further inventory occurs in Owyhee County, the model statistics discussed here should be updated. Basically, the model should be continually evaluated. Ease of re-evaluation is an important reason for our use of simple calculations and statistical procedures. When (or as) the model appears to work less well, then it should be adjusted – perhaps first through changing weighting factors or using better environmental data.

Finally, we would be remiss if we did not call some attention to the precedents set and continued by this project. BLM other federal agencies and tribes manage tens of millions of acres in the western United States. Executive orders notwithstanding, those lands will never be fully inventoried. Model-based approaches to actual undertakings – like the Owyhee Land

Exchange – will become more common over time as confidence in the use of models increases and models improve in predictive power. This project has benefitted from model-based approaches used elsewhere in southern Idaho (cf. Drews et al. 2004; Halford and Aiello 2012; Henrikson 2002; Plager et al. 2004; Ringe 1995) and we, as cultural resource professionals, are interested to see how federal and state agencies as well as tribal governments can make use of these approaches to inform decision making. Our suspicion, and hope, is that the profession as a whole will blend model-based planning and survey strategies with effective fieldwork, yielding real knowledge of our past.

Modeling represents a tool for Section 106 compliance that presents a cost effective method for analyzing large project areas and we would argue represents a reasonable and good faith effort in the analysis of effects of a project on historic properties and cultural resources in general. Most importantly they allow research based approaches to considering human behavior on a landscape level benefitting from over 100 years of archaeological inquiry and deeply embedded Native American knowledge. In sum, a more meaningful and thoughtful investigation of human land use patterns can be realized.

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ARTICLE

Using X-Ray Fluorescence Spectrometry to Assess Variance in Obsidian Source Distribution in Southern Idaho

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Abstract

This study explores the use of portable X-ray fluorescence (pXRF) and X-ray fluorescence (XRF) spectrometry to assist in associating artifacts with geological sources of obsidian from Southern Idaho. XRF spectrometry measures trace element abundance within obsidian artifacts, which is then compared, using a variety of statistical techniques, with known obsidian source geochemical profiles. Results from previous obsidian provenance studies have been used in archaeology as a proxy in measuring prehistoric hunter-gatherer mobility. Artifacts from 11 site assemblages were measured using pXRF to augment data for previously analyzed sites and to collect artifact geochemical data from previously unanalyzed sites. Using pXRF geochemical reference profiles from only one lab, artifact-to-source assignment resulted in 75% of analyzed artifacts attributed to an obsidian source. The addition of XRF geochemical reference profiles from a second lab and standardized values of all geochemical reference profiles and artifacts allows for a more complete assignment of artifacts to sources. With the original and additional geochemical reference profiles, artifact-to-source assignment increased to 87%. This study demonstrates the need for regional databases of standardized geochemical reference profiles as well as a thorough understanding of the underlying XRF technology to inform conclusions regarding prehistoric mobility. An additional, and possibly even more important, conclusion of this study is to question the validity and assumptions of previous XRF analysis studies based on past methodologies.

KEYWORDS: XRF, Southern Idaho, Obsidian, Trace Elements

Introduction

X-Ray fluorescence spectrometry (XRF) in archaeology is used to determine the geochemical characteristics of obsidian artifacts and is measured in parts per million. Certain elements, or sets of elements, appear to be unique to the geologic history of particular regions. Using a variety of multivariate statistical techniques, this study compares XRF analysis results from two labs: the Idaho Museum of Natural History (IMNH) and the Northwest Research Obsidian Studies Laboratory (NWROSL). In addition, it determines the set of elements most important in assigning obsidian sources to artifacts in Southern Idaho. A comprehensive regional obsidian source reference database would provide the means for provenance assignment of previously unsourced artifacts by assessing the regionally relevant set of elements.

One main area of interest in prehistoric archaeology is prehistoric mobility and settlement patterns, specifically the manner in which humans move across the landscape in relation to the location of subsistence resources (edible and nonedible) and their settlement patterns (Binford 1980; Kelly 1983, 1992). Since there is no direct way to measure the mobility of prehistoric peoples, proxies in the form of resource distribution studies have been used to examine mobility and its relationship to past settlement patterns (Beck and Jones 1988, 1990a, 1990b, 1997; Beck et al. 2002; Jones and Beck 1999; Jones et al. 2003; Kelly 1988, 1992, 2001; Smith 2005a, 2005b). Binford (1979) and Goodyear (1979), among others, helped establish lithic source distribution studies. Since the 1980s numerous researchers have continued to argue for large lithic procurement ranges for prehistoric hunter-gatherers (Hughes 1986; Kelly and Todd 1988; Shackley 1990, 1996).

In reality, obsidian sourcing studies are a "measure of the physical displacement of materials, not direct evidence for trade, exchange, direct procurement, or mobility" (Hughes 1998:110). Obsidian distribution studies allow for the interpretation of distances and directions in which lithic resources were naturally or culturally conveyed from their primary or secondary source locations (Shackley 2005). The movement of resources, especially lithics, from their primary or secondary locations to archaeological residential/logistical sites is one line of evidence that can suggest the use of resources as well as the movement and settlement of people in relation to these resources in the past, but not the specific mechanisms of such accomplishments (Binford 1973, 1977, 1979; Jones et al. 2003; Kuhn 1995; Parry and Kelly 1987; Shott 1989). Interpretation of prehistoric mobility inferred from the spatial location of obsidian in relation to an archaeological site, assumes a direct relationship between obsidian conveyance and human mobility that may not have existed.

Although the presence of obsidian artifacts in archaeological sites has been used as evidence of prehistoric mobility, in reality such presence could be due to direct procurement, exchange, or a combination or the two (Hughes 2012). While the distinction between direct procurement and exchange can be impossible to distinguish, it is useful to recognize modes of conveyance that could be represented by any archaeological assemblage. To arrive at potential explanations for these questions, it is useful to consider the petrogenesis of obsidian and have a basic understanding of what conditions lead to the geochemical variation with a source. There are two sources of variation: 1) variability within the geologic source and 2) variation originating in the instruments used to measure the geochemical profiles of obsidian.

Regional Setting

The study area includes obsidian sources and archaeological sites within Idaho. The 11 archaeological sites are located in Southern Idaho and adjacent upland areas, while obsidian sources are located in the uplands and mountains that surround the arc of the Snake River Plain (Figure 1). The Snake River Plain extends across approximately 23,550 square miles in Southern Idaho (Freeman et al. 1945:71). The western Snake River Plain is bounded on the north and south by extensive mountain ranges, whereas the central plain is bounded by mountains to the north and rolling hills to the south. The eastern Snake River Plain rises in elevation and blends into the surrounding mountain foothills while curving northeast toward

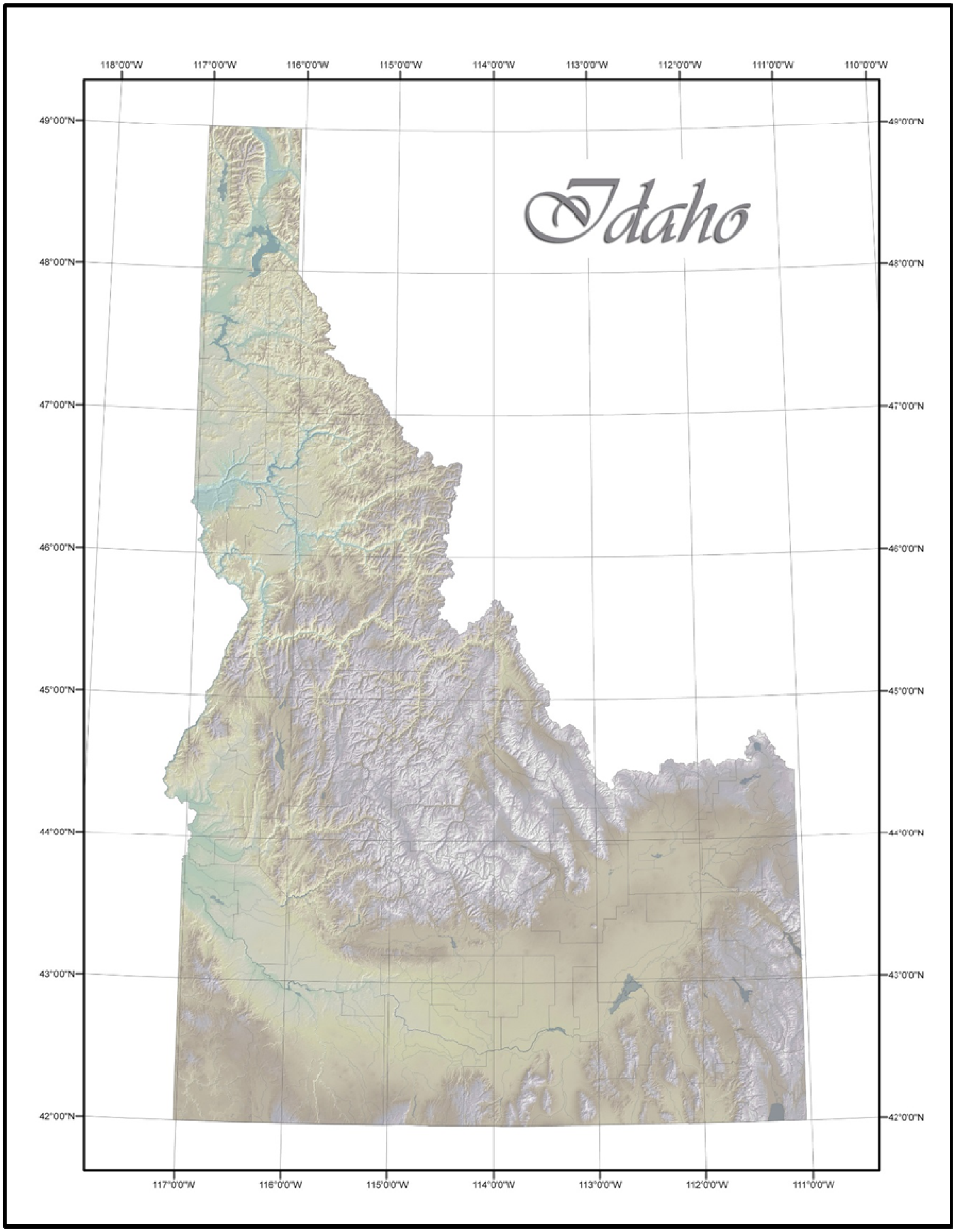

Figure 1. Relief Map of Idaho (Idaho State University 2014).

the Yellowstone Plateau. The Snake River Plain has a geologic history of explosive silicic (high silica content) volcanic events and floods, which create diversity in obsidian source geochemistry as well as extensive secondary obsidian source locations (Armstrong 1975; Clemens 1993; Malde 1991; Perkins et al. 1995). Ninety percent of the Snake River Plain is covered with Quaternary basalts with many areas of minimal soil coverage (Thornbury 1965:459). The "Quaternary feature of the Snake River Plain express the latest stages of tectonic and depositional events that began in late Tertiary times" (Malde 1965:255).

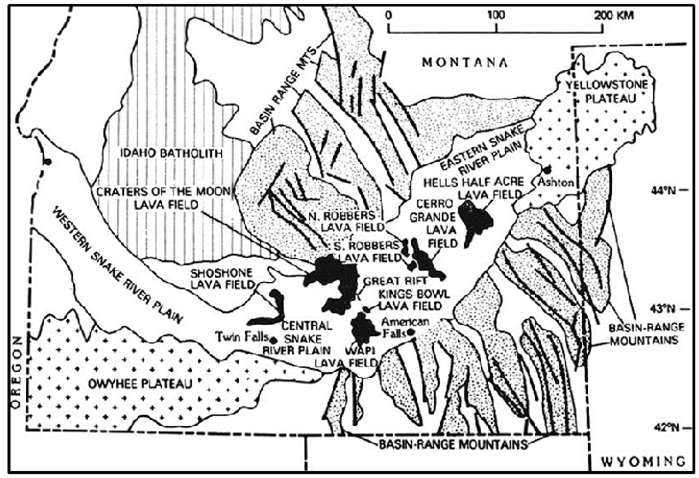

Figure 2. Idaho Volcanics (after Kuntz et al. 1982).

Idaho Obsidian Source Formation

Obsidian can be found in numerous settings in central and Southern Idaho (Figure 2). These settings include Challis volcanic rocks, Idavada volcanics, the Owyhee Plateau, the Snake River Plain, and the Basin and Range Province. The Challis volcanic rocks cover approximately 1,900 square miles in North-Central Idaho and are interbedded with rhyolitic volcanic flows. The Idavada volcanics consist of rhyolitic volcanic rocks located along U.S. Highway 93 and the Idaho-Nevada border. The Owyhee Plateau, located in Southwest Idaho, is characterized by intrusive rhyolites and the Bruneau-Jarbidge eruptive center with rhyolitic flows, located on the eastern margin of the plateau. The Snake River Plain is divided into west and east and was formed by the movement of the continent from northeast to southwest over a volcanic hotspot that creates settling in the crust as it is passed over (Brott et al. 1978; Pierce and Morgan 1992). The western Snake River Plain consists of rhyolite and basalt. The eastern Snake River Plain consists of rhyolite from extinct silicic volcanoes along the hotspot's path (Pierce and Morgan 1992). The western Snake River Plain trends northwest to southeast, parallel to the orientation of the Basin and Range Province formation of which it is a member. The northern margin of the Basin and Range Province extends into the eastern half of Idaho and is divided into north and south by the Snake River Plain. The Basin and Range Province is riddled with open fissures constituting the Great Rift, which has created a thin layer of basalt over the rhyolite present throughout the Snake River Plain (Pierce and Morgan 1992). This suggests that rhyolite flows that may contain obsidian are likely patchy throughout the Snake River Plain. The differing ages and modes of formation of the Challis volcanic rocks, Idavada volcanics, Owyhee Plateau, Snake River Plain, and Basin and Range Province hint at the diversity of the geochemical profiles of any geologic obsidian sources found within similar and very different geologic formations. This diversity of individual elements in the geochemical profiles of known obsidian sources affirms the variability within Idaho. The potentially patchy nature of the rhyolite and possible obsidian outcroppings suggest that our knowledge of the different obsidian sources within Idaho is incomplete.

Idaho Obsidian Deposition

Deposition of obsidian nodules and boulders of varying sizes occurs through volcanic and non-volcanic activity. Water erodes and moves obsidian clasts. For example, catastrophic events such as the Bonneville Flood 14,500-15,000 years ago moved large amounts of sediment and rock through Red Rock Pass in Southeastern Idaho westward all the way through the Snake River Plain (Malde 1965; O'Connor 1993). Over the duration of the flood, any loose obsidian clasts could have moved downstream hundreds of miles and potentially been deposited up side drainages along the route of the flood. These types of events allow for the possibility of movement downstream, upstream, downhill, and even uphill. These processes can compromise the implied integrity of primary obsidian resource location resulting in a secondary, although equally archaeologically important, obsidian resource location. In addition, there can be an expansion of the original size of the source by a factor of 10 or more (Shackley 2005).

Background

X-Ray Fluorescence (XRF) Spectrometry of Archaeological Obsidian

Obsidian source characterization on a regional level has become increasingly important because samples that were originally considered to originate from a single source have been assigned to multiple sources (Hughes 1998; Shackley 1998a). In the past, entire areas have been grouped as a single source as a result of field sampling strategies and not based on geochemistry or geologic mapping (Hughes 1998).

X-Ray Fluorescence Spectrometry and Obsidian

Obsidian has many attributes relevant to sourcing of artifacts. Obsidian sources are typically geographically restricted to areas of volcanism, except where transported as alluvial clasts. The assumption is that a particular source or flow is relatively chemically homogeneous, whereas different sources or flows are chemically heterogeneous in a way that can be measured by XRF (Glascock et al. 1998; Nelson 1984). In the past, the analyses performed by physicists and chemists have focused on the precision of XRF measurements rather than the archaeological context and application. Archaeologists have often trusted the accuracy and precision of XRF results without a technical understanding of the process and sources of error (Shackley 2005).

X-ray fluorescence spectrometry measures trace elements in parts per million by either a destructive (ground and pressed pellet sample) or non-destructive (whole rock sample) method of geochemical profile detection (Shackley 2011). An obsidian sample is irradiated and will re-emit radiation, or fluoresce, which is detected by the instrument in varying intensities depending on the element detected (Jenkins 1974; Goffer 1980; Shackley 2005).

Characterization of obsidian is possible due to trace elements concentrated in the liquid silicic magma, which are often variable between sources and also potentially variable between different eruptions of the same magma source (see Hughes and Smith 1993; Shackley 1992, 1998b, 1998c). For example, obsidian deposited on one side of a caldera can be geochemically heterogeneous from those found miles away (Shackley 2005). Therefore, when these conditions are met, trace elements can be used to indicate an obsidian source and possible sub-sources.

Portable XRF

Over the past decade numerous studies have compared the results of a laboratory XRF analyzer (lXRF) and those of a laboratory based pXRF (lpXRF) (e.g., Craig et al. 2007; Nazaroff and Shackley 2009; Pessanha et al. 2009; Shackley 2005; Williams-Thorpe 2008). Craig et al. (2007) analyzed the same obsidian artifacts with both types of instruments and concluded that there was statistically significant agreement between the source assignment results although there were significant differences between some individual elements. Pessanha et al. (2009:497) concluded that the lpXRF had a relatively high background (atmospheric effects) when compared to an lXRF, to the point where "some of the trace elements were almost not detected."

Idaho Obsidian Source Studies

Before 1969, the majority of Idaho obsidian sources were unknown or not geochemically characterized, but within a span of three years there were 11 known and recorded obsidian quarry areas (Holmer 1997). Geochemical analysis was performed on these quarry areas by Charles Nelson at the University of Massachusetts, although no publications resulted from this analysis (Holmer 1997). In 1979, Lee Sappington began a comprehensive study of Idaho obsidian (Sappington, 1981a, 1981b).Idaho obsidian source geochemical studies continued throughout the 1980s (Green 1982, 1983, 1984; Reed 1985). Bailey's (1992) analysis of obsidian artifacts from the 1988-1989 excavations of Wilson Butte Cave nearly doubled the number of known geochemically distinct Idaho obsidian sources.

Obsidian source geochemical characterization studies in Idaho have continued throughout the intervening years (e.g., Holmer 1997; Skinner et al. 1995; Plager 2001; Willson 2005). Holmer (1997) surveyed the obsidian sources in the 24 eastern counties of Idaho to coincide with the Idaho Museum of Natural History's curated archaeological collections from those same counties. Hughes and Pavesic (2009) examined an existing collection from the DeMoss site in 1985, conducting XRF analysis to augment existing information about the site. There have also been numerous masters' theses regarding Idaho obsidian sources in the last 15 years (e.g. Corn 2006; Plager 2001; Thompson 2004; Willson 2005). Plager (2001) focused on the distribution patterns of obsidian in Southern Idaho and concluded that relatively little exchange occurred across the Snake River. Thompson (2004) focused on the Malad source on the Snake River Plain and the conveyance of obsidian through direct procurement or exchange/trade to places as far away as Arkansas and Texas. Additionally, Willson (2005) addressed issues of mobility, concluding that the incomplete knowledge and point provenance nature of current obsidian source studies in Idaho constrains potential interpretations based on obsidian source characterizations.

In the last decade, only one master's thesis has directly characterized an obsidian source before drawing conclusions about prehistoric mobility. Corn (2006) recorded the extent of the Timber Butte source and established the extent of the geochemical profile of the primary depositional context of the source as part of a systematic survey of the source material and any sites encountered.

Methodology

XRF and Obsidian Sourcing Methods

One issue with lithic sourcing is the difficulty in differentiating between lithic sources geochemically, especially when there is variation within a single source (Jones et al. 2003; Shackley 1998a, 2005). A potential source of error exists when comparing data from different labs and different XRF units. This potential source of error can be mitigated to some extent by using sourcing data for artifacts determined by the same laboratory, increasing the likelihood of meaningful comparisons between sites. Creating an accurate or meaningful analysis necessitates recognizing that currently, as well as in the past, there is incomplete knowledge (characterization) of the obsidian sources that were available to prehistoric peoples of any region.

XRF and Obsidian: Methodological Concerns

Potential limitations in XRF analysis include artifact size and morphology, variable accuracy due to analysis techniques, and inability of some elements to be detected by XRF (Burley et al. 2011; Davis et al. 2011; Eerkens et al. 2007; Forster and Grave 2012; Frahm 2013; Goodale et al. 2012; Liritzis and Zacharias 2011; Lundblad et al. 2008; Nazaroff et al. 2010; Phillips and Speakman 2009; Shackley 2005, 2011). Potential issues with pXRF highlighted by Eerkens et al. (2007), Goodale et al. (2012), and Shackley (2005, 2011) include morphological, chemical/elemental, and technical protocols.

XRF or pXRF, as a mass analysis technique, cannot measure variation within an individual artifact (e.g., banding and multicolor obsidian). The accuracy can be variable, due to the absence of widely accepted and appropriate analytical protocols and standardized techniques. Additionally, only some elements can be detected due to pXRF power constraints. Fortunately, the elements detected by pXRF are the most relevant to volcanic rocks, although some of the most discriminating elements (e.g., Ba) may not be detected due to power constraints.

There are differences between the two measurement techniques. Atmospheric effects (absorption of low energy x-rays) may become a concern for lpXRF, whereas lXRF runs samples in a vacuum. For both instruments, there is a trade-off between increased analysis time (greater precision) and time and effort requirements of each unit (Giauque et. al 1993; Shackley 2002). To create opportunities for comparison between lab and instrument results, it is necessary to calibrate all lpXRF and lXRF instruments using international standards (Shackley 2011).

Idaho Obsidian Source Profiles and Locations

Obsidian source profiles are a distinct set of elements (absolute measurements and ratios) that define and characterize a particular spatially restricted obsidian locality. Obsidian source data from Idaho Museum of Natural History (IMNH) indicates numerous sources in Eastern Idaho and a relative scarcity of sources in Western Idaho. Conversely, obsidian source data from Northwest Research Obsidian Studies Laboratory (NWROSL) indicates numerous sources in Western Idaho and a relative scarcity of sources in Eastern Idaho. Source data from both labs could be complimentary if pooled for future studies. Idaho obsidian data from the IMNH includes 19 unique source profiles and 33 unique source locations (Holmer 1997). This IMNH discrepancy between source data and location information exists because the data is unpublished and unavailable for analysis. Idaho obsidian source data from the NWROSL included 18 unique source profiles and the corresponding locations. Obsidian source profiles and locations from the two XRF labs do not have a one-to-one correspondence. There appear to be gaps in both labs' source profiles, as well as a problem of scale, likely due to a local or regional approach to data collection. Of the 37 total source profiles (19 from IMNH and 18 from NWROSL), ten have the same name and general location while 27 source profiles have different names and locations (Figure 3). NWROSL has source profiles from all the states in the northwest, while IMNH only has source profiles from Southern Idaho.

While IMNH may have many more distinct source profiles from the eastern half of Idaho at a smaller scale than NWROSL, NWROSL has source and sub-source profiles on a larger scale. Figures 3 and 4 and Table 1 show that NWROSL also has more distinct source profiles from the western half of Idaho but appears to aggregate potential subsources in Eastern Idaho (Black 2014).

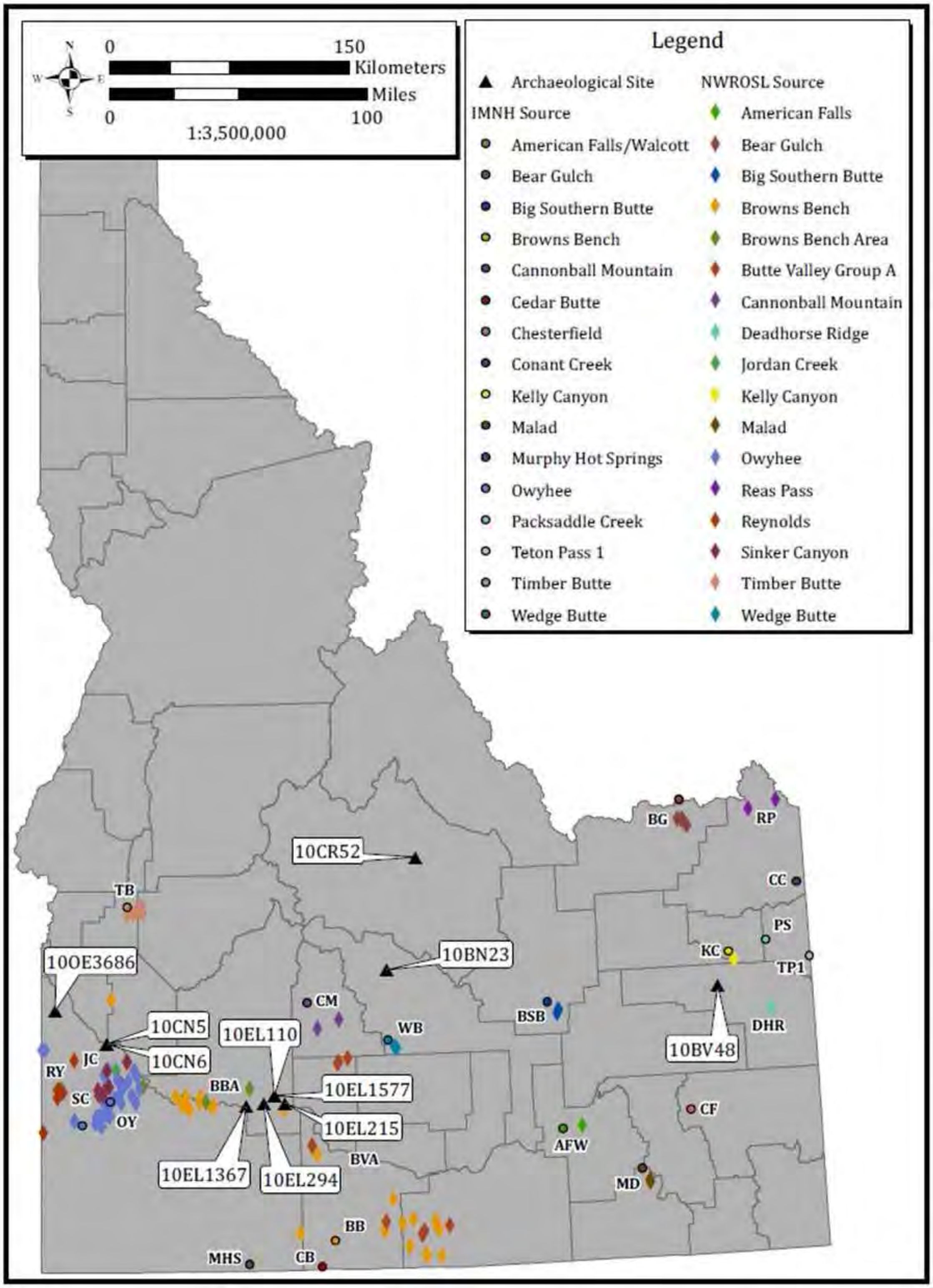

Figure 3. Idaho Obsidian Sources and Sites in this Study.

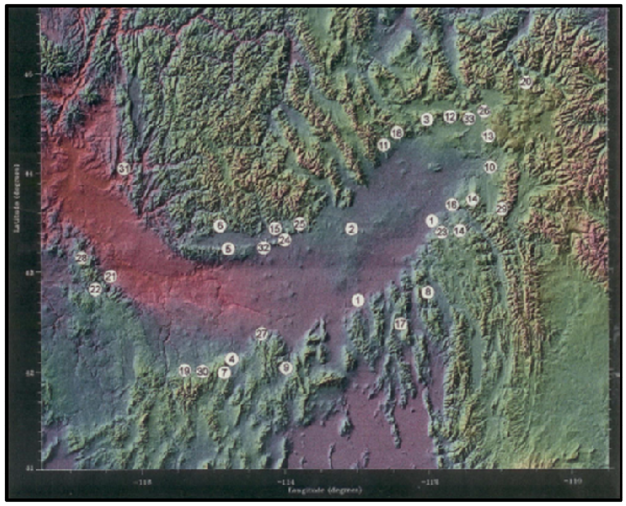

Figure 4. Volcanic Glass Quarry Locations (Holmer 1997).

TABLE 1. Idaho Obsidian Source Profiles by XRF Lab

Source	County	IMNH	NWROSL
American Falls/Walcott (AFW)	Power	X	X
Bear Gulch (BG)	Clark	X	X
Big Southern Butte (BSB)	Butte	X	X
Browns Bench (BB)	Cassia, Twin Falls, Owyhee	X	X
Browns Bench Area (BBA)	Elmore, Twin Falls, Owyhee	--	X
Butte Valley A (BVA)	Cassia, Gooding, Twin Falls, Owyhee	X	X
Cannonball Mountain/Cannonball Mountain 1 (CM/1)	Camas	X	X
Cannonball Mountain 2 (CM2)	Camas	X	—
Cedar Butte (CB)	Twin Falls	X	--
Chesterfield (CF)	Caribou	X	--
Conant Creek (CC)	Fremont	X	--
Deadhorse Ridge (DHR)	Bonneville	--	X
Jordan Creek (JC)	Owyhee	--	X
Kelly Canyon (KC)	Madison	X	X
Malad (MD)	Bannock, Oneida	X	X
Murphy Hot Springs (MHS)	Owyhee	X	--
Obsidian Cliff (OC)	In Wyoming State	X	--
Owyhee (OY)	Owyhee	X	X
Pack Saddle (PS)	Teton	X	--
Reas Pass (RP)	Fremont	X	X
Reynolds (RY)	Owyhee	X	X
Sinker Canyon (SC)	Owyhee	--	X
Striker Basin Gulch (SBG)	Owyhee	--	X
Teton Pass 1 (TP1)	Teton	X	--
Timber Butte (TB)	Boise, Gem	X	X
Wedge Butte (WB)	Blaine	X	X

Comparison of IMNH and NWROSL Obsidian Source Characteristics

Only 10 elements characterize the obsidian source profiles at IMNH, while the profiles at NWROSL are characterized by 13 elements. Skinner (personal communication 2014) has indicated that the analytical precision for rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb) at NWROSL is particularly good, and that barium (Ba) can be especially helpful in discriminating between obsidian subsources and sources. For example, Malad, Idaho, and Cow Canyon, Arizona, require a precise barium measurement to discern between the two sources (Shackley 2011). Due to power constraints, the Bruker lpXRF used at IMNH is unable to detect a measurable amount of barium (Ba). Because of this constraint, Ba cannot be used in inter-lab comparisons. This difference in measurable elements may provide an explanation for the incorrect assignment of sources (Hughes 1984; Shackley 2011).

Data Collection Methods

Analysis of 174 obsidian artifacts from 11 Idaho archaeological sites was performed with a pXRF Bruker Tracer 3-V spectrometer at IMNH in Pocatello, Idaho. The IMNH Bruker is equipped with a rhodium (Rh) tube, a 170 eV resolution silicon PIN diode detector, operating at 40 kilovolt (kV) and 12 microampere (μA) with an external power source (at 1000 counts per second) for 200 live seconds in an area of 7 mm2 (Bruker 2014).

Four of these sites were previously analyzed by NWROSL with a Spectrace 5000 spectrometer. This includes artifacts from 10CN5 (n=7), 10CN6 (n=7), 10EL110 (n=3), and 10EL215 (n=4) (Figure 5). Three of the 11 sites are from collections housed at the Idaho Museum of Natural History (IMNH): 10BN23, 10BV48, and 10CR52; and eight sites from Boise State University (BSU): 10CN5, 10CN6, 10EL110, 10EL215, 10EL294, 10EL1367, 10E L1577, and 10OE3686.

For the non-destructive lpXRF analysis two guidelines were used: 1) the size of the artifact needed to be at least 10 mm wide or cover the detector window to result in a consistent element profile, and 2) artifacts needed to be at least 3 mm thick (Forster et al. 2011; Nazaroff and Shackley 2009; Shackley 1998a). A stratified sample of artifacts was selected from each site using the following order of decreasing priority: any samples previously run by NWROSL; temporally or culturally diagnostic projectile points representative of each point type for each site; and samples from horizontally and vertically dispersed excavation units for relatively complete coverage of the site and relative temporal control. Specimens from the three IMNH sites include flakes and cores as well as diagnostic projectile points. Specimens from sites 10CN5, 10CN6, 10EL110, and 10EL215 (which were previously analyzed at NWROSL) included diagnostic projectile points in addition to flakes and cores.

Previous artifact analysis at Northwest Research Obsidian Studies Laboratory (NWROSL) was performed between 1995 and 2013 using a Spectrace 5000 X-ray fluorescence spectrometer, which detects 13 elements relevant to obsidian identification. The Spectrace 5000 is equipped with a Si (Li) detector having a resolution of 155 eV FWHM for 5.9 kiloelectronvolt (keV) X-rays (at 1000 counts per second) in an area of 30 mm2. It has a Bremsstrahlung type X-ray tube, a rhodium (Rh) target, and a 5 mil beryllium (Be) window with a 50 kV 1 μA high-voltage power supply and a voltage range of 4 to 50 kV (e.g. Skinner et al. 1995, Skinner and Thatcher 2013). The Spectrace 5000 measures 13 elements: manganese (Mn), iron (Fe), zinc (Zn), gallium (Ga), thorium (Th), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), barium (Ba), lead (Pb), and titanium (Ti).

The whole rock obsidian artifacts were analyzed at IMNH using a Bruker Tracer 3-V portable XRF spectrometer and accompanying S1PXRF software. The instrument was calibrated at the beginning of each day with an electronic file of element values of obsidian sources from around the world as determined by the University of Missouri Research Reactor Archaeometry Laboratory. The Bruker was mounted in a plastic stand to fix the position and standardize the distance between the detector and the artifact. Artifacts were analyzed for 200 live seconds three separate times with a slight rotation/shift over the instrument detector to address morphological variation and obtain an average reading. Artifacts were positioned with the unlabeled side (if there was one) toward the detector and positioned with the flattest or concave portion over the detector to minimize the diffusion of x-rays and maximize contact with the artifact (following Nazaroff et al., 2010). The Bruker measured 10 elements: manganese (Mn), iron (Fe), zinc (Zn), gallium (Ga), thorium (Th), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). Of these elements, Fe, Rb, Sr, Y, Zr, and Nb are considered most reliable for non-destructive XRF as well as geochemical markers for obsidian sourcing (e.g., Nelson 1984).

The initial artifact-to-source assignment was done non-statistically by manually comparing ratios of absolute mean values of elements in IMNH profiles, considering one standard deviation for each artifact and each source (Table.2). A total of 130 artifacts were assigned to a particular source using this approach, while 44 artifacts could not be assigned to any specific source. It appears that the farther west the location of the site, and possibly the source, the less likely the artifacts are to be assigned to a particular geologic source using IMNH source reference profiles (Figure 3). A potential reason for this is apparent in the map of Idaho obsidian sources provided by Holmer (1997) (Figure 4). While obsidian sources are distributed along the margins of the entire Snake River Plain, a preponderance of recorded sources occur in Eastern Idaho. Obsidian sources present in sites in Western Idaho may not have been adequately sourced by IMNH, or there may be fewer known obsidian sources. Another reason for the disparate number of sources between Eastern and Western Idaho could be related to the age of the obsidian source. Sources in Western Idaho are older than those in Eastern Idaho and are more likely to be eroded or covered in silt and therefore less defined or recognizable as sources.

TABLE 2. XRF Sourcing of Archaeological Site Samples

Site	County	Known	Unknown (UNK)	Total	Assigned to Source
10BN23	Blaine	25	7	32	78%
10BV48	Bonneville	21	3	24	88%
10CN5	Canyon	4	4	8	50%
10CN6	Canyon	8	5	13	62%
10CR52	Custer	16	6	22	73%
10EL110	Elmore	13	1	14	93%
10EL215	Elmore	20	5	25	80%
10EL294	Elmore	4	1	5	80%
10EL1367	Elmore	3	2	5	60%
10EL1577	Elmore	12	0	12	100%
10OE3686	Owyhee	4	10	14	29%
Total		**130**	**44**	**174**	

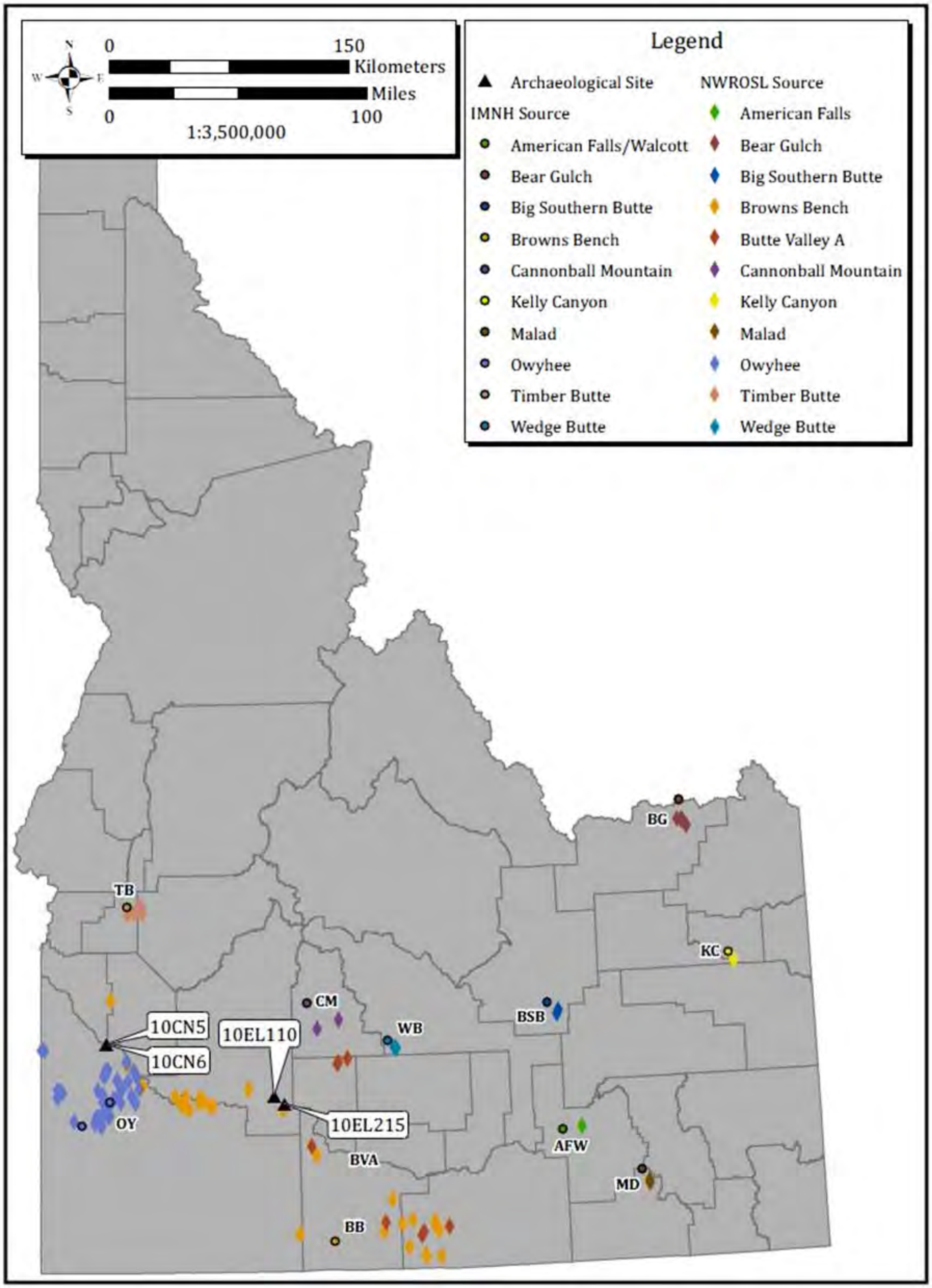

Figure 5. Similarly Named Obsidian Sources and Selected Sites.

Data Analysis

XRF Analysis Steps

First, the analysis of a library standard was used to determine the reliability or drift inherent in the pXRF instrument used in the analysis. This was accomplished by performing a one-sample t-test on the means and coefficients of variation obtained over the course of the analysis (Black 2014; Glascock et al. 1998). After the Bruker pXRF instrument was determined to be internally reliable, the next step was to perform a paired sample t-test on the means and coefficients of variation for artifact geochemical profiles of samples run at both the IMNH and NWROSL labs. This was done in an effort to determine to what extent the artifact profiles might be comparable. As a last check of inter-lab comparability, a one-tailed Pearson's correlation coefficient was used to compare the measurements of elements at each lab.

Analysis of Obsidian Profiles

Common source profiles indicate the relative frequency of a set of elements. A comparison of means and coefficients of variation was performed on the common source profiles and the obsidian artifacts run at both labs. The mean assesses the between-lab reliability while the coefficient of variation indicates within-lab reliability and precision. Additionally, Pearson's correlation coefficient was performed element by element to measure the standardized strength of any relationship that might exist between the elements as measured at each lab.

Artifact Profile Means, Coefficients of Variation, and Correlation

Comparison of the means for artifacts analyzed at both labs shows that iron (Fe), rubidium (Rb), and yttrium (Y) are consistently measured differently at each lab. The means for the other elements are not significantly different between labs, suggesting that such means are comparable. The coefficient of variation is significantly different for all elements except manganese (Mn) and iron (Fe), suggesting that NWROSL has greater measurement variation (lower within-lab reliability) for seven elements (Zn, Ga, Th, Sr, Y, Zr, and Nb) and lower measurement variation for one element (Rb) (Table 3). The results of the paired sample t-tests of means and coefficients of variation on the same artifacts suggest that there is measurement error between the instruments.

Table 4 suggests that as the concentration (ppm) increases or decreases at one lab, a similar increase or decrease in the absolute measurement value should occur at the other lab. Positively correlated elements between labs for a given artifact should reflect the same relative abundance across all elements in a profile, even though the absolute values of individual elements may be significantly different. Significant correlations exist for most of the elements between the two labs despite having a relatively small sample size because the correlations were so strong (between .929 and .999). A larger sample size would permit determining if the weaker correlation (Ga) would have a significant relationship.

Source Profile Means, Coefficients of Variation, and Correlation

The obsidian source profile comparison of means between labs also shows that the elements gallium (Ga), rubidium (Rb), strontium (Sr), and yttrium (Y) are consistently detected differently between the labs. The means for the other elements are not significantly different between labs, suggesting the means for those elements are comparable. The coefficients of variation are significantly different for iron (Fe) and gallium (Ga), suggesting that NWROSL has greater measurement variation (lower within-lab reliability) than IMNH for these

TABLE 3. Obsidian Artifact Profile Comparison between Labs

Element	Test	IMNH	NWROSL
Manganese (Mn)	Mean CV	258 .19	235 .19
Iron (Fe)	Mean CV	10140* .09	9779* .12
Zinc (Zn)	Mean CV	59 .09*	63 .19*
Gallium (Ga)	Mean CV	17 .02*	18 .30*
Thorium (Th)	Mean CV	22 .05*	21 .21*
Rubidium (Rb)	Mean CV	198* .04*	224* .02*
Strontium (Sr)	Mean CV	35 .08*	35 .29*
Yttrium (Y)	Mean CV	43* .05*	46* .08*
Zirconium (Zr)	Mean CV	253 .03*	253 .05*
Niobium (Nb)	Mean CV	29 .06*	29 .10*

*means or coefficients of variation are significantly different between labs, paired-sample t-tests, $p < .05$.

TABLE 4. Pearson's Correlation Coefficient of Artifact Elements

Element	Coefficient
Manganese (Mn)	.852**
Iron (Fe)	.915**
Zinc (Zn)	.941**
Gallium (Ga)	.321
Thorium (Th)	.402*
Rubidium (Rb)	.945**
Strontium (Sr)	.929**
Yttrium (Y)	.993**
Zirconium (Zr)	.999**
Niobium (Nb)	.996**

*significant correlation between elements at both labs, $p < .05$.
**significant correlation between elements at both labs, $p < .01$.

elements (Table 5). The results of the paired sample t-tests of means and coefficients of

TABLE 5. Obsidian Source Profile Comparison between Labs

Element	Test	IMNH	NWROSL
Manganese (Mn)	Mean CV	328 .17	317 .17
Iron (Fe)	Mean CV	13162 .06*	15333 .12*
Zinc (Zn)	Mean CV	92 .15	105 .14
Gallium (Ga)	Mean CV	20* .05*	24* .18*
Thorium (Th)	Mean CV	27 .07	27 .14
Rubidium (Rb)	Mean CV	222* .04	249* .05
Strontium (Sr)	Mean CV	36* .09	33* .10
Yttrium (Y)	Mean CV	78* .05	87* .08
Zirconium (Zr)	Mean CV	314 .08	326 .04
Niobium (Nb)	Mean CV	78 .10	80 .07
*means or coefficients of variation are significantly different between labs, paired-sample t-tests, $p < .05$.			

TABLE 6. Pearson's Correlation Coefficient of Source Elements

Element	Coefficient
Manganese (Mn)	.904**
Iron (Fe)	.774**
Zinc (Zn)	.882**
Gallium (Ga)	.918**
Thorium (Th)	.830**
Rubidium (Rb)	.996**
Strontium (Sr)	.994**
Yttrium (Y)	.990**
Zirconium (Zr)	.995**
Niobium (Nb)	.993**
*significant correlation between elements at both labs, $p < .05$. **significant correlation between elements at both labs, $p < .01$.	

variation on the same artifacts suggest that there is measurement error between the instruments as well as natural variation within the source.

Table 6 suggests that as the concentration (ppm) increases or decreases in measurements at one lab, the other lab should see a correlated increase or decrease in measurements. Positively correlated elements between labs for a given source should reflect the same relative abundance across all elements in a profile, even though the absolute values of individual elements may be significantly different. Significant correlations exist for the elements between the two labs despite having a relatively small sample size because the correlations were so strong (between .774 and .996).

Summary of IMNH and NWROSL Source Profiles Comparison

The preceding statistical tests provide information about the viability of using pXRF and the IMNH lab's profiles to be used in conjunction with a wider dataset. The Bruker's measurement of trace elements was internally reliable over the course of the analysis. The results of the means and coefficients of variation tests indicates the between-lab and within-lab analysis is to be cautiously optimistic in moving forward with further analysis. The Pearson's correlation coefficient indicates that, although the means and coefficients of variation differences suggest caution, the significantly positive correlations on an element-by-element basis reflect a potentially quantifiable consistent and systematic difference between the labs. Thus a future application of a correction may be appropriate for a direct one-to-one comparison between labs in a master database of regional obsidian source geochemical profiles. Given that most variation is between-source (not between-lab), and that sourcing methods are more sensitive to the relative abundance of elements across a profile rather than to differences in absolute amounts of single elements, minor measurement variations between these labs should not preclude a pooling of profiles from the two labs in statistical procedures that assign geologic sources to artifacts.

Additional Data Analysis

Additional XRF Analysis Steps

The comparison of elements between labs using the Pearson's correlation coefficient (Table 6) suggests that a comparison of standardized measurements of the data is possible. Glascock et al. (1998), Craig et al. (2007), Millhauser et al. (2011) has found that "best practice" for obsidian source comparison and assignment is to carry out a Log-10 transformation of both artifact and source data. A Log-10 transformation has two purposes: 1) it normalizes the data, and 2) it standardizes the values to help insure that each element contributes relatively equal weight in determining source attributions (Glascock et al. 1998). Therefore, all additional statistical tests were conducted on Log-10 transformed values.

The sample size of individual source profiles provided by the NWROSL was reduced from 769 to 705 after initial data exploration to remove the outliers. These outliers are explored more fully in the discussion section, but it is relevant to know that 64 samples were not statistically indicative of the obsidian sources to which they were attributed and were therefore removed.

Analysis of Obsidian Profiles

Multivariate statistical analysis, such as discriminant function analysis and principal component analysis, can isolate the elements most indicative of obsidian resources in a region and provide a means to assign artifacts to particular obsidian sources (Glascock et al. 1998). Hierarchical cluster analysis can combine cases from the bottom up, assigning sources and artifacts into clusters of similar cases.

Discriminant Function Analysis (DFA) of Obsidian Sources

DFA creates a predictive model of group membership based on the combination of a set of variables (in this case, elements) that discriminate the best between known groups (SPSS 20.0). The variables have been entered with a step-wise method using a Mahalanobis distance technique that measures how much a case's values differ from the average of all cases (Glascock et al. 1998; Hughes 1984). The Mahalanobis distance is used to identify and measure the similarity between an unknown and known sample. A potential limitation of using DFA is that it assumes that all artifacts and/or sources belong to a known group (Glascock et al. 1998). Due to this limitation, DFA is only used to check source-to-source assignment.

DFA identified a set of elements that best discriminated 16 geographic sources for 705 NWROSL samples of known origin in Idaho. The variables were entered using a step-wise method that entered variables forward and backward, with addition or removal depending on the Mahalanobis distance. The results of DFA of individual Log-10 transformed NWROSL source profiles observations, including all 13 elements (12 elements retained), show that only five elements (Zr, Y, Sr, Th, Rb) common between labs are necessary to account for 98.6% of the variation observed (Table 7). The 13th element gallium (Ga) was dropped entirely, suggesting that it is not an important element in discriminating obsidian sources in Idaho (Craig et al. 2007).

TABLE 7. Discriminant Function Analysis Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation	Element(s)
1	224.264	69.2	69.2	.998	Zr
2	47.195	14.6	83.7	.990	Zr, Y
3	30.739	9.5	93.2	.984	Zr, Y, Sr
4	9.977	3.1	96.3	.953	Zr, Y, Sr, Th
5	7.550	2.3	98.6	.940	Zr, Y, Sr, Th, Rb
6	1.756	.5	99.1	.798	Zr, Y, Sr, Th, Rb, Pb
7	1.316	.4	99.5	.754	Zr, Y, Sr, Th, Rb, Pb, Mn
8	.809	.2	99.8	.669	Zr, Y, Sr, Th, Rb, Pb, Mn, Nb
9	.370	.1	99.9	.520	Zr, Y, Sr, Th, Rb, Pb, Mn, Nb, Zn
10	.167	.1	100.0	.378	Zr, Y, Sr, Th, Rb, Pb, Mn, Nb, Zn, Ba
11	.101	.0	100.0	.303	Zr, Y, Sr, Th, Rb, Pb, Mn, Nb, Zn, Ba, Ti
12	.030	.0	100.0	.170	Zr, Y, Sr, Th, Rb, Pb, Mn, Nb, Zn, Ba, Ti, Fe

The first 12 canonical discriminant functions were used in the analysis.

Bi-Plot Analysis

Bi-plot analysis uses the two most discriminatory elements to indicate the relationship between obsidian sources in a graphical format. Bi-plots are ideal for comparing relatively small groups of sources. As the number of sources increases, the ability of a bi-plot to indicate differentiation between sources diminishes. Bi-plots are one of the most common statistical exploratory methods in obsidian studies (e.g., Craig et al. 2007; Frahm 2013; Glascock et al. 1998; Millhauser et al. 2011; Shackley 2005). For this analysis, the Log-10 transformations of the three most discriminating elements (Zr, Y, and Sr) for all Idaho obsidian sources included in this study are used to indicate the relationship between sources at both labs.

The bi-plot of two Log-10 transformed elements (zirconium [Zr] and yttrium [Y]), which explains 84.0% of the variation (determined by the DFA), was conducted on source profiles, resulting in grouping of profiles by source (rather than by lab). In the case of the paired sources, Figure 6 shows a consistent underestimation of IMNH means compared to NWROSL means for these elements (Black 2014). Except for one source (KC), measurement error between labs is far smaller than the natural variation occurring between sources, suggesting that source profiles from both labs may be pooled despite systematic measurement error (Nazaroff et al., 2010; Sheppard et al. 2010).

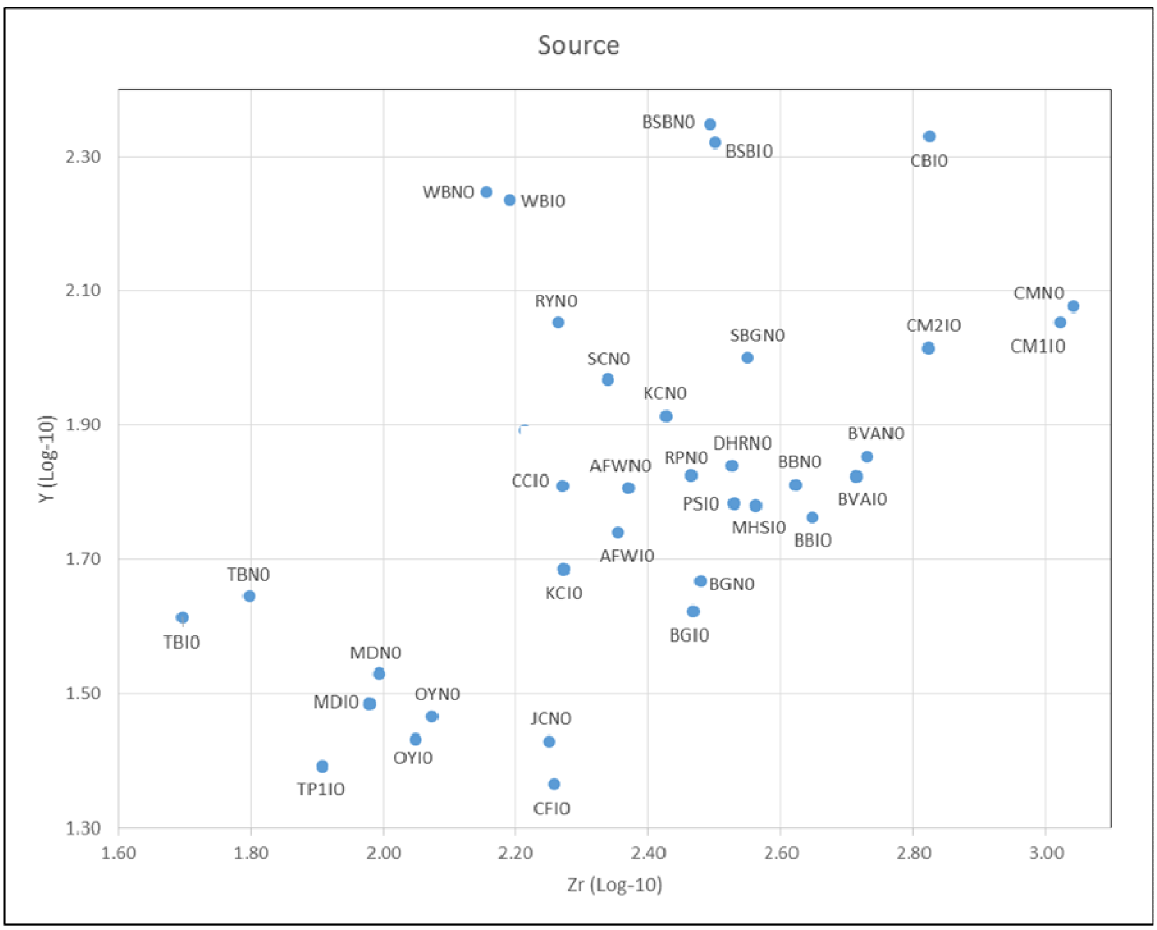

Figure 6. Bi-Plot of Zirconium and Yttrium (Log-10 Transformation).

The bi-plot of two Log-10 transformed elements (zirconium [Zr] and strontium [Sr]), two of the three elements important in discriminating obsidian sources (determined by the DFA), was conducted on source profiles, resulting in grouping of profiles by source (rather than by lab). In the case of the paired sources, Figure 7 shows a consistent underestimation of IMNH means compared to NWROSL means for these elements (Black 2014). Except for two sources (CM and KC), measurement error between labs is far smaller than the natural variation occurring between sources, suggesting that source profiles from both labs may be pooled despite systematic measurement error (Nazaroff et al., 2010; Sheppard et al., 2010).

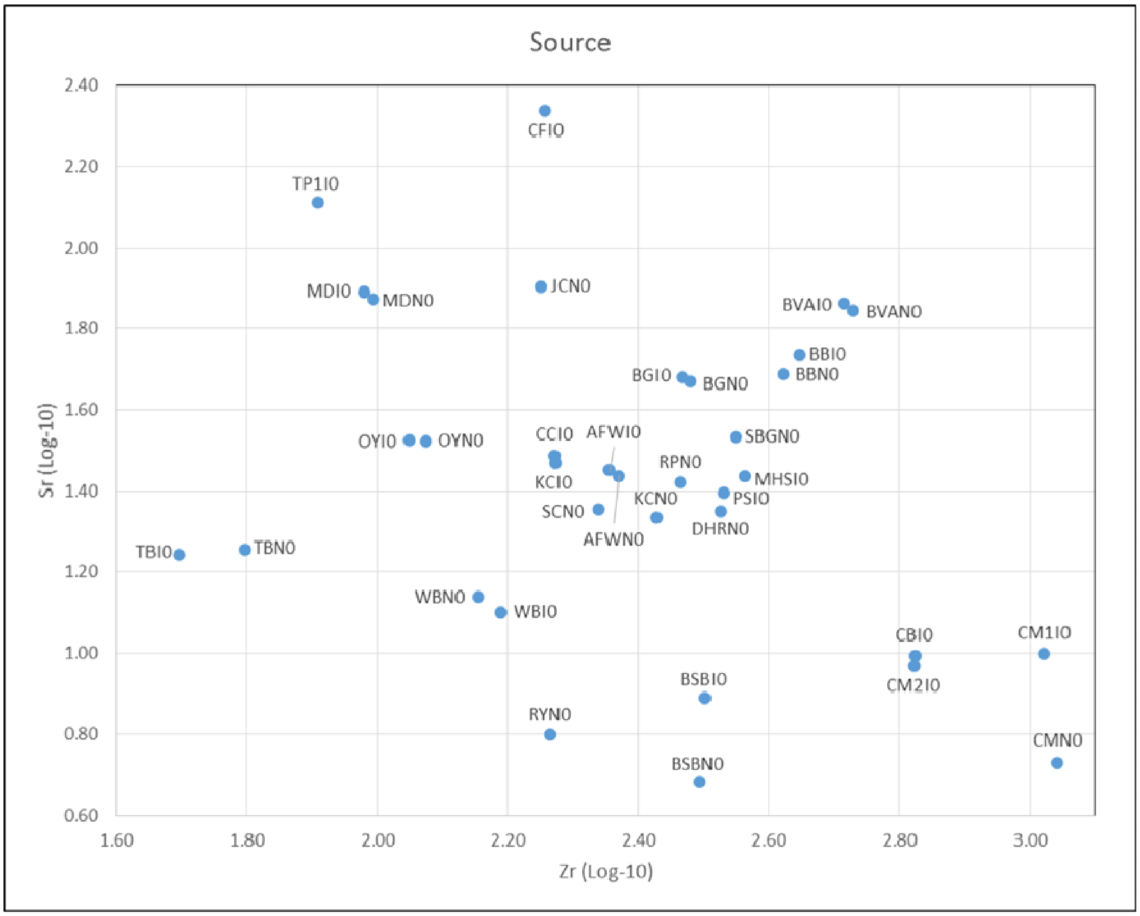

Figure 7. Bi-plot of Zirconium and Strontium (Log-10 Transformation).

The bi-plot of two Log-10 transformed elements (yttrium [Y] and strontium [Sr]), two of the three elements important in discriminating obsidian sources (determined by the DFA), was conducted on source profiles, resulting in grouping of profiles by source (rather than by lab). In the case of paired sources, Figure 8 shows a consistent underestimation of IMNH means compared to NWROSL means for these elements (Black 2014). Except for two sources (CM and KC), measurement error between labs is far smaller than the natural variation occurring between sources, suggesting that source profiles from both labs may be pooled despite systematic measurement error (Nazaroff et al., 2010; Sheppard et al., 2010).

Measurement error between labs is less than the natural variation within a geographic source, as demonstrated by the three bi-plots. However, measurement error between labs does not necessarily rule out further analysis, since source assignment methods are more

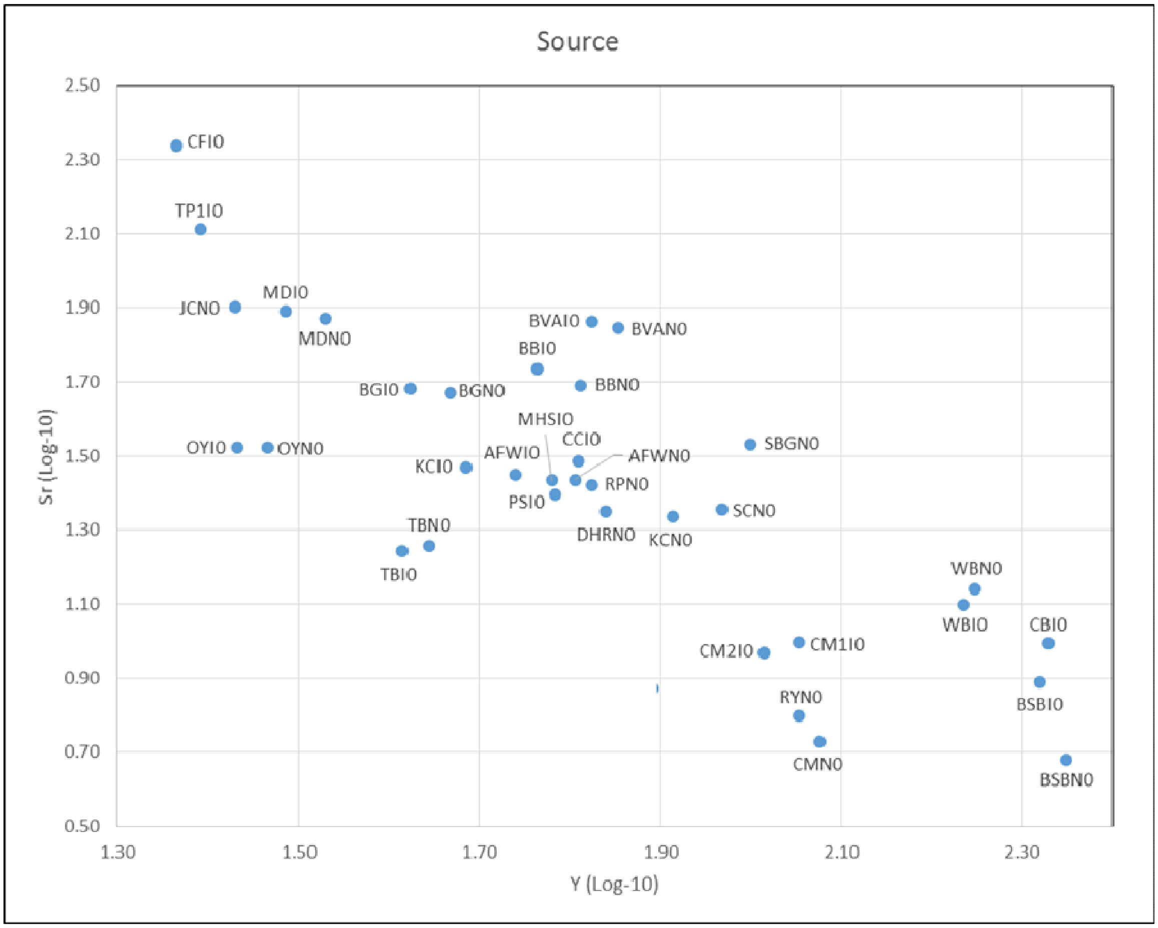

Figure 8. Bi-Plot of Yttrium and Strontium (Log-10 Transformation).

sensitive to relative proportions of elements across source profiles, not absolute amounts of individual elements.

Principal Component Analysis (PCA)

PCA in GAUSS Runtime determines the principal components that explain the variation, much as DFA does (Aptech Systems, Inc. 2006). PCA accounts for as much variation as possible while reducing the dimensionality of the set of variables by maximizing the correlations of quantified variables for the number of dimensions (components) specified (Glascock et al. 1998; SPSS 20.0). The first principal component accounts for the most variability in the data (the largest variance) while each succeeding component explains the remaining variation uncorrelated with the preceding components (Figure 9, Table 8). Like DFA, a potential limitation to using PCA is that it also assumes that all artifacts and/or sources belong to a known group (Glascock et al. 1998).

Source group assignment through GAUSS Runtime is determined through group membership probabilities computed using Mahalanobis distance, which measures how much a case's values differ from the average of all cases within a given group or source (Aptech Systems, Inc. 2006). The benefit of using all or most of the elements for PCA is that the relationship between all or most of the elements can be analyzed whereas with a bi-plot or ternary plot only two or three elements can be used.

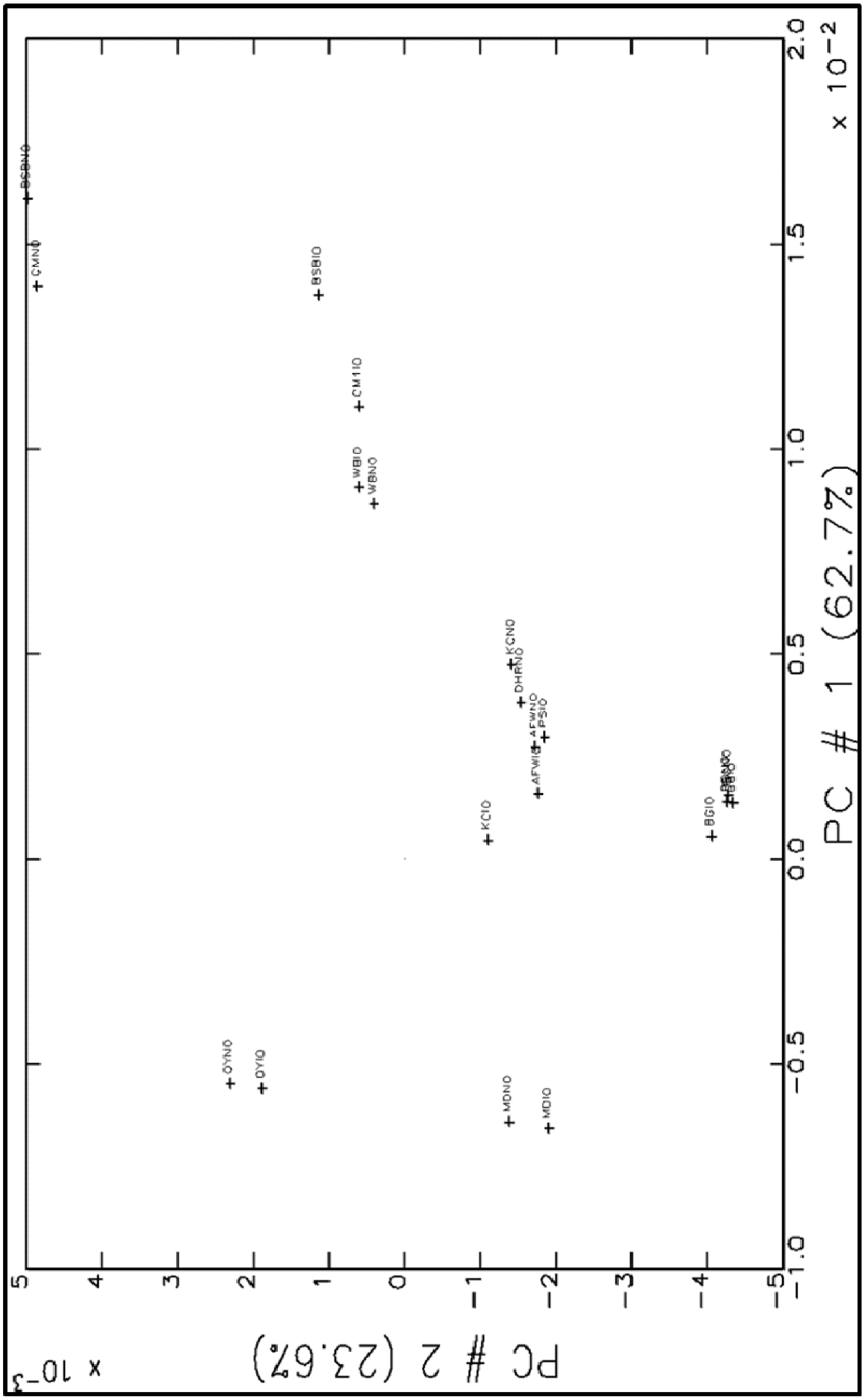

Figure 9. Principal Components 1 and 2 of Same Named Obsidian Source Means.

According to Glascock (personal communication, 2014), group membership probabilities based on PCA through GAUSS Runtime are ideally applied to ceramic sourcing studies rather than to obsidian sourcing studies, and source group assignments should include those that fall within two standard deviations of the probability mean for the group. Additionally, in using this program to assign sources, there are two requirements: 1) the number of samples included in the analysis must exceed the number of elements under consideration by at least 2 for each group or source, and 2) the source sample size should be at least 2 ½ times the number of elements under consideration. These guidelines require that only eight principal components using the 10 elements in common between labs be used in analysis and that the Browns Bench Area data be dropped from further analysis. Unfortunately, the "best practices" (i.e., sample size at least 2 ½ times the number of elements for each group or source) cannot be completely adhered to in this instance while using the geochemical source profiles provided. It is expected that PCA will not provide a relatively good percentage of artifact-to-source assignments because of the insufficient number of geologic samples characterizing each source.

TABLE 8. Principal Component Analysis Eigenvalues

PC	Eigenvalue	% of Variance	Cumulative %
1	0.022959	62.7	69.2
2	0.008642	23.6	86.3
3	30.739	5.6	91.9
4	9.977	3.0	94.9
5	7.550	2.3	97.2
6	1.756	1.7	98.9
7	1.316	.8	99.7
8	.809	.3	100

Another limitation to using PCA for this study is that the GAUSS Runtime program assumes that all existing sources are included in the analysis, and that there are no unknown sources (Aptech Systems, Inc. 2006). As a result, every individual source profile is assigned to a known group even if it may belong to an as yet unknown source. Therefore, because of the incomplete characterization of known and unknown sources and the huge range of probabilities, only one standard deviation was used to assign obsidian source group membership. Two standard deviations results in all sources being assigned to the source group in which they originated, even though the program assigns a different source. Additionally, two standard deviations includes negative probability values and values greater than 100, which results in all sources being assigned to the source group in which they originated, thus inflating the results of the PCA. One standard deviation was used in the assignments to try to minimize the possible inflation, as noted by Hughes (1984), of the percent correctly classified. The cause of potential inflation of results is due to the cases assigned to groups, which are used to determine the group profile. In theory, PCA is well suited for artifact-to-source assignment with sufficient geologic sample size (Glascock et al. 1998). In this study, PCA is used to confirm source-to-source assignment and to highlight the issues with sample size of the current geologic source.

Hierarchical Cluster Analysis (HCA)

HCA is used to identify groups based on the homogeneity of selected variables (in this instance, elements) by initially pairing like cases, then clusters, until only one is left. Clustering is an exploration tool to evaluate the relationship between artifact samples and sources (Glascock et al. 1998). The Ward's clustering method was applied to the z-scores of the Log-10 transformation of these data. Ward's clustering method minimizes the variance of the squared Euclidean distances among cases within clusters to determine groups (SPSS 20.0). HCA was performed on the sources from both labs and on all artifacts using SPSS 20.0 and GAUSS Runtime 8.0 (Aptech Systems, Inc. 2006; Black 2014; IBM Corp. 2011; MURR 2014).

The results of the HCA exhibit like-named source profiles from both labs in the same cluster, indicating the profiles are not clustering by lab but by source (Black 2014). Therefore, artifacts can potentially be sourced on a broad scale, while refinement of sub-source profiles may allow more exact matches. The five most discriminatory elements from the DFA were included in the SPSS HCA of all artifacts and mean source profile values in order to detect any grouping of source profiles by lab. No grouping by lab was present. The GAUSS Runtime HCA was conducted using all 10 elements to analyze all artifacts, mean source profiles from IMNH, and individual source profiles from NWROSL. Artifacts should be reliably classified and grouped with the geochemically closest source profile, assuming that systematic measurement differences between labs do not cause samples to cluster by the lab of measurement. The GAUSS Runtime HCA assigned each source and artifact into an individual cluster, creating visually apparent source assignments as well as highlighting artifacts having unknown source profiles (Aptech Systems, Inc. 2006).

Site versus IMNH and NWROSL Source Profiles

The results of the artifact-to-source assignments using manual assignment, PCA, and HCA suggest that in this instance hierarchical cluster analysis is the most reliable method in assigning sources-to-artifacts with an 86.8% assignment rate (Table 9).

TABLE 9. Proportion of Artifacts Assigned to a Source by Method

Site	Visual Assignment		PCA Assignment		HCA Assignment	
10BN23	25/32	78.1%	0/32	0.0%	31/32	96.9%
10BV48	21/24	87.5%	18/24	75.0%	23/24	95.8%
10CN5	4/8	50.0%	6/8	75.0%	7/8	87.5%
10CN6	8/13	61.5%	7/13	53.8%	9/13	69.2%
10CR52	16/22	72.7%	1/22	4.5%	16/22	72.7%
10EL110	13/14	92.9%	3/14	21.4%	14/14	100.0%
10EL215	20/25	80.0%	8/25	32.0%	24/25	96.0%
10EL294	4/5	80.0%	3/5	60.0%	5/5	100.0%
10EL1367	3/5	60.0%	3/5	60.0%	5/5	100.0%
10EL1577	12/12	100.0%	2/12	16.7%	12/12	100.0%
10OE3686	4/14	28.6%	5/14	35.7%	5/14	35.7%
Total	**130/174**	**74.7%**	**56/174**	**32.2%**	**151/174**	**86.8%**

Source versus IMNH and NWROSL Source Profiles

The results of the source-to-source assignments using DFA, PCA, and HCA suggest that in this instance discriminant function analysis and hierarchical cluster analysis are the most reliable in assigning sources at 99.4% and 98.0%, respectively (Table 10).

TABLE 10. Source Assignment Results by Method

Source	DFA Assignment		PCA Assignment		HCA Assignment	
American Falls (Walcott)	24/24	100.0%	23/24	95.8%	24/24	100.0%
Bear Gulch	56/56	100.0%	53/56	94.6%	56/56	100.0%
Big Southern Butte	10/10	100.0%	10/10	100.0%	10/10	100.0%
Browns Bench	109/109	100.0%	101/109	92.7%	109/109	100.0%
Browns Bench Area	N=5, therefore dropped from further inclusion in analysis					
Butte Valley A	26/26	100.0%	24/26	92.3%	21/26	80.8%
Cannonball Mountain/ Cannonball Mountain 1	25/25	100.0%	23/25	92.0%	25/25	100.0%
Cannonball Mountain 2	N=1, therefore dropped from further inclusion in analysis					
Cedar Butte	N=1, therefore dropped from further inclusion in analysis					
Chesterfield	N=1, therefore dropped from further inclusion in analysis					
Conant Creek	N=1, therefore dropped from further inclusion in analysis					
Deadhorse Ridge	9/10	90.0%	10/10	100.0%	9/10	90.0%
Jordan Creek	10/10	100.0%	10/10	100.0%	9/10	90.0%
Kelly Canyon	12/12	100.0%	9/12	75.0%	11/12	91.7%
Malad	25/25	100.0%	22/25	88.0%	25/25	100.0%
Murphy Hot Springs	N=1, therefore dropped from further inclusion in analysis					
Obsidian Cliff	N=1, therefore dropped from further inclusion in analysis					
Owyhee	246/249	98.8%	231/249	92.8%	248/249	99.6%
Pack Saddle	N=1, therefore dropped from further inclusion in analysis					
Reas Pass	22/22	100.0%	16/22	72.7%	17/22	77.3%
Reynolds	24/24	100.0%	24/24	100.0%	24/24	100.0%
Sinker Canyon	39/39	100.0%	39/39	100.0%	39/39	100.0%
Striker Basin Gulch	N=1, therefore dropped from further inclusion in analysis					
Teton Pass 1	N=1, therefore dropped from further inclusion in analysis					
Timber Butte	38/38	100.0%	37/38	97.4%	38/38	100.0%
Wedge Butte	26/26	100.0%	25/26	96.2%	26/26	100.0%
Total	**701/705**	**99.4%**	**657/705**	**93.2%**	**691/705**	**98.0%**

Discussion and Conclusion

Statistical Analyses

Multiple statistical analyses were applied throughout this study to confirm source assignments and to avoid potential limitations associated with utilizing each approach separately (e.g., Glascock et al. 1998; Hughes 1984; Shackley 2005). As demonstrated in this study and other pXRF vs. XRF studies (e.g., Craig et al. 2007; Millhauser et al. 2011), the source profiles and same artifact comparison allowed for pooling transformed data from both labs to attain an increased percentage of artifact source assignments that were not otherwise possible. The ability to assign sources to obsidian artifacts when both labs do not have exhaustive source profiles of the region appears feasible with the caveat to proceed cautiously by applying multiple statistical analyses. Some studies (e.g., Craig et al. 2007) have determined that, while there may be significant differences in element concentration values, these differences had no bearing on consistency of the obsidian source assignment.

The PCA source-to-source assignment resulted in the removal of 64 individual NWROSL cases due to the GAUSS Runtime program assigning those cases to sources other than the named grouping from which they originated. All statistical analyses were performed again with 705 instead of 769 NWROSL cases. All results reported within this thesis are based on 705 NWROSL cases and the means from both NWROSL and IMNH. The incorrect assignment of these 64 source cases could be a direct result of the collection method of obtained geologic samples to characterize the source. In other words, these particular cases may not be representative of the obsidian source to which they are attributed. If these cases are in fact from the obsidian source to which they are attributed, it would suggest that the obsidian source is highly variable.

The source-to-source assignments and artifact-to-source assignments using DFA, PCA, and HCA achieved varying degrees of success in assigning sources, but the combination of all approaches contributed to corroboration of all but four sources. The instances in which PCA was “Unknown” while the other methods resulted in a named source were a direct result of using only one standard deviation for source-to-source assignment because the individual values had such a large range that in some cases two standard deviations in either direction accounted for all the cases — even those assigned to a different source (Black 2014). A possible explanation for the wide range of source means is likely related to the variation within the geologic source samples, which may or may not have come from the same geologic formation.

Artifact Source Assignment

The obsidian sources used in this study were restricted to only known sources within Idaho. Therefore, any “Unknown (UNK)” obsidian sources originate either from outside Idaho or are unknown and uncharacterized sources within Idaho (Willson 2005). A total of 86.8% of artifacts were assigned to a source using all of the statistical approaches. Without the inclusion of the NWROSL sources, only 74.7% of the artifacts would have been assigned to a source. Of the 21 artifacts run between both labs, four were not assigned to the same obsidian source (Black 2014). Obsidian source geochemical profiles for only one state does not account for all the sources represented by the artifact profiles. The other three instances of conflicting source assignments (UNK-C) are relatively close spatially, and this emphasizes the need for a geologic re-survey of the sources to increase the geologic sample sizes and to refine the characterization of the sources.

10BN23

No previous obsidian XRF studies had been performed on this artifact collection. Site 10BN23 artifact samples appear to have been conveyed to the site from sources to the south and southeast. The one unknown source may be explained by either the existence of an unknown obsidian source or procurement from a source outside of Idaho (Figure 10 and Table 11).

TABLE 11. 10BN23: All-Method Artifact Source Assignments

AFW	BB	BSB	BVA	CM/1	MD	WB	UNK	Total
9	5	5	3	6	1	2	1	32
28%	**16%**	**16%**	**9%**	**19%**	**3%**	**6%**	**3%**	**100%**

10BV48

No previous obsidian XRF studies had been performed on this artifact collection. Site 10BV48 artifact samples appear to have been conveyed to the site from sources to the north, east, and southwest. The one unknown source may be explained by either the existence of an unknown obsidian source or the procurement from a source outside of Idaho (Figure 11 and Table 12).

TABLE 12. 10BV48: All-Method Artifact Source Assignments

BG	MD	PS/DHR	TP1	UNK	Total
3	1	18	1	1	24
13%	**4%**	**75%**	**4%**	**4%**	**100%**

10CN5

Site 10CN5 artifact samples had been previously analyzed at NWROSL (Hunter et al. 1998). The results of previous sample analysis indicate the presence of obsidian from sources north of the site and in southeastern Oregon. The samples included in the current analysis appear to have been conveyed to the site from nearby sources to the south. In one instance (10CN5, Artifact 76), analyzed at both labs, the "Unknown" is attributed to a source in Oregon (Figure 12 and Table 13a-c). The pattern indicated by the analyzed samples from both studies and both labs are in agreement (based on the obsidian sources included).

TABLE 13a. 10CN5: Previous Artifact Source Assignments

OY	TB	Oregon	Total
6	1	3	10
60%	**10%**	**30%**	**100%**

TABLE 13b. 10CN5: All-Method Artifact Source Assignments.

JC	OY	UNK	Total
1	6	1	8
12.5%	**75.0%**	**12.5%**	**100%**

TABLE 13c. 10CN5: Comparison of Previous Analysis with Current Study

Specimen	All Methods	NWROSL
A5	N/A	Indian Creek Buttes, Oregon
12	Owyhee	Owyhee
13	Jordan Creek	N/A
A34	N/A	Timber Butte
35	Owyhee	Owyhee
A50	Owyhee	Owyhee
A59	N/A	Sourdough Mountain, Oregon
67	Owyhee	Owyhee
76	Unknown	Coyote Wells, Oregon
161	Owyhee	Owyhee
1134	Owyhee	Owyhee

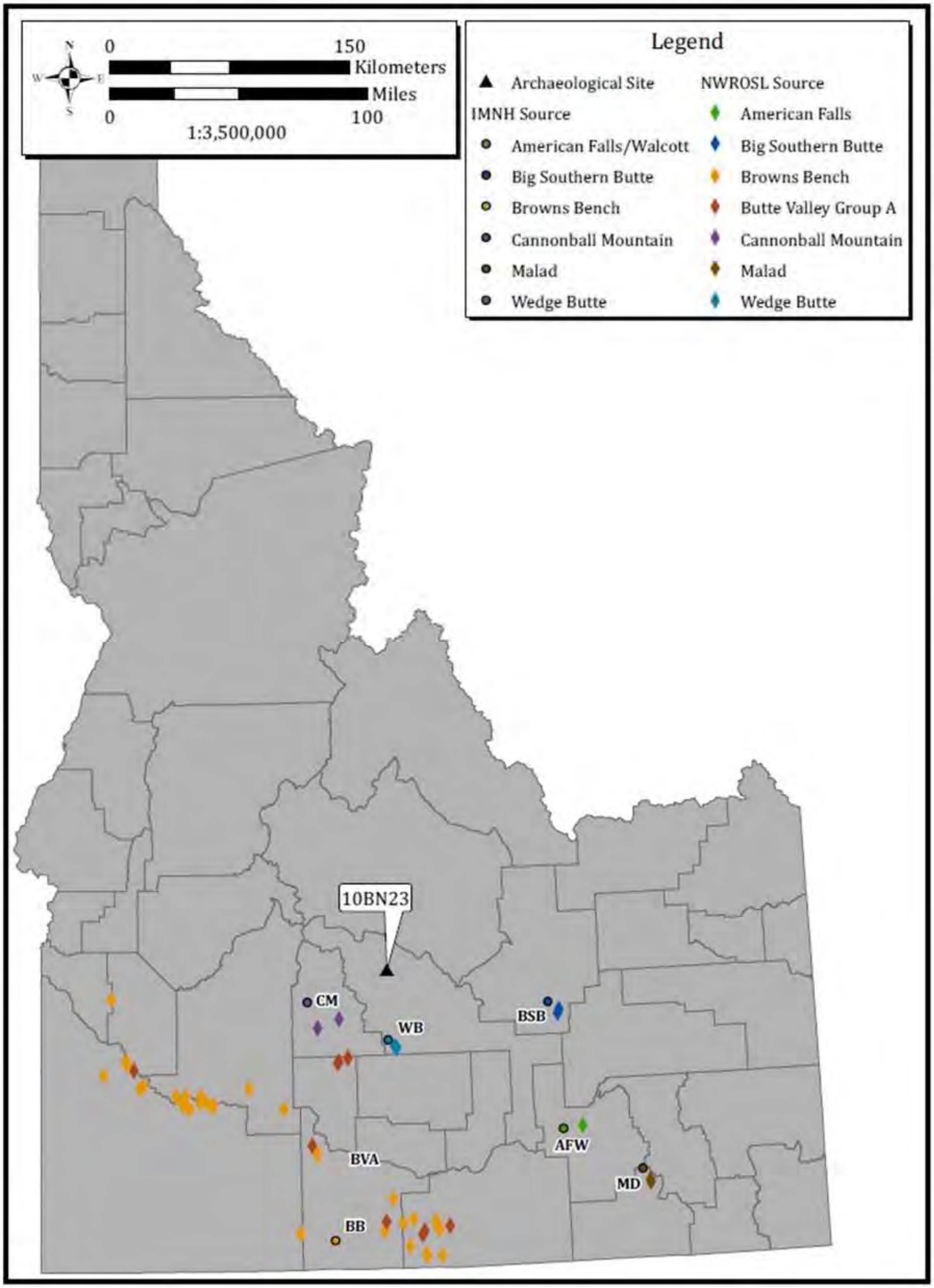

Figure 10. Site and Idaho Obsidian Sources Present in Assemblage.

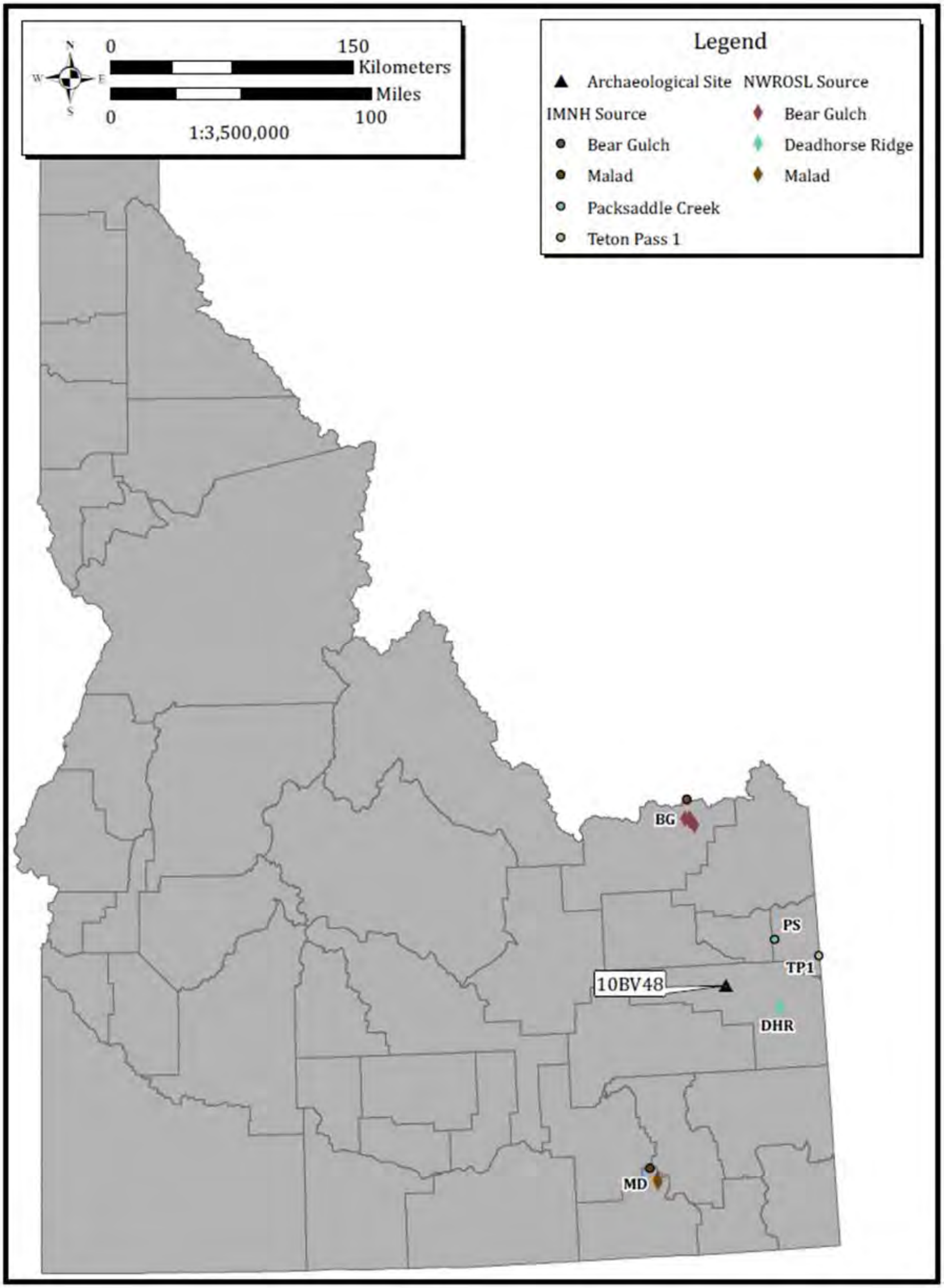

Figure 11. Site and Idaho Obsidian Sources Present in Assemblage.

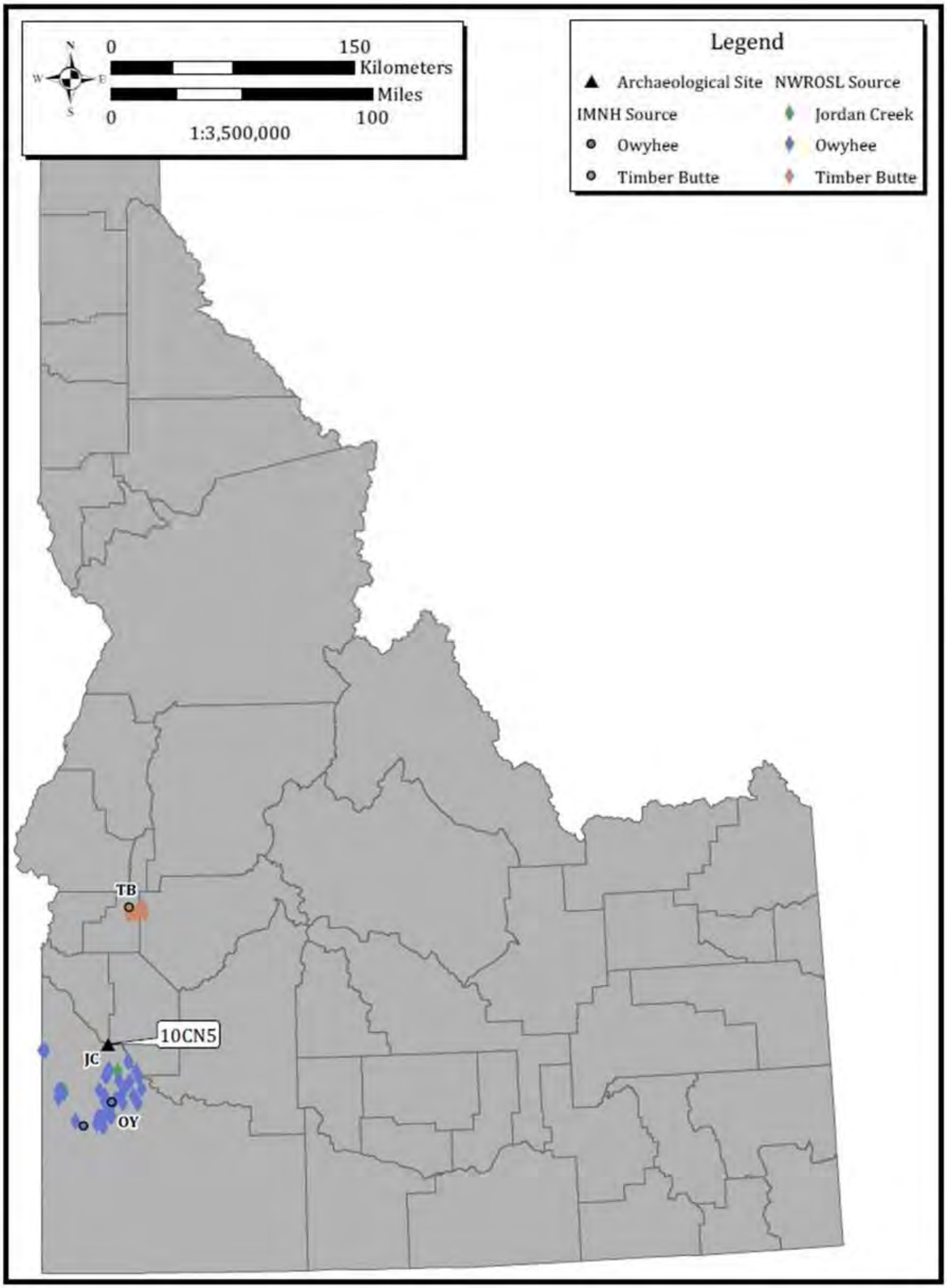

Figure 12. Site and Idaho Obsidian Sources Present in Assemblage.

10CN6

Site 10CN6 artifact samples had been previously analyzed at NWROSL (Plew et al. 2006). The results of previous sample analysis indicate the presence of obsidian in sources from southeastern Oregon. The samples included in the current analysis appear to have been conveyed to the site from sources to the north and south. The three unknown sources may be explained by either the existence of unknown obsidian source(s) or the procurement from source(s) outside of Idaho (Figure 13 and Table 14a-c). The pattern indicated by the analyzed samples from both studies and both labs are in agreement (based on the obsidian sources included).

TABLE 14a. 10CN6: Previous Artifact Source Assignments

OY	SC	TB	Oregon	UNK	Total
12	1	5	3	1	22
54.5%	**4.5%**	**22.8%**	**13.7%**	**4.5%**	**100%**

TABLE 14b. 10CN6: All-Method Artifact Source Assignments

OY	SC	TB	UNK	Total
8	1	1	3	13
61.5%	**7.7%**	**7.7%**	**23.1%**	**100%**

Table 14c. 10CN6: Comparison of Previous Analysis with Current Study

Specimen	All Methods	NWROSL
1	N/A	Owyhee
2	N/A	Coyote Well, Oregon
3	N/A	Unknown
4	N/A	Timber Butte
5	Timber Butte	Timber Butte
6	Owyhee	Owyhee
31	Unknown	N/A
32	Unknown	N/A
A34	N/A	Owyhee
A35	N/A	Timber Butte
45	N/A	Owyhee
A46	N/A	Coyote Well, Oregon
A48	Owyhee	Owyhee
56	Owyhee	N/A
A57	N/A	Venator, Oregon
A60	Owyhee	Owyhee
74	Unknown	N/A
77	N/A	Owyhee
A78	Owyhee	Owyhee
79	N/A	Owyhee
92	N/A	Owyhee
95	N/A	Timber Butte
96	N/A	Owyhee
100	Owyhee	N/A
A110	N/A	Timber Butte
A116	Owyhee	Owyhee
117	Owyhee	N/A
A121	Sinker Canyon	Sinker Canyon

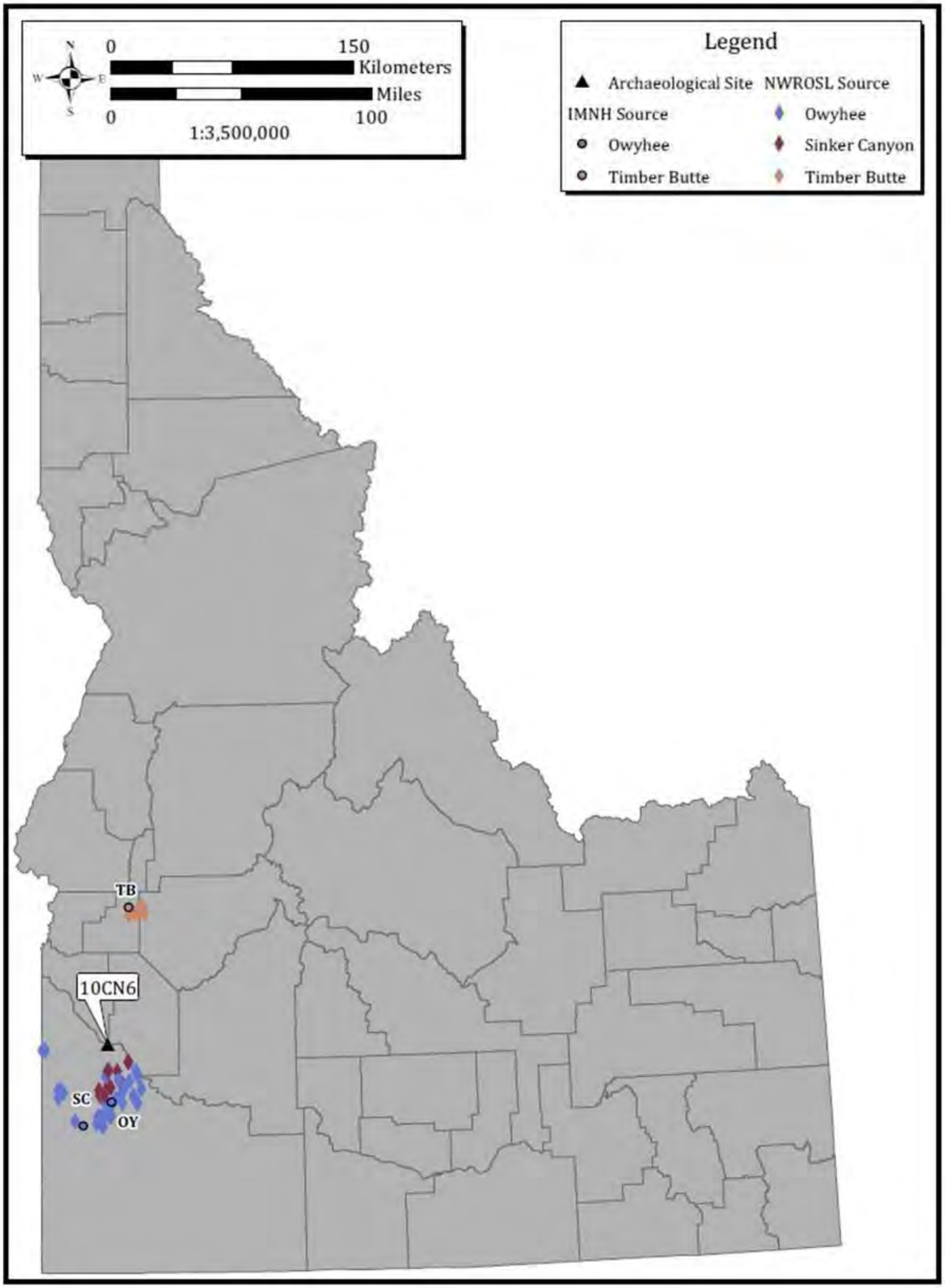

Figure 13. Site and Idaho Obsidian Sources Present in Assemblage.

10CR52

No previous obsidian XRF studies had been performed on this artifact collection. Site 10CR52 artifact samples appear to have been conveyed to the site from sources to the south and east. The six unknown sources are perhaps explained by either the existence of unknown obsidian source(s) or procurement from source(s) outside of Idaho (Figure 14 and Table 15).

TABLE 15. 10CR52: All-Method Artifact Source Assignments

AFW	BG	BSB	CM/1	PS/DHR	UNK	Total
7	5	1	2	1	6	22
31.8%	**22.7%**	**4.6%**	**9.0%**	**4.6%**	**27.3%**	**100%**

10EL110

Site 10EL110 artifact samples had been previously analyzed at NWROSL (Willson and Plew 2007). The pattern indicated by the analyzed samples from both studies and both labs are in agreement and in fact, expanded to the east and south (based on the obsidian sources included in this study). The samples included in the current analysis appear to have been conveyed to the site from sources to the north, west, and south with the majority originating from the east. There are no unknown sources (Figure 15 and Table 16a-c).

TABLE 16a. 10EL110: Previous Artifact Source Assignments

BB	BBA	BSB	CM/1	OY	SC	Total
1	2	1	2	2	1	9
11.1%	**22.2%**	**11.1%**	**22.2%**	**22.2%**	**11.1%**	**100%**

TABLE 16b. 10EL110: All-Method Artifact Source Assignments

AFW	BB	BG	BVA	CM/1	CM2	MHS	OY	Total
1	2	1	1	6	1	1	1	14
7%	**15%**	**7%**	**7%**	**43%**	**7%**	**7%**	**7%**	**100%**

TABLE 16c. 10EL110: Comparison of Previous Analysis with Current Study

Specimen	All Methods	NWROSL
1	Cannonball Mountain 2	N/A
A9	N/A	Sinker Canyon
A21	Murphy Hot Springs	Browns Bench Area
A42	N/A	Big Southern Butte
A52	N/A	Browns Bench Area
A67	N/A	Cannonball Mountain/1
82	Cannonball Mountain/1	N/A
89	Cannonball Mountain/1	N/A
A93	Owyhee	Cannonball Mountain/1
96	Cannonball Mountain/1	N/A
A99	Browns Bench	Browns Bench
A118	N/A	Owyhee
191	Butte Valley A	N/A
A208	N/A	Owyhee
A216	American Falls/Walcott	N/A
228	Bear Gulch	N/A
234	Browns Bench	N/A
247	Cannonball Mountain/1	N/A
259	Cannonball Mountain/1	N/A
261	Cannonball Mountain/1	N/A

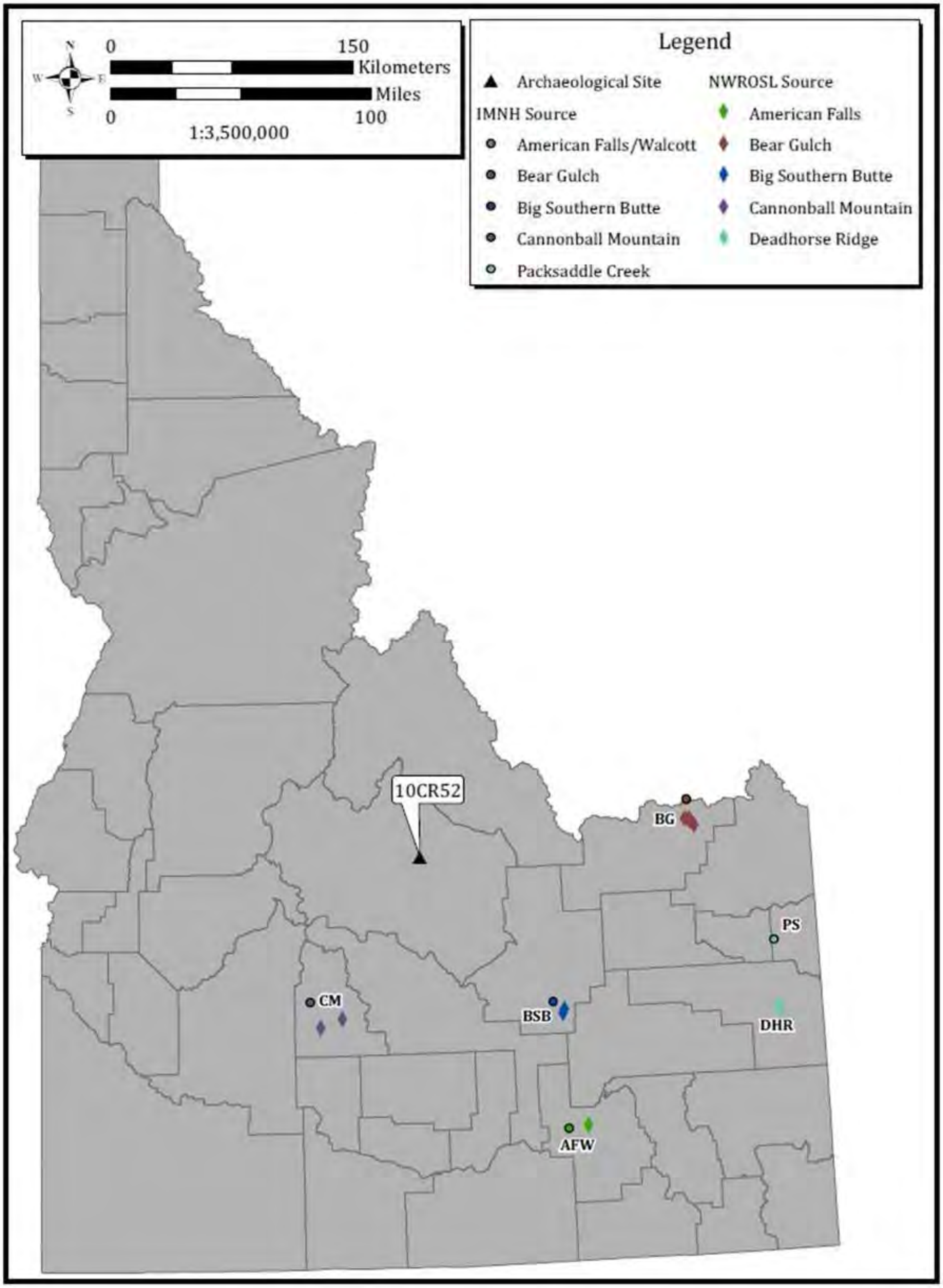

Figure 14. Site and Idaho Obsidian Sources Present in Assemblage.

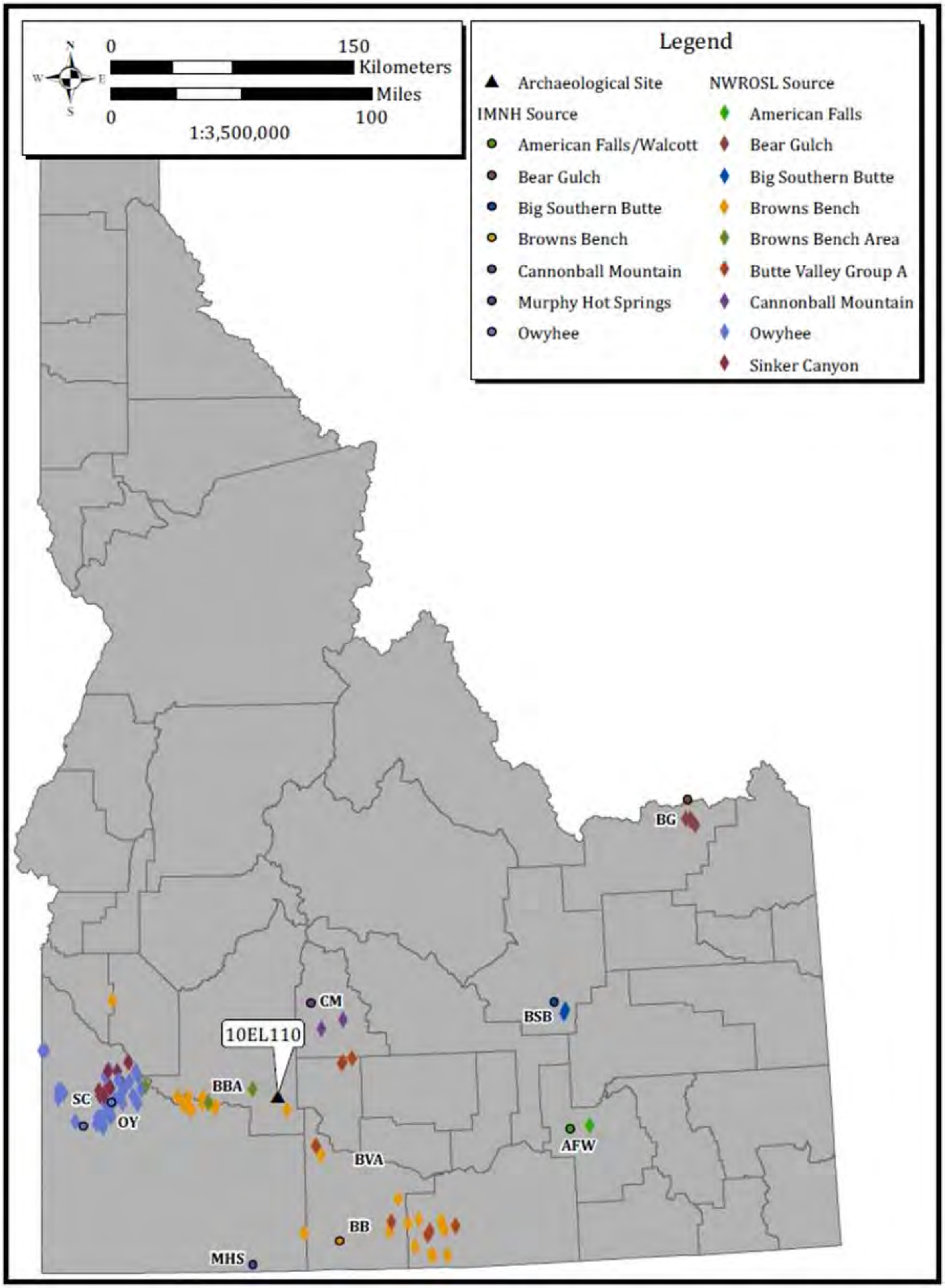

Figure 15. Site and Idaho Obsidian Sources Present in Assemblage.

10EL215

Site 10EL215 artifact samples had been previously analyzed at NWROSL (Plew and Willson 2011). The patterns indicated by the analyzed samples from both studies and both labs are in agreement and in fact, have expanded the number of sources originating from the west and south (based on the obsidian sources included in this study). The samples included in the current analysis appear to have been conveyed to the site from sources to the north, southeast, and west. The one unknown source is perhaps explained by either the existence of an unknown obsidian source or the procurement from a source outside of Idaho. There are four instances of disagreement; the PCA results were not the same as the non-statistical or

TABLE 17a. 10EL215: Previous Artifact Source Assignments

BB	CM/1	Total
9	3	12
75%	**25%**	**100%**

TABLE 17b. 10EL215: All-Method Artifact Source Assignments

BB	BVA	CM/1	CM2	OY	UNK	UNK-C	Total
7	1	7	1	4	1	4	25
28%	**4%**	**28%**	**4%**	**16%**	**4%**	**16%**	**100%**

TABLE 17c. 10EL215: Comparison of Previous Analysis with Current Study

Specimen	All Methods	NWROSL
1	N/A	Browns Bench
2	N/A	Browns Bench
3	N/A	Cannonball Mountain/1
4	Unknown-Conflict	Browns Bench
5	N/A	Browns Bench
6	N/A	Cannonball Mountain/1
7	Browns Bench	Browns Bench
8	Browns Bench	Browns Bench
9	Browns Bench	Browns Bench
10	N/A	Browns Bench
11	Cannonball Mountain/1	Cannonball Mountain/1
12	N/A	Browns Bench
29	Browns Bench	N/A
37	Unknown-Conflict	N/A
42	Unknown	N/A
78	Browns Bench	N/A
88	Butte Valley A	N/A
95	Cannonball Mountain/1	N/A
117	Browns Bench	N/A
118	Cannonball Mountain/1	N/A
131	Cannonball Mountain/1	N/A
158	Cannonball Mountain/1	N/A
172	Cannonball Mountain/1	N/A
179	Unknown-Conflict	N/A
180	Owyhee	N/A
193	Cannonball Mountain 2	N/A
216	Browns Bench	N/A
225	Cannonball Mountain/1	N/A
252	Browns Bench	N/A
270	Owyhee	N/A
280	Owyhee	N/A
289	Owyhee	N/A

HCA assignment. Therefore, a source could not be confidently assigned (Figure 16 and Table 17a-c).

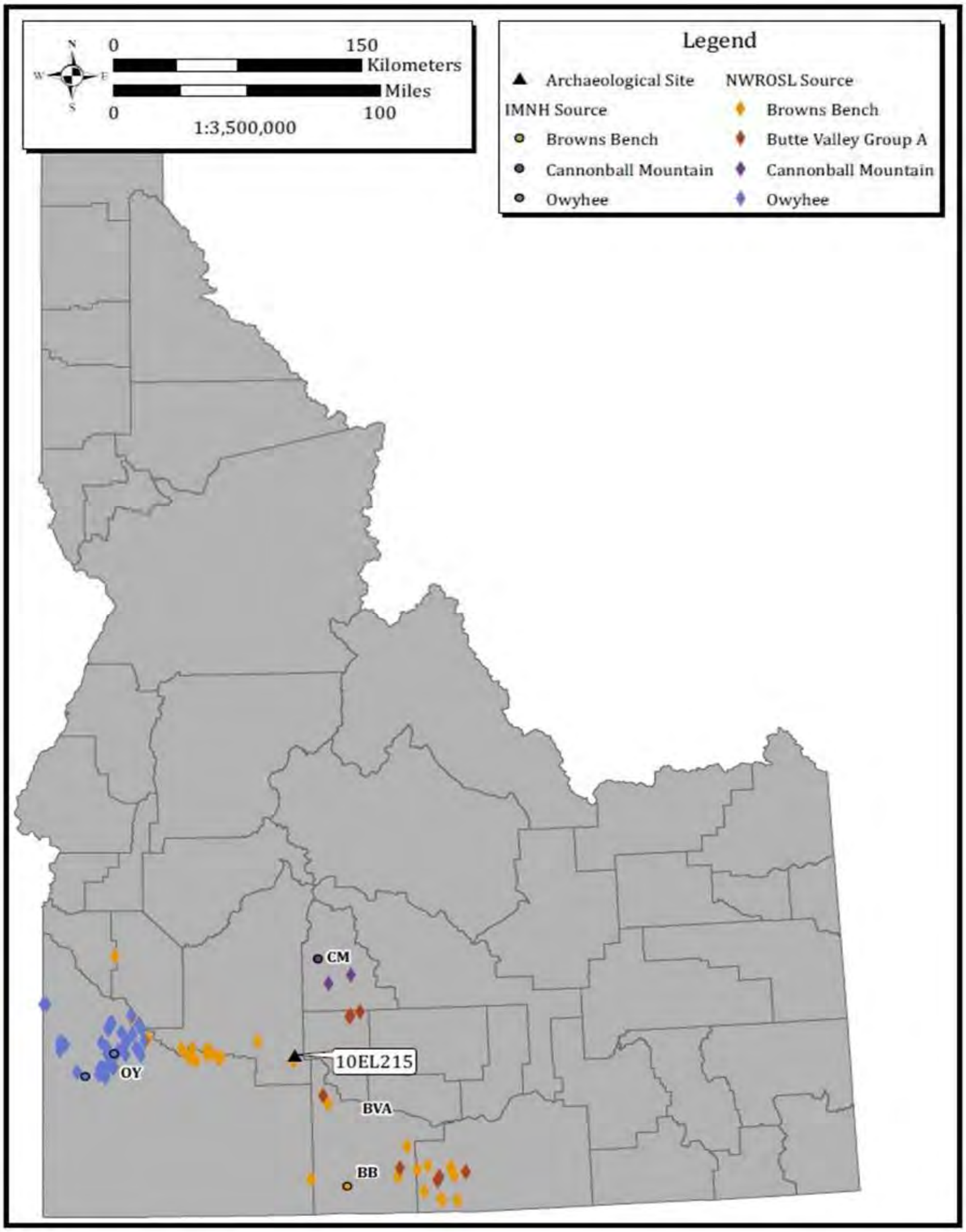

Figure 16. Site and Idaho Obsidian Sources Present in Assemblage.

10EL294

Site 10EL294 artifact samples had been previously analyzed at NWROSL (Gould and Plew 2001). The pattern indicated by the previously analyzed samples and the current study are in agreement and the current study has added an obsidian source (based on the obsidian sources included in this study). The samples included in the current analysis appear to have been conveyed to the site from sources to the north and south. There are no unknown sources. One PCA result did not agree with the non-statistical or HCA assignment and therefore could not be confidently assigned to a source (Figure 17 and Table 18a-c).

TABLE 18a. 10EL294: Previous Artifact Source Assignments

AFW	BB	BBA	BG	OY	TB	Total
2	6	1	4	2	1	16
12.5%	**37.5%**	**6.25%**	**25.0%**	**12.5%**	**6.25%**	**100%**

TABLE 18b. 10EL294: All-Method Artifact Source Assignments

BB	CM/1	UNK-C	Total
3	1	1	5
60%	**20%**	**20%**	**100%**

TABLE 18c. 10EL294: Comparison of Previous Analysis with Current Study

Specimen	All Methods	NWROSL
1	N/A	Bear Gulch
2	N/A	Browns Bench Area
3	N/A	Browns Bench
4	N/A	Bear Gulch
5	N/A	American Falls/Walcott
6	N/A	American Falls/Walcott
7	N/A	Bear Gulch
8	N/A	Browns Bench
9	N/A	Owyhee
10	N/A	Browns Bench
74	Browns Bench	N/A
88	Browns Bench	N/A
109	Browns Bench	N/A
116	Unknown-Conflict	N/A
158	Cannonball Mountain/1	N/A
381	N/A	Browns Bench
382	N/A	Bear Gulch
569	N/A	Browns Bench
970	N/A	Browns Bench
972	N/A	Timber Butte
1173	N/A	Owyhee

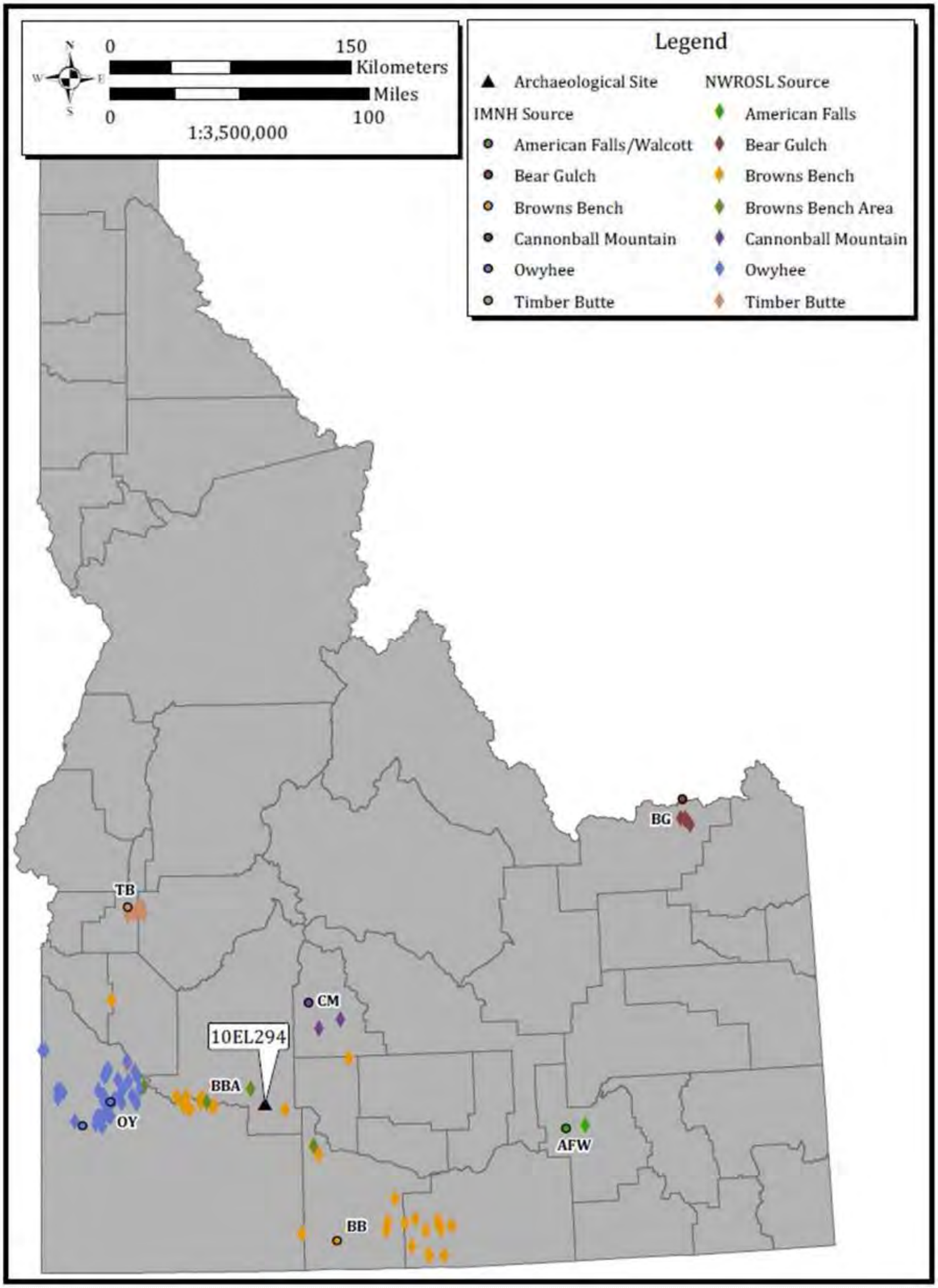

Figure 17. Site and Idaho Obsidian Sources Present in Assemblage.

10EL1367

Site 10EL1367 artifact samples had been previously analyzed at NWROSL (Plew and Willson 2005). The patterns indicated by the previously analyzed samples and the current study are in agreement (based on the obsidian sources included in this study). The samples included in the current analysis appear to have been conveyed to the site from sources to the northeast and southeast. There are no unknown sources (Figure 18 and Table 19a-c).

TABLE 19a. 10EL1367: Previous Artifact Source Assignments

BB	BBA	CM/1	OY	Total
4	1	2	2	9
44.5%	**11.1%**	**22.2%**	**22.2%**	**100%**

TABLE 19b. 10EL1367: All-Method Artifact Source Assignments

BB	BVA	CM/1	Total
2	2	1	5
40%	**40%**	**20%**	**100%**

TABLE 19c. 10EL1367: Comparison of Previous Analysis with Current Study

Specimen	All Methods	NWROSL
1	N/A	Owyhee
2	N/A	Browns Bench
3	N/A	Cannonball Mountain/1
4	N/A	Browns Bench
5	N/A	Owyhee
9	Butte Valley A	N/A
A10	N/A	Browns Bench
11	Browns Bench	N/A
19	Butte Valley A	N/A
22	Browns Bench	N/A
26	Cannonball Mountain/1	N/A
A29	N/A	Browns Bench Area
A30	N/A	Cannonball Mountain/1
A34	N/A	Browns Bench

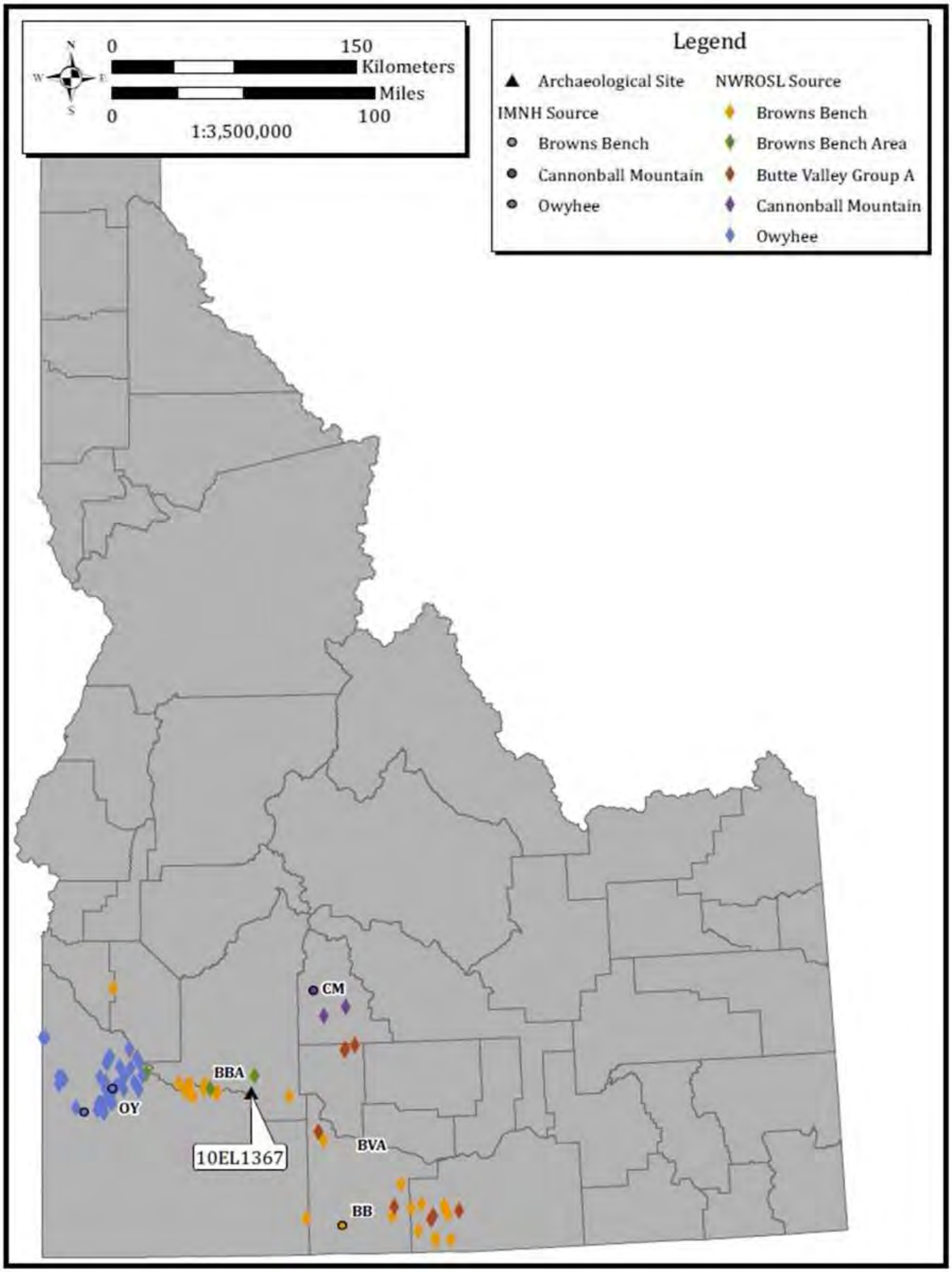

Figure 18. Site and Idaho Obsidian Sources Present in Assemblage.

10EL1577

Site 10EL1577 artifact samples had been previously analyzed at NWROSL (Plew et al. 2002). The patterns indicated by the previously analyzed samples and the current study are in agreement and the current study has and have expanded the number of sources originating from the east and south (based on the obsidian sources included in this study). The samples included in the current analysis appear to have been conveyed to the site from sources to the north, east, and south with the majority from the east. There are no unknown sources in this site sample (Figure 19 and Table 20a-c).

TABLE 20a. 10EL1577: Previous Artifact Source Assignments

BB	BG	CM/1	OY	UNK	Total
3	1	1	2	12	19
15.8%	**5.3%**	**5.3%**	**10.5%**	**63.1%**	**100%**

TABLE 20b. 10EL1577: All-Method Artifact Source Assignments

BB	BG	BSB	BVA	CM/1	MD	MHS	OY	Total
2	2	1	1	3	1	1	1	12
17.0%	**17.0%**	**8.2%**	**8.2%**	**25.0%**	**8.2%**	**8.2%**	**8.2%**	**100%**

TABLE 20c. 10EL1577: Comparison of Previous Analysis with Current Study

Specimen	All Methods	NWROSL
3	N/A	Unknown
5	N/A	Unknown
10	N/A	Unknown
16	N/A	Bear Gulch
25	N/A	Unknown
30	N/A	Unknown
42	N/A	Owyhee
54	N/A	Unknown
60	N/A	Unknown
63	N/A	Browns Bench
86	N/A	Browns Bench
91	Bear Gulch	N/A
92	N/A	Cannonball Mountain/1
173	Browns Bench	N/A
226	Bear Gulch	N/A
246	Big Southern Butte	N/A
267	Malad	N/A
274	Owyhee	N/A
282	N/A	Unknown
320	N/A	Unknown
335	N/A	Unknown
361	N/A	Unknown
371	N/A	Unknown
412	Browns Bench	N/A
457	Butte Valley A	N/A
476	Cannonball Mountain/1	N/A
501	Cannonball Mountain/1	N/A
522	N/A	Owyhee
532	Cannonball Mountain/1	N/A
537	N/A	Browns Bench
564	Murphy Hot Springs	N/A

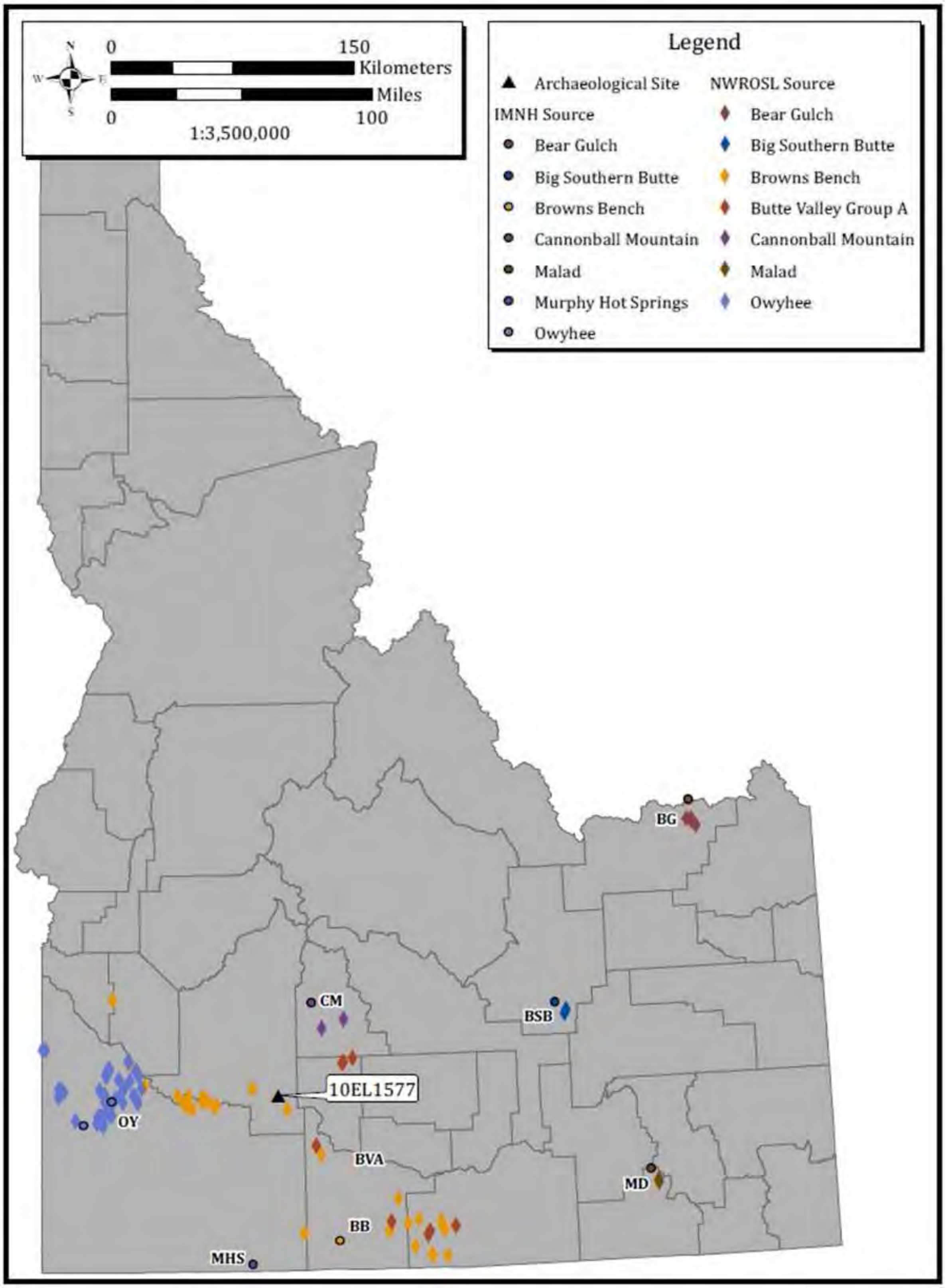

Figure 19. Site and Idaho Obsidian Sources Present in Assemblage.

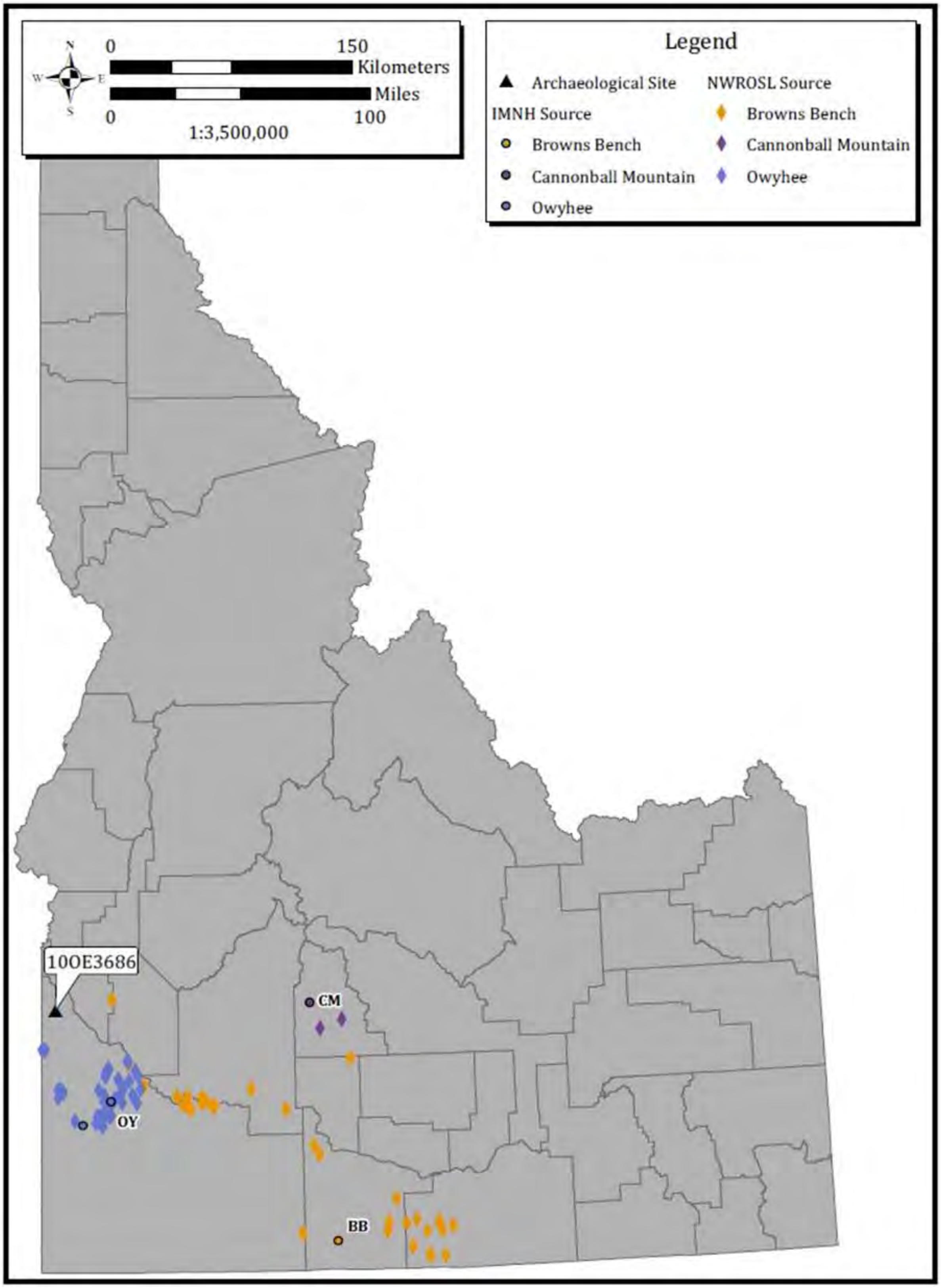

Figure 20. Site and Idaho Obsidian Sources Present in Assemblage.

10OE3686

No previous obsidian XRF studies had been performed on this artifact collection. Site 10OE3686 artifact samples appear to have been conveyed to the site from sources to the east, southeast, and south. However, the majority of artifacts appear to be from unknown source(s). The nine unknown sources are perhaps explained by either the existence of unknown obsidian source(s) or by procurement from source(s) outside of Idaho (Figure 20 and Table 21).

TABLE 21. 10OE3686: All-Method Artifact Source Assignments.

BB	CM/1	OY	UNK	Total
1	1	3	9	14
7.1%	**7.1%**	**21.5%**	**64.3%**	**100%**

Conclusion

Hughes and Bennyhoff (1986:238) caution that "it is one thing to determine the geographic source area for a commodity, but it is quite another matter to infer the social mechanism responsible for the occurrence of that material at an archaeological site."

The addition of obsidian samples sourced in this study have contributed some new information regarding the source of obsidian artifacts, but more importantly have confirmed previous conclusions regarding the source of obsidian artifacts.

The comparison of obsidian source profiles between labs, the discrepancy in names, and the low between-lab reliability for some elements of these source profiles suggests that interpretations of prehistoric human activity in Southern Idaho should be evaluated with skepticism due to the incomplete knowledge of obsidian sources. A systematic survey and re-survey of geologic obsidian sources and a sampling strategy to address variation within and between obsidian sources may provide an opportunity to develop more reliable inferences. A survey of the sources should incorporate information on the geologic context, petrogenesis, and geochemical character of the obsidian sources. A more detailed, centralized, and accessible regional database of geologic obsidian sources that goes beyond state boundaries would provide researchers with access to the same source geochemical profiles and allow formore direct comparison(s). The preceding recommendations would increase the validity of source and artifact assemblage geochemical characterizations and provide a foundation for more useful interpretations of past human behavior.

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REPORT

Basal-Notched Arrow Points: A View from Kwahadu Rockshelter

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Abstract

Excavations at Kwahadu Rockshelter, Jerome County, Idaho, in 1991, yielded faunal remains of pronghorn, several hearths, remnants of sleeping mats, arrow points and point fragments, an arrow shaft fragment, and lithic manufacturing debris. The points were in all stages of production, including some clearly broken during manufacture. Analysis of these materials indicate that square-barbed, basal-notched points are most likely a distinctive type on the Snake River Plain. Formerly called "Eastgate," these are now generally lumped with small corner-notched points to yield a more generalized "Rosegate" series projective, a practice which may in some regards misinterpret the archaeological record for the Snake River Plain.

KEYWORDS: Eastgate Point, Experimental Manufacture, Great Basin Point Typology, Kwahadu Rockshelter, Late Period Basal-Notched Point, Rosegate, Rose Springs, Square-barbed Point

Introduction

Since the pioneering years of Great Basin archaeology, projectile points have been shuffled into various categories based on form. First, the categories were descriptive, based on overall dimensions or configuration, primarily of the basal portion of the point. Eventually, they took on additional interpretive value as time markers or even cultural indicators. Though the numbers and names have evolved, archaeologists still devote lots of time and print to discussions and arguments about various point types and their design differences, age, or cultural affiliation. This paper addresses one such point type—the small, late prehistoric basal-notched arrow point.

Kwahadu Rockshelter

In 1991, Gene Titmus and I excavated a small rockshelter located on private land just below the rim of the Snake River Canyon in Jerome County, Idaho. A preliminary summary of our findings was reported at the Idaho Archaeological Society annual meeting in October of 1991 (Titmus and Woods 1991). Results indicated this rockshelter was used just over 1000 years ago, and was occupied for one or two short episodes primarily as a retooling site for the manufacturing and repair of arrows and small arrow points. Features included four fire hearths, two distinct areas of *phragmites* matting, concentrations of pronghorn *(Antilocapra Americana)* hair, a groundstone mortar, and 1 kg of crushed pronghorn bone. These were all located between the rear vertical wall of the rockshelter and several large boulders (Figure 1)

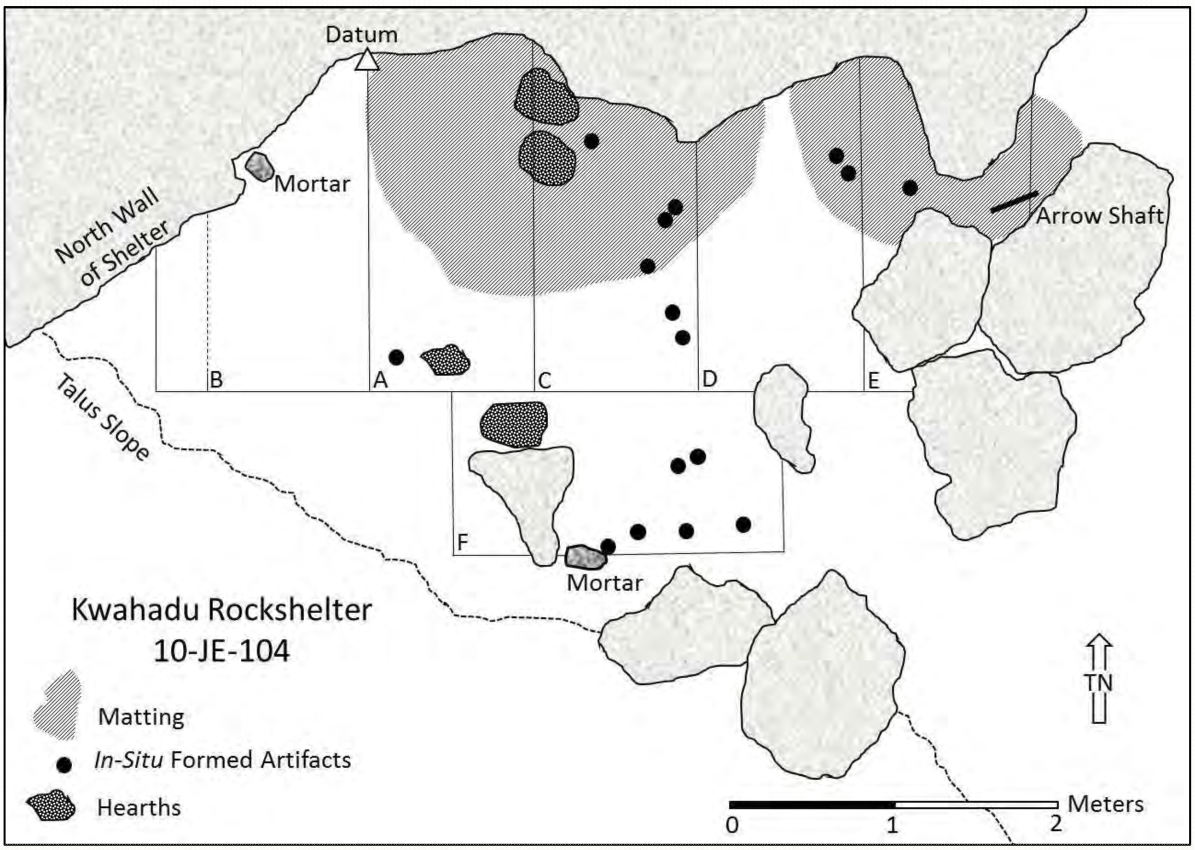

Figure 1. Map of Kwahadu Rockshelter.

Formed flaked-stone artifacts included a twenty-five arrow points plus assorted fragments, eleven point preforms, twenty-five small bifaces plus assorted fragments, 2 flake cores, and 5 dart points. The recovery of dart points in what appears to be a site dominated by later-period square-barbed arrow points is interesting, but beyond the scope of this paper. A single radiocarbon date of 1,140 +/- 60 (BETA 47486) was obtained from this rockshelter. It was derived from twigs and grass matting which contained a *phragmites* arrow shaft fragment. This date fits well within the chronology of other small, basal-notch bearing sites in the region.

Also recovered, using 1/8” screen, were 4600 pieces of lithic debitage. To give this number some interpretive value, Titmus made a single basal-notched arrow point of similar size and form to those recovered in the excavations, then sorted the debitage through 1/8” inch and

1/16” screens. From this single point made on a thin, flat flake, 59 flakes (1.5 gm) were recovered in the 1/8” screen, 267 flakes were recovered in the 1/16” screen (1.4 gm), and ca. 13,000 flake fragments remained which were smaller than 1/16” (1.0 gm). Since we used a 1/8” screen in the Kwahadu Rockshelter excavations and recovered about 4600 flakes, we deduced that if about 60 flakes larger than 1/8” were produced per point, the debitage we recovered from Kwahadu Rockshelter was likely the result of manufacturing approximately 77 different points. Twenty-three of these were recovered more or less intact at Kwahadu Rockshelter, so about 54 points were hypothetically manufactured there and removed to other locations.

12B, Rose Spring, Eastgate, or Rosegate?

The purpose of this paper is to look specifically at the collection of arrow points and arrow point preforms abandoned at Kwahadu Rockshelter with the intention of considering, yet once again, the issue of late-period arrow point typologies, specifically as they may apply to the Snake River Plain.

Historically, many early archaeologists working in the region, like Jennings, Swanson, Gruhn, and others, used numbers to distinguish categories of projectile points in an effort to maintain objectivity. For example, in her seminal Wilson Butte Cave report, Ruth Gruhn used the typological number “12B” for what would today be called a “Rosegate” point (Gruhn 1961b:70). However, these numbers were ultimately replaced by type specimen names, and these names varied from region to region and author to author.

In 1978, Heizer and Hester examined late period basal- and corner-notched points and concluded “In the past few years, many archaeologists working in the Great Basin have come to suspect that both series, since they usually occur together, represent in fact a continuum, with only minor morphological differences distinguishing the two groups” (Heizer and Hester 1978:8). They took issue with this suggestion citing what they perceived was a significant difference between the two types, specifically regarding the shape of the barb. They also suggested a distribution difference, with Eastgate points in central and western Nevada, and Rose Spring points found throughout the Basin.

Based on on objective comparison of metric variables, Thomas later suggested that “...Rose Spring and the Eastgate types should be combined into a single Rosegate series. The types obviously grade into one another, and it is extremely difficult in practice to separate the two consistently; in fact.” He felt the statement by Heizer and Hester regarding regional distinctions was not valid and concluded “the two types are merely morphological designations, and I suggest they be combined into a single temporal indicator.” (Thomas 1981:19). These two publications are seminal contributions to the ongoing arguments about small late-period arrow point nomenclature. A cursory review of contemporary literature still finds proponents of both points of view though most now apparently have adopted the term “Rosegate.”

The Kwahadu Arrow Points

The collection of square-barbed arrow points from Kwahadu Rockshelter offers an opportunity to reconsider this issue, at least as it applies to the Snake River Plain in the Northern Great Basin (Figure 2). Seventeen of the twenty-five points and numerous point fragments from Kwahadu Rockshelter are of the square-barbed form, the other 7 appear to have started as square barbed, but were likely modified into corner-notched forms as will be

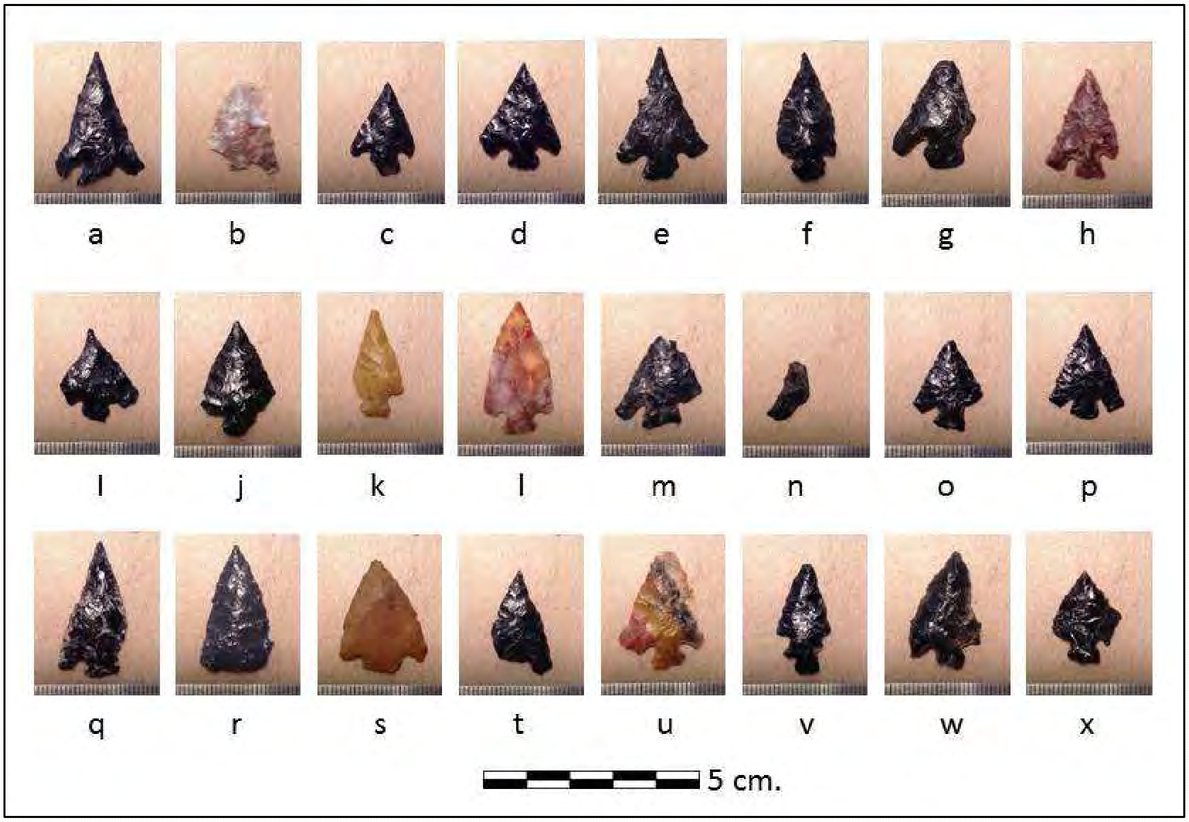

Figure 2. Square-Barbed Arrow Points from Kwahadu Rockshelter.

illustrated momentarily. If this later statement is valid, then Kwahadu Rockshelter represents a site that is dominated by square-barbed points, and re-sharpening and repair of broken Eastgate points may be one way to explain the co-existence of Eastgate and Rose Spring points as so well documented by Thomas and many others.

In 1988, as part of my MA thesis, I replicated one hundred lanceolate points, corner-notched dart points, and basal-notched arrow points for an experimental breakage study (Woods 1988). Thirty-six of these were small, basal-notched arrow points. Of those, six were broken during manufacture including one broken early on in the manufacturing process, and five others broken during the last step of notching (Figure 3). Thirty others were successfully completed, hafted, and then propelled at assorted targets using a modern bow and arrows to induce breakage (Figure 4). The resulting broken pieces were collected, when possible, then correlated with the target material in order to learn about variations in breakage (Figure 5). The 1991 archaeological collection from Kwahadu Rockshelter can be compared and contrasted with these 1987 experimental projectiles to infer some of the archaeological materials were most likely broken during use, but others were clearly broken during manufacturing. Finding both

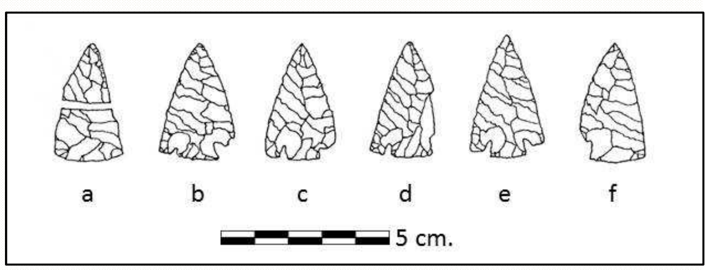

Figure 3. Experimental Basal-Notched Arrow Points Broken during Manufacture.

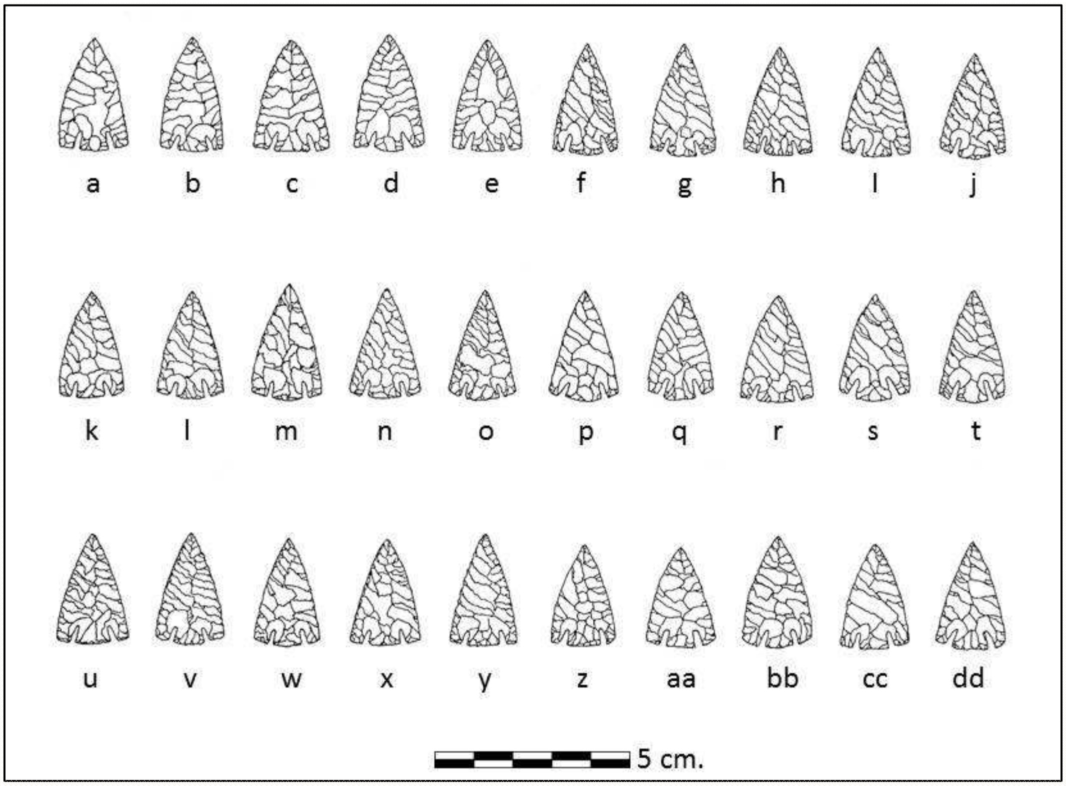

Figure 4. Experimentally Manufactured Basal-Notched Arrow Points.

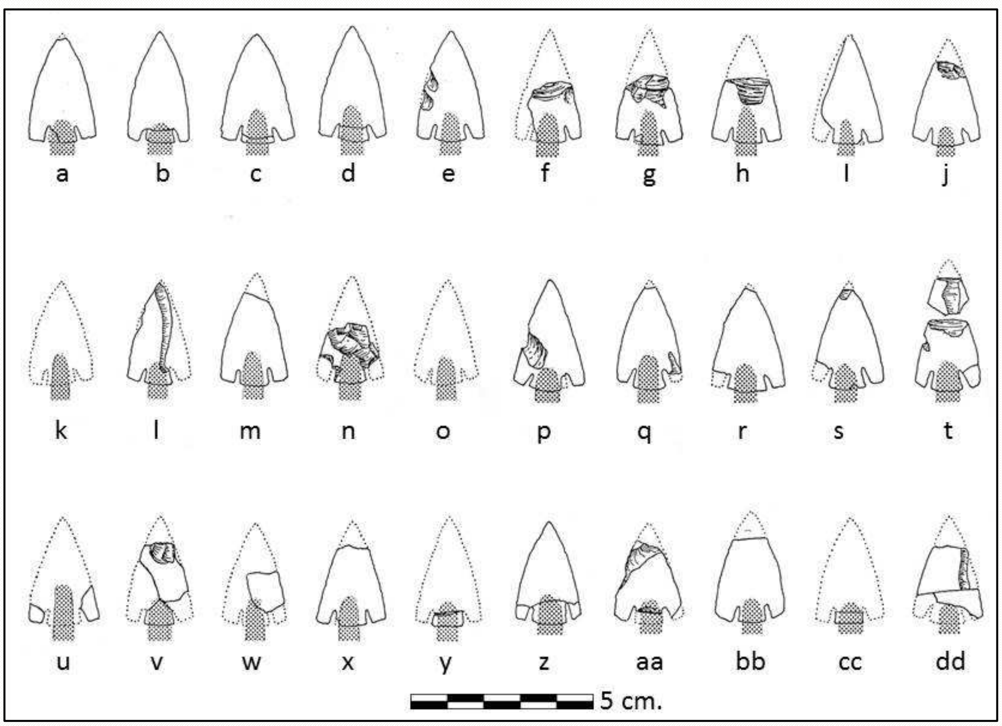

Figure 5. Experimentally Used and Broken Basal-Notched Arrow Points.

together in Kwahadu Rockshelter offers an unusual opportunity to consider point morphology from a slightly different perspective than is normally possible.

What was not considered in the 1991 thesis was the minimal amount of work that would be required to rejuvenate many of the experimental pieces broken during manufacture and use into usable arrow points. Nor was it considered how the form of those projectiles might change upon the minimal amount of refurbishing required to make the broken thesis specimens once again functional. Given their small starting size, anything other than the most basic reworking would render them too small to be functional.

Looking at these again with a fresh perspective, of the thirty points broken during experimental use, 8 were of sufficient size and form to be easily re-worked into other, smaller square-barbed points (Figure 4a, c, e, j, m, p, x, bb). Seven other broken points were damaged in such a way that the only viable way to rejuvenate them would result in much narrower, corner-notched points (Figure 4b, d, i, q, r, s, z). Of the six points broken during experimental manufacture, one could not be reworked into a point of sufficient dimension (Figure 3a). Five of the points broken during manufacture could have been rejuvenated into completed, though smaller points (Figure 3 b-f). If maintaining maximum length and width was the motive, only one broken point could have been reworked into a shorter square barbed point (Figure 3e) The remaining four could only be made into corner-notched points because they lacked a minimum width of 17 mm needed to make square barbs (Figure 3b, c, d, f). This minimal width estimate is derived from the averaged combined width of the two square barbs, the width of two notches, and average width of the base.

Other factors that must have been controlled for in the production of square-barbed points included the preform length and thickness. The collections from Kwahadu Rockshelter provide some insight on these as well. Three preform specimens recovered from Kwahadu Rockshelter were broken and discarded during the early shaping process. These clearly show the preferred preform shape and dimensions. The preferred shape included a wide, three-facet base. The basal margin of the preform was specifically shaped early in the flaking process so when the two basally-oriented notches were created, the result was the distinctive square barbs and narrow stem of the proper width to be fitted to an arrow foreshaft (Figure 6a). This base configuration is clearly preserved on a specimen that was broken during the first notch removal (Figure 6b) and discarded. The break started at the apex of the still-incomplete notch and burinated one margin of the preform. One of the 1991 thesis specimens broke in a very similar way (Figure 3d). The Kwahadu Rockshelter specimen indicates the distinctive square barbs, a hallmark of the Eastgate Point, were clearly established early in the preform stage, prior to notching and seem to be a key design feature of the Eastgate archetype.

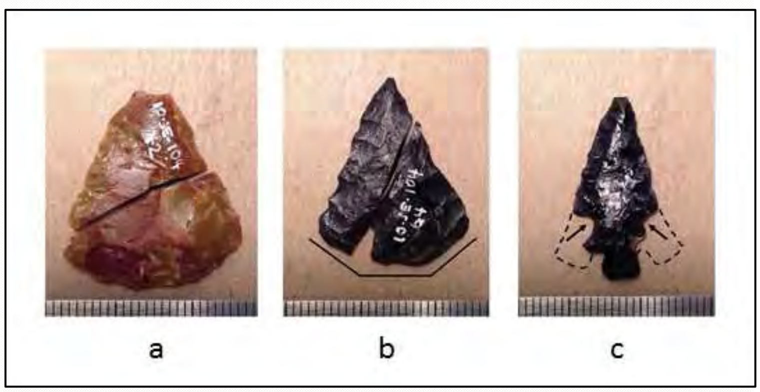

Figure 6. Manufacturing Errors, a) Broken Heat-Treated Preform; b) Point Broken during Notching; c) Abandoned Attempt to Rejuvenate Square-Barbed Point into a Corner-Notched Point.

One more complicated specimen from Kwahadu Rockshelter consists of what started as a square-barbed point that was damaged either during manufacture or use, and was in the process of being reworked into a corner notched point when it was abandoned. The initial square barbs are missing but can be inferred as shown by the dotted outline. Partial remnants of the original basal notches are still visible. Subsequently, corner notches were being formed as indicated by the arrows. This attempted repair was abandoned before the distinctive base of the original square-barbed point had been removed (Figure 6c). This shows the reworking of a damaged square-barbed point into what would have likely been a smaller corner-notched point. Furthermore, recovery of numerous bases of other square-barbed points were recovered at Kwahadu Rockshelter (Figure 7). These represent remnants of points that were likely broken during use elsewhere, and brought back to the site inside foreshafts for replacement with new points. None of the points broken during experimental manufacture in 1987 broke in this manner. However, seven of 30 experimentally used replicas broke like this, leaving the distinctive-shaped bases inside the arrow foreshafts (Figure 5b, c, d, l, o, z, cc).

In sum, manufacturing and use breakage combined with the discard evidence cited above suggests the preferred projectile form among the Kwahadu toolmakers was triangular, thin in

Figure 7. Broken Point Bases of Square-Barbed Points from Kwahadu Rockshelter.

cross section, with a distinctive faceted basal outline, and deep basal notches that resulted in wide, square barbs and a distinctive stem. These features essentially describe the Eastgate form as reported widely throughout the west and on the Snake River Plain. When manufacturing or use breakage left a point fragment that was still of sufficient size and form to be usable, but of insufficient basal width for square barbs, it could be modified into a narrower corner notched point, aka a Rose Spring point.

Regional Comparisons

Numerous sites in south-central Idaho with late period deposits contain both small corner-notched and square-barbed arrow points, often in close contextual and chronological relationship to each other. Three of many examples include Dry Creek Rockshelter (Webster 1978), Nahas Cave (Plew 1986) and Baker Caves (Plew, Pavesic, and Davis 1987). In many instances, both square-barbed and small corner notched points are found in close association.

Baker Caves is of particular importance to this present study. The archaeological collections from Baker Caves are of similar age and similar form to the Kwahadu Rockshelter specimens. The Baker Cave materials appear to have been deposited in two distinct events, the older being A.D. 600-700 and the younger being A.D. 1200. The illustrated arrow points include sixteen corner-notched and basal-notched points most likely from the earlier event and fifteen small side-notched points most likely from the later event. Of the sixteen points illustrated from what was likely the earlier event, half are square-barbed basal-notched points and half are corner notched points (1987:47).

In Meatte's summary of the Western Snake River Plain for the time period of 2,000 to 1,000 years ago, ten excavated sites are listed (Meatte 1990:57). All but one of these (10-AA-17) contain square-notched and corner-notched arrow points. Thirty-eight Eastgate/Rose Spring points were also recovered at the Rattlesnake Canyon Cremation Site (Bonnichsen 1964). Although called Columbia basal-notched points by the author, these are clearly of the same form as what have since been called Eastgate and Rose Spring Points. Eastgate/Rose Spring points are common at other excavated sites just to the east of Kwahadu Rockshelter including Pence-Duerig Cave (Gruhn 1961a), and Wilson Butte Cave (Gruhn 1961b).

Clearly then, small square-barbed and corner-notched arrow point forms co-occur across the central and western portion of the Snake River Plain as Thomas would predict. In most instances, the dates compare favorably with Kwahadu Rockshelter.

Conclusion

Kwahadu Rockshelter was used for one or very few short durations primarily for the manufacturing of basal-notched arrow points, presumably for the subsequent repair of use-damaged arrows. Evidence from Kwahadu Rockshelter shows that the idealized point form most likely was the square-barbed "Eastgate" point. And, when completion of that form was not possible due to insufficient point preform width, or breakage during notching, a narrower corner-notched "Rose Spring" point was produced. Looked at from this perspective, the square -barbed Eastgate point is the archetypal basal-notched arrow point form for the crafts-persons at Kwahadu Rockshelter, and the narrower corner-notched arrow points were fallback alternatives when the preferred form was not possible due to size limitations of the preform. Therefore, the most accurate point form nomenclature would acknowledge this close relationship between the two forms and acknowledge the technological primacy of the square-barbed form over the corner-notched form. It might be more reasonable to simply refer to them as two different variations of Eastgate, or dropping the conflicted names altogether and referring to them as "late-period basal-notched arrow points."

Acknowledgments

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BOOK REVIEW

Lithics in the West: Using Lithic Analysis to Solve Archaeological Problems in Western North America

Edited by Douglas H. MacDonald, William Andrefsky, Jr., and Pei-Lin Yu

Missoula, Montana: The University of Montana Press
191 pp., 1 plate, 74 figures, 31 tables, $20.00 (paper)

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Lithics in the West represents a solid contribution to the area of New World stone tool technology, with a cadre of experienced researchers exploring methodological, organizational, settlement, and exchange-related topics in ten well-written chapters. Co-editor William Andrefsky, Jr. begins the volume with an experimental paper comparing the cutting efficiency of unretouched flake blanks with that of retouched flake tools. By whittling sections of ocean spray, Andrefsky presents a compelling case that unretouched chert and obsidian flakes are typically more effective cutting implements than more formal unifaces or bifaces fashioned from similar materials. If this is the case, then many aboriginal groups may have preferred to use unretouched flakes for various processing and manufacturing activities, especially when suitable tool stone sources were nearby or lithic cores were available on-site. Such behavior has been documented historically among the Alyawara of central Australia and the Xeta' of southern Brazil.

Pei-Lin Yu and Jackie Cook use ethnographic and archaeological data concerning fish processing along the upper Columbia River to develop expectations for characteristics of fish butchering tools recovered from prehistoric sites in the Rocky Mountains. Ethnographic accounts from the Columbia and Fraser River basins indicate that Native women were the predominant processors of salmonids, and typically employed tabular stone knives for many fish butchering tasks such as removing heads, intestines, and fillets. After generating ethnographically-derived expectations for primary attributes of fish processing tools, the authors then discuss the formal characteristics and probable functions of 235 tabular stone tools from six archaeological sites in the Kettle Falls area of northeastern Washington. They believe that stone fish processing implements used at major fishing locales should 1) have low transport and manufacture costs; 2) display both piercing and cutting features; 3) exhibit multiple working edges; and 4) occur in large numbers.

In regard to the Kettle Falls assemblage, Yu and Cook found that most tabular stone artifacts had been made from either locally available quartzite or argillite, and that most of them had piercing and filleting capabilities. Furthermore, a majority of the ~11,500 tabular tools that were recovered from the Kettle Falls sites were found in high numbers within thin occupational strata. Over half (56%, n=132) of the analyzed sample exhibits a single working edge, which did not conform to one expectation of the authors' model, but this pattern may reflect the durable nature of quartzite and argillite, which probably reduced the rate of edge wear. Based upon these ethnographic and archaeological data sets from the Plateau culture area, Yu and Cook believe that prehistoric fish processing tools used by highly mobile foragers in the Rocky Mountain region would be difficult to identify because they presumably were multi-functional, highly curated, and often deposited in small numbers at sites that served different purposes over their occupational history. Protein residue analysis of lithic implements should reveal whether or not they were used to process fish, but Yu and Cook contend that "Overprinting of functions would likely eliminate residue or use wear evidence of fish butchering." This chapter certainly would have benefitted from a more in-depth discussion of ethnographic and archaeological information concerning aboriginal fishing in the Rocky Mountain region.

In chapter 3, Nicole Waguespack and Todd Surovell present a method for identifying interior and exterior activity areas associated with ancient domestic structures based on the distribution of lithic artifacts. This piece combines a simulation exercise with archaeological data to produce a convincing pattern of prehistoric household artifact production, cleaning, and refuse disposal supported by ethnoarchaeological accounts. The authors simulated artifact accumulation within a 3 m diameter house structure, and then modeled discard patterns within and outside the residence informed by ethnoarchaeologically-documented behavior among various forager groups. Waguespack and Surovell then compared their simulated spatial patterns to actual ones documented at Barger Gulch Locality B, a Folsom camp located in Middle Park, Colorado.

Spatial analysis of lithic debris and charcoal within the four excavation blocks at Barger Gulch revealed a general inverse relationship between artifact density and the percentage of burned artifacts. The authors believe that this pattern resulted from the cleaning and dumping of hearths in which areas of low artifact densities and relatively high amounts of burned materials mark the locations of extramural disposal areas. The opposing pattern of high artifact density and largely unburned materials are thought to represent interior work areas that were tethered to hearths. In acknowledging the unlikely universal applicability of this scenario, the authors state that this pattern might be common in regions where climatic conditions or cultural practices resulted in most debris-producing tasks being performed indoors near hearth features, and where occupational span is sufficient to subsume multiple cleaning episodes.

The next chapter is written by Mary Prasciunas, who employs Minimum Analytical Nodule Analysis (MANA) to study Clovis technological organization at the Sheaman site in eastern Wyoming. MANA was developed by Mary Lou Larson and Marcel Kornfeld (1997) and classifies lithic material into analytical units, or "nodules," based on raw material types, each of which are then sub-divided by any other discernible attribute such as color or texture. This classification system ideally produces nodules consisting of flakes that were removed from the same piece of tool stone. Therefore, one nodule should represent a single flintknapping event. Prasciunas identified 79 distinct nodules within the Sheaman site lithic assemblage, which consists of ~4,900 artifacts. Fifty-three nodules are comprised of multiple items, whereas 26 of them are single items. The author then uses her MANA results to characterize the settlement practices of the Clovis people who occupied Sheaman. She believes that 98% of the site's lithic assemblage consists of non-local raw material, thereby reflecting a "high technology forager" settlement system. This high mobility settlement regime is defined primarily by a reliance upon highly curated and recycled lithic artifacts, bifacial technology, and exotic raw materials that were obtained from distant sources.

Chapter 5 is by Robert Brunswig and David Diggs, who present the results of GPS mapping and GIS modeling of several thousand lithic artifacts from Ballinger Draw, northern Colorado, in an attempt to discriminate between prehistoric camps and activity areas. Of the nine sites that were documented within the study area, two are classified as large, multi-component camps, four are viewed as short-term camps, two are special function activity areas, and one is an isolated rock-filled hearth or roasting pit. Sites were defined as camps if they contained diverse tool kits and cooking/heating features, whereas activity areas yielded typologically narrow assemblages and lacked hearths and/or roasting pits.

The authors employed several statistical techniques available through ArcGIS 10.0 to study the distribution of surface artifacts at each site. Hot and cold spot analysis as well as average nearest neighbor analysis proved to be particularly useful in exploring spatial relationships within some of the Ballinger Draw sites. Horizontal plotting of formal and informal tools, lithic debitage, and fire-cracked rock resulted in single- and multiple layer GIS maps that clearly revealed major activity areas at the two large camps. This chapter is an excellent example of how contemporary technology can be joined with traditional field methods to produce multi-scale reconstructions of human landscape use, especially at the meso (locality) and micro (site) levels.

Kenneth Reid provides a thought-provoking regional treatment of igneous tool stone use and "valuation" in chapter 6, as he examines economic patterns at workshops associated with various Snake River Plain obsidian sources and exposures of fine-grained volcanics along the eastern margin of the Columbia River Basalt Group. By comparing the different qualities and archaeological distributions of these two material types, Reid presents a convincing interpretation of their relative value to Native groups of the southern Plateau. Key economic geology terms introduced here are "place value" and "unit value," in which *high place value* would refer to tool stone that was almost exclusively used at or near its place of origin. *High unit value*, on the other hand, would characterize a rock type whose qualities made it desirable to a larger and more dispersed population, and therefore this raw material was transported and exchanged over long distances. Among ancient people who were heavily invested in lithic tools, workability, accessibility, clast size/form, and durability are criteria that probably were used to evaluate tool stone and how much time and energy should be invested in its acquisition, reduction, and transportation.

Reid reports that of the approximately 70 known obsidian sources in the Snake River Plain, no more than six of them were traded extensively. He believes that most high quality obsidian sources were regularly exploited by local populations primarily through a cobble harvesting program that was embedded in their settlement and subsistence practices. Besides the direct acquisition of obsidian by tool-depleted residents, some sources (such as Timber Butte, Brown's Bench, and Bear Gulch/Big Table Mountain?) also were targeted by trade specialists who provided surplus material for regional exchange. In this context, certain Snake River Plain obsidian sources had a high unit value. In contrast, the more localized archaeological distribution of the Columbia River Basalt Group andesites and dacites indicate that they had a relatively high place value. These resilient materials allowed knappers to produce durable cutting and scraping tools, and the author believes that many of the southern Plateau fine-grained volcanics sources/workshops such as Craig Mountain and Mesa Hill also functioned as industrial loci where wood, bone, and antler were fashioned into tools such as digging sticks and handles for knives and scrapers. Interestingly, evidence for labor-intensive quarrying or mining of either obsidian or fine-grained volcanics within the study area is scarce.

Chapter 7 is co-authored by Brian Ostahowski and Robert Kelly in which they use data gleaned from lithic debitage and tools to make inferences about the shifting function of Alm Rockshelter, a highly stratified site located in the Bighorn Mountains of northcentral Wyoming. This study tested two hypotheses: 1) when the region supported higher populations due to cooler/wetter climatic intervals, people used the site as a residential base; and 2) during times of decreased population because of warmer/drier climate, local groups used Alm Shelter as a logistical camp. In making inferences about site function, the authors focused on patterns of core reduction, stone tool production and curation, the ratio of local to non-local tool stone, debitage density, and formal chipped and ground stone tools. The site assemblage consists of over 18,000 flakes, 45 projectile points/knives, 43 bifaces, 20 unifaces, 61 retouched flakes, and 12 manos—all of which were recovered from three 1 x 1 m test units.

They associated low flake density and late stage reduction debris with logistical use of the site, whereas high debitage density and multiple stage reduction materials signaled more of a residential occupation. Based on debitage and tool patterns, Ostahowski and Kelly believe that Alm Shelter was used mostly by logistical parties focused on large game hunting during three periods (pre-10,000–9000 BP, 9000–8000 BP, and 3000–2000 BP). Similarly, they detected three periods (~9000 BP, 7500–4500 BP, and ~3200 BP) when the site functioned primarily as a residential base. This study is an excellent example of the interpretive potential contained in a lithic assemblage associated with the small-scale excavation of a rockshelter in the uplands of Wyoming.

Douglas McDonald combines ethnohistorical and archaeological data to craft an interesting argument that Yellowstone Lake in northwestern Wyoming was a territorial nexus for different contemporaneous ethnic groups over thousands of years. Since at least the late Holocene, medicinal and food plants, ungulates, and cutthroat trout may have been the primary resources that brought people to Yellowstone Lake during the six month interval when the lake shore zone could support residential camps. Ethnographic accounts indicate that during late prehistoric and early historic times, a number of Native groups frequented the area in and around Yellowstone Lake, especially the Eastern Shoshone, Bannock, Nez Perce, Crow, Blackfeet, Salish, and Kiowa.

The author presents both obsidian sourcing and locality-specific chert data from 28 archaeological sites located on the northwest, northeast, southeast, and southwest lake shores to infer the general points of origin/settlement area focus for prehistoric groups who used Yellowstone Lake. The greater lake ecozone has been utilized by aboriginal groups since Paleoindian times, with human use and occupation increasing significantly at the start of the Middle Archaic period. Lithic sourcing data suggest that multiple groups from three major regions used Yellowstone Lake over the course of several millennia. Sites on the northwest shore contain obsidian and chert tools and debitage from Obsidian Cliff and Bear Gulch, and the Yellowstone, Madison, and Gardiner River Valleys to the west and northwest. On the northeast shore, people regularly worked chert from the Clear Creek and Shoshone River Valleys to the east (Obsidian Cliff glass also occurs in large amounts at these sites). Camps along the southeast shore contain high frequencies of chert artifacts, many of which may derive from the Absoraka Mountains, suggesting a settlement focus to the east and southeast. Southwest shore sites contain a mixture of northern, western, and southern lithic sources, including 14 different obsidian sources.

McDonald presents a strong case for the occupation of Yellowstone Lake by multiple ethnic groups as opposed to a single group such as the Wind River Shoshone as some researchers (e.g., Scheiber and Finley 2011) have suggested. His essay is yet another example of how lithic sourcing data can improve our understanding of regional settlement practices and the multi-ethnic use of the same ecosystem.

In chapter 9, Kathryn Harris discusses the lithic technology and obsidian sources represented at Kyle Canyon Spring (site 10-BT-8), a prehistoric camp located in the southern Lemhi Range of far eastern Idaho. This site dates back to at least 3000 BP and occurs in an area where Native people had relatively easy access to several major obsidian sources such as Big Southern Butte and Bear Gulch. Because 10-BT-8 occurs only 50 km north of Big Southern Butte, Harris logically assumed that most obsidian at the site would come from this source. In order to explore this possibility, a sample of 101 obsidian tools and flakes were geochemically sourced and yielded non-intuitive results—nearly 80% of the sample derives from the American Falls (aka, Walcott Tuff) source, the main exposures of which are located 125 km to the south. Surprisingly, only 8% of the sourced artifacts are from Big Southern Butte, whereas 12% derive from Bear Gulch, located about 100 km northeast of 10-BT-8.

Harris also hypothesized that most cores from 10-BT-8 would be from local sources, that most non-hafted obsidian bifaces from more distant sources would be smaller in size and of late reduction stages, and that the amount of dorsal cortex on proximal obsidian flakes from distant sources should be low. Analysis of these artifacts revealed that all three obsidian cores were of the American Falls/Walcott Tuff geochemical type; the majority (81%, n=16) of obsidian bifaces were either middle or late in reduction stage; and most of them are made of American Falls glass. American Falls obsidian flakes exhibited the highest diversity of cortex, suggesting that various artifact types fashioned from this obsidian source were regularly transported to the site.

While some of the author's expectations for the obsidian assemblage were supported by her lithic analysis, some were not. If the bulk of American Falls/Walcott Tuff tool stone at Kyle Canyon Spring was acquired from the American Falls Reservoir/Lake Walcott area, then most groups who occupied 10-BT-8 probably moved within a relatively extensive home range, with a core (winter?) zone located more than 100 km south. In discussions of the distribution of Walcott Tuff, researchers such as Hughes and Smith (1993) and Morgan and McIntosh (2005) report that this ash-flow tuff obsidian (aka, ignimbrite) occurs across a broad swath of the eastern Snake River Plain. What we did not know about this far-flung distribution was whether any tool quality exposures of Walcott Tuff existed in the northern periphery between Arco and Dubois. Recent research by Arkush and Hughes (2015) has demonstrated that artifact quality, fist-sized ignimbrite nodules of the American Falls/Walcott Tuff geochemical type occur in the Howe Point area of the southern Lemhi Range as well as in the Deep Creek and Medicine Lodge Creek drainages of the southern Beaverhead Range east of the Lemhi Mountains. This new information, coupled with the geochemical and lithic technology data from 10-BT-8, strongly suggest that the prehistoric occupants of Kyle Canyon Spring were acquiring and knapping American Falls/Walcott Tuff glass from local exposures located within 20 to 50 km of the site.

The final chapter is by Scott Carpenter and Philip Fisher, in which they describe an ochre-covered obsidian artifact cache that recently was found eroding out of a cutbank south of the Yellowstone River near Livingston, Montana. The Yearling Spring Cache consists primarily of early stage bifaces (n=31) and flake tools (n=27), although a large bifacial core weighing 2.5 kg also occurs in this assemblage. Sixty of the artifacts were geochemically sourced and all derive from the Obsidian Cliff locality in Yellowstone National Park, located 155 km to the south.

In an attempt to establish a general age for the cache, 24 specimens were submitted for obsidian hydration analysis. This produced a narrow range of hydration rim measurements ranging between 3.9 and 4.1 microns, with an estimated age of about 3,680 years. Optically stimulated luminescence dating of two sediment samples from the cache feature bracketed the hydration age calculation, indicating that the Yearling Spring Cache was established during mid Middle Archaic times. Protein residue analysis of three artifacts and one ochre sample yielded interesting results, with one artifact testing positive for cervid protein and another testing positive for salmonid protein. Analysis of the ochre sample indicated that it contained bear protein. The latter result demonstrates that the ochre had been formulated with bear by-products such as oil and/or fat.

With an assemblage of 62 artifacts, the Yearling Spring Cache is one of the largest features of its kind in southwest Montana. The lack of human skeletal remains strongly suggests that the cache served a utilitarian purpose, functioning as a hidden source of early stage tools from which finished products could easily be manufactured. The inclusion of ochre certainly is interesting, as the small number of artifact caches in western North America that contain ochre typically include human remains (e.g., Anzick, Montana) or are thought to have once contained human remains (e.g., Simon, Idaho), indicating that the mineral pigment was an offering associated with burial ritual. Further evidence that the Yearling Spring cache is not primarily ritual/ideological in nature is provided by the state of the artifacts themselves, all of which are in early stages of reduction and production. In this respect, the cache is similar to the East Wenatchee Cache, which was not associated with human remains, but three large chalcedony Clovis blades had been smeared with ochre (Kilby and Huckell 2014:261). Additionally, some of the lithics in the Wenatchee Cache tested positive for bison, deer, and rabbit/hare protein. All in all, this small feature has provided us with an important data set and a great deal of food for thought—a fairly remarkable discovery.

The only real complaint that I have about this book is the poor binding that plagued my copy. Several pages fell away from the spine soon after I began to read this publication, and by the time that I had finished the book, at least one-third of the pages were loose. I hope that mine is an isolated incident, but even if it is not, this certainly does not detract from the overall high quality, innovative research approaches, and breadth of the volume. *Lithics in the West* would be a fine and affordable addition to any prehistoric archaeologist's library, especially those who focus on western North American foraging societies and New World lithic analysis.

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ERRATA

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An improper reference to the use of comparative collections at The College of Idaho was given in a recently published note entitled, "An Analysis of Faunal Remains from Little Owl Cave (35-ML-1088), Southeastern Oregon"— *Idaho Archaeologist* 37(1):11, 2014. Comparative collections utilized in the analysis were examined at the Orma J. Smith Museum of Natural History, The College of Idaho.