Obsidian Source Filtering: Assessing Multiple XRF Protocols for Geochemical Analysis of NW Wyoming Collections

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ABSTRACT

Greybull River Sustainable Landscape Ecology (GRSLE) archaeology's Shoshone National Forest, Wyoming project has had source analysis completed for 1087 specimens by Geochemical Research Laboratory (GRL). Roughly 67% (N=720) are attributed to Obsidian Cliff. The Buffalo Bill Center of the West, Conservation Department provided a Bruker Tracer III-SD portable XRF spectrometer for this regional source analysis program. While in-house identification of the full spectrum of potential obsidian sources is not feasible for the project, use of the Bruker to record elemental intensity values using a sample of 238 previously sourced pieces builds a baseline for assessing the utility of a multi-protocol approach. Samples are initially scanned and analyzed to develop a binary source assignation – Obsidian Cliff or "other." To differentiate Obsidian Cliff from other obsidian sources, a logistic regression model is constructed using a modified backwards stepwise selection procedure. Results of this filtering are used to more effectively select samples for submission for full GRL quantitative analysis.

2002-2018 GRSLE PROJECT: OBSIDIAN SOURCES

Beginning in 2002, the Greybull River Sustainable Landscape Ecology Project (GRSLE) has recorded locational and attribute data on over 190,000 pieces of chipped stone in northwestern Wyoming's Absaroka Mountains, Shoshone National Forest. Of the chipped stone, 4.8% (N=9270) has been recorded as obsidian. Bohn (2007) reported on source analysis of 127 pieces of obsidian collected by GRSLE teams in 2004-2005. Since then, samples have continued to be submitted to Dr. Richard Hughes' Geochemical Research Laboratory (GRL) for analysis (e.g., Hughes 2017, 2018) and the total 11 of obsidian pieces with source data from the project is now 1087 items represented by 17 source areas (Table 1; artifacts only, does not include 11 unmodified source area control samples). The most commonly identified source area, Obsidian Cliff, accounts for nearly 67% of the total artifacts, and 82.9% of the 123 temporally diagnostic obsidian projectile points.

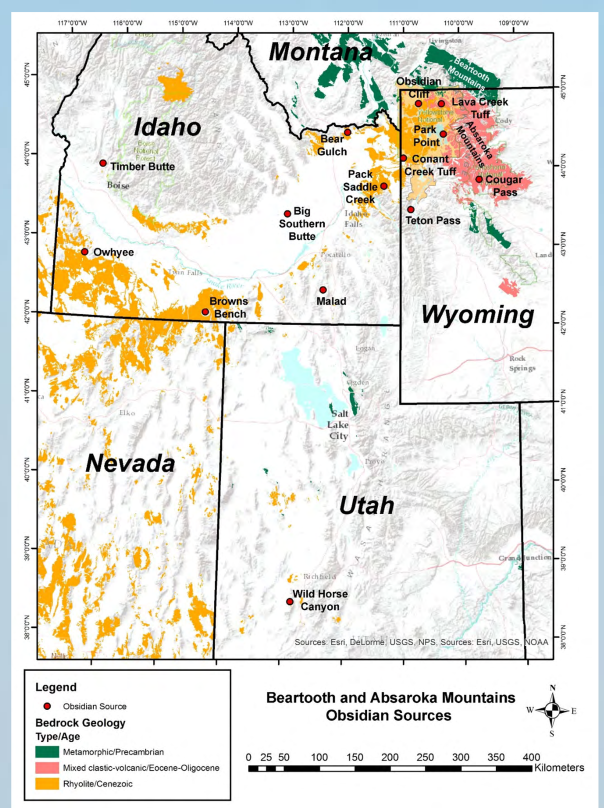

Figure 1. Locations of major obsidian source areas represented in GRSLE sample.

Table 1. 2004-2018 GRSLE obsidian source data.

Source Area	N	%	Mean Max Length (mm)	Mean Elevation (m)	N Projectile Points: Paleoindian	Early Archaic	Middle Archiac	Late Archaic	Late Prehistoric
Obsidian Cliff (OC)	720	66.9	19.4	2667			3	11	69
Teton Pass (TP)	104	9.7	23.1	2691				2	16
Bear Gulch (BG)	64	5.9	20.9	2634				2	5
Cougar Pass (TWI)	46	4.3	24.5	3292					1
Malad (M)	42	3.9	19.3	2625				2	8
Cresent H (CH)	38	3.5	19.6	2586				1	1
Lava Creek Tuff (LCT)	23	2.1	23.9	2638					
Unknown (UNK)	11	1.0	19.9	2514					1
Wild Horse Canyon (WHC)	8	.7	16.2	2700					
Packsaddle Creek (PSC)	6	.6	26.2	2353					
Conaut Creek Tuff (CCT)	4	.4	15.5	2761					
Philps Pass (PLP)	3	.3	21.7	2487					
West Gros Vente Butte (WGVB)	2	.2	17.9	2740					
Brown's Bench (BB)	1	.1	16.8	3450					1
Big South Butte (BSB)	1	.1	17.0	2593					
Dunraven Flow (DF)	1	.1	20.2	2356					
Park Point (PP)	1	.1	18.3	3107					
Timber Butte (TB)	1	.1	22.4	2538					
Total	**1076**	**100.0**	**20.2**	**2693**	**0**	**0**	**3**	**18**	**102**

Bohn's preliminary study indicated both temporal trends (obsidian more common in later assemblages) and hints at drainage level spatial patterns in obsidian use with the Washakie Wilderness (Figure 2) and adjacent Forest lands. Work with the larger sample supports Bohn's temporal pattern observations (Table 1) with no obsidian points older than Middle Archaic having been recorded and Late Prehistoric obsidian arrowpoint swamping the distributions. While drainage level patterning is still evident in the larger sample size, the nature of these distributions is not clear-cut and requires additional investigation.

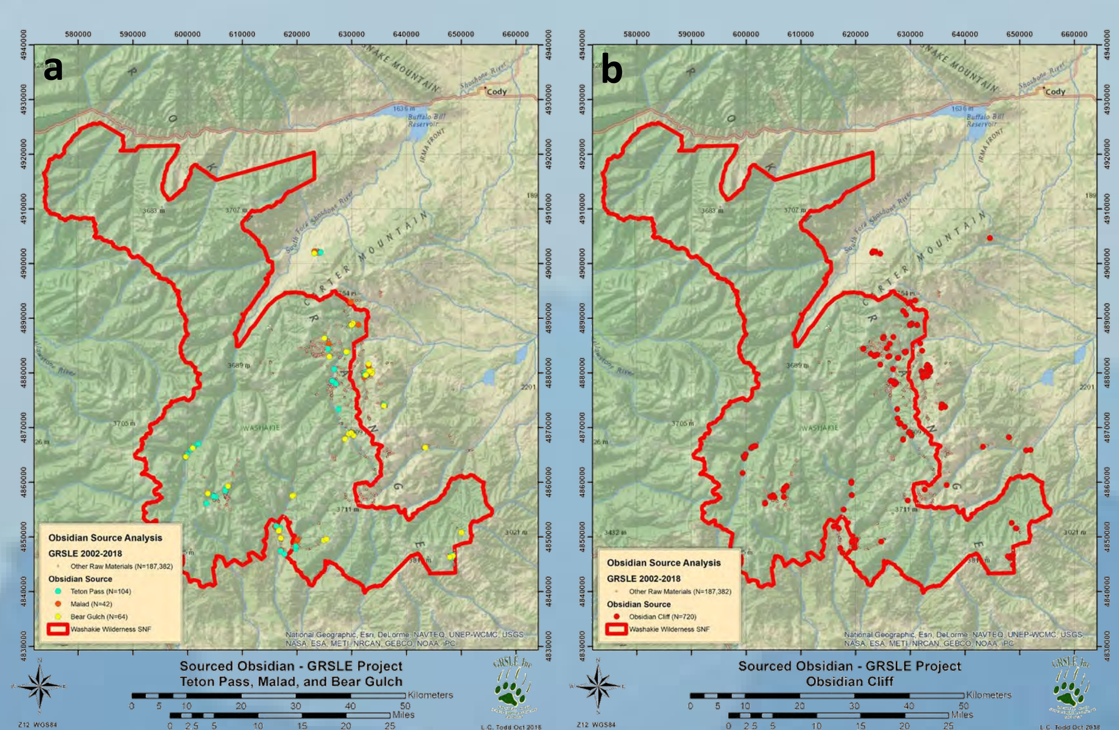

Figure 2. Distributions of sourced obsidian from the GRSLE project in relation to Washakie Wilderness, Shoshone National Forest, Wyoming: a) items from three common source areas, and b) items from the Obsidian Cliff source area.

A recent synthesis of these data (Reckin and Todd 2018) indicates that, in comparison to other regional studies (Finley, et al. 2015; Kunselman 1994; Kunselman and Husted 1996; MacDonald 2018; Morgan, et al. 2016; Scheiber and Finley 2011), the landscapes investigated by the GRSLE project seem to indicate a distinct pattern of obsidian procurement, use, and discard. Given that we have so far been able to fund analysis of only a small number (31%) of the GRSLE obsidian items collected for sourcing (N=3445), the potential for examining regional patterning using a much larger data base is high.

2018 BUFFALO BILL CENTER OF THE WEST pXRF PROJECT

In order to explore the possibility of using an initial, local basic assessment of source area, we have used the Buffalo Bill Center of the West (Cody, Wyoming) Conservation Department Bruker Tracer III-SD portable XRF spectrometer to collection spectral data for 238 pieces of GRSLE project obsidian that had previously been analyzed by GRL (Hughes 2015). The evaluative sample was undertaken by a team that did not have access to the prior source identifications for these artifacts. The goal of the project was to evaluate the degree to which a single major source – Obsidian Cliff – could reliably and consistently be distinguished from all other sources using the portable XRF. If successful, this distinction could then be used to separate collected GRLSE obsidian into pieces requiring additional GRL analysis (all non-Obsidian Cliff pieces) from those that could be identified locally at a much reduced cost per specimen.

METHODS

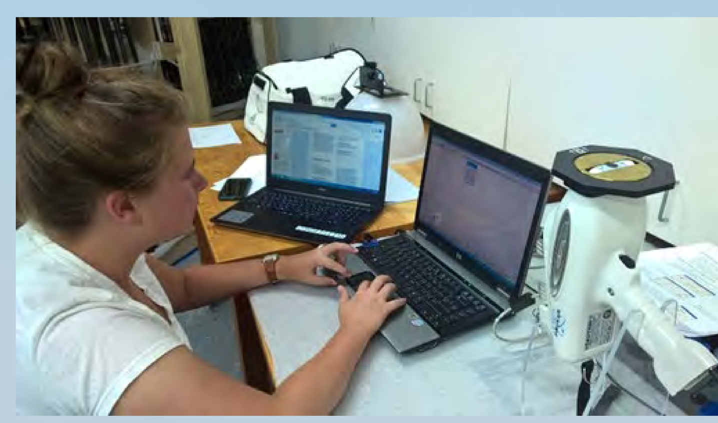

Figure 3. Buffalo Bill Center of the West summer Intern in the Conservation Department, Kate Breitenstein analyzing an obsidian lithic using the pXRF spectrometer [photo: Alyssa Rina].

Obsidian lithics analyzed in the Conservation Department at The Buffalo Bill Center of the West were supervised by Chief Conservator, Beverly Perkins (Figure 3). Lithics were analyzed with energy dispersive X-ray Fluorescence (EDXRF) using a portable Bruker Tracer III-SD equipped with a Rhodium (Rh) target. 238 samples were analyzed using the green filter (12mil Al, 1mil Ti, 6mil Cu) at 40 kV and 12 µA. All samples were analyzed for 179 seconds. The Bayes deconvolution method was applied to the data in the ARTAX. All data collected from the pXRF spectrometer is expressed as luminescence data (photon quantities / intensities) in keV.

Between 2004 and 2018, 1,087 obsidian lithics were analyzed at the Geochemical Research Lab in Portola Valley, California. Analyses were performed using a Thermo Electron Corporation QuanX-EC™ energy dispersive x-ray fluorescence (EDXRF) spectrometer with a silver (Ag) x-ray tube, a 50 kV x-ray generator, digital pulse processor with automated energy calibration, and a Peltier cooled solid state detector with 145 eV resolution (FWHM) at 5.9 keV. X-ray tube voltage and current varied in conjunction with the elements selected for analysis: rubidium (Rb Kα), strontium (Sr Kα), yttrium (Y Kα), zirconium (Zr Kα), niobium (Nb Kα), barium (Ba Kα) and to develop iron manganese ratios (Fe Kα/Mn Kα). All data collected from the Geochemical Research Lab is expressed in a quantitative unit: parts per million (ppm).

RESULTS

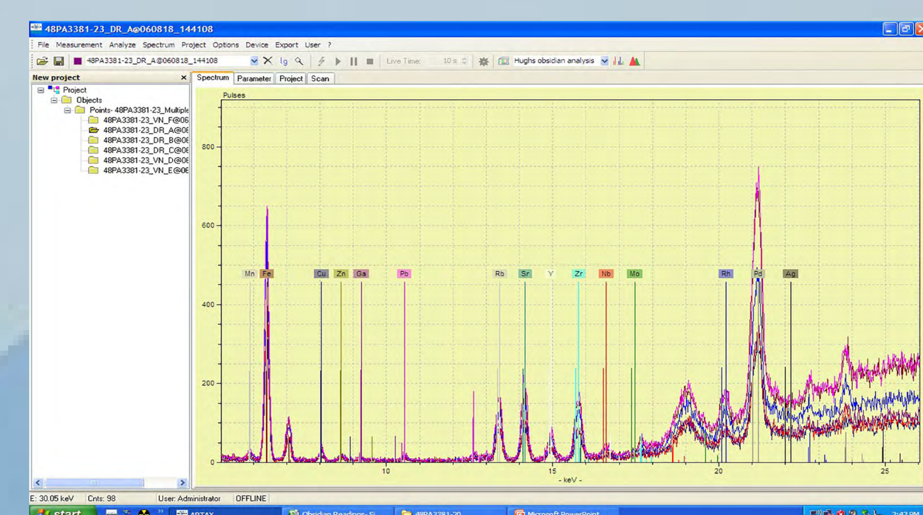

Figure 4. Data once the Bayes deconvolution method was applied in ARTAX

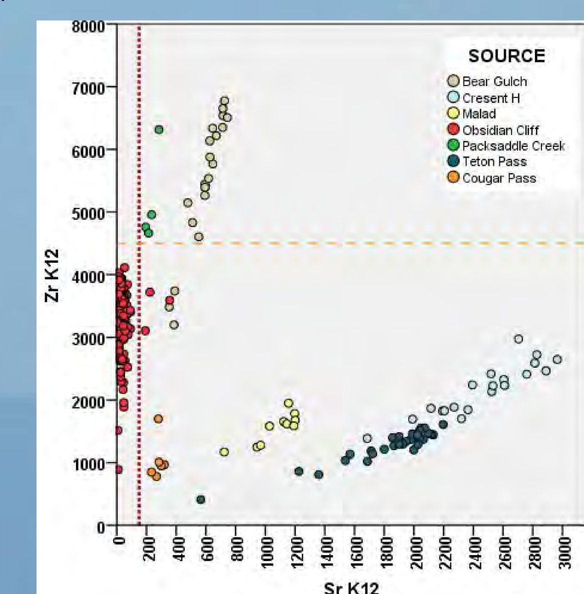

Figure 5. Strontium (Sr) and zirconium (Zr) luminescence intensity values (keV) indicate that most of the Obsidian Cliff items in our sample are distinct.

Preliminary analysis of data from the BBCW project (Figure 4) suggests that we may well be able to use the Bruker Tracer as an initial step in selecting specimens to send to GRL for the more experienced expert source quantified (ppm) source characterization. While a simple bivariate plot (Figure 5) of two elements (strontium and zirconium) works to segregate the majority of items from Obsidian Cliff, ternary plots provide a much better filter (Figures 6 and 7).

Plotting strontium, zirconium, and rubidium (Figure 7) provides the best discrimination for Obsidian Cliff materials with sample artifacts from other source areas being clearly differentiated. Using protocols developed by this project produces data amenable for providing a solid foundation for a preliminary assessment of obsidian samples from the GRSLE project.

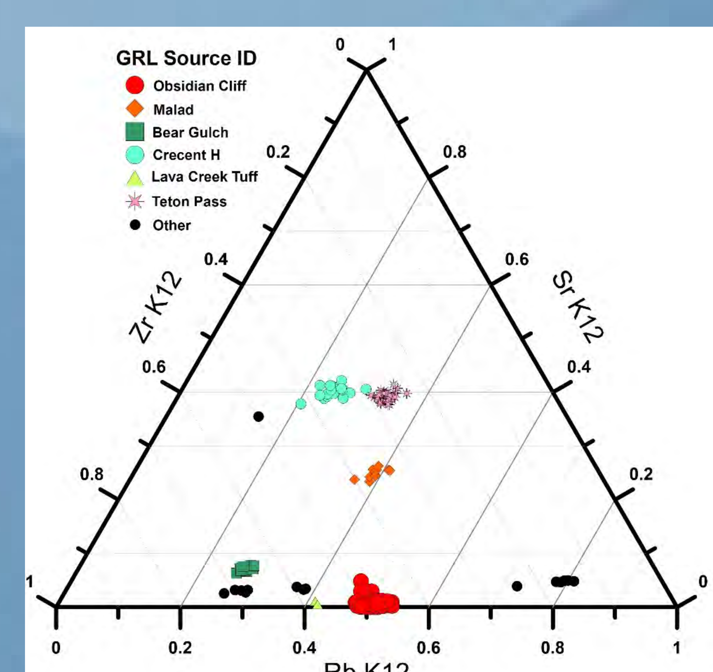

Figure 7. Full separation of the Obsidian Cliff specimens in ternary plot of strontium (Sr), zirconium (Zr) and rubidium (Rb).

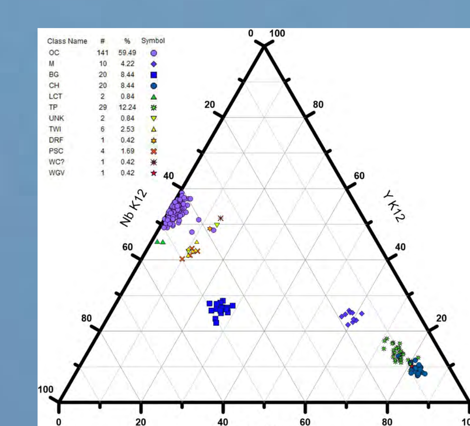

Figure 6. Ternary plot of strontium, zirconium, and yttrium segregate most source areas.

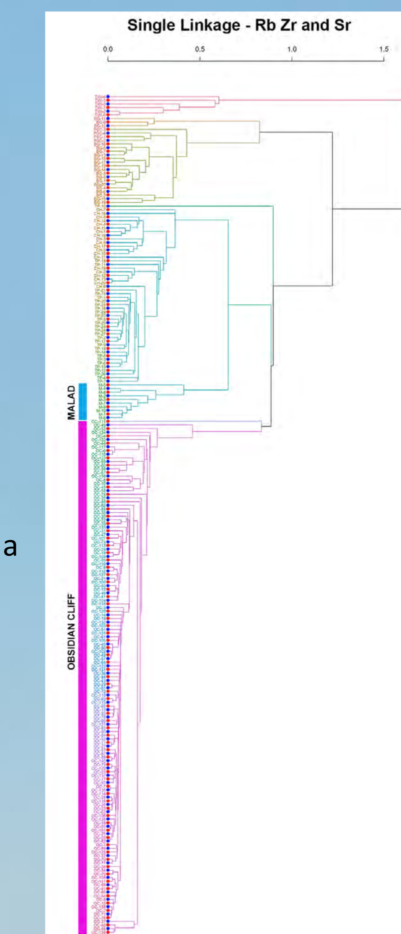

Figure 8. Dendrogram of single-linkage cluster analysis.

CLUSTER ANALYSIS

A cluster analysis is simply using statistical methods to understand how data are related given a similar set of variables. Unlike regression, cluster analysis requires a greater amount of personal interpretation. In the case of our Obsidian trace elements we are interested in looking for unique differences in trace element values for a given source. Since these data are measured on different scales multidimensional scaling is applied to compare variances between variables.

A common method for identifying clusters quantitatively is using a form of hierarchical clustering measured with Euclidean distances. Single-linkage clustering pairs data from the most similar to least similar for an expected number of clusters. Using single-linkage clustering Obsidian Cliff differentiates itself quite well from the remainder of potential obsidian sources. Figure 8 illustrates a single linkage model using Rb, Zr, and Sr cleanly segregates all Obsidian Cliff samples from other sources.

CONCLUSIONS

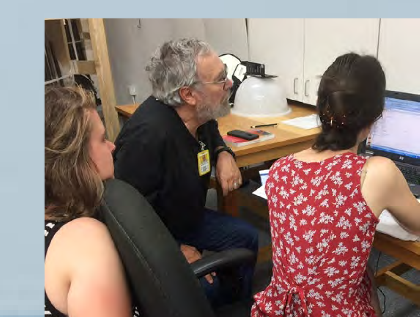

Figure 9. Summer interns Kate Brietenstein (*far left*) and Alyssa Rina (*far right*), work with L. Todd (*center*) in analyzing obsidian lithics with a pXRF spectrometer.

The goal of this project was not to develop a stand alone obsidian sourcing program. The GRSLE project, which operates largely with volunteer participants, does not have a stable staff able to invest the time into learning complexities of distinguishing the full suite of potential obsidian sources that are likely to be found in our research area. However, as a tool to more economically have the more the wider array of source areas for specialized analysis, the protocols applied here are clearly a useful addition to our analytical toolkit. During the coming year, we plan to conduct a preliminary scan of all obsidian items collected during the 2018 field season to identify those that are likely from Obsidian Cliff versus those that are not. A combination of all of the 'non-Obsidian Cliff' and a 10% sample of the items thought to be from Obsidian Cliff will be submitted to GRL for sourcing. In addition, as schedules allow, we hope to complete the Bruker intensity data collection for the other GRSLE sourced items that were not included in this preliminary study.

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