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2013-2014 PROJECTS

MAGNETIC AND GEOCHEMICAL CHARACTERIZATION OF IN SITU OBSIDIAN, NEW MEXICO*:*
Faculty: *ROB STERNBERG*, Franklin & Marshall College, *JOSHUA FEINBERG*, Univ. Minnesota, *STEVEN SHACKLEY,* Univ. California, Berkeley, *ANASTASIA STEFFEN*, Valles Caldera Trust, and Dept. of Anthropology, University of New Mexico
Students: *ALEXANDRA FREEMAN*, Colorado College, *ANDREW GREGOVICH*, Colorado College, *CAROLINE HACKETT*, Smith College, *MICHAEL HARRISON,* California State Univ.-Chico, *MICHAELA KIM*, Mt. Holyoke College, *ZACHARY OSBORNE*, St. Norbert College, *AUDRUANNA POLLEN*, Occidental College, *MARGO REGIER*, Beloit College, *KAREN ROTH*, Washington & Lee University

TECTONIC EVOLUTION OF THE FLYSCH OF THE CHUGACH TERRANE ON BARANOF ISLAND, ALASKA*:*
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Keck Geology Consortium: Projects 2013-2014
Short Contributions— Obsidian Provenance, New Mexico Project

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ALEXANDRA FREEMAN, The Colorado College
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Research Advisors: Christian M. Schroder, Colorado College and Joshua M. Feinberg, University of Minnesota

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MARGO REGIER, Beloit College
Research Advisors: James Rougvie, Beloit College and Joshua M. Feinberg, University of Minnesota

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GEOCHEMICAL VARIABILITY OF OBSIDIAN IN WESTERN NEW MEXICO WITH LABORATORY-BASED PXRF

KAREN ROTH,Washington and Lee University
Research Advisor: Jeffrey Rahl

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HYSTERESIS AND LOW-TEMPERATURE MAGNETIC PROPERTIES OF MOUNT TAYLOR OBSIDIAN

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INTRODUCTION

Obsidian has been historically valued by ancient peoples as a natural material for producing stone tools because of its ability to be worked to a sharpened edge. Archaeologists can use chemical and physical attributes of the obsidian to study the corridors through which it was transported, from its geologic source to its ultimate archaeological deposition. A problem of interest involves the social and economic patterns that led to the final distribution of obsidian tools. To address this problem, obsidian artifacts must be connected to their geological sources. The most common approach has been to use the trace element geochemistry of individual obsidian samples and artifacts. More recently, several studies have considered whether magnetic properties can be used to distinguish geologic sources of obsidian within a region or a particular flow (Sternberg et. al., 2011; Frahm and Feinberg, 2013). For this project, over 3,000 obsidian samples were collected during four weeks of field work at three localities in New Mexico (see Figure 1).

These localities included Mule Creek, Mount Taylor, and Valles Caldera. This project specifically focuses on the Mount Taylor locality. For the purpose of this study, 29 obsidian samples were selected for magnetic analysis. The purpose of this contribution was to determine whether analysis of obsidian magnetic properties using hysteresis parameters and low-temperature magnetic susceptibility could distinguish samples from three separate sites at the Mount Taylor locality: Grants Ridge, Horace Mesa, and La Jara Mesa (see Figure 2).

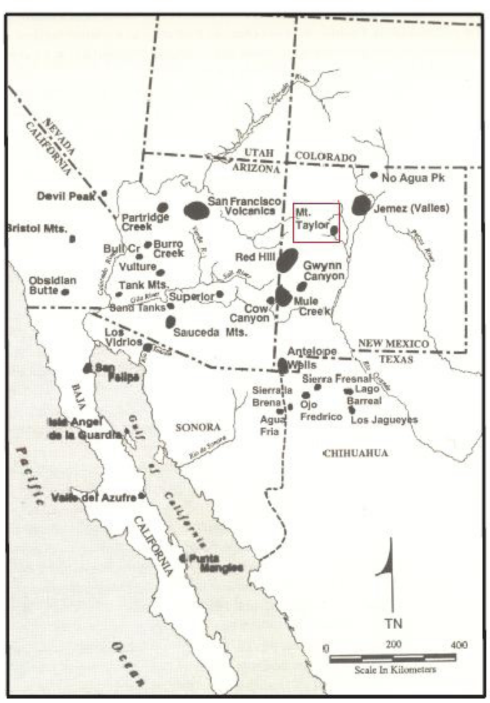


Figure 1. General location of archaeological obsidian in Southwestern North America. Mount Taylor area is outlined in red. From Shackley (2005).

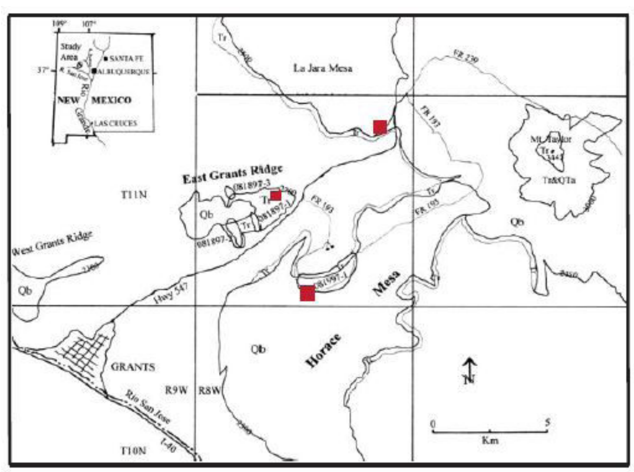


Figure 2. General topographical and geological map of the Mt. Taylor area. Base map taken from Shackley (2005). Contour lines are approximate, but accurate at points noted. All measurements given in meters. Red squares indicate relative locations of the project sources.

OBSIDIAN OVERVIEW

Obsidian is volcanic glass, formed by the quenching of felsic lava after eruption from a volcano. The color of obsidian generally does not come from the glass itself, but from micrometer-scale minerals held within the glass. The common black color of most obsidian comes from magnetite (Fe3O4) grains; other common magnetic minerals include hematite, ilmenite, and chromite. These magnetic minerals provide a characteristic signal that allows us to create a magnetic "fingerprint" for each sample. The magnetic properties are a product of the grain sizes, concentrations, compositions, and spatial arrangements of the minerals within the obsidian. Magnetic minerals are also sensitive recorders of conditions of the formation environment. The conditions that affect obsidian's primary magnetic properties include local flow conditions i.e. cooling rate, viscosity, oxygen and water availability, vesicularity, and deformation. Outside factors that may add secondary magnetization include the strength and direction of Earth's magnetic field and later reheating by a lava flow, forest fire, or lightning (Frahm and Feinberg, 2013).

GEOLOGY OF MOUNT TAYLOR

The Mount Taylor Volcanic Field (MTVF) in northwestern New Mexico has been the focus of geologic investigation due to the uranium and coal-bearing rock in the surrounding area and MTVF's position near the union of the Colorado Plateau and Basin and Range Provinces. A principal interest involves the relationship between basaltic volcanism and the formation of an andesitic composite volcano within a continental interior setting. The rhyolite exposed at the core of Mount Taylor is part of a pyroclastic cone that erupted early in the evolution of the volcano. A larger volume of andesite and latite erupted later and is thought to represent a differentiated basaltic magma chamber. The eruption of the felsic-intermediate lava was then followed by extensive basaltic eruptions. The trimodal character of MTVF is partly responsible for the differing composition of the obsidian. The age of the Grants Ridge rhyolite is 3.2 ± 0.3 Ma (Shackley, 2005) and is derived from potassium-argon dating. The field and analytical data indicate that the obsidian on Horace Mesa is probably the result of early Mount Taylor eruptions while the Grants Ridge obsidian probably formed during a separate, later event. The absence of sanidine crystallites in the Horace Mesa obsidian argues for extremely rapid cooling, whereas the presence of sanidine crystallites at Grants Ridge suggests slower cooling (Shackley 2005).

FIELD METHODS AND OBSERVATIONS

The obsidian samples were collected from three sites at the Mount Taylor locality: Grants Ridge, Horace Mesa, and La Jara Mesa. At Grants Ridge, samples were mainly collected from a perlitic lava outcrop and from black, glassy sand alluvium float immediately below the outcrop; the outcrop and float area is about 255 m^2 in size. Additional Grants Ridge obsidian samples were collected within a total area of about 0.056 km^2. Sample locations were noted using GPS. Obsidian nodules were black in color, opaque, exhibited a vitreous luster, and a mostly flawed surface texture. They varied in size between 3 and 6 cm in diameter, with larger sizes up to 10 cm. Many of the nodules exhibit sanidine crystals commonly less than 1 to 3 mm in diameter, with larger sizes up to 5 mm. Collection on Horace Mesa and La Jara Mesa was completed over a larger area than Grants Ridge; approximately 0.190 km^2 on Horace Mesa and approximately 0.124 km^2 on La Jara Mesa. The position of the obsidian samples collected from the ground alluvium was referenced using GPS. All obsidian samples located in the alluvium were between 2 and 4 cm, black in color, opaque with a vitreous luster, and had smooth and flawed surface textures. Few samples contained mineral inclusions. Any inclusions that were present did not appear to be sanidine like the crystallites found in the nodules at Grants Ridge. The weight of each sample and magnetic susceptibility measurements were taken at the field campsite.

LABORATORY METHODS

Sample preparation and laboratory analysis for this project was conducted at the Institute for Rock Magnetism (IRM) at the University of Minnesota. Each of the 29 obsidian samples was reduced until a piece of suitable dimensions for the instruments was created. All debitage was saved and a portion was used in Curie temperature measurements. The samples were measured for low-field magnetic susceptibility, susceptibility as a function of temperature (Curie temperature estimates), and for major hysteresis loops and their parameters, including saturation remanence (M_r), saturation magnetization (M_s), bulk coercivity (H_c), and coercivity of remanence (H_{cr}). Low field magnetic susceptibility (χ) is measured by submitting a sample to an applied magnetic field and measuring the response. The applied field is weak enough so as to not remagnetize the sample. This was measured at 300 A/m and 920 Hz using a KLY-2 KappaBridge susceptibility bridge and MAGNON variable-frequency susceptibility meter. Hysteresis measurements involve the application of a magnetic field to the sample, which increases in strength until the sample's induced magnetization is saturated and will no longer increase. The magnetic field is then decreased until it returns to zero. The hysteresis measurement continues by cycling the applied field in the opposite direction until negative saturation is achieved and then returning to positive saturation; this completes the major hysteresis loop. The hysteresis parameters were measured using a Princeton Measurements vibrating sample magnetometer (VSM) and used variable field strengths. Curie temperatures were estimated by measuring the low-field magnetic susceptibility as a function of temperature. Measurements were conducted using a KLY-2 KappaBridge; where the initial temperature was 30°C and was increased to 700°C, then progressively cooled back to room temperature.

LABORATORY RESULTS

Mass normalized bulk susceptibility, reported in m^3/kg, measures the induced magnetization of a sample in response to a small applied field. In its simplest sense, it is thought of as a representation of the concentration of magnetic material in a sample. However, a more detailed interpretation of susceptibility includes the effects of composition, grain size, and mineral fabric. Hysteresis parameters collectively tell you the relative magnetic grain size and concentration within the sample. The hysteresis parameters are defined as follows: mass normalized saturation magnetization, M_s (Am^2/kg), is the induced magnetization of a sample that is completely saturated and is directly related to the concentration of magnetic minerals; mass-normalized saturation remanence, M_r (Am^2/kg), is the maximum possible magnetization recording and is a reflection of concentration and grain size; bulk coercivity, B_c (mT), is the applied field strength that reduces the induced magnetization to zero and is inversely related to grain size; and coercivity of remanence, B_{cr} (mT), represents the field needed to

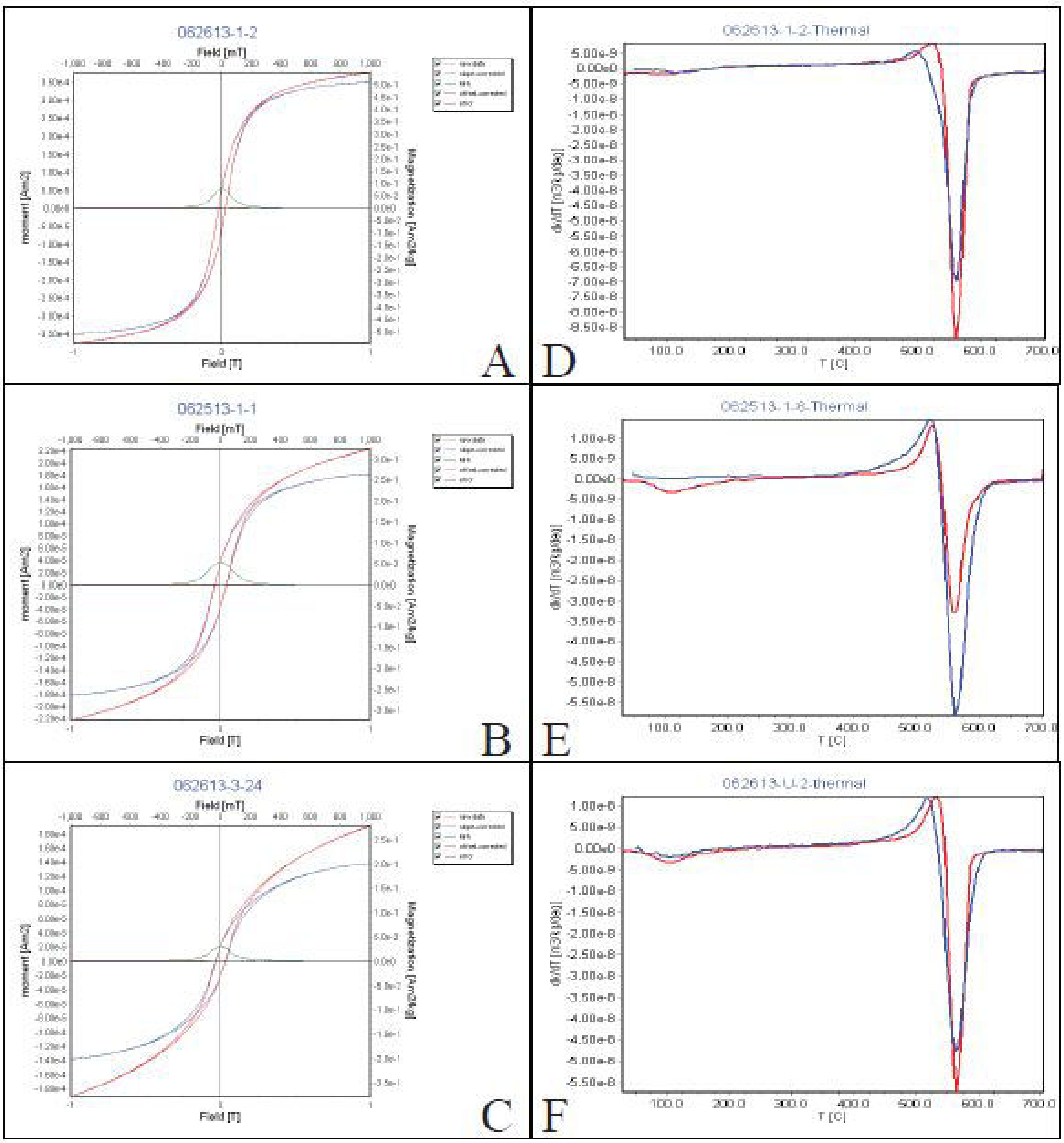
Table 1. Table of results for magnetic measurements. Shown magnetic properties include bulk susceptibility (χ), saturation magnetization (Ms), saturation remanence (Mr), coercivity (Bc), coercivity of remanence (Bcr), and Curie temperature. The localities of Grants Ridge, Horace Mesa, and La Jara Mesa are shown. The minimum value, maximum value, average value, and standard deviation are shown for each locality.

	χ [m³/kg]	Ms [Am²/kg]	Mr [Am²/kg]	Bc [mT]	Bcr [mT]	Mr/Ms	Bcr/Bc	Curie Temp. [°C]
Grants Ridge								
Minimum	5.27E-07	1.85E-01	2.02E-02	21.7	49.4	0.109	2.02	-
Maximum	1.70E-06	4.15E-01	6.15E-02	32.9	79.2	0.172	3.16	-
Average	1.22E-06	3.23E-01	4.83E-02	26.2	61.5	0.147	2.36	560
Standard Deviation	4.74E-07	4.30E-02	9.62E-03	5.9	13.6	0.018	0.21	-
Horace Mesa								
Minimum	5.39E-07	2.06E-01	3.18E-02	28.6	58.2	0.146	2.03	-
Maximum	1.33E-06	3.42E-01	6.99E-02	50.5	109.5	0.206	2.73	-
Average	8.18E-07	2.84E-01	5.04E-02	39.9	93.7	0.177	2.36	561
Standard Deviation	2.20E-07	8.70E-02	1.56E-02	3.6	8.9	0.020	0.30	-
La Jara Mesa								
Minimum	4.00E-07	1.63E-01	2.16E-02	33.6	70.5	0.124	2.06	-
Maximum	9.19E-07	3.09E-01	5.25E-02	44.6	101.2	0.198	2.79	-
Average	6.43E-07	2.38E-01	3.70E-02	38.1	90.2	0.154	2.38	561
Standard Deviation	1.52E-07	4.71E-02	1.02E-02	3.7	9.5	0.025	0.25	-

remagnetize half of a sample's magnetic recording and is inversely related to grain size. These parameters are frequently reported as two ratios, the remanence ratio (M_r/M_s) which is inversely related to grain size, and the coercivity ratio (B_{cr}/B_c) which is directly related to grain size. The results of these tests are shown in Table 1; these include the range of values (minimum and maximum), the average value, and the standard deviation.

The Curie temperature is the temperature during heating at which a magnetic material goes from being ferromagnetic to paramagnetic and can be used for mineral identification. However, in rare instances different magnetic minerals can have the same Curie temperature. The average Curie temperature is also noted in Table 1. The plots of susceptibility vs temperature for Grants Ridge, Horace Mesa, and La Jara Mesa, all showed a curie temperature between 560 and 563° C. This Curie temperature corresponds to low-Titanium Titanomagnetite. Selected hysteresis loop and Curie temperature graphs are shown in Figure 3.

Figure 3. Representative hysteresis loops and derivative Curie temperature graphs. Figures [3A], [3B], and [3C] are representative hysteresis loops for Grants Ridge, Horace Mesa, and La Jara Mesa. Figures [3D], [3E], and [3F] are representative derivative Curie temperature graphs for Grants Ridge, Horace Mesa, and La Jara Mesa.



DATA ANALYSIS AND DISCUSSION

Frahm and Feinberg (2013) compared the potential use of magnetic sourcing with the already established method of geochemical sourcing. The primary anticipated use of magnetic sourcing was as a potential tool for sourcing artifacts. Magnetic analyses are faster, cheaper, and less destructive compared to most geochemical techniques. However, geochemical techniques are proven able to readily identify the flow where obsidian artifacts came from; magnetic sourcing would have to be equal or fulfill a different role to be considered a worthwhile method. Based on the results of a large-scale study of obsidian started in 2009, Frahm and Feinberg (2013) proposed using magnetic properties to identify quarrying locations within a particular flow. Enough success was experienced to consider continued research. This proposal was developed partially because several earlier studies tried to differentiate separate flows and had mediocre success; commonly reported were overlapping sources and high intra-flow variability. It is clear that conditions that determine the properties of magnetic minerals within obsidian flows are far more variable than those that determine the glass composition. The obsidian localities sampled from the Mount Taylor Volcanic Field are thought to be separate flows. The purpose of this project is to look at the magnetic properties of these flows to see if differentiation between sources is possible. Better differentiation between sources would include measurements that show very little, if any, scatter within each source and little to no overlap of sources. Multiple graphs plotting different parameters were created to see which, if any, parameters could clearly distinguish the three sources. Figure 4 shows several of these graphs.

Figure 4A (Day Plot) plots the hysteresis ratios. There is significant scattering in each source, and

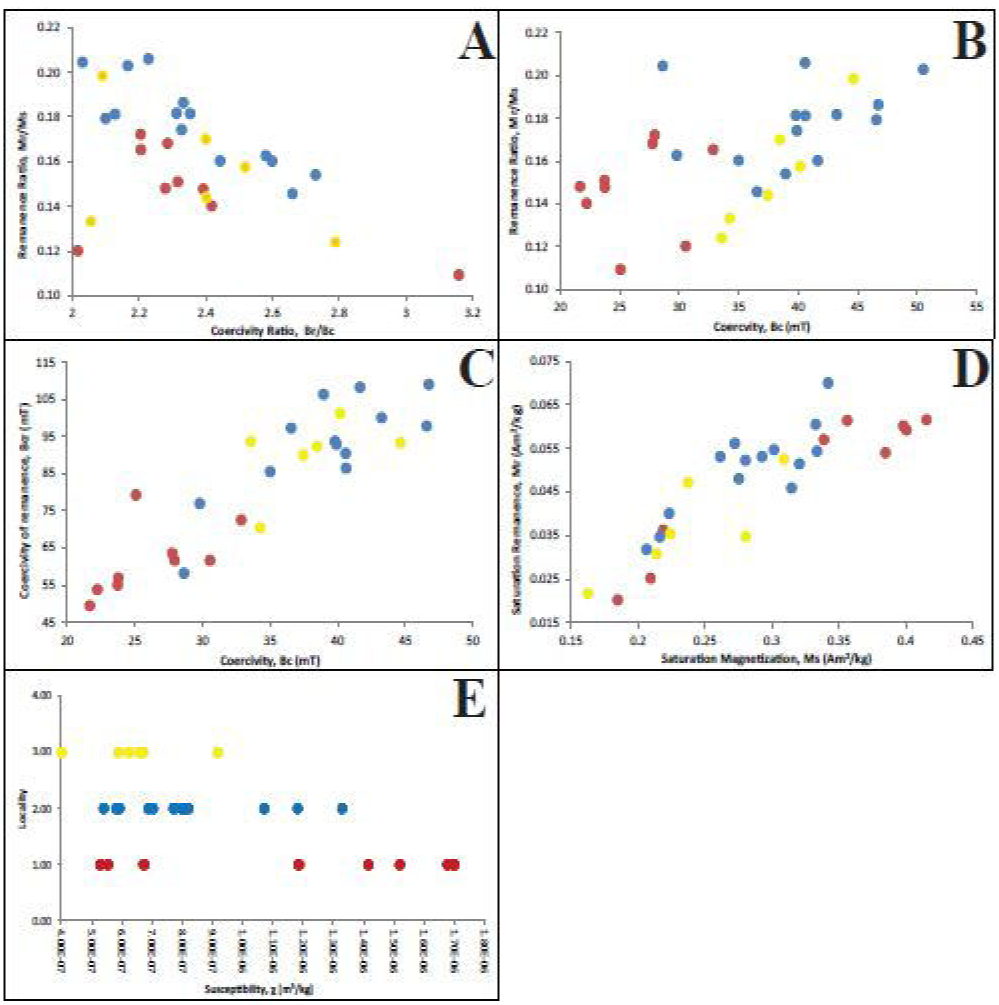


Figure 4. A graphical comparison of different magnetic parameters for different localities within the study area. [4A] plot of the coercivity ratio against remanence ratio (Day Plot). [4B] plot of coercivity against remanence ratio (Squareness of Coercivity). [4C] plots coercivity against coercivity of remanence. [4D] plots saturation magnetization against saturation remanence. [4E] plots the susceptibility relative to each location. The different colored dots indicate each locality: Red (Grants Ridge), Blue (Horace Mesa), Yellow (La Jara Mesa).

the most scatter is shown by samples from La Jara Mesa. Importantly, each source appears to overlap the others. The mean magnetic grain size for all three localities is pseudosingle domain. Figure 4B (squareness vs. coercivity) plots the remanence ratio against the bulk coercivity. There is scatter within each locality, but samples from Grants Ridge clearly show lower coercivities and squareness ratios than samples from either Horace Mesa or La Jara Mesa. Thus, the Grants Ridge obsidian displays a larger/coarser grain size relative to the Horace and La Jara Mesa obsidians. The Horace and La Jara Mesa points intermix and partially overlap with the Grants Ridge points at the lowest extent of their ranges. Figure 4C plots coercivity against coercivity of remanence. The overall trend of the samples is similar to that of Figure 4B, where although there is scatter within each source, the Grants Ridge samples display lower values for each parameter. Again, these lower values suggest larger grain size relative to the Horace and La Jara Mesa obsidians. The Horace and La Jara Mesa samples intermix and slightly overlap with the Grants Ridge samples. Figure 4D plots saturation magnetization against saturation remanence. There is moderate scatter within each source. The distribution from Grants Ridge is bimodal, where most of the Grants Ridge samples display higher saturation magnetization values than the Horace or La Jara Mesa samples; however three samples taken from a lower elevation at Grants Ridge display significantly lower saturation magnetizations than most of the Horace and La Jara samples. Although there is overlap between the samples from Horace and La Jara Mesas, on average the Horace Mesa samples display higher Ms and Mr values than those from La Jara Mesa, suggesting that Horace Mesa obsidian contains slightly more ferromagnetic material than La Jara Mesa obsidian. Figure 4E plots the bulk susceptibility of each locality. As with all obsidian parameters, geochemical or magnetic, there is scatter within each locality. On average, the La Jara Mesa obsidian has the lowest susceptibilities and therefore the lowest concentration of ferromagnetic material. The Horace Mesa obsidian shows an intermediate average value. The susceptibilities from Grants Ridge are again bimodal and define both the highest and lowest average values.

One of the limitations for magnetic sourcing described by Frahm and Feinberg (2013) was insufficient number of specimens. Valid results can frequently be obtained in geochemical sourcing by characterizing only a few specimens from a particular source; this approach has seen success because of the geochemical homogeneity of many obsidian flows. Magnetic properties of obsidian flows, however, have not shown the same homogeneity. Many early magnetic studies have not used enough specimens to obtain complete representation of an obsidian flow. It seems that analyzing 6 to 14 samples per flow (29 total) was not enough to obtain an accurate representation of each flow, which could explain why these sources are not clearly differentiated in the graphs.

CONCLUSION

The results of this study mirrored some of the results of the Frahm and Feinberg (2013) paper. None of the graphical representations of data could distinguish these three sources from each other. The plots in Figure 4B and Figure 4C somewhat grouped the Grants Ridge source apart from the Horace Mesa and La Jara Mesa sources. However, as seen in each graph, there was too much scatter within each source and too much overlap between sources to clearly differentiate between sources. As discussed in the Data Analysis section, the number of specimens analyzed was too small to obtain an accurate representation of each flow and further analysis would need to be undergone to concretely determine the differentiation potential of these localities. Future studies should aim to collect > 20 samples within narrowly defined outcrops or float in order to more tightly constrain the magnetic properties within an obsidian flow.

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REFERENCES

Frahm, E. and Feinberg, J.M, 2013, From flow to quarry: magnetic properties of obsidian and changing the scale of archaeological sourcing. Journal of Archaeological Science, v. 40, i. 10, p. 3706–3721. Print.

Shackley, M. S., 2005, Obsidian - Geology and Archaeology in the North American Southwest. Tucson: The University of Arizona Press. Print.

Sternberg, R.S., Jackson, M. J., and Shackley, M. S., 2011, Hysteresis, thermomagnetic, and low-temperature magnetic properties of Southwestern U. S. obsidians, 2011. Poster, American Geophysical Union Fall Meeting.