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SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM THE CORNING MUSEUM OF GLASS COLLECTION, CORNING, NEW YORK

Large Glass Butte, Oregon biface (65.1.19)

by

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INTRODUCTION

The analysis here of 16 obsidian artifacts from the Corning Glass Museum indicates an extremely diverse provenance assemblage from five U.S. states and two states of Mexico. While it is difficult to determine whether all the artifacts were produced prehistorically (Cat. # 62.7.2B certainly was not, given its provenance), there are some inferences in this regard that can be made and are included in the discussion. Additionally, bibliographic citations and some comments on the sources in this collection are also offered (see Tables 1 and 2).

LABORATORY SAMPLING, ANALYSIS AND INSTRUMENTATION

All archaeological samples are analyzed whole. The results presented here are quantitative in that they are derived from "filtered" intensity values ratioed to the appropriate x-ray continuum regions through a least squares fitting formula rather than plotting the proportions of the net intensities in a ternary system (McCarthy and Schamber 1981; Schamber 1977). Or more essentially, these data through the analysis of international rock standards, allow for inter-instrument comparison with a predictable degree of certainty (Hampel 1984; Shackley 2011).

All analyses for this study were conducted on a ThermoScientific *Quant'X* EDXRF spectrometer, located at the Geoarchaeological XRF Laboratory, Albuquerque, New Mexico. It is equipped with a thermoelectrically Peltier cooled solid-state Si(Li) X-ray detector, with a 50 kV, 50 W, ultra-high-flux end window bremsstrahlung, Rh target X-ray tube and a 76 µm (3 mil) beryllium (Be) window (air cooled), that runs on a power supply operating 4-50 kV/0.02-1.0 mA at 0.02 increments. The spectrometer is equipped with a 200 l min^{-1} Edwards vacuum pump, allowing for the analysis of lower-atomic-weight elements between sodium (Na) and titanium (Ti). Data acquisition is accomplished with a pulse processor and an analogue-to-digital converter. Elemental composition is identified with digital filter background removal, least squares empirical peak deconvolution, gross peak intensities and net peak intensities above background.

The analysis for mid Zb condition elements Ti-Nb, Pb, Th, the x-ray tube is operated at 30 kV, using a 0.05 mm (medium) Pd primary beam filter in an air path at 100 seconds livetime to generate x-ray intensity $K\alpha_1$-line data for elements titanium (Ti), manganese (Mn), iron (as $Fe_2O_3^T$), cobalt (Co), nickel (Ni), copper, (Cu), zinc, (Zn), gallium (Ga), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), lead (Pb), and thorium (Th). Not all these elements are reported since their values in many volcanic rocks are very low. Trace element intensities were converted to concentration estimates by employing a least-squares calibration line ratioed to the Compton scatter established for each element from the analysis of international rock standards certified by the National Institute of Standards and Technology (NIST), the US. Geological Survey (USGS), Canadian Centre for Mineral and Energy Technology, the Centre de Recherches Pétrographiques et Géochimiques in France, and the Japan Geological Survey (Govindaraju 1994). Line fitting is linear (XML) for all elements. When barium (Ba) and cerium (Ce) is analyzed in the High Zb condition, the Rh tube is operated at 50 kV and up to 1.0 mA, ratioed to the bremsstrahlung region (see Davis 2011; Shackley 2011). Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1995, 2005, 2011; also Mahood and Stimac 1990; and Hughes and Smith 1993). Nineteen specific pressed powder standards are used for the best fit regression calibration for elements Ti-Nb, Pb, Th, Ba, and Ce include G-2 (basalt), AGV-2 (andesite), GSP-2 (granodiorite), SY-2 (syenite), BHVO-2 (hawaiite), STM-1 (syenite), QLO-1 (quartz latite), RGM-1 (obsidian), W-2 (diabase), BIR-1 (basalt), SDC-1 (mica schist), TLM-1 (tonalite), SCO-1 (shale), NOD-A-1 and NOD-P-1 (manganese) all US Geological Survey standards, NIST-278 (obsidian), U.S. National Institute of Standards and Technology, BE-N (basalt) from the Centre de Recherches Pétrographiques et Géochimiques in France, and JR-1 and JR-2 (obsidian) from the Geological Survey of Japan (Govindaraju 1994).

The data from the WinTrace™ software were translated directly into Excel for Windows software for manipulation and on into SPSS for Windows (ver. 21) or JMP 12.0.1 as appropriate for statistical analyses. In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run. RGM-1 a USGS obsidian standard is analyzed during each sample run of ≤19 for obsidian artifacts to check machine calibration (Table 1).

Source assignments were made by reference to a number of published and unpublished references as cited below, and the Skinner-Shackley database for North American obsidian sources. The choice of elements for North American obsidian compositional analysis is discussed in Shackley (1989, 2011; Shackley et al. 2016, 2018). Further information on the laboratory instrumentation can be found at: http://www.swxrflab.net/. Trace element data exhibited in Table 1 are reported in parts per million (ppm), a quantitative measure by weight (see also Figure 1).

DISCUSSION

As noted above, since there is no provenience (site origin) for the artifacts, inferences concerning the archaeological origin of the artifacts is limited. However, some of the artifacts, assuming they were produced in prehistory are distinctive.

Glass Buttes, Oregon and Large Biface Production

Foremost among these is the large biface (65.1.19) illustrated in the cover image. Produced from the Glass Buttes source in the Cascade Mountain chain in Oregon, these bifaces are some of the most significant obsidian objects from northwestern North American Indian society (Dillian 2002; Hughes 1978; Figure 2 herein). These large bifaces, some as much as a meter in length were used by northwestern groups (Hupa, Wiyot, Yurok) in the White Deerskin ceremony, a redistributive ceremony given annually by more wealthy members of the group to indicate wealth and power (Dillian 2002; Goldschmidt and Driver 1940; Gould 1996; Hughes

1978; Kroeber 1976; Loud 1918). During the ceremony a black and a red (mahogany) colored biface hidden in white deerskins would alternately be shown in order to create awe among the crowd. These ceremonies were often part of a potlatch ceremony where goods would be distributed from the wealthy to those less so. These bifaces are still of value to northwest coast California groups as ritual objects. The caveat here is that they are a popular biface reproduced by accomplished modern flintknappers in North America (Whittaker 2004). I have produced them myself from the Buck Mountain source in the Warner Mountains of northeastern California, and for many years a retired quite skilled knapper would camp at the source for a week or so and produce these large bifaces in the summers. The same process occurs at the Glass Buttes source in Oregon, a favorite flintknapping source (Heflin 1979; Whittaker 2004). I suspect that this biface is aboriginal, but without obsidian hydration dating, a destructive method, it is impossible to determine with any degree of confidence.

The other Glass Buttes object (62.7.2B) is certainly modern. A number of flintknappers will create a "slab" to better initiate flake removals in order to produce a large biface, and lapidarists frequently polish obsidian (see Whittaker 1994, 2004). It has been called a "mirror", but there were no mirrors produced in North America north of Mexico.

The small concave based projectile point (66.7.10) likely produced from the Obsidian Cliffs source in Oregon is typical of that style from the late period in the North American Northwest. The Obsidian Cliffs source is one of the largest and prehistorically frequently quarried in Oregon (see Connolly et al. 2015; Hughes 1993).

Obsidian Sources of the North American Southwest

A number of projectile points were produced from sources in Arizona (Bull Creek), and New Mexico (Cerro Toledo Rhyolite, El Rechuelos Rhyolite, and Valles Rhyolite-Cerro del Medio; Shackley 2005, http://swxrflab.net/swobsrcs.htm; see Table 2 and Figure 2 herein). The New Mexico sources are all from the Jemez Mountains volcanic field in northern New Mexico, and Cerro del Medio obsidian was distributed throughout western North America including south into Mexico (Mills et al. 2013; Shackley 2005; Steffen 2016). All of these artifacts appear to be prehistoric in origin.

The piece of debitage produced from the Bull Creek source in western Arizona, is somewhat of an enigma (Shackley 2005, 2009; Figure 3 herein). While the obsidian produced at Bull Creek is a high quality raw material, it is not distributed (via direct procurement or exchange) over a large area, generally restricted to western Arizona. I surmise that it was picked up at a site in western Arizona.

Blade Production in Mexican Obsidian Sources

The two obsidian polyhedral blades (59.7.1D; 95.1.10) the former produced from one of the sources in Sierra de Pachuca in Hidalgo state, Mexico, and the other likely from the El Paraiso source also in Mexico are typical of polyhedral blades produced from these important sources (Argote-Espino 2011; Glascock 2011; Figure 4 herein). The Pachuca obsidian source was a large prehistoric mining complex, and artifacts mostly polyhedral blades from Pachuca, have been recovered infrequently throughout North America as well as frequently in Mesoamerica, and as far north as Kansas (Barker et al. 2002; Dolan and Shackley 2020; Hoard et al. 2008).

The Borax Lake Obsidian Complex

The Borax Lake obsidian source in Lake County, northern California was used for at least 14,000 years (see Table 2 and Figure 5). The large bifaces in this collection produced from Borax Lake obsidian are more typical of Early and Middle Horizon periods in northern and central California (Hughes 2018; Meighan and Haynes 1970). The source today has been mostly destroyed by modern construction.

Other California Sources

Two other relatively large bifaces (62.7.1A; 62.7.1E) from the Bodie Hills source, West Sugarloaf (Coso) source, and the small late period corner-notched projectile point produced from Casa Diablo source all in eastern California are both frequently utilized sources in prehistory (Ericson 1981; Ericson and Glascock 2004; Hughes 1988, 1994, 2018). Not much more can be said here (see Figure 5).

Disposition of the Obsidian Artifacts

Most of the artifacts in this collection are typical of North America including Mexico. The only object that could be of interest to American Indian groups would be the large mahogany colored biface produced from Glass Buttes, Oregon (65.1.19). Since it is considered by many of the groups mentioned as a ritual object, it could be covered by the Native American Graves Protection and Repatriation Act (NAGPRA). The disposition of which is up to Corning. The rest of the objects are likely not in that category.

REFERENCES CITED

Ambroz, J.A., M.D. Glascock, and C.E. Skinner
2001 Chemical Differentiation of Obsidian within the Glass Buttes Complex, Oregon. *Journal of Archaeological Science* 28:741-746.

Anttonen, G.J.
1972 *Trace Elements in High Cascade Volcanic Rocks, Three Sisters Area, Oregon.* Ph.D. dissertation, Department of Geology, Stanford University, Palo Alto, California.

Argote-Espino, D., J. Solé, P. López-Garcia, and O. Sterpone
2011 Obsidian Subsource Identification in teh Sierra de Pachuca and Otumba Volcanic Regions, Central Mexico, by ICP-MS and DBSCAN Statistical Analysis. *Geoarchaeology* 27:48-62.

Barker, A.W., C.E. Skinner, M.S. Shackley, M.D. Glascock, and J.D. Rogers
2002 Mesoamerican Origin for an Obsidian Scraper from the Precolumbian Southeastern United States. *American Antiquity* 67(1):103-108.

Connolly, T.J., C.E. Skinner, and P.W. Baxter
2015 Ancient Trade Routes for Obsidian Cliffs and Newberry Volcano Toolstone in the Pacific Northwest. In *Toolstone Geography of the Pacific Northwest*, edited by T.L. Ozbun, and R.L. Adams, pp. 180-192. Archaeology Press, Simon Fraser University, British Columbia.

Davis, M.K., T.L. Jackson, M.S. Shackley, T. Teague, and J. Hampel
2011 Factors Affecting the Energy-Dispersive X-Ray Fluorescence (EDXRF) Analysis of Archaeological Obsidian. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M.S. Shackley, pp. 45-64. Springer, New York.

Dillian, C.D.
2002 *More than Toolstone: Differential Utilization of Glass Mountain Obsidian.* Ph.D. dissertation, Department of Anthropology, University of California, Berkeley.

Dolan, S. G. and M.S. Shackley
2020 Obsidian Prismatic Blades from the US Southwest: Implications for Connections Between the US Southwest/Mexican Northwest and Mesoamerica. Manuscript in preparation.

Ericson, J.E.
1981 *Exchange and Production Systems in Californian Prehistory: The Results of Hydration Dating and Chemical Characterization of Obsidian Sources.* British Archaeological Reports, International Series 110.

Ericson, J.E., and M.D. Glascock
2004 Subsource Characterization: Obsidian Utilization of Subsources of the Coso Volcanic Field, Coso Junction, California, USA. *Geoarchaeology* 19:779-805.

Frahm, E. and J.M. Feinberg
2014 Reassessing Obsidian Field Relationships at Glass Buttes, Oregon. *Journal of Archaeological Science: Reports* 2.

Glascock, M.D.
2011 Comparison and Contrast Between XRF and NAA: Used for Characterization of Obsidian Sources in Central Mexico. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M.S. Shackley, pp. 161-182. Springer, New York.

Glascock, M.D., J.M. Elam, and K. Ayoama
1990 Provenience Analysis of Obsidian Artifacts from the La Entrada Region, Honduras. In Proceedings of the 1990 Archaeometry Symposium, edited by E. Pernicka, and G.A. Wagner, pp. 395-404. Birkhäuser Verlag, Basel.

Goldschmidt, W.R., and H.E. Driver
1940 The Hupa White Deerskin Dance. *University of California Publications in American Archaeology and Ethnology* 35:103-142.

Gould, R.A.
1996 The Wealth Quest Among the Tolowa Indians of Northwestern California. *Proceedings of the American Philosophical Society* 110:67-89.

Govindaraju, K.
1994 1994 Compilation of Working Values and Sample Description for 383 Geostandards. *Geostandards Newsletter* 18 (special issue).

Hampel, Joachim H.
1984 Technical Considerations in X-ray Fluorescence Analysis of Obsidian. In *Obsidian Studies in the Great Basin*, edited by R.E. Hughes, pp. 21-25. Contributions of the University of California Archaeological Research Facility 45. Berkeley.

Heflin, E.
1979 Oregon's Incredible Glass Buttes. *Gems and Minerals* 503:72-75, 80-81, 83.

Hildreth, W.
1981 Gradients in Silicic Magma Chambers: Implications for Lithospheric Magmatism. *Journal of Geophysical Research* 86:10153-10192.

Hoard, R.J., C.T. Bevitt, and J. McLean
2008 Source Determination of Obsidian from Kansas Archaeological Sites Using Compositional Analysis. *Transactions of the Kansas Academy of Science* 111:219-229.

Hughes, R.E.
1978 Aspects of Prehistoric Wiyot Exchange and Social Ranking. *Journal of California Anthropology* 5:53-66.

1988 The Coso Volcanic Field Reexamined: Implications for Obsidian Sourcing and Hydration Dating Research. *Geoarchaeology* 3:253-265.

1993 Trace Element Chemistry of Volcanic Glass from the Obsidian Cliffs Flow, Three Sisters Wilderness, Oregon. *Northwest Science* 67:199-207.

1994 Intrasource Chemical Variability of Artefact-Quality Obsidians from the Casa Diablo Area, California. *Journal of Archaeological Science* 21:263-271.

2018 Obsidian Studies in California Archaeology. *Quaternary International* 482:67-82.

Hughes, Richard E., and Robert L. Smith
1993 Archaeology, Geology, and Geochemistry in Obsidian Provenance Studies. *In Scale on Archaeological and Geoscientific Perspectives*, edited by J.K. Stein and A.R. Linse, pp. 79-91. Geological Society of America Special Paper 283.

Kroeber, A.L.
1976 *Yurok Myths*. University of California Press, Berkeley.

Loud, L.L.
1918 Ethnogeography and Archaeology of the Wiyot Territory. *University of California Publications in American Archaeology and Ethnology* 14:221-436.

Mahood, Gail A., and James A. Stimac
1990 Trace-Element Partitioning in Pantellerites and Trachytes. *Geochemica et Cosmochimica Acta* 54:2257-2276.

McCarthy, J.J., and F.H. Schamber
1981 Least-Squares Fit with Digital Filter: A Status Report. In *Energy Dispersive X-ray Spectrometry*, edited by K.F.J. Heinrich, D.E. Newbury, R.L. Myklebust, and C.E. Fiori, pp. 273-296. National Bureau of Standards Special Publication 604, Washington, D.C.

Meighan, C.W., and C.V. Haynes
1970 The Borax Lake Site Revisited. *Science* 167:1213-1221.

Mills, B.J., J.J. Clark, M.A. Peeples, W.R. Haas, Jr., J.M. Roberts, Jr., J.B. Hill, D.L. Huntley, L. Borck, R.L. Breiger, A. Clauset, and M.S. Shackley
2013 Transformation of Social Networks in the Late Pre-Hispanic US Southwest. *Proceedings of the National Academy of Sciences* 110:5785-5790.

Nelson, F.W., and D.G. Tingey
1997 X-ray Fluorescence Analysis of Obsidians in Western North America, Mexico, and Guatemala: Data Base for Source Identification. Manuscript in possession of author.

Ponomarenko, A.L.
2004 The Pachuca Obsidian Source, Hidalgo Mexico: A Geoarchaeological Perspective. *Geoarchaeology* 19:71-91.

Schamber, F.H.
1977 A Modification of the Linear Least-Squares Fitting Method which Provides Continuum Suppression. In *X-ray Fluorescence Analysis of Environmental Samples*, edited by T.G. Dzubay, pp. 241-257. Ann Arbor Science Publishers.

Shackley, M. Steven
1989 *Early Hunter-Gatherer Procurement Ranges in the Southwest: Evidence from Obsidian Geochemistry and Lithic Technology*. Ph.D. dissertation, Departments of Anthropology and Geology, Arizona State University, Tempe.

1995 Sources of Archaeological Obsidian in the Greater American Southwest: An Update and Quantitative Analysis. *American Antiquity* 60:531-551.

2005 *Obsidian: Geology and Archaeology in the North American Southwest*. University of Arizona Press, Tucson.

2009 Two Newly Discovered Sources of Archaeological Obsidian in the Southwest: Archaeological and Social Implications. *Kiva* 74(3):269-280.

2011 An Introduction to X-Ray Fluorescence (XRF) Analysis in Archaeology. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M.S. Shackley, pp. 7-44. Springer, New York.

Shackley, M.S., F. Goff, and S.G. Dolan
2016 Geologic origin of the source of Bearhead rhyolite (Paliza Canyon) obsidian, Jemez Mountains, Northern New Mexico. *New Mexico Geology* 38:52-62.

Shackley, M.S., L. E. Morgan, and D. Pyle
2018 Elemental, isotopic, and geochronological variability in Mogollon-Datil Volcanic Province archaeological obsidian, southwestern USA: solving issues of inter-source discrimination. *Geoarchaeology* 33:486-497.

Skinner, C.E.
2005 Results of X-Ray Fluorescence Trace Element Analysis of Project Obsidian Artifacts. In Fingerprints in the Great Basin: *The Nellis Air Force Base Regional Obsidian Sourcing Study*, edited by L. Haarklau, L. Johnson, and D.L. Wagner, pp. D1-107 (Appendix D). US Army Corps of Engineers, Fort Worth District, Fort Worth, Texas.

Steffen, A.
2016 The High-Elevation Archaeological Record of the Valles Caldera. *Archaeology Southwest* 30, 9-12.

Steuber, D.O., and C.E. Skinner
2015 Glass Buttes, Oregon: 14,000 Years of Continuous Use. In *Toolstone Geography of the Pacific Northwest*, edited by T.L. Ozbun and R.L. Adams, pp. 193-207. Archaeology Press, Simon Fraser University, British Columbia.

Tenorio D., A. Cabral, P. Bosch, J. Jiménez-Reyes, and S. Bulbulian
1998 Differences in Coloured Obsidians from Sierra de Pachuca, Mexico. *Journal of Archaeological Science* 25:229-234.

Whittaker, J.C.
1994 *Flintknapping: Making and Understanding Stone Tools*. University of Texas Press, Austin.

2004 *American Flintknappers*. University of Texas Press, Austin.

Table 1. Elemental concentrations and source assignments for the archaeological specimens and USGS RGM-1 rhyolite standard. All measurements in parts per million (ppm).

Cat #	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
59.7.1A	1010	448	8103	155	12	24	79	47	8	33	32	21	El Rechuelos Rhy, NM
59.7.1B	926	409	8090	151	12	28	74	51	51	54	24	22	El Rechuelos Rhy, NM
59.7.1G	984	494	10528	205	11	67	178	98	3	65	38	13	Cerro Toledo Rhy, NM
59.7.1K	1421	323	12440	161	99	19	189	18	1299	71	40	28	Casa Diablo, CA
59.7.8	1050	414	11215	174	9	46	176	57	171	62	41	23	Valles Rhy (Cerro del Medio), NM
59-7-1D	1422	1028	20462	223	11	114	985	95	0	67	35	17	Pachuca, Hidalgo, MEX
62.7.1A	1037	400	8301	176	101	12	101	13	637	71	40	32	Bodie Hills, CA
62.7.1B	1000	237	10221	238	16	46	104	11	76	60	35	20	Borax Lake, CA
62.7.1C	941	238	10208	237	18	46	106	9	69	38	31	21	Borax Lake, CA
62.7.1D	1144	245	10941	229	17	40	107	14	59	50	33	18	Borax Lake, CA
62.7.1E	808	272	10297	261	15	56	138	50	36	43	28	49	W Sugarloaf, Coso, CA
62.7.2B	1059	363	8691	112	66	27	98	7	1306	24	14	19	Glass Butte, OR
65.1.19	1081	301	10085	118	59	18	153	18	883	50	16	24	Glass Butte, OR
66.7.10	1260	458	8940	68	79	26	86	5	915	31	16	7	Obsidian Cliffs, OR?
73.1.12D	880	464	9367	207	15	24	82	26	157	37	29	24	Bull Creek, AZ
95.7.10	1465	533	31028	255	13	132	1212	60	19	159	76	44	El Paraiso, MEX?
RGM1-S4	1537	302	13241	150	108	25	215	7	759	40	22	12	standard

Table 2. Relevant archaeological and geological references for each artifact.

Cat #	Source	Relevant References
59.7.1A	El Rechuelos Rhy, NM	Shackley 2005
59.7.1B	El Rechuelos Rhy, NM	Shackley 2005
59.7.1G	Cerro Toledo Rhy, NM	Shackley 2005
59.7.1K	Casa Diablo, CA	Hughes 1994
59.7.8	Valles Rhy (Cerro del Medio), NM	Shackley 2005
59-7-1D	Pachuca, Hidalgo, MEX	Argote-Espino et al. 2012; Glascock 2011; Ponomarenko 2004; Tenorio et al. 1998; Dolan and Shackley 2020
62.7.1A	Bodie Hills, CA	Hughes 2018; Singer and Ericson 1977;
62.7.1B	Borax Lake, CA	Hughes 2018; Jackson 1989; Meighan and Haynes 1983;
62.7.1C	Borax Lake, CA	Hughes 2018; Jackson 1989; Meighan and Haynes 1983
62.7.1D	Borax Lake, CA	Hughes 2018; Jackson 1989; Meighan and Haynes 1983
62.7.1E	W Sugarloaf, Coso, CA	Ericson and Glascock 2004; Hughes 1984, 1988, 2018
62.7.2B	Glass Buttes, OR	Ambroz et al. 2001; Frahm and Feinberg 2014; Hughes 1978; Steuber and Skinner 2015
65.1.19	Glass Buttes, OR	Ambroz et al. 2001; Frahm and Feinberg 2014; Hughes 1978; Steuber and Skinner 2015
66.7.10	Obsidian Cliffs, OR?	Anttonen 1972; Connolly et al. 2015; Hughes 1993
73.1.12D	Bull Creek, AZ	Shackley 2005:37-39, 2009
95.7.10	El Paraiso, MEX?	Glascock 2011

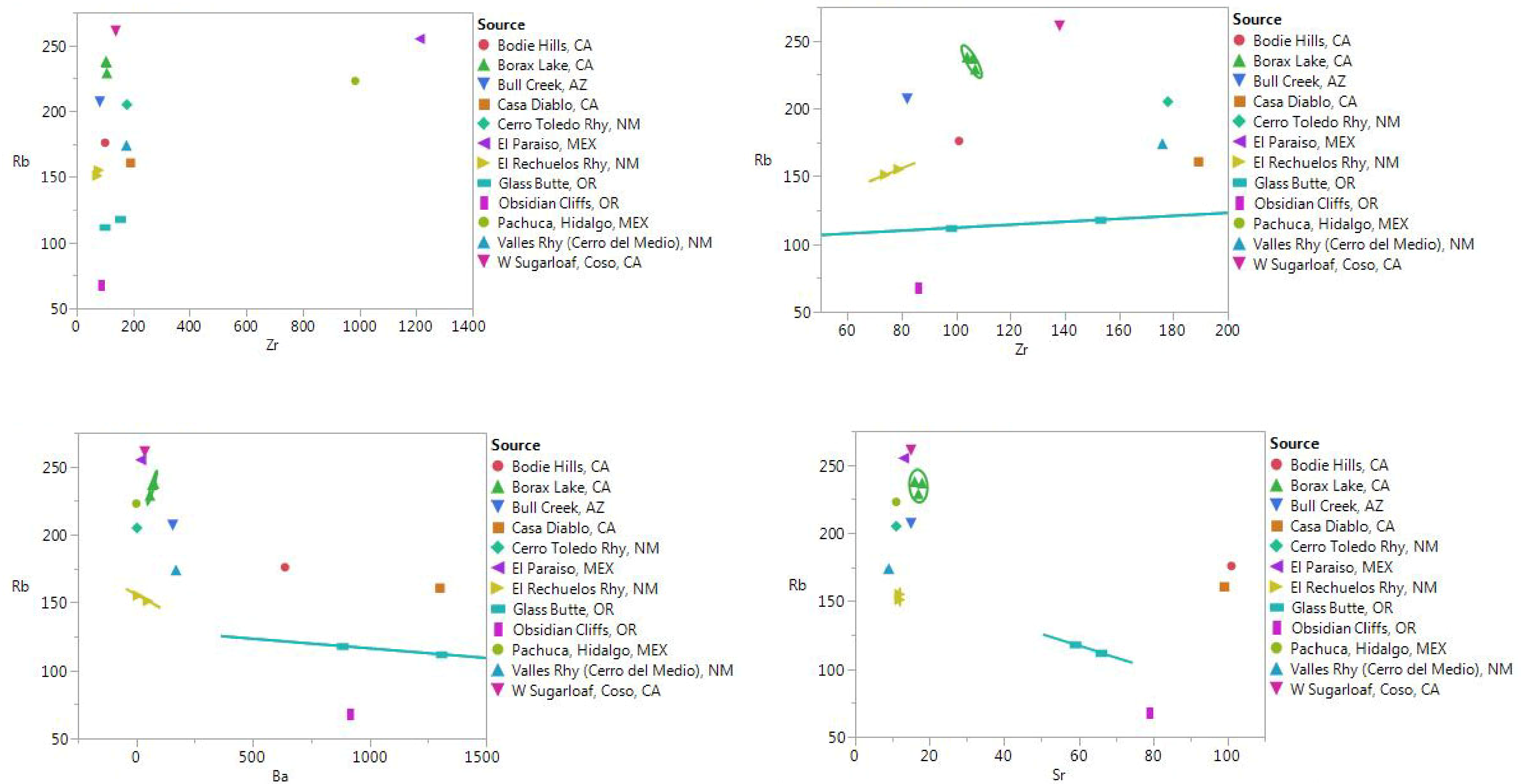

Figure 1. Bivariate plots of the archaeological samples employing four elements to provide discrimination (see Table 1; see Shackley et al. 2018): Zr/Rb (upper left of all samples); Zr/Rb (upper right) of the lower Zr samples deleting the two Mexican sources; Ba/Rb (lower left); and Sr/Rb (lower right). Confidence ellipses and lines at 95%.

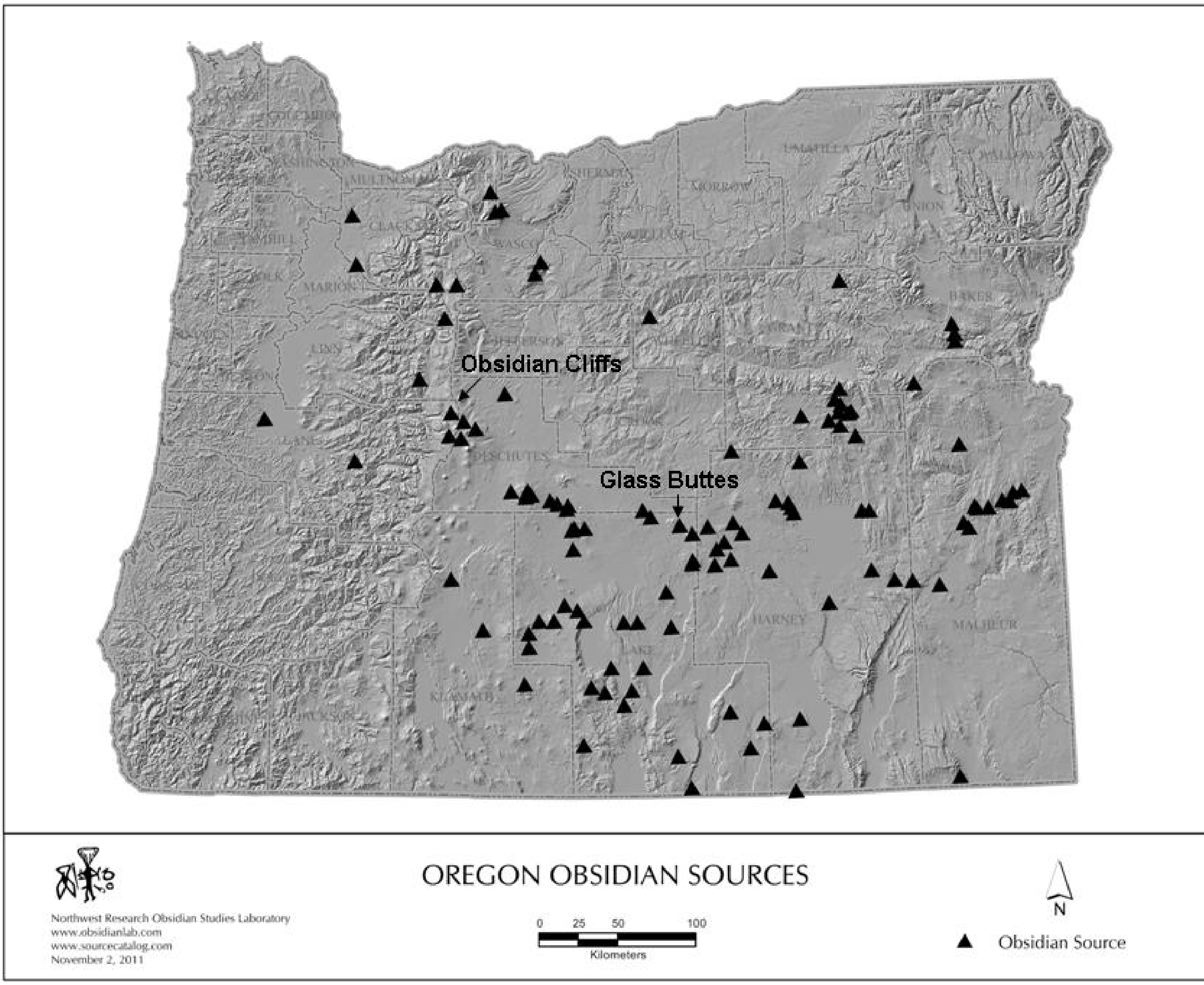

Figure 2. Oregon obsidian sources with the location of Glass Buttes and Obsidian Cliffs labeled (from: https://www.sourcecatalog.com/image_maps/image_maps.html)

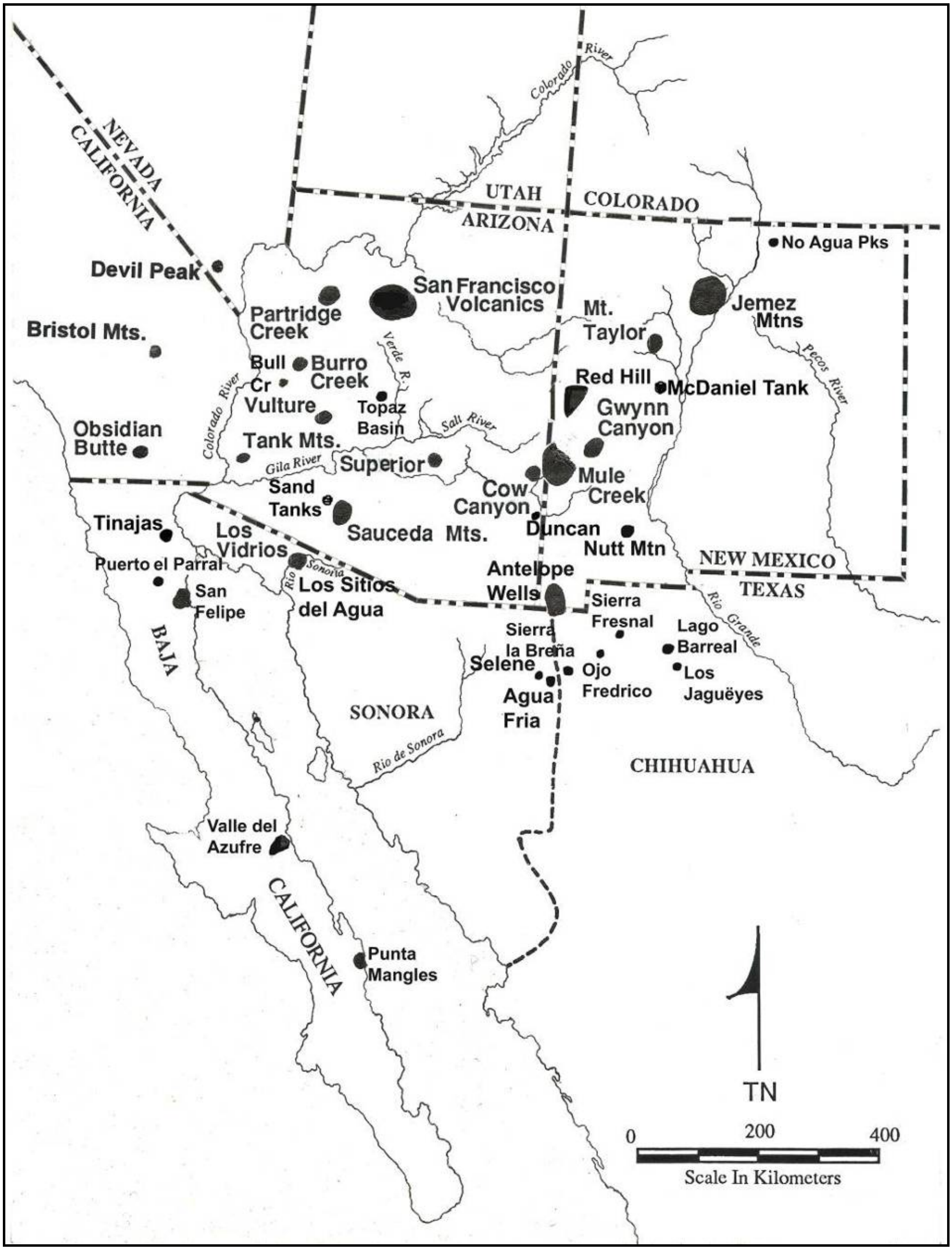

Figure 3. Obsidian sources in southwestern North America (adapted from Shackley 2005). The Jemez Mountains include all the New Mexico sources in the collection. Source configurations not to scale.

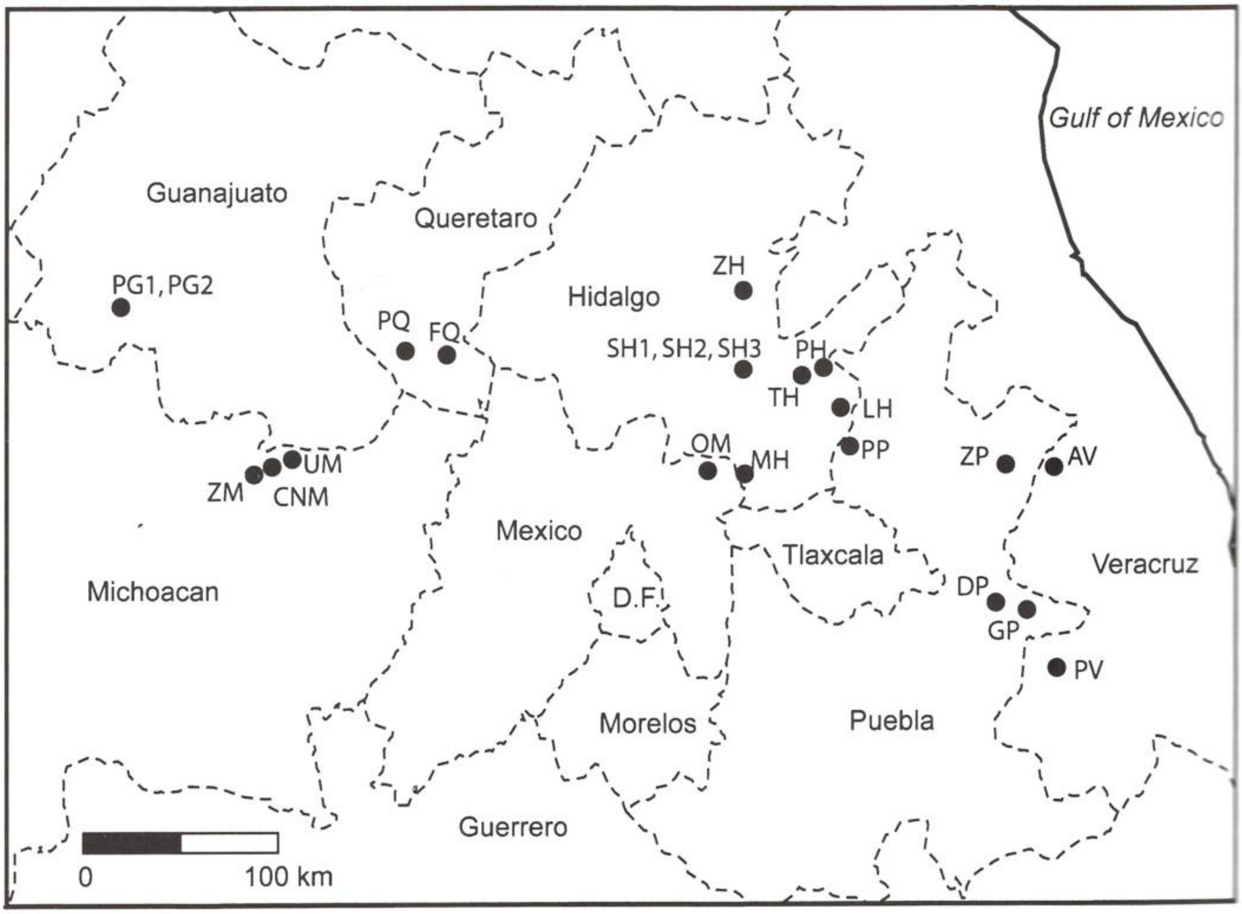

Figure 4. Sources of archaeological obsidian in central Mexico (from Glascock 2011). Pachuca is noted by SH 1, 2, 3; El Paraiso by PQ.

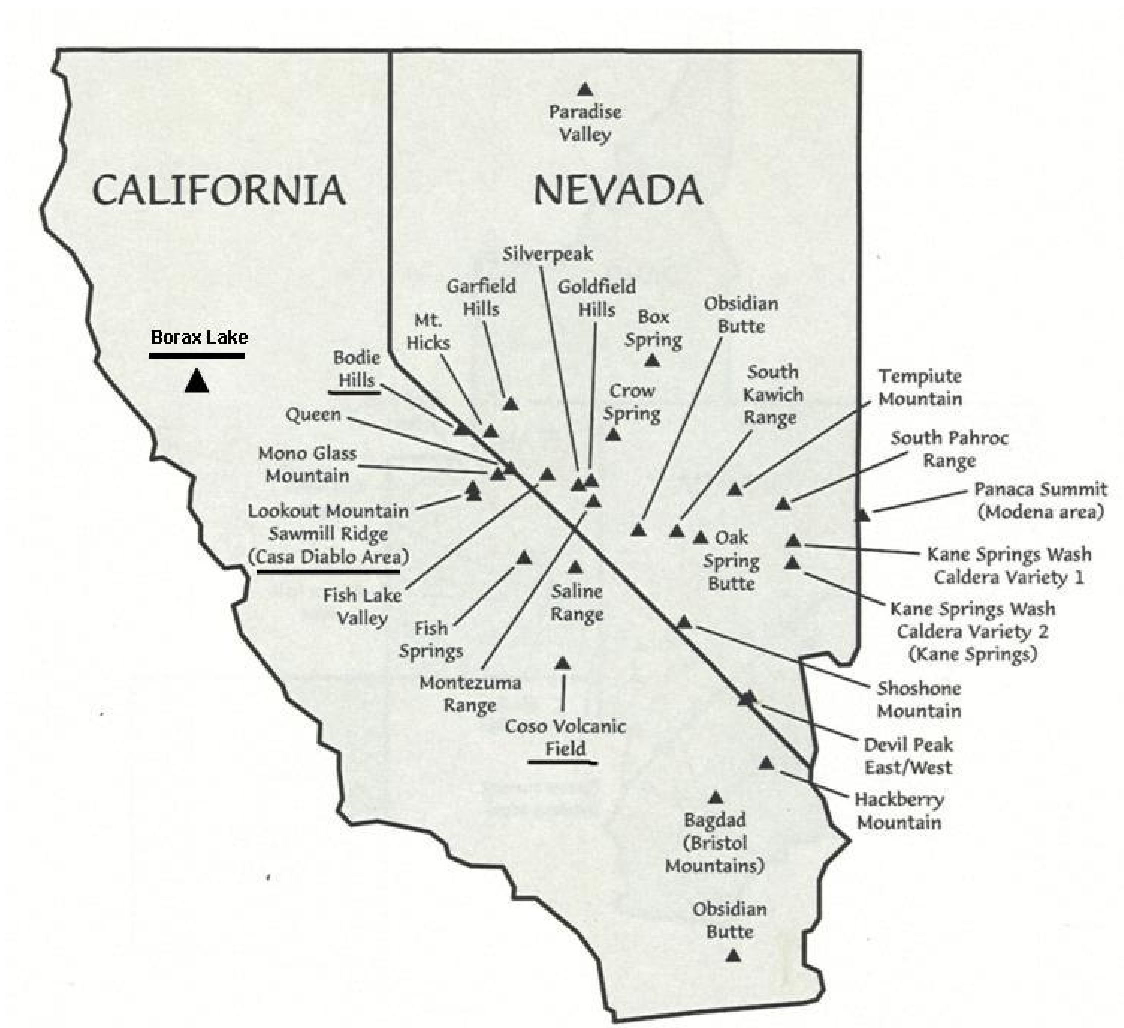

Figure 5. California and Nevada archaeological obsidian sources with the four California sources in the collection underlined (from Skinner 2005).