

**X-Ray Fluorescence Analysis of Artifact Obsidian from the Craters of the Moon
National Monument and Preserve, Butte and Blaine Counties, Idaho**

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Seventy-eight obsidian artifacts from sites located at the Craters of the Moon National Monument and Preserve, Butte and Blaine Counties, Idaho, were submitted for energy dispersive X-ray fluorescence trace element provenance analysis. The samples were prepared and analyzed at the Northwest Research Obsidian Studies Laboratory under the accession number 2009-75.

Analytical Methods

X-Ray Fluorescence Analysis. Nondestructive trace element analysis of the samples was completed using a Spectrace 5000 energy dispersive X-ray fluorescence spectrometer. The system is equipped with a Si(Li) detector with a resolution of 155 eV FWHM for 5.9 keV X-rays (at 1000 counts per second) in an area 30 mm². Signals from the spectrometer are amplified and filtered by a time variant pulse processor and sent to a 100 MHz Wilkinson type analog-to-digital converter. The X-ray tube employed is a Bremsstrahlung type, with a rhodium target, and 5 mil Be window. The tube is driven by a 50 kV 1 mA high voltage power supply, providing a voltage range of 4 to 50 kV. For the elements Zn, Rb, Sr, Y, Zr, Nb, and Pb that are reported in Table A-1, we analyzed the collection with a collimator installed and used a 45 kV tube voltage setting and 0.60 mA tube current setting.

The diagnostic trace element values used to characterize the samples are compared directly to those for known obsidian sources reported in the literature and with unpublished trace element data collected through analysis of geologic source samples (Northwest Research 2009a). Artifacts are correlated to a parent obsidian source (or geochemical source group) if diagnostic trace element values fall within about two standard deviations of the analytical uncertainty of the known upper and lower limits of chemical variability recorded for the source. Occasionally, visual attributes are used to corroborate the source assignments although sources are never assigned solely on the basis of megascopic characteristics.

Additional details about specific analytical methods and procedures used for the analysis of the elements reported in Table A-1 are available at the Northwest Research Obsidian Studies Laboratory World Wide Web site at www.obsidianlab.com.

Results of Analysis

X-Ray Fluorescence Analysis. Nine geochemical groups, all of which were correlated with known obsidian sources, were identified from among the 77 obsidian artifacts that were characterized by X-ray fluorescence analysis. The trace element composition of one of the specimens indicates that it is not obsidian. The locations of the sites and the identified sources are shown in Figure 1. Analytical results are presented in Table A-1 in the Appendix and are summarized in Table 1 and Figure 2.

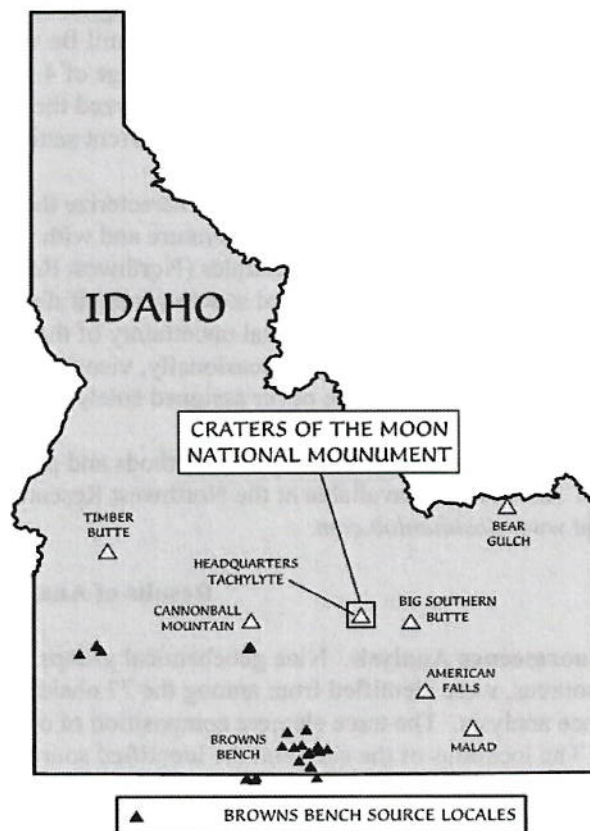
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Table 1. Summary of results of trace element studies of artifacts from the project sites.

OBSIDIAN SOURCE	N=	PERCENTAGE
American Falls	21	26.9
Bear Gulch	4	5.1
Big Southern Butte	36	46.1
Browns Bench	6	7.7
Cannonball Mountain	1	1.3
Headquarters Tachylyte	1	1.3
Malad	1	1.3
Not Obsidian	1	1.3
Timber Butte	2	2.6
Unknown Tachylyte A	5	6.4
TOTAL	78	100.0

Figure 1. Locations of the sites and the sources of the obsidian artifacts.



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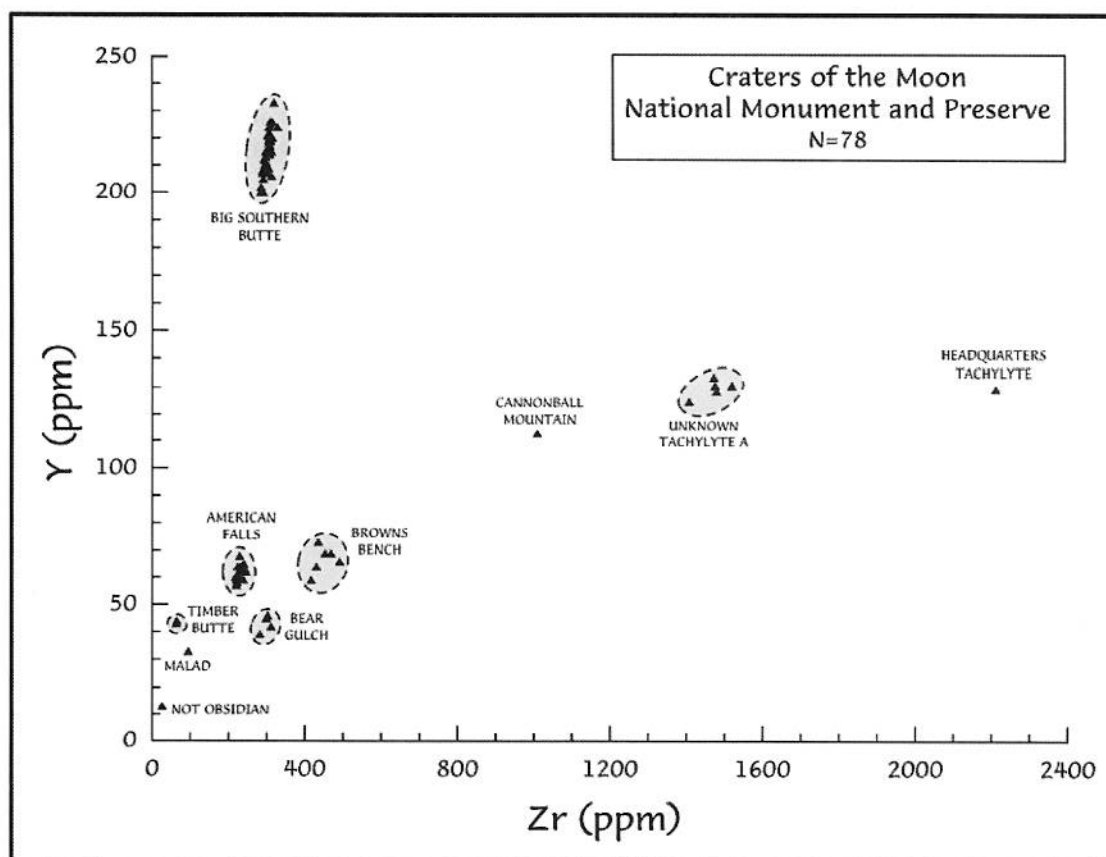


Figure 2. Scatterplot of zirconium (Zr) plotted versus yttrium (Y) for all analyzed samples.

Two geochemical varieties of basaltic volcanic glass (tachylite) – Headquarters Tachylite and Unknown Tachylite A – were identified among the artifacts that were submitted for analysis. Tachylites are distinguished from the more common rhyolitic obsidians by their elevated iron and titanium content combined with their high degree of opacity and a large crystalline component that usually results in the presence of visible phenocrysts in the glassy matrix. The Headquarters Tachylite had been previously characterized from two geologic specimens recovered during construction activities near the Craters of the Moon National Monument Visitor Center. The source of the Unknown Tachylite A variety remains unknown although it has been previously encountered at two archaeological sites (10-BN-389 and 10-BN-1066) that lie within the boundaries of the Craters of the Moon National Monument.

Information about the geologic setting and prehistoric use of the obsidian sources identified in the current investigation may found in Bailey (1992), Corn (2006), Ekren et al. (1984), Ferguson and Skinner (2003), Henrikson (2008), Holmer (1997), Hughes (1990, 2006), Hughes and Nelson (1987), Hughes and Smith (1993), Nelson (1984), Plager (2001), Sappington (1981), Thompson (2004), Willingham (1995), Wtigh and Chaya (1995), and Wright et al. (1990).

Additional information about the sources may be found at www.sourcecatalog.com (Northwest Research 2009b).

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References Cited

- Bailey, Jeff
1992 *X-Ray Fluorescence Characterization of Volcanic Glass Artifacts from Wilson Butte Cave, Idaho*. Unpublished Master's Thesis, Department of Anthropology, University of Alberta, Edmonton, Alberta, Canada.
- Corn, Tyrone L.
2006 *Timber Butte Obsidian Source Survey: Geology, Prehistory, Chemical Sourcing, and Debitage Analysis*. Unpublished Master's Thesis, Department of Anthropology, University of Idaho, Moscow, Idaho.
- Ekren, E. B., D. H. McIntyre, and E. H. Bennett
1984 *High-Temperature, Large-Volume, Lavalike Ash-Flow Tuffs Without Calderas in Southwest Idaho*. U. S. Geological Survey Professional Paper 1272.
- Ferguson, Jeffrey R. and Craig E. Skinner
2003 Colorado Obsidian? Preliminary Results of a Statewide Database of Trace Element Analysis. *Southwestern Lore* 69:35–50.
- Henrikson, L. Suzann
2008 Going With the Flow: The Impact of Fissure Eruptions on Obsidian Source Use in Southeastern Idaho. *Journal of California and Great Basin Anthropology* 28:153–165.
- Holmer, Richard N.
1997 Volcanic Glass Utilization in Eastern Idaho. *Tebiwa* 26:186–204.
- Hughes, Richard E.
1990 Appendix C: Obsidian at James Creek Shelter, and Trace Element Geochemistry of Some Northeastern Nevada Volcanic Glasses. In *The Archaeology of James Creek Shelter, Nevada*, edited by R. G. Elston and E. Budy, pp. 297–305. University of Utah Anthropological Papers 115, Salt Lake City, Utah.
2006 The Sources of Hopewell Obsidian: Forty Years After Griffin. In *Recreating Hopewell*, edited by Douglas K. Charles and Jane E. Buikstra, pp. 361–375. University Press of Florida, Gainesville, Florida.
- Hughes, Richard E. and Fred W. Nelson
1987 New Findings on Obsidian Source Utilization in Iowa. *Plains Anthropologist* 37(117):313–316.
- Hughes, Richard E. and Robert L. Smith
1993 Archaeology, Geology, and Geochemistry in Obsidian Provenance Studies, in *Effects of 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, Boulder, Colorado.
- Nelson, Fred W., Jr.
1984 X-Ray Fluorescence Analysis of Some Western North American Obsidians. In *Obsidian Studies in the Great Basin*, edited by Richard E. Hughes, pp. 27–62.
- Northwest Research Obsidian Studies Laboratory
2009a Northwest Research Obsidian Studies Laboratory World Wide Web Site (www.obsidianlab.com).
2009b Northwest Research U. S. Obsidian Source Catalog (www.sourcecatalog.com).
- Plager, Sharon
2001 *Patterns in the Distribution of Volcanic Glass Across Southern Idaho*. Unpublished Master's Thesis, Department of Anthropology, Idaho State University, Pocatello, Idaho.
- Sappington, Robert L.
1981 A Progress Report on the Obsidian and Vitrophyre Sourcing Project. *Idaho Archaeologist* 4(4):4–17.
- Thompson, Randy A.
2004 *Trade or Transport: Occurrence of Obsidian from the Malad, Idaho, Source in the Great Plains*. Unpublished Master's Thesis, Department of Anthropology, Idaho State University, Pocatello, Idaho.

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Willingham, Charles G.

- 1995 Big Table Mountain: An Obsidian Source in the Centennial Mountains of Eastern Idaho. *Idaho Archaeologist* 18(1):3-7.

Wright, Gary A. and Henry J. Chaya

- 1985 Obsidian Source Analysis in Northwestern Wyoming: Problems and Prospects. *Plains Anthropologist* 30(109):237-242.

Wright, Gary A., Henry Chaya, and James McDonald

- 1990 The Location of the Field Museum Yellowstone (F.M.Y., 90) Group Obsidian Source. *Plains Anthropologist* 35(127):71-74.

Appendix

Results of X-Ray Fluorescence Analysis

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Table A-1. Results of XRF Studies: Artifacts Associated With the Craters of the Moon National Monument and Preserve, Idaho

Site	Specimen No.	Catalog No.	Trace Element Concentrations										Ratios			Geochemical Source
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	Fe ²⁺ O ³ T	Fe:Mn	Fe:Ti	
Craters of the Moon	1	272	233 ± 16	69 6	296 5	7 9	208 4	289 7	293 3	937 99	257 32	NM NM	1.38 0.14	44.3	48.2	Big Southern Butte
Craters of the Moon	2	273	49 ± 16	24 5	184 4	26 9	57 4	220 7	46 2	1452 100	410 33	861 25	0.95 0.14	20.0	22.3	American Falls
Craters of the Moon	3	304	258 ± 16	90 5	312 5	7 9	218 4	306 7	301 3	NM NM	NM NM	NM NM	NM NM	29.6	48.3	Big Southern Butte *
Craters of the Moon	4	514	249 ± 16	78 5	288 5	6 9	210 4	294 7	289 3	1101 99	433 33	NM NM	1.37 0.14	26.4	40.7	Big Southern Butte
Craters of the Moon	5	515	233 ± 16	74 5	297 5	5 11	214 4	307 7	304 3	943 99	473 33	NM NM	1.42 0.14	25.1	49.0	Big Southern Butte
Craters of the Moon	6	534	260 ± 16	81 5	318 5	ND ND	220 4	306 7	303 3	645 98	306 32	NM NM	1.83 0.14	48.5	89.4	Big Southern Butte
Craters of the Moon	7	556	281 ± 16	85 5	321 5	7 9	226 4	314 7	295 3	NM NM	NM NM	NM NM	NM NM	55.4	102.8	Big Southern Butte *
Craters of the Moon	8	559	253 ± 16	85 6	307 5	5 13	211 4	298 7	295 3	NM NM	NM NM	NM NM	NM NM	60.6	108.5	Big Southern Butte *
Craters of the Moon	9	561	281 ± 19	22 7	80 4	306 9	134 4	1472 9	136 3	8802 118	1740 35	1891 27	10.79 0.14	49.1	38.2	Unknown Tachylite A
Craters of the Moon	10	588-1	266 ± 16	74 6	325 5	7 9	220 4	315 7	308 3	NM NM	NM NM	NM NM	NM NM	52.2	92.2	Big Southern Butte *
Craters of the Moon	11	588-2	77 ± 16	34 5	197 4	28 9	64 4	224 7	49 2	NM NM	NM NM	NM NM	NM NM	40.2	30.5	American Falls *
Craters of the Moon	12	735	57 ± 16	30 5	201 4	28 9	62 4	227 7	50 2	1225 101	384 33	823 25	1.21 0.14	26.5	32.8	American Falls
Craters of the Moon	13	736	231 ± 16	74 6	294 5	8 9	200 4	290 7	287 3	815 98	260 32	NM NM	1.53 0.14	48.0	60.4	Big Southern Butte
Craters of the Moon	14	737-1	71 ± 16	29 5	199 4	18 9	44 4	64 7	37 2	NM NM	NM NM	NM NM	NM NM	7.0	22.1	Timber Butte *
Craters of the Moon	15	737-2	277 ± 16	85 6	312 5	8 9	209 4	305 7	292 3	NM NM	NM NM	NM NM	NM NM	32.0	52.7	Big Southern Butte *

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide. NA = Not available; ND = Not detected; NM = Not measured; * = Small sample; FGV = Fine-grained volcanic specimen.

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Table A-1. Results of XRF Studies: Artifacts Associated With the Craters of the Moon National Monument and Preserve, Idaho

Site	Specimen No.	Catalog No.	Trace Element Concentrations											Ratios		Geochemical Source
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	Fe ² O ^{3T}	Ratios		
														Fe:Mn	Fe:Ti	
Craters of the Moon	16	813-1	74 ± 16	27 5	205 4	26 9	65 4	240 7	46 2	NM NM	NM NM	NM NM	22.5	35.0	American Falls *	
Craters of the Moon	17	813-2	65 ± 16	27 5	193 4	26 9	64 4	231 7	48 2	NM NM	NM NM	NM NM	41.1	35.3	American Falls *	
Craters of the Moon	18	851-1	81 ± 16	35 6	193 5	51 9	69 4	453 7	49 2	1786 102	267 32	1065 25	2.10 0.14	63.1	37.8	Browns Bench
Craters of the Moon	19	851-2	235 ± 16	78 6	299 5	8 9	216 4	305 7	305 3	NM NM	NM NM	NM NM	49.4	82.4	Big Southern Butte *	
Craters of the Moon	20	852	73 ± 16	26 5	201 4	49 9	73 4	435 7	53 2	NM NM	NM NM	1067 25	NM NM	35.9	33.1	Browns Bench *
Craters of the Moon	21	856	268 ± 19	23 7	72 4	295 9	125 4	1407 9	136 3	NM NM	NM NM	NM NM	NM NM	53.6	38.8	Unknown Tachylite A *
Craters of the Moon	22	859	58 ± 16	25 5	201 4	28 9	63 4	234 7	51 2	1368 101	327 32	834 25	1.07 0.14	27.7	26.3	American Falls
Craters of the Moon	23	864-1	247 ± 16	78 5	305 5	5 10	213 4	296 7	297 2	1065 99	239 32	NM NM	1.50 0.14	51.3	45.8	Big Southern Butte
Craters of the Moon	24	864-2	53 ± 16	26 5	199 4	30 9	61 4	225 7	48 2	1409 101	503 33	841 25	1.03 0.14	17.7	24.8	American Falls
Craters of the Moon	25	868-1	73 ± 15	33 5	201 4	20 9	43 4	63 7	34 2	NM NM	NM NM	NM NM	NM NM	6.9	23.0	Timber Butte *
Craters of the Moon	26	868-2	210 ± 19	38 7	95 5	223 9	130 4	2211 11	142 3	NM NM	NM NM	NM NM	NM NM	51.1	47.3	Headquarters Tachylite *
Craters of the Moon	27	868-3	203 ± 17	60 6	269 5	6 10	207 4	303 7	298 3	NM NM	NM NM	NM NM	NM NM	27.2	31.6	Big Southern Butte *
Craters of the Moon	28	868-4	270 ± 16	84 5	315 5	5 10	221 4	310 7	299 3	465 97	421 33	NM NM	1.71 0.14	33.5	115.1	Big Southern Butte
Craters of the Moon	29	868-5	219 ± 17	80 6	295 5	5 11	207 4	289 7	290 3	862 98	221 32	NM NM	1.26 0.14	46.8	47.8	Big Southern Butte
Craters of the Moon	30	868-6	238 ± 17	72 6	284 5	5 11	217 4	308 7	291 3	NM NM	NM NM	NM NM	NM NM	51.0	106.2	Big Southern Butte *

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
 NA = Not available; ND = Not detected; NM = Not measured; * = Small sample; FGV = Fine-grained volcanic specimen.

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Table A-1. Results of XRF Studies: Artifacts Associated With the Craters of the Moon National Monument and Preserve, Idaho

Site	Specimen No.	Catalog No.	Trace Element Concentrations										Ratios			Geochemical Source
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	Fe ² O ₃ ^T	Fe:Mn	Fe:Ti	
Craters of the Moon	31	873-1	56 ± 16	19 5	201 4	28 9	59 4	239 7	46 2	1544 101	222 32	842 25	1.00 0.14	38.2	22.1	American Falls
Craters of the Moon	32	873-2	57 ± 16	21 5	192 4	51 9	42 4	311 7	60 2	1726 101	358 33	641 24	1.26 0.14	29.6	24.4	Bear Gulch
Craters of the Moon	33	873-3	43 ± 16	22 5	168 4	42 9	39 4	282 7	54 2	1792 101	365 32	609 25	1.04 0.14	24.4	19.7	Bear Gulch
Craters of the Moon	34	874	232 ± 16	73 5	293 5	6 9	202 4	285 7	284 3	1271 99	399 33	NM NM	1.49 0.14	31.1	38.4	Big Southern Butte
Craters of the Moon	35	878-1	325 ± 16	84 5	306 5	6 9	221 4	303 7	299 3	NM NM	NM NM	NM NM	NM NM	27.7	41.2	Big Southern Butte *
Craters of the Moon	36	886-1	80 ± 15	31 5	201 4	30 9	62 4	245 7	48 2	1708 102	298 32	907 25	1.64 0.14	44.9	31.3	American Falls
Craters of the Moon	37	889-1	246 ± 16	82 5	320 5	7 9	224 4	328 7	311 3	501 98	296 32	NM NM	1.76 0.14	48.4	109.8	Big Southern Butte
Craters of the Moon	38	889-2	50 ± 16	33 5	186 4	29 9	58 4	222 7	43 2	1168 100	267 32	794 25	1.11 0.14	34.9	31.7	American Falls
Craters of the Moon	39	889-3	47 ± 16	27 5	190 4	48 9	46 4	302 7	59 2	1867 101	314 32	584 25	1.47 0.14	38.7	26.0	Bear Gulch
Craters of the Moon	40	889-4	68 ± 15	39 5	202 4	28 9	68 4	229 7	50 2	1304 101	281 32	872 25	1.26 0.14	37.3	32.0	American Falls
Craters of the Moon	41	889-5	271 ± 17	82 6	352 5	7 9	226 4	309 7	308 3	NM NM	NM NM	NM NM	NM NM	47.9	75.2	Big Southern Butte *
Craters of the Moon	42	889-6	201 ± 16	49 6	368 5	8 9	113 4	1009 8	115 2	NM NM	NM NM	NM NM	NM NM	68.8	99.7	Cannonball Mountain *
Craters of the Moon	43	889-7	75 ± 16	27 6	193 5	27 9	61 4	222 7	48 2	NM NM	NM NM	NM NM	NM NM	37.0	29.3	American Falls *
Craters of the Moon	44	891-1	63 ± 16	29 5	190 4	28 9	60 4	224 7	45 2	1454 101	241 32	885 25	1.07 0.14	37.5	24.9	American Falls
Craters of the Moon	45	891-2	65 ± 15	24 5	206 4	27 9	60 4	228 7	50 2	1365 101	309 32	781 25	1.06 0.14	29.1	26.1	American Falls

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide. NA = Not available; NID = Not detected; NM = Not measured; * = Small sample; FGV = Fine-grained volcanic specimen.

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Table A-1. Results of XRF Studies: Artifacts Associated With the Craters of the Moon National Monument and Preserve, Idaho

Site	Specimen No.	Catalog No.	Trace Element Concentrations											Ratios		Geochemical Source
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	Fe ² O ₃ ^T	Fe:Mn	Fe:Ti	
Craters of the Moon	46	891-3	260 ± 19	29 7	86 4	285 9	129 4	1479 9	137 3	NM NM	NM NM	NM NM	NM	60.8	38.4	Unknown Tachlylte A *
Craters of the Moon	47	891-4	255 ± 19	34 7	74 5	299 9	131 4	1475 9	134 3	8035 116	1279 34	2063 28	10.04 0.14	62.2	39.0	Unknown Tachlylte A
Craters of the Moon	48	891-5	201 ± 17	77 6	291 5	6 10	206 4	312 7	284 3	NM NM	200 NM	NM NM	1.21 NM	49.6	112.4	Big Southern Butte
Craters of the Moon	49	891-6	214 ± 17	73 6	276 5	6 9	200 4	284 7	286 3	782 99	345 32	NM NM	2.08 0.14	48.8	84.0	Big Southern Butte *
Craters of the Moon	50	891-7	270 ± 20	32 7	78 4	303 9	131 4	1519 9	144 3	NM NM	1507 NM	NM NM	11.33 NM	59.5	36.8	Unknown Tachlylte A
Craters of the Moon	51	891-8	248 ± 16	83 6	310 5	7 ND	233 4	319 7	315 3	NM NM	235 NM	NM NM	1.51 NM	52.4	128.9	Big Southern Butte *
Craters of the Moon	52	924-1	229 ± 16	84 5	310 5	7 9	225 4	310 7	303 3	NM NM	310 NM	NM NM	1.44 NM	38.3	49.3	Big Southern Butte *
Craters of the Moon	53	924-2	70 ± 16	30 5	189 4	47 9	45 4	299 7	60 2	2422 103	401 33	603 24	2.13 0.14	43.2	28.4	Bear Gulch *
Craters of the Moon	54	925	70 ± 16	33 5	185 4	51 9	64 4	430 7	47 2	NM NM	191 NM	NM NM	1.61 NM	67.8	27.4	Browns Bench
Craters of the Moon	55	1145-1	239 ± 16	87 5	321 5	6 9	222 4	306 7	306 2	1317 100	500 33	NM NM	1.78 0.14	29.4	43.7	Big Southern Butte *
Craters of the Moon	56	1145-2	58 ± 16	26 5	193 4	31 9	63 4	243 7	48 2	1418 101	272 32	848 25	1.27 0.14	38.8	29.7	American Falls
Craters of the Moon	57	2260-1	89 ± 15	26 5	193 4	28 9	60 4	218 7	47 2	1616 101	269 32	836 24	1.14 0.14	35.7	23.8	American Falls
Craters of the Moon	58	2355	222 ± 17	69 6	291 5	ND ND	215 4	312 7	292 3	697 98	379 33	NM NM	1.97 0.14	42.3	89.0	Big Southern Butte
Craters of the Moon	59	2436-1	248 ± 16	74 6	296 5	8 9	215 4	297 7	297 3	613 98	381 33	NM NM	1.79 0.14	38.6	92.3	Big Southern Butte
Craters of the Moon	60	2436-2	65 ± 15	22 5	199 4	26 9	60 4	230 7	49 2	1606 101	236 32	838 24	1.16 0.14	41.0	24.2	American Falls

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
 NA = Not available; ND = Not detected; NM = Not measured; * = Small sample; FGV = Fine-grained volcanic specimen.

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Table A-1. Results of XRF Studies: Artifacts Associated With the Craters of the Moon National Monument and Preserve, Idaho

Site	Specimen No.	Catalog No.	Trace Element Concentrations										Ratios			Geochemical Source
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	Fe ² O ₃ ^T	Fe:Mn	Fe:Ti	
Craters of the Moon	61	2441	36 ± 17	60 5	0 4	65 9	13 4	26 7	2	980 102	8500 43	NM NM	1.66 0.14	1.7	54.7	Not Obsidian
Craters of the Moon	62	2442	56 ± 16	22 5	203 4	31 9	64 4	235 7	52 2	1531 101	440 33	NM NM	1.05 0.14	20.4	23.1	American Falls
Craters of the Moon	63	2443	56 ± 16	32 5	189 4	28 9	57 4	221 7	45 2	2095 102	496 33	857 25	1.28 0.14	21.7	20.3	American Falls
Craters of the Moon	64	2444	58 ± 16	35 6	204 5	55 9	69 4	468 7	57 2	NM NM	NM NM	NM NM	NM NM	65.3	39.6	Browns Bench *
Craters of the Moon	65	2445	255 ± 16	77 5	301 5	5 10	205 4	291 7	289 3	NM NM	NM NM	NM NM	NM NM	25.7	44.0	Big Southern Butte *
Craters of the Moon	66	2446-1	268 ± 16	80 5	308 5	7 9	219 4	305 7	290 3	661 98	294 32	NM NM	1.85 0.14	51.0	88.2	Big Southern Butte
Craters of the Moon	67	2446-2	233 ± 16	69 6	294 5	11 9	209 4	299 7	295 3	NM NM	NM NM	NM NM	NM NM	46.2	44.9	Big Southern Butte *
Craters of the Moon	68	2446-3	246 ± 16	75 5	306 5	6 9	213 4	297 7	296 3	NM NM	NM NM	NM NM	NM NM	50.4	40.4	Big Southern Butte *
Craters of the Moon	69	2447-1	223 ± 17	77 6	293 5	6 9	224 4	306 7	295 3	NM NM	NM NM	NM NM	NM NM	50.1	87.3	Big Southern Butte *
Craters of the Moon	70	2447-2	229 ± 17	74 6	295 5	7 9	209 4	292 7	291 3	NM NM	NM NM	NM NM	NM NM	58.4	101.9	Big Southern Butte *
Craters of the Moon	71	2448	236 ± 17	72 6	281 5	11 9	219 4	310 7	287 3	1664 102	544 33	NM NM	2.52 0.14	37.6	48.2	Big Southern Butte
Craters of the Moon	72	2449	56 ± 16	30 5	194 5	53 9	66 4	491 7	47 2	NM NM	NM NM	NM NM	NM NM	70.1	34.7	Browns Bench *
Craters of the Moon	73	1451	29 ± 17	29 5	195 4	29 9	59 4	225 7	48 2	NM NM	NM NM	NM NM	NM NM	20.8	23.8	American Falls *
Craters of the Moon	74	2573	257 ± 16	76 5	286 5	7 9	208 4	300 7	287 3	842 99	262 32	NM NM	1.56 0.14	48.7	59.8	Big Southern Butte
Craters of the Moon	75	306	258 ± 16	75 6	300 5	8 9	212 4	293 7	293 3	793 98	431 33	NM NM	1.69 0.14	32.3	68.2	Big Southern Butte

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
 NA = Not available; ND = Not detected; NM = Not measured; * = Small sample; FGV = Fine-grained volcanic specimen.

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Table A-1. Results of XRF Studies: Artifacts Associated With the Craters of the Moon National Monument and Preserve, Idaho

Site	Specimen No.	Catalog No.	Trace Element Concentrations										Ratios		Geochemical Source	
			Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	Fe ² O ^{3T}	Fe:Mn		Fe:Ti
Craters of the Moon	76	505	52 ± 16	25 6	110 4	68 9	33 4	95 7	15 2	2395 104	354 33	1499 25	2.14 0.14	48.9	28.9	Malad
Craters of the Moon	77	513	49 ± 17	25 6	204 5	51 9	59 4	416 7	43 2	1981 102	254 32	1100 25	2.32 0.14	72.9	37.6	Browns Bench
Craters of the Moon	78	863-1	42 ± 16	19 5	188 4	29 9	59 4	220 7	41 2	1052 100	261 32	825 25	1.03 0.14	33.4	32.9	American Falls
NA	RGM-1	RGM-1	41 ± 16	25 5	158 4	107 9	22 4	221 7	10 2	1576 101	542 33	792 25	1.75 0.14	26.7	36.1	RGM-1 Reference Standard

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
 NA = Not available; ND = Not detected; NM = Not measured; * = Small sample; FGV = Fine-grained volcanic specimen.