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

Craig E. Skinner and Jennifer J,. Thatcher
Northwest Research Obsidian Studies Laboratory

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 FHWM for 5.9 keV X-rays (at 1000 counts per second) in an area 30 mm^2. 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characterize the samples are compared directly to those for known obsidian sources reported in the literature and with unpublished trace element data collected through analysis of geologic source samples (Northwest Research 2009a).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.

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**

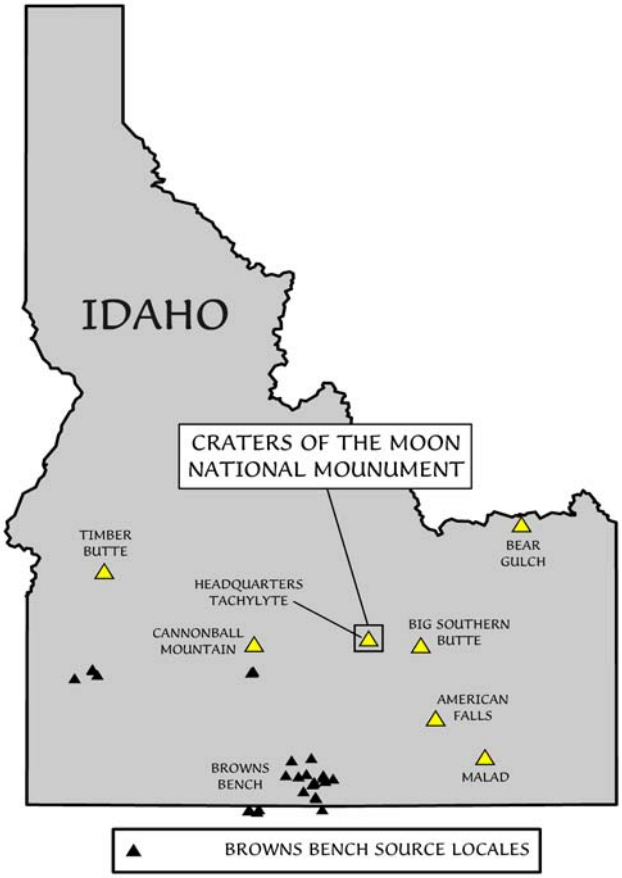

Figure 1. Locations of the sites and the sources of the obsidian artifacts.

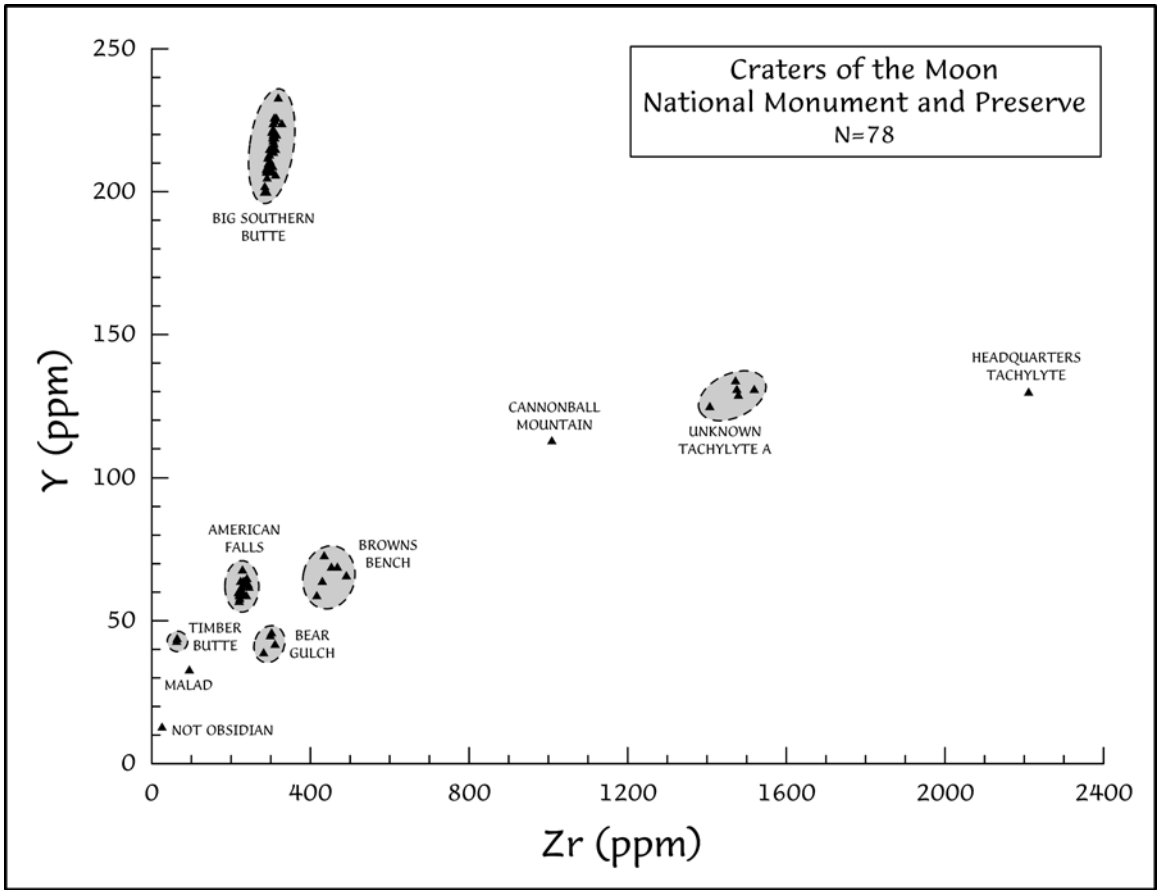

Figure 2. Scatterplot of zirconium (Zr) plotted versus yttrium (Y) for all analyzed samples.

Two geochemical varieties of basaltic volcanic glass (tachylyte) – Headquarters Tachylyte and Unknown Tachylyte A – were identified among the artifacts that were submitted for analysis. Tachylytes 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 Tachylyte 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 Tachylyte 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), Wtight and Chaya (1995), and Wright et al. (1990).

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

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.

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

Northwest Research Obsidian Studies Laboratory

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	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Craters of the Moon	1	272	233	69	296	7	208	289	293	937	257	NM	1.38	44.3	48.2	Big Southern Butte
			± 16	6	5	9	4	7	3	99	32	NM	0.14			
Craters of the Moon	2	273	49	24	184	26	57	220	46	1452	410	861	0.95	20.0	22.3	American Falls
			± 16	5	4	9	4	7	2	100	33	25	0.14			
Craters of the Moon	3	304	258	90	312	7	218	306	301	NM	NM	NM	NM	29.6	48.3	Big Southern Butte *
			± 16	5	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	4	514	249	78	288	6	210	294	289	1101	433	NM	1.37	26.4	40.7	Big Southern Butte
			± 16	5	5	9	4	7	3	99	33	NM	0.14			
Craters of the Moon	5	515	233	74	297	5	214	307	304	943	473	NM	1.42	25.1	49.0	Big Southern Butte
			± 16	5	5	11	4	7	3	99	33	NM	0.14			
Craters of the Moon	6	534	260	81	318	ND	220	306	303	645	306	NM	1.83	48.5	89.4	Big Southern Butte
			± 16	5	5	ND	4	7	3	98	32	NM	0.14			
Craters of the Moon	7	556	281	85	321	7	226	314	295	NM	NM	NM	NM	55.4	102.8	Big Southern Butte *
			± 16	5	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	8	559	253	85	307	5	211	298	295	NM	NM	NM	NM	60.6	108.5	Big Southern Butte *
			± 16	6	5	13	4	7	3	NM	NM	NM	NM			
Craters of the Moon	9	561	281	22	80	306	134	1472	136	8802	1740	1891	10.79	49.1	38.2	Unknown Tachylyte A
			± 19	7	4	9	4	9	3	118	35	27	0.14			
Craters of the Moon	10	588-1	266	74	325	7	220	315	308	NM	NM	NM	NM	52.2	92.2	Big Southern Butte *
			± 16	6	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	11	588-2	77	34	197	28	64	224	49	NM	NM	NM	NM	40.2	30.5	American Falls *
			± 16	5	4	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	12	735	57	30	201	28	62	227	50	1225	384	823	1.21	26.5	32.8	American Falls
			± 16	5	4	9	4	7	2	101	33	25	0.14			
Craters of the Moon	13	736	231	74	294	8	200	290	287	815	260	NM	1.53	48.0	60.4	Big Southern Butte
			± 16	6	5	9	4	7	3	98	32	NM	0.14			
Craters of the Moon	14	737-1	71	29	199	18	44	64	37	NM	NM	NM	NM	7.0	22.1	Timber Butte *
			± 16	5	4	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	15	737-2	277	85	312	8	209	305	292	NM	NM	NM	NM	32.0	52.7	Big Southern Butte *
			± 16	6	5	9	4	7	3	NM	NM	NM	NM			

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.

Northwest Research Obsidian Studies Laboratory

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	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Craters of the Moon	16	813-1	74	27	205	26	65	240	46	NM	NM	NM	NM	22.5	35.0	American Falls *
			± 16	5	4	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	17	813-2	65	27	193	26	64	231	48	NM	NM	NM	NM	41.1	35.3	American Falls *
			± 16	5	4	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	18	851-1	81	35	193	51	69	453	49	1786	267	1065	2.10	63.1	37.8	Browns Bench
			± 16	6	5	9	4	7	2	102	32	25	0.14			
Craters of the Moon	19	851-2	235	78	299	8	216	305	305	NM	NM	NM	NM	49.4	82.4	Big Southern Butte *
			± 16	6	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	20	852	73	26	201	49	73	435	53	NM	NM	1067	NM	35.9	33.1	Browns Bench *
			± 16	5	4	9	4	7	2	NM	NM	25	NM			
Craters of the Moon	21	856	268	23	72	295	125	1407	136	NM	NM	NM	NM	53.6	38.8	Unknown Tachylyte A *
			± 19	7	4	9	4	9	3	NM	NM	NM	NM			
Craters of the Moon	22	859	58	25	201	28	63	234	51	1368	327	834	1.07	27.7	26.3	American Falls
			± 16	5	4	9	4	7	2	101	32	25	0.14			
Craters of the Moon	23	864-1	247	78	305	5	213	296	297	1065	239	NM	1.50	51.3	45.8	Big Southern Butte
			± 16	5	5	10	4	7	2	99	32	NM	0.14			
Craters of the Moon	24	864-2	53	26	199	30	61	225	48	1409	503	841	1.03	17.7	24.8	American Falls
			± 16	5	4	9	4	7	2	101	33	25	0.14			
Craters of the Moon	25	868-1	73	33	201	20	43	63	34	NM	NM	NM	NM	6.9	23.0	Timber Butte *
			± 15	5	4	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	26	868-2	210	38	95	223	130	2211	142	NM	NM	NM	NM	51.1	47.3	Headquarters Tachylyte *
			± 19	7	5	9	4	11	3	NM	NM	NM	NM			
Craters of the Moon	27	868-3	203	60	269	6	207	303	298	NM	NM	NM	NM	27.2	31.6	Big Southern Butte *
			± 17	6	5	10	4	7	3	NM	NM	NM	NM			
Craters of the Moon	28	868-4	270	84	315	5	221	310	299	465	421	NM	1.71	33.5	115.1	Big Southern Butte
			± 16	5	5	10	4	7	3	97	33	NM	0.14			
Craters of the Moon	29	868-5	219	80	295	5	207	289	290	862	221	NM	1.26	46.8	47.8	Big Southern Butte
			± 17	6	5	11	4	7	3	98	32	NM	0.14			
Craters of the Moon	30	868-6	238	72	284	5	217	308	291	NM	NM	NM	NM	51.0	106.2	Big Southern Butte *
			± 17	6	5	11	4	7	3	NM	NM	NM	NM			

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.

Northwest Research Obsidian Studies Laboratory

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	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Craters of the Moon	31	873-1	56	19	201	28	59	239	46	1544	222	842	1.00	38.2	22.1	American Falls
			± 16	5	4	9	4	7	2	101	32	25	0.14			
Craters of the Moon	32	873-2	57	21	192	51	42	311	60	1726	358	641	1.26	29.6	24.4	Bear Gulch
			± 16	5	4	9	4	7	2	101	33	24	0.14			
Craters of the Moon	33	873-3	43	22	168	42	39	282	54	1792	365	609	1.04	24.4	19.7	Bear Gulch
			± 16	5	4	9	4	7	2	101	32	25	0.14			
Craters of the Moon	34	874	232	73	293	6	202	285	284	1271	399	NM	1.49	31.1	38.4	Big Southern Butte
			± 16	5	5	9	4	7	3	99	33	NM	0.14			
Craters of the Moon	35	878-1	325	84	306	6	221	303	299	NM	NM	NM	NM	27.7	41.2	Big Southern Butte *
			± 16	5	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	36	886-1	80	31	201	30	62	245	48	1708	298	907	1.64	44.9	31.3	American Falls
			± 15	5	4	9	4	7	2	102	32	25	0.14			
Craters of the Moon	37	889-1	246	82	320	7	224	328	311	501	296	NM	1.76	48.4	109.8	Big Southern Butte
			± 16	5	5	9	4	7	3	98	32	NM	0.14			
Craters of the Moon	38	889-2	50	33	186	29	58	222	43	1168	267	794	1.11	34.9	31.7	American Falls
			± 16	5	4	9	4	7	2	100	32	25	0.14			
Craters of the Moon	39	889-3	47	27	190	48	46	302	59	1867	314	584	1.47	38.7	26.0	Bear Gulch
			± 16	5	4	9	4	7	2	101	32	25	0.14			
Craters of the Moon	40	889-4	68	39	202	28	68	229	50	1304	281	872	1.26	37.3	32.0	American Falls
			± 15	5	4	9	4	7	2	101	32	25	0.14			
Craters of the Moon	41	889-5	271	82	352	7	226	309	308	NM	NM	NM	NM	47.9	75.2	Big Southern Butte *
			± 17	6	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	42	889-6	201	49	368	8	113	1009	115	NM	NM	NM	NM	68.8	99.7	Cannonball Mountain *
			± 16	6	5	9	4	8	2	NM	NM	NM	NM			
Craters of the Moon	43	889-7	75	27	193	27	61	222	48	NM	NM	NM	NM	37.0	29.3	American Falls *
			± 16	6	5	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	44	891-1	63	29	190	28	60	224	45	1454	241	885	1.07	37.5	24.9	American Falls
			± 16	5	4	9	4	7	2	101	32	25	0.14			
Craters of the Moon	45	891-2	65	24	206	27	60	228	50	1365	309	781	1.06	29.1	26.1	American Falls
			± 15	5	4	9	4	7	2	101	32	25	0.14			

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.

Northwest Research Obsidian Studies Laboratory

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	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Craters of the Moon	46	891-3	260	29	86	285	129	1479	137	NM	NM	NM	NM	60.8	38.4	Unknown Tachylyte A *
			± 19	7	4	9	4	9	3	NM	NM	NM	NM			
Craters of the Moon	47	891-4	255	34	74	299	131	1475	134	8035	1279	2063	10.04	62.2	39.0	Unknown Tachylyte A
			± 19	7	5	9	4	9	3	116	34	28	0.14			
Craters of the Moon	48	891-5	201	77	291	6	206	312	284	NM	200	NM	1.21	49.6	112.4	Big Southern Butte
			± 17	6	5	10	4	7	3	NM	NM	NM	NM			
Craters of the Moon	49	891-6	214	73	276	6	200	284	286	782	345	NM	2.08	48.8	84.0	Big Southern Butte *
			± 17	6	5	9	4	7	3	99	32	NM	0.14			
Craters of the Moon	50	891-7	270	32	78	303	131	1519	144	NM	1507	NM	11.33	59.5	36.8	Unknown Tachylyte A
			± 20	7	4	9	4	9	3	NM	NM	NM	NM			
Craters of the Moon	51	891-8	248	83	310	7	233	319	315	NM	235	NM	1.51	52.4	128.9	Big Southern Butte *
			± 16	6	5	ND	4	7	3	NM	NM	NM	NM			
Craters of the Moon	52	924-1	229	84	310	7	225	310	303	NM	310	NM	1.44	38.3	49.3	Big Southern Butte *
			± 16	5	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	53	924-2	70	30	189	47	45	299	60	2422	401	603	2.13	43.2	28.4	Bear Gulch *
			± 16	5	4	9	4	7	2	103	33	24	0.14			
Craters of the Moon	54	925	70	33	185	51	64	430	47	NM	191	NM	1.61	67.8	27.4	Browns Bench
			± 16	5	4	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	55	1145-1	239	87	321	6	222	306	306	1317	500	NM	1.78	29.4	43.7	Big Southern Butte *
			± 16	5	5	9	4	7	2	100	33	NM	0.14			
Craters of the Moon	56	1145-2	58	26	193	31	63	243	48	1418	272	848	1.27	38.8	29.7	American Falls
			± 16	5	4	9	4	7	2	101	32	25	0.14			
Craters of the Moon	57	2260-1	89	26	193	28	60	218	47	1616	269	836	1.14	35.7	23.8	American Falls
			± 15	5	4	9	4	7	2	101	32	24	0.14			
Craters of the Moon	58	2355	222	69	291	ND	215	312	292	697	379	NM	1.97	42.3	89.0	Big Southern Butte
			± 17	6	5	ND	4	7	3	98	33	NM	0.14			
Craters of the Moon	59	2436-1	248	74	296	8	215	297	297	613	381	NM	1.79	38.6	92.3	Big Southern Butte
			± 16	6	5	9	4	7	3	98	33	NM	0.14			
Craters of the Moon	60	2436-2	65	22	199	26	60	230	49	1606	236	838	1.16	41.0	24.2	American Falls
			± 15	5	4	9	4	7	2	101	32	24	0.14			

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.

Northwest Research Obsidian Studies Laboratory

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	61	2441	36	60	0	65	13	26	2	980	8500	NM	1.66	1.7	54.7	Not Obsidian
			± 17	5	4	9	4	7	3	102	43	NM	0.14			
Craters of the Moon	62	2442	56	22	203	31	64	235	52	1531	440	NM	1.05	20.4	23.1	American Falls
			± 16	5	4	9	4	7	2	101	33	NM	0.14			
Craters of the Moon	63	2443	56	32	189	28	57	221	45	2095	496	857	1.28	21.7	20.3	American Falls
			± 16	5	4	9	4	7	2	102	33	25	0.14			
Craters of the Moon	64	2444	58	35	204	55	69	468	57	NM	NM	NM	NM	65.3	39.6	Browns Bench *
			± 16	6	5	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	65	2445	255	77	301	5	205	291	289	NM	NM	NM	NM	25.7	44.0	Big Southern Butte *
			± 16	5	5	10	4	7	3	NM	NM	NM	NM			
Craters of the Moon	66	2446-1	268	80	308	7	219	305	290	661	294	NM	1.85	51.0	88.2	Big Southern Butte
			± 16	5	5	9	4	7	3	98	32	NM	0.14			
Craters of the Moon	67	2446-2	233	69	294	11	209	299	295	NM	NM	NM	NM	46.2	44.9	Big Southern Butte *
			± 16	6	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	68	2446-3	246	75	306	6	213	297	296	NM	NM	NM	NM	50.4	40.4	Big Southern Butte *
			± 16	5	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	69	2447-1	223	77	293	6	224	306	295	NM	NM	NM	NM	50.1	87.3	Big Southern Butte *
			± 17	6	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	70	2447-2	229	74	295	7	209	292	291	NM	NM	NM	NM	58.4	101.9	Big Southern Butte *
			± 17	6	5	9	4	7	3	NM	NM	NM	NM			
Craters of the Moon	71	2448	236	72	281	11	219	310	287	1664	544	NM	2.52	37.6	48.2	Big Southern Butte
			± 17	6	5	9	4	7	3	102	33	NM	0.14			
Craters of the Moon	72	2449	56	30	194	53	66	491	47	NM	NM	NM	NM	70.1	34.7	Browns Bench *
			± 16	5	5	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	73	1451	29	29	195	29	59	225	48	NM	NM	NM	NM	20.8	23.8	American Falls *
			± 17	5	4	9	4	7	2	NM	NM	NM	NM			
Craters of the Moon	74	2573	257	76	286	7	208	300	287	842	262	NM	1.56	48.7	59.8	Big Southern Butte
			± 16	5	5	9	4	7	3	99	32	NM	0.14			
Craters of the Moon	75	306	258	75	300	8	212	293	293	793	431	NM	1.69	32.3	68.2	Big Southern Butte
			± 16	6	5	9	4	7	3	98	33	NM	0.14			

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.

Northwest Research Obsidian Studies Laboratory

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	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Craters of the Moon	76	505	52	25	110	68	33	95	15	2395	354	1499	2.14	48.9	28.9	Malad
			± 16	6	4	9	4	7	2	104	33	25	0.14			
Craters of the Moon	77	513	49	25	204	51	59	416	43	1981	254	1100	2.32	72.9	37.6	Browns Bench
			± 17	6	5	9	4	7	2	102	32	25	0.14			
Craters of the Moon	78	863-1	42	19	188	29	59	220	41	1052	261	825	1.03	33.4	32.9	American Falls
			± 16	5	4	9	4	7	2	100	32	25	0.14			
NA	RGM-1	RGM-1	41	25	158	107	22	221	10	1576	542	792	1.75	26.7	36.1	RGM-1 Reference Standard
			± 16	5	4	9	4	7	2	101	33	25	0.14			

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.