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Hunter-gatherer Igneous Toolstone Procurement in Northern Arizona: A Geochemical Study of Projectile Points and Raw Material Sources

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This paper focuses on patterns of hunter-gatherer igneous (flaked) toolstone procurement on the Coconino Plateau of northern Arizona. The two-part study combined an X-ray fluorescence (XRF) source sampling survey with an XRF analysis of projectile points. Our focus is on the sources of archaeological obsidian and fine-grained volcanic (FGV) material in the San Francisco and Mount Floyd Volcanic Fields and a sample of Paleoindian and Archaic period igneous projectile points (n = 274) recovered from the area. We update the XRF data for the sources with additional analysis of the geologic source material. We also determine the geologic source for the majority of the points. In addition, this paper presents data on three previously undocumented sources of archaeological toolstone.

Este documento se centra en los patrones de cazadores-recolectores ígnea (escamas) de herramientas de piedra de adquisiciones en la meseta de Coconino del norte de Arizona. El estudio de dos partes combina una fluorescencia de rayos X (XRF) Encuesta de muestreo de la fuente con un análisis XRF de puntas de proyectil. Nuestra atención se centra en las fuentes de material arqueológico de obsidiana y de grano fino volcánica (FGV) en los campos volcánicos de San Francisco y el Monte Floyd y una muestra de puntas de proyectil periodo ígnea paleoindios y arcaicos (n = 274) extraídos de la zona. Actualizamos los datos XRF para las fuentes con un análisis adicional del material de origen geológico. También determinamos la fuente geológica para la mayoría de los puntos. Además, este trabajo presenta datos sobre tres fuentes previamente indocumentados de herramientas de piedra arqueológico.

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Introduction

More than forty years have passed since Robert Jack (1971) applied X-ray fluorescence (XRF) spectrometry techniques to archaeological obsidian in Arizona. In doing so, Jack introduced many Southwestern archaeologists to the high research potential of the geochemical method and to obsidian studies in general. Since then, numerous archaeologists and geologists, including Bush (1986), Cartledge (1985), Findlow (1981), Lesko (1989), Mitchell and Shackley (1995), Sanders (1981), Schreiber and Breed (1971), and most notably, Shackley (1988, 1990, 1995, 2005), have contributed to our understanding of this technique and more importantly, to the potential of XRF studies in Arizona. This paper builds upon these previous contributions with a particular emphasis on hunter-gatherers in northern Arizona.

XRF is a geochemical method often used to characterize igneous raw material sources and artifacts of volcanic origin based on the identification of trace element frequencies. This suite of trace element frequencies is commonly diagnostic of a particular source. When the sources of archaeological toolstone in a region are well documented geochemically, it allows archaeologists to match artifacts to sources and to consider distances and directions of toolstone transport across the landscape (Smith 2010:865).

This paper presents the results of a study (Roberts 2008) focused on patterns of igneous toolstone procurement in and around the San Francisco Peaks region within the Coconino Plateau of northern Arizona. The two-part study combined a geochemical source sampling survey with an analysis of projectile points. The first portion of the study consisted of augmenting the current comparative chemical signature library (source standards) for the region (Shackley 1988, 1995, 2005) by providing a more robust geologic sample. We conducted an obsidian and fine-grained volcanic (FGV) source survey designed to integrate with the analysis of 271 Archaic projectile points and three Paleoindian (Clovis) points (N=274) recovered as surface finds from the Coconino Plateau. Limited studies since Roberts' (2008) research have continued to expand our understanding of igneous toolstone in the area. One of us (Bryce) recently located an additional FGV source (Frenchy Hill), expanded the known geochemistry of Black Tank FGV, and submitted a previously known Clovis point (the Wupatki National Monument point [Downum 1993]) for XRF analysis.

Background

Because the current issue of this journal is dedicated to the application of archaeological sciences in Arizona, it is important to reflect upon the regional origins of one of the premier geochemical techniques used in Arizona archaeology today. Attempts at identifying and differentiating northern Arizona obsidian and fine-grained volcanic source materials date back nearly a century. H. H. Robinson, with the United States Geological Survey (USGS), conducted the first systematic survey of the San Francisco Volcanic Field (Robinson 1913). Nearly fifty years passed before researchers began synthesizing quantitative geological and archaeological data in the region. The first study, carried out by Schreiber (1967), aimed to locate, describe, and differentiate obsidian source localities in the San Francisco volcanic field for the purposes of archaeological research.

While Schreiber concentrated on macroscopic identification in the baseline study, a later collaboration with Breed (1971) initiated geochemical application in archaeology in the region. Following Schreiber's early efforts, Jack conducted the first widely accepted study employing geochemical (XRF) methods.

During the last thirty years, many archaeologists have pursued obsidian research and XRF studies, but none more so than Shackley (1986, 1988, 1990, 1995, 2003, 2005), who has conducted more research aimed at obsidian source information, procurement, use, and geochemistry in the Southwest than any other individual archaeologist. The past decades have also seen the development of new instrumentation and increasingly sophisticated techniques. The commonly destructive wavelength dispersive XRF (WXRF) gave way to the much more nondestructive, more user-friendly energy dispersive XRF (EDXRF) in the 1990s. Recently, archaeologists have begun experimenting with an emerging portable technology (PXRF) that is currently offering promising results as an expedient and inexpensive field alternative to the traditional laboratory techniques.

Geologic Setting

This study was conducted on the southern Coconino Plateau in the general vicinity of Flagstaff, Arizona. The plateau comprises 9,300 square miles bound on the north by the Grand Canyon and on the south by the Mogollon Rim and the Verde River drainage. On the west, the Coconino Plateau extends to the Aubrey Cliffs while the Little Colorado Drainage bounds the landform to the east. The Coconino Plateau makes up the southwestern-most portion of the Colorado Plateau, a geographic region covering roughly 130,000 square miles. Germane here is the occurrence across the Coconino Plateau of a series of Cenozoic basalt volcanic fields, including the San Francisco and Mount Floyd fields.

The Quaternary aged San Francisco Volcanic Field covers some 1,800 square miles and is "composed of numerous basaltic, intermediate, and silicic volcanic centers which are genetically related" (Bush 1986:15). Together with the Late Tertiary Mount Floyd Volcanic Field located to the west, volcanism was started by the intrusion of hot basaltic magma into the upper crust that migrated along major crustal fracture zones (Bush 1986). The eruptions began in the western part of the study area and migrated northeasterly over time (Bezy 2003:15). More than seven hundred individual volcanoes rise from the volcanic fields, although relatively few produce highly tractable, homogeneous material (referred to herein as toolstone) adequate for, and prehistorically demonstrably used in, flaked stone manufacture (referred to herein as artifact quality) (also see Woods 2011) (Figure 1). We now know the region contains at least fourteen sources of archaeological obsidian and FGV material (andesites, basalts, dacites, rhyodacites, and rhyolites).

Cultural Setting

The hunter-gatherer occupation of the Coconino Plateau spans approximately 9,600 years (circa 11,500 to 2400 B.P.). Hunter-gatherers occupied the region for the bulk

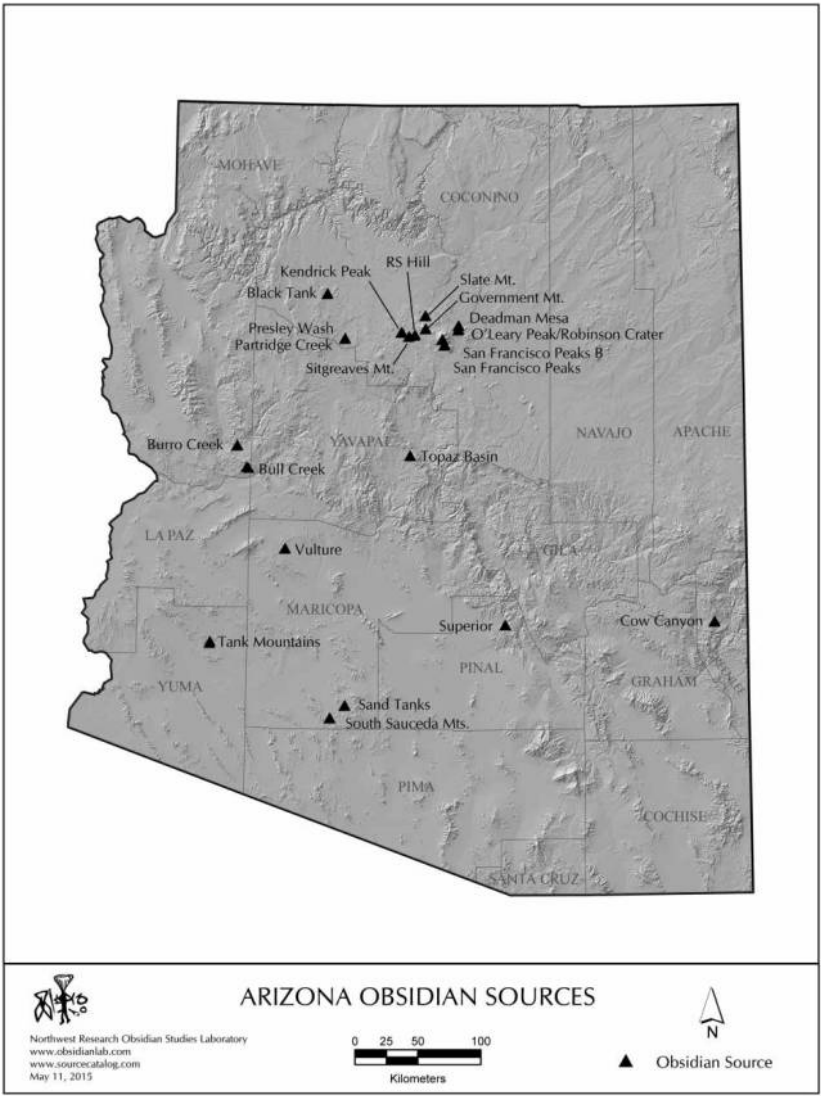

FIGURE 1.

of the cultural history yet much of their way of life remains poorly understood. The Paleoindian occupation of the Coconino Plateau is slight and evidence is generally limited to isolated surface points. Clovis (11,500–11,000 B.P.) groups were organized into small bands practicing extensive seasonal mobility (Kelly and Todd 1988; Mabry 1998). Many Paleoindian sites yield extralocal raw materials, and sometimes these materials are recovered several hundreds of miles from the geological outcrop (Amick 1996:413; Haynes 2002:117; Kelly and Todd 1988). Clovis groups are often believed to have subsisted on highly ranked food resources (i.e. megafauna) with little reliance on vegetal resources. However, recent research in other areas of the continent includes evidence of significant plant and small animal exploitation (Hill 2007; Kitchel 2008; Kuehn 1998) by Paleoindian populations. Such evidence has changed the way we view the Paleoindian Period.

The Paleoindian to Archaic transition on the plateau is best characterized by a decrease in mobility and increased reliance on vegetal resources and small animal exploitation. Mobility decreased as a result of "increased populations and diminution of territories" (Walthall 98: 234). As Jones et al. (2003:5) state, "changes in mobility appear to coincide with the changing climatic conditions and biotic reorganization during the early Holocene." The more diversified diet of Archaic groups in comparison to Paleoindian groups is frequently evidenced by the occurrence of manos and metates on Archaic sites. As Reid and Whittlesey (1997:43) assert, "Plant food gathering, so conspicuous in the seed-milling stones of the archaeological record, was the essential component of the Archaic economy." In all likelihood, both Paleoindian and Archaic period hunter-gatherers obtained toolstone through direct procurement and not via trade.

The Archaic Period in the Southwest spans several thousands of years. Various researchers have assigned an assortment of date ranges to the Archaic (Cordell 1997:153; Fish and Fish 1977:11; Matson 1991; Reid and Whittlesey 1997:42) It is indicative both of the ephemeral nature of Archaic material culture, varying field methods, and the continued inclusion and development of chronometric analyses that the disparity in dates is so large. For example, recent publications of chronometric research on Black Mesa in northeastern Arizona provide increased resolution to the dating problem on the plateau. Smiley (2002:30) designates 9000 B.P. as the beginning of the Early Archaic Period, while the Middle Archaic lies between 6000 B.P. and 4000 B.P. Lyndon (2005) built upon this to establish the chronology of the Coconino Plateau. The hunter-gatherer era commenced during the Paleoindian period (12,000–9000 B.P.) and continued throughout the Early Archaic (9000–6200 B.P.) and the Middle Archaic (6200–4600 B.P.) periods, and ceased at the end of the Late Archaic period (4600–2400 B.P.). In addition, the Late Archaic refers specifically to a lifeway and in fact overlaps the Early Agricultural period (4000–1500 B.P.) on the Coconino Plateau (Geib 2011). The Early Agricultural Period begins with the adoption of domesticates and a shift from hunting and gathering to an increase in diet breadth through food production (Matson 1991; Merrill et al. 2009; Smiley 1994, 2002). This paper does not include those projectile points associated with early agriculturalists. Early Agriculturalist points on the Colorado Plateau vary from side to corner notched (Bryce 2010). The most recognizable form is a deeply side-notched form diagnostic of Basketmaker II assemblages (Bryce 2010; Guernsey and Kidder 1921; Matson 1991; Morris and Burgh 1954). While some metrical overlap occurs between Basketmaker II and the well-known Elko forms of the Great Basin, these types differ in manufacture, blade form, notch form, and notch placement (Geib 1996, 2002). Furthermore, temporal schema relying on Elko forms is at best contentious resulting in these forms being admitted from the current study. In addition, the projectile point types used for this project do not show similarity to Early Agricultural projectile point types.

The southern Coconino Plateau projectile point typology developed by Lyndon (2005) contains 13 projectile point types pertinent to the current study. The sole Paleoindian type recovered from the plateau within this study is the Clovis point

(11,000–11,500 B.P.). Early Archaic Period (6200 B.P.–9000 B.P.), point types include Jay, Bajada, and Northern Side Notched. Gradually, these three types were replaced by three new types beginning around 6200 B.P. Middle Archaic (4600 B.P.–6200 B.P.) projectile points include the Pinto/San Jose, Sudden Side-Notched, and the Rocker Side Notched. Late Archaic (2400 B.P.–4600 B.P.) projectile points manufactured on the Coconino Plateau include the Armijo, Chiricahua, Elko-Eared, Gatecliff Split-Stemmed, Gypsum Cave, and San Rafael Side-Notched.

Methods

Although a variety of physical, optical, petrographic, and chemical attributes are used to characterize volcanic glasses, the use of trace element abundances to "fingerprint" obsidian sources and artifacts has shown the greatest overall success. X-ray fluorescence analytical methods, with their ability to nondestructively and accurately measure trace element concentrations in obsidian (and to a certain extent, FGVs), have been widely adopted for this purpose (Glascock et al. 1998; Harbottle 1982; Herz and Garrison 1998; Lambert 1998; Rapp 1985; Williams-Thorpe 1995). During XRF, the artifact or obsidian sample is irradiated with X-rays that elicit the emittance of fluorescent wavelengths characteristic of the trace elements present in the specimen. Thus, the wavelength of the fluorescent radiation provides a qualitative indication of specific elements present while the relative intensity of each wavelength provides the quantitative measure of each trace element (Shackley 2005). Hughes (1986:22) describes the benefits of XRF analysis over alternate techniques when he writes, "(1) it requires no special sample preparation (2) it is completely nondestructive (3) analyses of certain trace element concentrations can be completed in only a few minutes; and (4) data generated for significant trace elements are sufficiently precise to use in quantitative comparisons between laboratories."

Analysis of samples for titanium (Ti), manganese (Mn), zinc (Zn), gallium (Ga), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), iron ($Fe_2O_3^T$), and barium (Ba) concentrations 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. The principles of X-ray fluorescence analytical methods are reviewed in detail by Norrish and Chappell (1967), Potts and Webb (1992), and Williams (1987).

The diagnostic trace element values and ratios (these may typically include Ti, Mn, $Fe_2O_3^T$, Zn, Rb, Sr, Y, Zr, Nb, and Ba) used to characterize the samples were compared directly to those for known obsidian sources such as those reported in the literature and with unpublished trace element data collected through analysis of geologic source samples. Artifacts were correlated to a parent obsidian source or chemical source group if diagnostic trace element values fall within about two

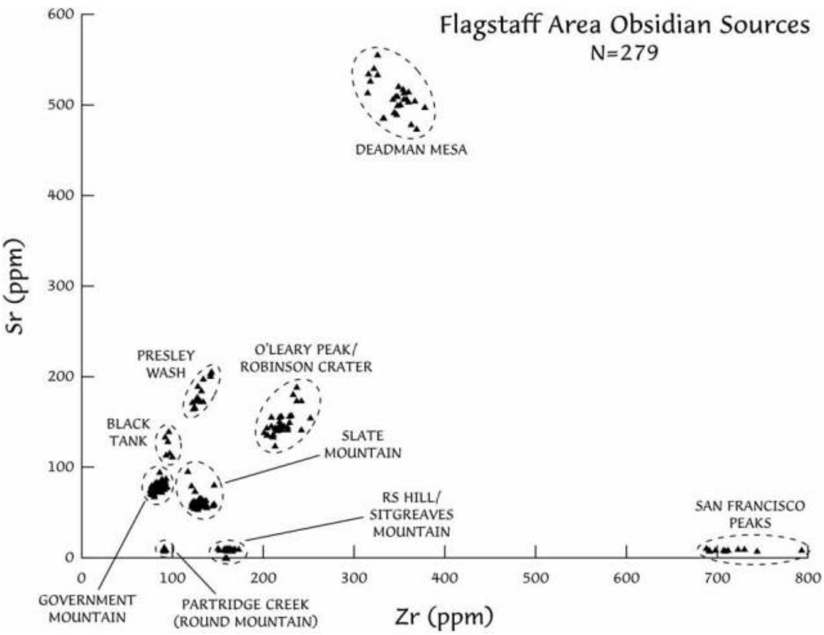

FIGURE 2.

standard deviations of the analytical uncertainty of the known upper and lower limits of chemical variability recorded for the source. Occasionally, visual attributes were used to corroborate the source assignments although sources were not assigned on the basis of megascopic characteristics alone. Diagnostic trace elements, as the term is used here, refer to trace element abundances that show low intrasource variation and uncertainty along with distinguishable intersource variability. In addition, this refers to elements measured by X-ray fluorescence analysis with high precision and low analytical uncertainty. In short, diagnostic elements are those that allow the clearest geochemical distinction between sources.

Results of the Source Survey

As Shackley (1995:532) pointed out, "the source standard data must be available to all interested archaeologists and archaeometrists and be presented in a form internally valid as well as reliable." During the source survey phase, we visited 13 discrete obsidian sources in order to draw a sample "sufficiently large and physically widespread to contain the full range of internal, or intra-source variation" (Jarvis 1988:3). A fourteenth FGV source (Frenchy Hill) was discovered subsequent to the initial survey phase. Additional survey near Black Tank provided samples that augmented the geochemical signature obtained during the source survey. This entailed gathering samples ranging between 6 and 61 individual specimens from each source. We sampled 14 sources, the 11 previously known sources and three previously undocumented sources: Deadman Mesa, Frenchy Hill, and San Francisco Peaks B. In sum, the sources sampled include Black Tank, Deadman Mesa, Frenchy Hill, Government Mountain, Kendrick Peak, Partridge Creek, Presley Wash, RS Hill, Sitgreaves Mountain, O'Leary Peak/Robinson Crater, San Francisco Peaks A, San Francisco Peaks B, and Slate Mountain (Figure 2). RS Hill and Sitgreaves Mountain sources, although separate lava domes, are geochemically identical and are "derived from the same magma" (Shackley 2005:32). Therefore, the two sources plot as one. In addition, geologic samples were collected from both O'Leary Peak and Robinson Crater (and areas between) and these are also geochemically undifferentiated. Shackley's source and material descriptions (1988, 1995, 2005) remain unchanged so herein we provide descriptive information only on the newly characterized sources and Black Tank, because of the minimal current description and expanding understanding of the source.

Black Tank

Black Tank refers to a location north of Mount Floyd and Round Mountain known locally as the source of a high quality, distinctive mahogany (brick red) and black obsidian. The source survey located four Black Tank varieties including one variety of obsidian and three FGVs within the tank and the wash feeding into the tank. The slightly subvitreous obsidian is black and brick red in color, exhibiting a smooth texture and waxy luster. The aphyric material is translucent when very thin. The second variety is a dark gray, medium grainy textured FGV. The opaque material appears basaltic and displays slightly uneven fracture properties. The third variety is rhyolitic and gray or greenish gray with smooth texture and waxy luster. The subvitreous material lacks phenocrysts and fractures conchoidally. The fourth variety is flow-banded, displaying inter-bedded black and gray basalts megascopically similar to Presley Wash FGV.

After the sourcing survey Roberts noted that the Black Tank area deserved additional attention to determine the extent of the Black Tank material geochemistry. Parallel to Roberts' work, Bryce's visits to the area focused on the mesa top to the west. FGV cobbles pave the mesa top and include the four varieties geochemically sourced by Roberts during the survey as well as a fifth variety. This fifth variety was previously unidentified and labeled as "Unknown FGV A."

Deadman Mesa

Deadman Mesa protrudes as a large fan-shaped mesa extending from the north slope of O'Leary Peak. The mesa stretches approximately 3 kilometers to the northeast of the summit of O'Leary Peak and rises roughly 300 meters from the surrounding terrace. FGV occurs along the northern extent either as bedrock outcrops or eroded nodules at elevations ranging from 1,900 to 2,200 meters. The material was encountered primarily along the slope and around the flanks of the northwest side of the mesa. Visually, two varieties occur. The first, a poor-quality granular basalt exhibits brick red flow banding within a dark gray matrix. The second variety is dark gray to black and exhibits a medium grainy texture. This FGV variety exhibits predictable fracture properties, making the material quite suitable for biface manufacture. Both varieties of Deadman Mesa are not vitreous and generally lack inclusions. The cortex is brown and highly textured. Deadman Mesa material resembles the lower quality FGV material at Presley Wash. The two visually distinct types exhibit the same geochemical signature.

Frenchy Hill

The source is an unnamed Upper Tertiary volcanic cone immediately northeast of Frenchy Hill and west of Sitgreaves Mountain. The material occurs in the form of cobbles on the south and west faces of the hill. Ponderosa Pine grows throughout the talus and colluvial fill defining the ground surface. We encountered the material approximately half way up the hill, between 2,173 and 2,195 meters, eroding out of the talus on the south and west faces, as well as within road cuts. The survey and collection locations suggest a spatially discrete distribution. The presence of cobbles eroding out of the colluvium and the substantial amount of colluvial deposition suggests a larger spatial distribution, however, we did not locate the primary source. Quite similar megascopically to O'Leary Peak, moderate to heavy amount of phenocrysts, both singular and clustered, interrupts the predictable fracture and renders Frenchy Hill FVG a low-quality toolstone. The material exhibits various hues of gray and may exhibit a dark purplish tint. Similar to the Spring Valley Group obsidians to the east, Frenchy Hill FVG is opaque with edges displaying translucency.

San Francisco Peaks B

This source can be found in the form of cobbles on all faces of Mount Agassiz surrounding the summit, including directly opposite the Inner Basin flow on the southern slope. The immediate area encompassing the obsidian source is a barren boulder field consisting of talus and discontinuous Bristlecone Pine (*Pinus aristata*). The Peaks B material occurs throughout the Shultz Creek drainage system, including the numerous intermittent drainages feeding the creek. We encountered the obsidian as low as, 2,134 meters, a vertical distance in excess of 1,280 meters below the primary outcrop. San Francisco Peaks B is low-quality and contains abundant phenocrysts. The material is very dark gray to black but also grades into a deep brown. The material is generally opaque although freshly broken edges are translucent. Peaks B material also displays numerous inclusions of ash, greatly affecting its workability.

Our characterizations of previously documented sources are generally consistent with those in the literature. Due to the larger sample size, however, the trace element ranges for certain sources are greater than previously known. The new geologic source survey also provided increased resolution to intrasource variability. For example, our XRF analysis showed two sources (Presley Wash and Black Tank) produced obsidian and a fine-grained volcanic material (FGV). In addition, it was determined that two distinct sources occur within the San Francisco Peaks, one of which was previously known (San Francisco Peaks A) as a low quality source located on the northwest slope of Fremont Peak. Our sample of Kendrick Peak (n = 35) exhibits a mean strontium (Sr) value of 62, while the sample (n = 10) published by Shackley (1995) exhibits a mean Sr value of 10.99. Therefore, the Kendrick Peak and Slate Mountain sources cluster tightly based on Sr and Zirconium (Zr) alone (Figure 2) indicating the two sources are geochemically disparate. In addition, the Tertiary cone Frenchy Hill (this paper) is megascopically very similar to the Quaternary

TABLE 1.

MEAN AND CENTRAL TENDENCY DATA FOR THE NORTHERN ARIZONA OBSIDIAN AND FGV SOURCES. THE THREE NEWLY DISCOVERED SOURCES ARE PROVIDED FIRST.

Trace Element	Mean	S.D.	Minimum	Maximum	N
Deadman Mesa FGV					
Rb	47	2.5469	44	54	27
Sr	508	19.2686	474	556	27
Y	29	1.7079	25	32	27
Zr	344	15.6636	315	369	27
Nb	39	2.2522	34	43	27
Ba	1271	44.5182	1149	1346	27
Frenchy Hill FGV					
Rb	59	3.4008	53	68	20
Sr	207	10.1180	190	223	20
Y	10	1.4171	7	12	20
Zr	101	4.0509	92	109	20
Nb	48	1.6730	45	50	20
Ba	934	24.0301	880	974	20
San Francisco Peaks B Obsidian					
Rb	32	3.5212	22	37	21
Sr	786	99.6506	677	1114	21
Y	26	2.8006	20	33	21
Zr	228	24.6962	161	263	21
Nb	36	4.5281	22	43	21
Ba	961	40.4099	870	1038	21
San Francisco Peaks A Obsidian					
Rb	140	6.865023	133	155	12
Sr	9	1.061208	8	11	12
Y	80	3.732613	73	85	12
Zr	716	29.26303	691	793	12
Nb	139	6.268541	127	150	12
Ba	2	3.498068	0	12	12
Government Mountain Obsidian					
Rb	103	8.4937	90	141	61
Sr	78	4.838649	68	95	61
Y	19	1.364284	17	23	61
Zr	84	5.309573	76	94	61
Nb	47	2.305686	43	52	61
Ba	387	117.4217	261	568	61

Continued

TABLE 1.

CONTINUED

Trace Element	Mean	S.D.	Minimum	Maximum	N
Black Tank Obsidian					
Rb	117	7.5456	102	128	9
Sr	130	14.0365	112	150	9
Y	19	1.6155	18	22	9
Zr	96	2.8267	92	100	9
Nb	26	1.5617	24	30	9
Ba	769	45.8615	702	851	9
Black Tank FGV					
Rb	105	5.6617	93	119	46
Sr	183	17.6231	154	217	46
Y	21	1.6851	18	27	46
Zr	103	4.4087	94	115	46
Nb	28	1.9776	23	32	46
Ba	735	41.3257	663	806	46
Kendrick Peak Obsidian					
Rb	106	5.655155	95	117	36
Sr	62	8.044457	55	96	36
Y	21	1.66358	18	25	36
Zr	129	7.158358	121	146	36
Nb	39	1.95931	35	44	36
Ba	598	24.55808	529	650	36
O'Leary Peak/Robinson Crater Obsidian					
Rb	69	3.8641	59	78	53
Sr	150	13.3747	124	189	53
Y	31	1.5152	27	34	53
Zr	222	11.4296	201	252	53
Nb	47	2.0635	42	51	53
Ba	1360	43.1773	1275	1461	53
RS Hill/Sitgreaves Mountain Obsidian					
Rb	401	16.05946	373	440	33
Sr	9	0.937115	8	11	33
Y	86	2.469975	79	91	33
Zr	163	5.613303	152	174	33
Nb	244	6.713633	231	260	33
Ba	4	7.197599	0	26	33
Partridge Creek Obsidian					

Continued

TABLE 1.

CONTINUED

Trace Element	Mean	S.D.	Minimum	Maximum	N
Rb	243	13.09339	223	262	6
Sr	10	1.625516	8	12	6
Y	39	1.287551	38	42	6
Zr	91	1.640385	91	94	6
Nb	50	2.394055	47	54	6
Ba	7	7.382164	0	18	6
Presley Wash Obsidian					
Rb	83	4.528857	73	92	16
Sr	181	13.87451	165	206	16
Y	14	1.902415	10	17	16
Zr	131	6.802447	122	143	16
Nb	19	1.2848	17	21	16
Ba	1141	50.1507	1027	1216	16
Presley Wash FGV					
Rb	74	5.293112	64	83	15
Sr	233	14.03561	214	254	15
Y	16	2.347397	13	24	15
Zr	137	7.015628	128	147	15
Nb	19	1.934872	15	23	15
Ba	1047	44.08138	983	1117	15
Slate Mountain Obsidian					
Rb	106	4.6035	96	117	67
Sr	60	3.1663	54	74	67
Y	21	1.4899	18	25	67
Zr	129	5.8156	121	146	67
Nb	38	1.9170	34	44	67
Ba	606	27.1724	529	657	67

O'Leary Peak/Robinson Crater material and in fact exhibits a similar Sr mean. However, these sources differ geochemically in Zr (102 ppm vs. 233 ppm). The elemental data for most of these sources have been published by Shackley (1988, 1995, 2005) so the current treatment serves as an update based on additional geological source analysis.

Results of the Artifact Analysis

After completing the source survey, we analyzed a sample of projectile points (n = 274) recovered as surface finds from the Coconino Plateau in the general area of Flagstaff

TABLE 2.
OBSIDIAN AND FGV SOURCE FREQUENCIES BY PERIOD.

Obsidian or FGV source	Paleoindian	Early Archaic	Middle Archaic	Late Archaic
Black Tank*	2	5	6	10
Deadman Mesa	0	0	1	0
Government Mountain	1	10	48	59
O'Leary Peak/Robinson Crater	0	0	1	0
RS Hill/Sitgreaves Mountain	0	2	2	9
Partridge Creek	0	2	9	27
Presley Wash	0	8	19	30
San Francisco Peaks B	0	0	1	1
Unknown FGV	0	2	7	1
Unknown Obsidian 1	0	0	3	1
Unknown Obsidian 2	0	0	1	0
Unknown Obsidian 3	0	0	0	1
Unknown Obsidian 4	0	0	1	0
Total	**3**	**33**	**99**	**139**

*Including previously classified Unknown FGV A

and Williams, Arizona. The sample includes every igneous projectile point dating to the Archaic (155) within the collections of the Kaibab National Forest. In addition, the sample contains every Archaic igneous projectile point (116) from a large private collection, all recovered from the Coconino and Kaibab National Forests and areas immediately adjacent to Flagstaff. Finally, the sample contains a single Clovis point from Wupatki National Monument collections and two Clovis points from the Kaibab National Forest collections. All were subjected to the same XRF analysis as were the source samples. Subsequently, the artifact characterizations were compared to the chemical signatures of sampled sources. Therefore, within the research area, both the chemical signatures of available raw material were determined and the artifacts found within the region have known points of origin.

Of the 14 analyzed obsidian sources included in the study, 10 were detected in the sample. These include Black Tank, Deadman Mesa, Government Mountain, O'Leary Peak/Robinson Crater, Partridge Creek, Presley Wash, RS Hill/Sitgreaves Mountain, and San Francisco Peaks B. The sources not detected in the study include Frenchy Hill, Kendrick Peak, San Francisco Peaks A, and Slate Mountain.

Two of the sources, Deadman Mesa and San Francisco Peaks B were detected for the first time in the archaeological record. Of the detected sources, five comprise 88 percent of the points recovered throughout the 9,600 years of hunter-gatherer occupation. The overwhelming majority of pre-ceramic projectile points recovered from northern Arizona contexts were manufactured from Government Mountain (43%), Presley Wash (21%), and Partridge Creek (14%) obsidian sources. In addition, Black Tank (11%) and RS Hill/Sitgreaves (9%) obsidian sources are also well represented (Table 2).

TABLE 3.
OBSIDIAN AND FGV SOURCE FREQUENCIES BY PROJECTILE POINT TYPE

		Paleoindian	*Early Archaic*				*Middle Archaic*				*Late Archaic*		
Obsidian or FGV source	Clovis (n = 3)	Jay (n = 3)	Bajada (n = 25)	Northern Side-Notched (n = 5)	Pinto/San Jose (n = 84)	Sudden Side-Notched (n = 10)	Rocker Side-Notched (n = 5)	Gatecliff Split-Stemmed (n = 5)	San Rafael Side-Notched (n = 3)	Gypsum Cave (n = 73)	Elko-Eared (n = 32)	Armijo (n = 17)	Chiricahua (n = 9)
Black Tank*	2	1	8	1	6	0	0	0	1	7	1	1	0
Deadman Mesa	0	0	0	0	1	0	0	0	0	0	0	0	0
Government Mountain	1	1	7	2	42	3	3	1	1	26	15	9	7
O'Leary Peak/Robinson Crater	0	0	0	0	1	0	0	0	0	0	0	0	0
RS Hill/Sitgreaves Mountain	0	0	1	0	1	1	0	0	0	3	2	2	2
Partridge Creek	0	0	1	1	8	1	0	3	0	14	5	5	0
Presley Wash	0	0	7	1	15	3	1	0	1	20	9	0	0
San Francisco Peaks B	0	0	0	0	1	0	0	0	0	1	0	0	0
Unknown FGV	0	1	1	0	5	1	1	0	0	1	0	0	0
Unknown Obsidian 1	0	0	0	0	2	1	0	1	0	0	0	0	0
Unknown Obsidian 2	0	0	0	0	1	0	0	0	0	0	0	0	0
Unknown Obsidian 3	0	0	0	0	0	0	0	0	0	1	0	0	0
Unknown Obsidian 4	0	0	0	0	1	0	0	0	0	0	0	0	0

*including previously classified Unknown FGV A

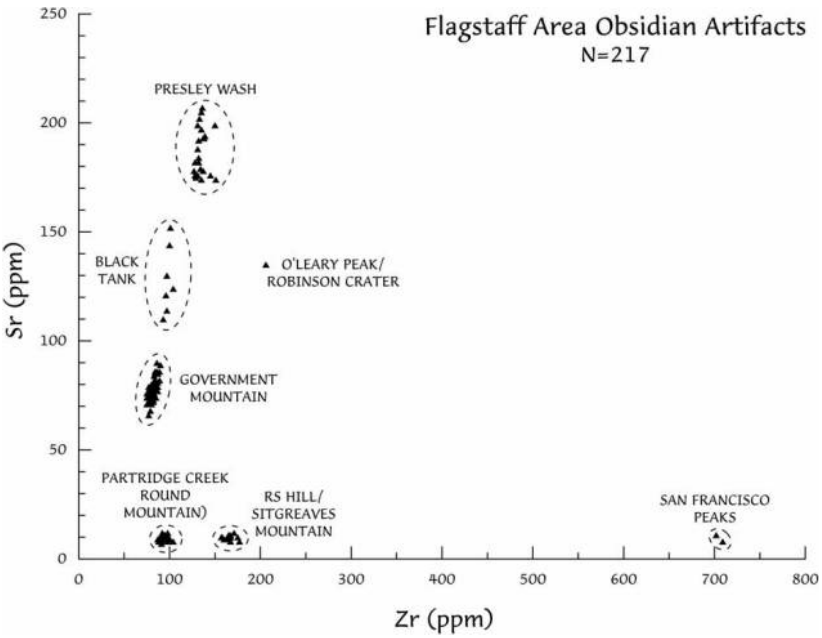

FIGURE 3

In addition to the 10 utilized sources noted, data reveal the presence of six previously unknown geochemical signatures. Thirty points from the current sample exhibited chemical signatures indicative of these six signatures. We have temporarily named the unknowns included in this study Unknown FGV A (n = 12), Unknown FGV (n = 10), Unknown Obsidian 1 (n = 4), Unknown Obsidian 2 (n = 1), Unknown Obsidian 3 (n=1), and Unknown Obsidian 4 (n = 1). None of these chemical signatures have been published and the geologic sources remain undiscovered. As of this paper, Unknown FGV A is now known to be a variety of Black Tank FGV, narrowing the point count of unknown material from 30 to 18 and increasing the frequency of points manufactured from locally available materials. Presumably, the unknown obsidians come from distant or virtually unused sources due to their paucity in the current sample. Conversely, the relatively intensive use of the unknown FGVs indicates these sources may be of local, as yet undetected, origin. Unfortunately, lacking geological source material, it remains unclear whether the five unknown signatures represent five undocumented sources or whether the signatures fall within the variability of fewer discrete sources.

The projectile point data reveals a general trend towards increased specialization over time. The five most frequently detected sources (Government Mountain, Presley Wash, Partridge Creek, Black Tank, and RS Hill/Sitgreaves Mountain) comprise 79 percent of the sample during the Early Archaic, increase to 82 percent during the Middle Archaic, and further increase to 94 percent of the sample during the Late Archaic period. Of course, the Paleoindian sample (n = 3) includes only Government Mountain and Black Tank (100 percent of the sample) so the small sample size cannot suggest either trend aberration or conformation. The overwhelming reliance on Government Mountain obsidian throughout prehistory has been documented numerous times (Brown 1981; Jack 1971; Slaughter et al. 1992:31). Our sample is also dominated by Government Mountain obsidian (n=118) and the material represents the only toolstone detected in all time periods and all point types.

Conclusions

Our sample of 274 hunter-gatherer projectile points represents a miniscule proportion of stone tools manufactured over the course of 9,600 years. However, the sample is thus far the most comprehensive landscape-scale assemblage yet analyzed using XRF on the Coconino Plateau. The results of the XRF analysis suggest localized and highly patterned hunter-gatherer toolstone procurement behavior. The sample of projectile points indicates an overwhelming reliance on local sources (~93%). This percentage may in fact increase if the unknown signatures are attributed to local sources, such as the current identification of Unknown FGV A as a Black Tank variety. Based on these data, hunter-gatherers began preferentially exploiting local sources from colonization during the Pleistocene and continued doing so until the terminus of the Late Archaic during the Holocene.

In this paper, we have provided an initial report of three previously unknown sources (Deadman Mesa, Frenchy Hill, and San Francisco Peaks B), report the presence of Black Tank FGV as well as obsidian, considerably different geochemistry for Kendrick Peak obsidian, and the detection of six unknown trace element signatures. The discovery of previously unknown sources within our sample illustrates the need for additional work on the Coconino Plateau. In addition, we present the geochemical characterizations of three Clovis points from the Coconino Plateau. Forty years after Jack's (1971) study, we continue to hone XRF techniques, develop new instrumentation, augment our signature standards, and find new sources.

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