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The Little Springs Volcanology and Archaeology Project, Grand Canyon-Parashant National Monument, Arizona

Investigators Final Report, Western National Parks Association Grant #03-09

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THE LITTLE SPRINGS VOLCANOLOGY AND ARCHAEOLOGY PROJECT, GRAND CANYON-PARASHANT NATIONAL MONUMENT, ARIZONA

The Little Springs Volcanology and Archaeology project, located in Grand Canyon-Parashant National Monument north of the Grand Canyon, was designed to provide information on both the nature of the Little Springs Volcano eruption and on the resulting prehistoric adaptation to this catastrophic event. This multidisciplinary study represents some of the first research specifically on Little Springs, largely because it was not until 2001, with the dating of the eruption to sometime within the past 1,800 years (Fenton et al. 2001), that the significance of this event to Southwest prehistory became known. A grant from Western National Parks Association (No. 03-09) to archaeologist Mark Elson and volcanologists Michael Ort and Wendell Duffield supported this research, as did in-kind funding from Northern Arizona University and Desert Archaeology, Inc. A longer version of this report, with descriptions and maps of recorded prehistoric sites and a more complete treatment of the geological research, can be found in Elson and Ort (2006).

INTRODUCTION

Sunset Crater Volcano, located in northern Arizona 25 km north of Flagstaff, is the best-known volcano in the southwestern United States (Figure 1). Research over the past 70 years suggests that Sunset Crater erupted for several weeks to perhaps a few years sometime between A.D. 1050 and 1125, spewing ash, cinders, and lava over an area of around 2,300 km^2, clearly impacting nearby prehistoric populations (Amos 1986; Colton 1932a, 1960; Elson and Ort 2003; Ort et al. 2002). Adaptive responses included population movement and alterations in trade, manufacturing, and settlement and subsistence systems (Colton 1946; Downum and Sullivan 1990; Elson et al. 2002, 2006; Pilles 1979).

Until very recently, Sunset Crater was believed to be the only eruption that occurred during the prehistoric ceramic-period occupation of the American Southwest. However, in 2001, University of Utah geologist Cassandra Fenton published the first dates for the Little Springs lava flow located approximately 25 km north of the Grand Canyon, just south of Mount Trumbull (see Figure 1). Using cosmogenic helium techniques, Fenton et al. (2001:1036) dated lava from the flow to 1300 ± 500 years before present (ca. A.D. 200-1200), placing it within the realm of human occupation.

The significance of this eruption became even more apparent late in 2001 when BLM archaeologist John Herron noted five sherds embedded in lava in the collections from a small pueblo habitation site (AZ A:12:74 [MNA/BLM]), located approximately 0.9 km east of the Little Springs flow. Several of the sherds were decorated and appeared to be of the type Hurricane Black-on-gray, which, while not well dated, has an approximate range between A.D. 1025 and 1200. These are the only sherds encased in lava known from the American Southwest, and to our knowledge, in all of North America.

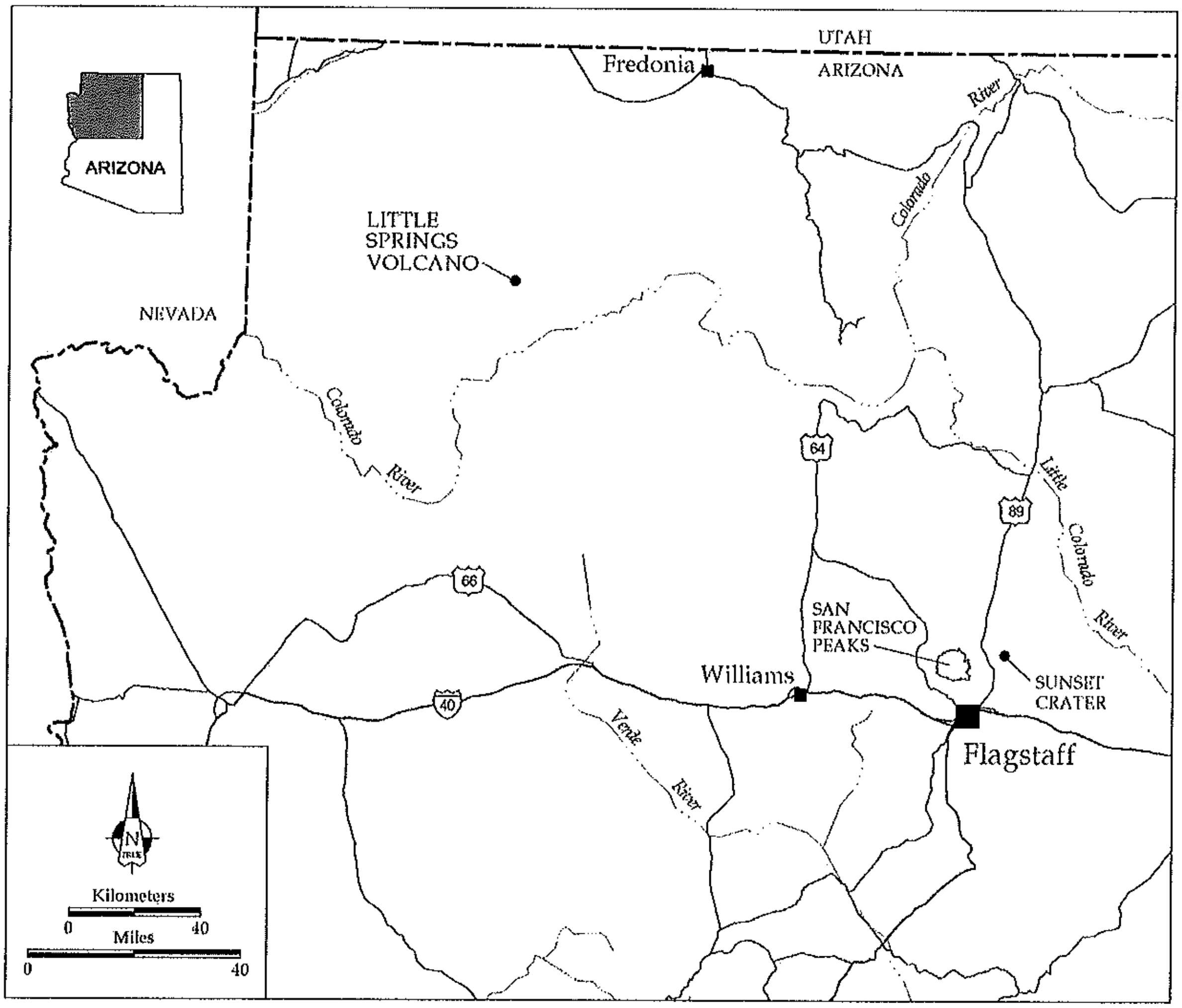

Figure 1. Overview of northern Arizona showing Little Springs Volcano project area and Sunset Crater Volcano.

ENVIRONMENTAL SETTING

Little Springs Volcano is situated in the Arizona Strip area north of the Grand Canyon at an elevation between 6,200 and 6,600 ft (1,890-2,012 m) above sea level. Vegetation within this area consists primarily of pinyon, juniper, Gambel oak, and sage, along with a few scattered ponderosa pine, mountain mahogany, and manzanita. The presence of relatively large flat areas covered by sage, particularly northeast of the Little Springs lava flow, suggests good groundwater retention (Moffitt and Chang 1978:195), which would likely have made these areas suitable for agriculture. Permanent springs are found on the slopes of Mt. Trumbull and Mt. Logan, where a basalt layer overlies Moenkopi sandstone. Within the lava-covered area, prehistoric remains and trails are associated with a spring and an ice cave/seep on the northern tip of the northern lava flow, both of which may have been used on a regular basis. Climate data from nearby weather stations suggests that temperature and precipitation were sufficient for agriculture in the Little Springs area (WRCC 2005), and that crops could have been raised during average years without supplemental water, with bumper crops possible during unusually wet years (see Elson and Ort 2006).

GEOLOGICAL RESEARCH

Little Springs Volcano was initially mapped as part of a larger project recording the Uinkaret volcanic field (Billingsley and Hamblin 2001). The Uinkaret volcanic field contains 213 identified volcanoes, ranging in age from 3.6 Ma to Recent, in an area that stretches from the Grand Canyon north to near the Utah/Arizona line and from the Hurricane Fault on the west to the Toroweap Fault and Toroweap Valley on the east. The youngest eruption in the field is the Little Springs Volcano, but a number of other volcanoes are less than 250,000 years old (Billingsley and Hamblin 2001; Fenton et al. 2001).

Little Springs Volcano is marked by a spatter rampart about 100 m high on the east side of a vent area (Figure 2). The vent area consists of small (1-5 m high) spatter ramparts and lava flows, with one prominent 10-m-high spatter mound to the southwest. No central cone is present today, although one may have existed at times during the eruption. Such a cone was probably never very large, as there is no significant fallout deposit from this eruption. This suggests any fountaining was low in height.

The eruption produced two main lava flow fields, one to the north (about 1.8 km^2) and the other to the south (about 2.4 km^2) of the vent. Including the vent area, a total of 4.8 km^2 was covered by volcanic deposits. The lava flows rafted away portions of the pyroclastic cones that existed around the vent during the eruption. The lava flow surfaces are morphologically quite young and rough, with little weathering. Most of the flow surfaces have little or no soil development, but some portions on the western edge of the northern lobe have developed significant amounts of vegetation and soil. This is probably due to finer grained breccia on the surface there, so that eolian dust may have filled the holes and started soil development. Chemical analysis indicates the Little Springs lava is a dark-gray to black alkali olivine basalt (see Elson and Ort 2006:Tables 1 and 2). The rock is finely porphyritic to glassy, with abundant olivine crystals.

Paleomagnetic Dating

Dating of the Little Springs Volcano is of great significance because of a desire to understand eruption risks in the area, but also to put the eruption into a temporal context for archaeological reconstruction. Cosmogenic helium (He) dates by Fenton et al. (2001) indicated that the eruption occurred about 1300 ± 500 years before present, or between A.D. 200 and 1200. The ceramics found in the lava further suggest an age of around A.D. 1025-1200 for the eruption. However, both of these dating methods contain relatively large error bars. In an attempt to better constrain both the absolute age and the age relative to Sunset Crater Volcano near Flagstaff, we undertook a detailed paleomagnetic study of the volcano.

At Little Springs, we sampled eleven sites on the lava flows for paleomagnetic analyses (see Elson and Ort 2006:Table 3). Unfortunately, the virtual geomagnetic pole (VGP) from the Little Springs lava does not plot on the secular variation curve for any time in the past 2000 years (Figure 3). It is near the curve at 2380 and 7870 ybp (380 B.C. and 5870 B.C.). Neither of these dates are likely based upon the cosmogenic He and prehistoric ceramic dates, but this paleomagnetic direction and VGP are nearly identical to those determined by Duane Champion in a reconnaissance study in the 1970s (D. Champion, written communication 2003) and appears

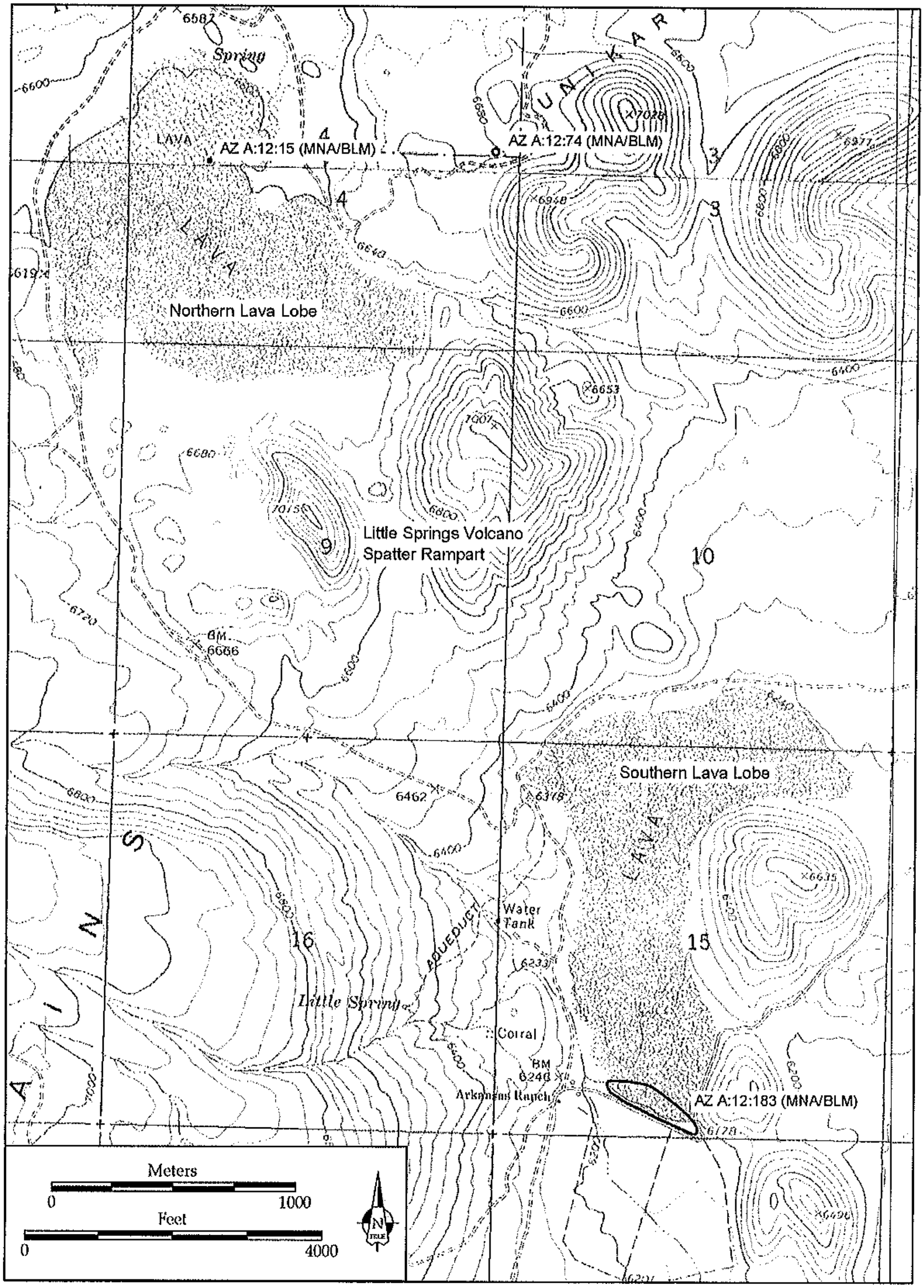

Figure 2. Little Springs Volcano spatter rampart, lava flows, and previously recorded archaeological sites. (USGS 7.5-minute quads Mt. Trumbull NW and Mount Logan, Mohave County, Arizona).

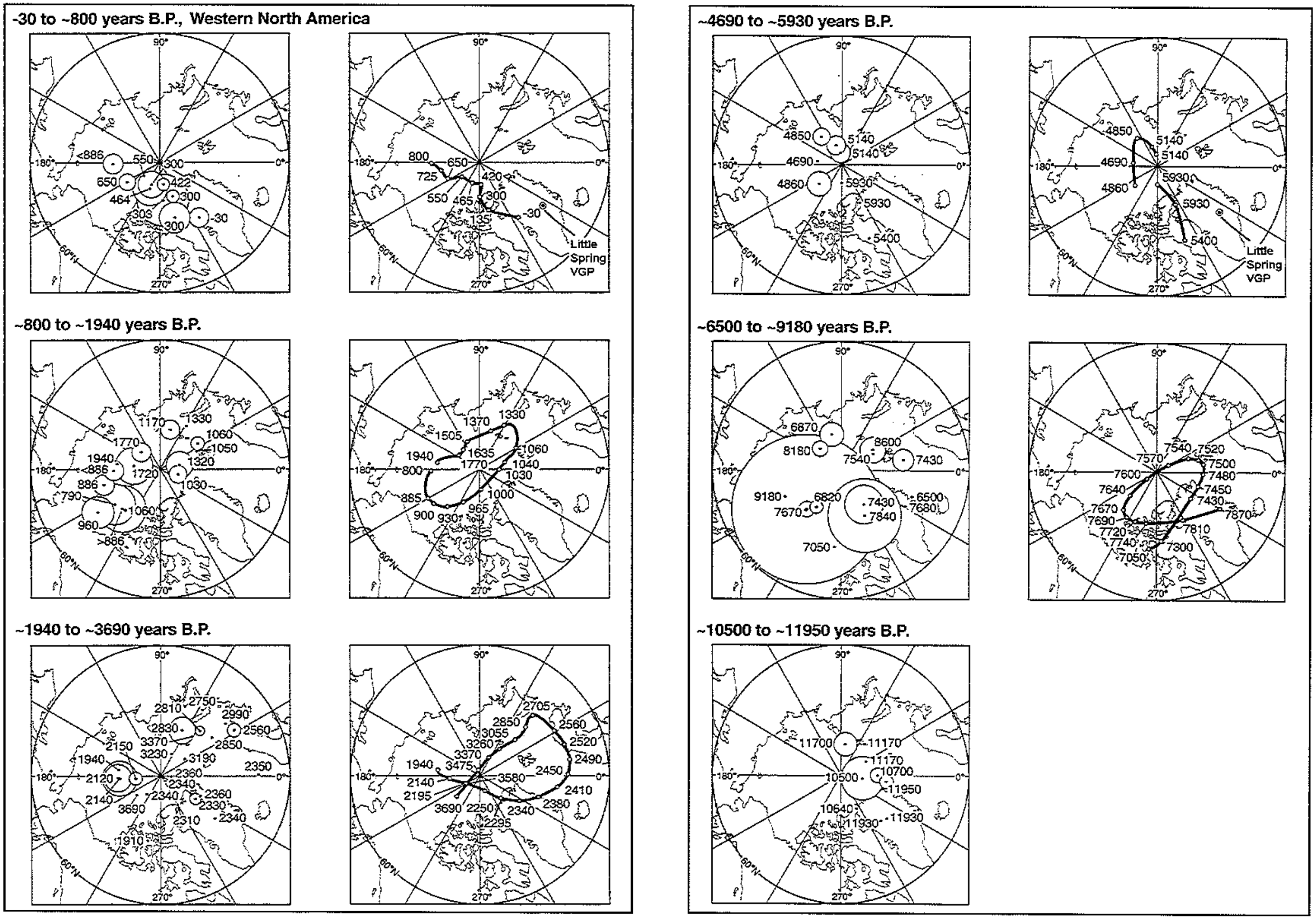

Figure 3. Virtual geomagnetic pole (VGP) positions with A_{95} confidence limits for Little Springs paleomagnetic samples. Ages are in calendar years before present (bp).

to accurately represent the rock. The aberrant direction could be due to unusual magnetic properties of the rock itself, or to a local magnetic anomaly, but further research is needed to resolve this problem.

Description of Lava with Embedded Sherds ("Sherd-Rocks")

Several spatter agglutinate samples with embedded sherds were found at the Lightning site (AZ A:12:74 [MNA/BLM]) situated approximately 0.9 km east of the Little Springs lava flow. Some of these rocks consist of highly vesicular lava that was clearly very fluid at the time it contacted the sherds, coating them with a shiny lava. The largest piece, about 20 cm in length, was welded cinder lapilli (2-8 mm in diameter) and larger vesicular fusiform (fluidal) clasts 20 cm in diameter. The cinders appear to be welded due to the heat from contact with the large fusiform clasts. In all cases, the rocks are particulate or clastic in nature, meaning they are made of chunks of hot rock rather than simply continuous lava. This suggests the rocks were created near a place where clasts were thrown into the air and could then land and weld together. We suggest that these "sherd rocks" formed in a manner similar to that described by Elson et al. (2002) for pieces of Sunset Crater lava embedded with prehistoric corn cobs recovered from a site 4 km removed from the Sunset lava flows. That is, the prehistoric inhabitants of the Lightning site placed whole ceramic pots or broken sherds at an *hornito* (spatter cone) or at a small lava vent, where spatter then covered the offering. Later, the "sherd rocks" were collected and brought to the Lightning site where they were incorporated into the wall of a structure.

ARCHAEOLOGICAL RESEARCH

The archaeological portion of this project consisted of a pedestrian survey around the southern lobe of the Little Springs lava flow and the intensive recording and mapping of the Lightning site (AZ A:12:74) where the sherds embedded in lava were found (Figures 4 and 5).

The archaeological survey focused on the southern lava lobe and covered it as intensively as possible in the four days allotted for survey. Most of the area around the east, south, and west edges of the southern lobe was surveyed (see Figure 4). The eastern half of the northern edge was also intensively examined and several sites recorded. In the western half of the northern edge, sites and features were observed but not fully explored or recorded, due primarily to time constraints. The northern lobe of the Little Springs lava flow was spot checked in a few places and a previously recorded site (AZ A:12:15 [MNA/BLM]) was visited (see Figure 2), but this was the only work undertaken in this area.

The survey recorded 15 new sites and collected additional information on two previously recorded sites (see Figure 4; see Elson and Ort 2006). In accordance with BLM policy, all newly recorded sites were given Arizona State Museum (ASM) site numbers to facilitate data entry into AZSITE. In addition, seven isolated finds (IFs) and 10 trails were recorded, although these were not given site numbers. All of the newly recorded sites and previously recorded site AZ A:12:183 (MNA/BLM) are situated on or at the base of the southern Little Springs lava lobe.

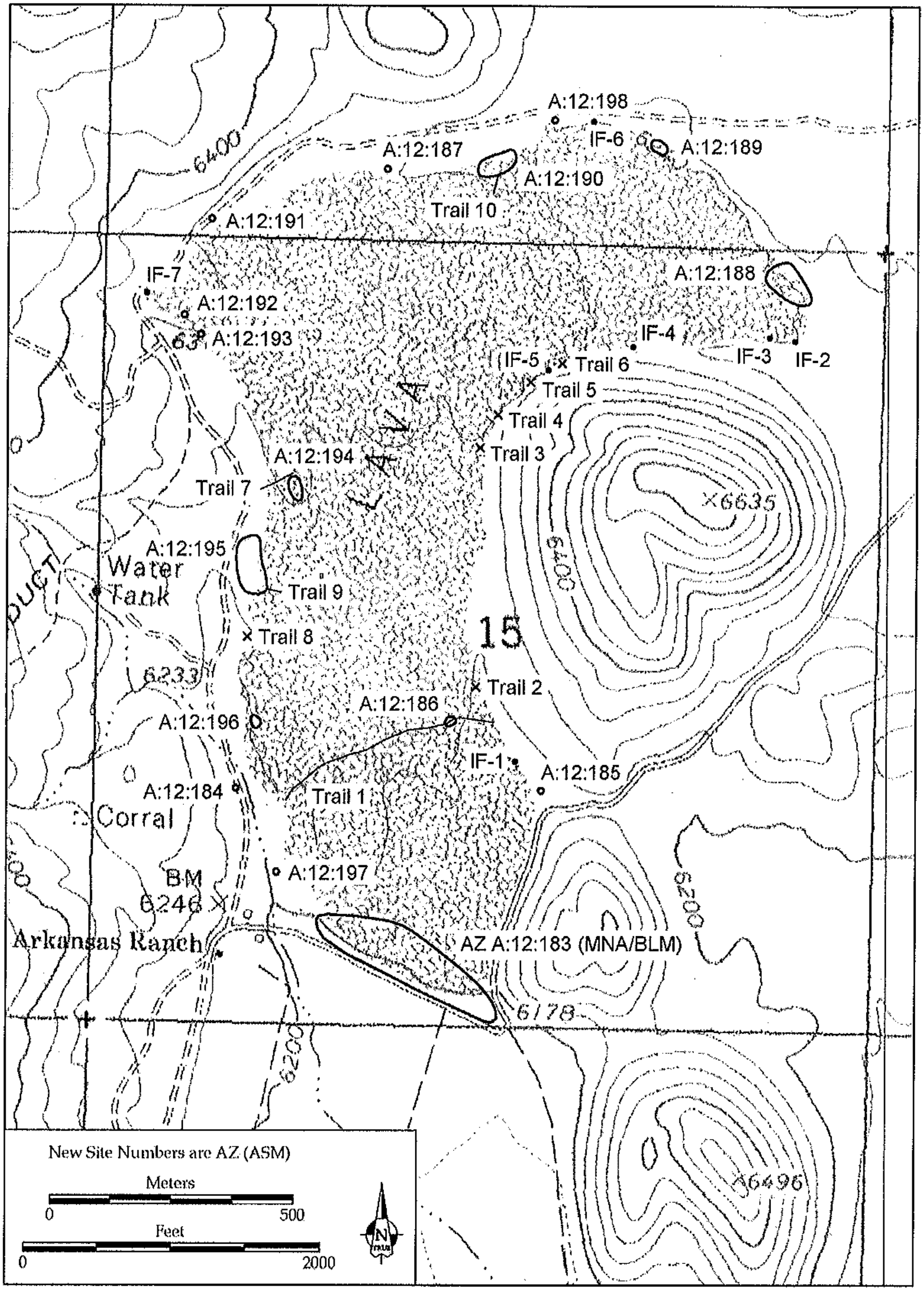

Figure 4. Sites recorded on the Little Springs archaeological survey.

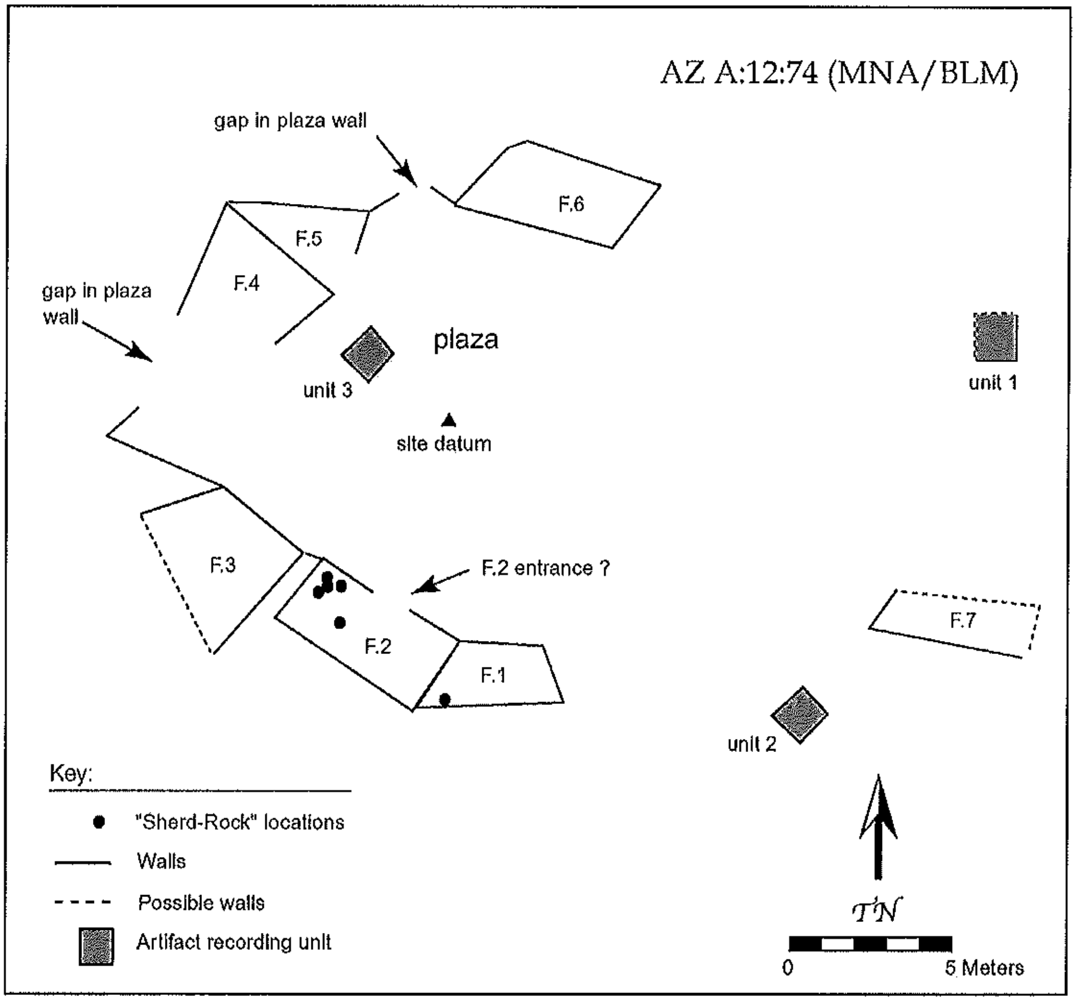

Figure 5. The Lightning site (AZ A:12:74 [MNA/BLM]).

DISCUSSION

Absolute dating of the Little Springs lava flow through analysis of paleomagnetic samples failed to provide interpretable dates for the eruption. Although the paleomagnetic analysis yielded well-constrained site and overall means, the plots of the samples do not lie on the available paleomagnetic secular variation curves during the likely period of the eruption (younger than 2000 ybp). Therefore, the archaeological ceramic data still provide the tightest dating and suggest an eruption date for the Little Springs Volcano sometime between A.D. 1025 and 1200. These dates make the Little Springs eruption roughly contemporaneous with the eruption of Sunset Crater, and it is possible that two volcanoes, located less than 200 km (125 mi) apart, erupted at the same time or within the lifespans of individual people. This occurrence would almost certainly have had profound significance to the prehistoric inhabitants of not only the immediate area, but of the greater Southwest.

The archaeological research further suggests that the area impacted by the Little Springs eruption was inhabited by small groups of prehistoric settlers. Data from Moffitt and Chang

(1978:190-191) along with our recording of a possible preceramic site (AZ A:12:184), suggest that the Mt. Trumbull area may have been sporadically occupied for several thousand years from the Archaic through PIII periods. Artifact densities at sites in the area are uniformly low, with a general lack of ground stone tools, suggesting the possibility that the occupations were only seasonal.

The response to the eruption by Little Springs inhabitants was distinct from that at the better-studied Sunset Crater (see Elson and Ort 2003, 2006; Elson et al. 2006). Because Little Springs had little cinder deposition, only the 4.8 km^2 area directly beneath the spatter rampart and lava flows had to be abandoned. At Sunset Crater, lava and deep cinder and ash deposits (greater than 30 cm) covered over 400 km^2, almost certainly causing abandonment of a large area. Although archaeological investigations in the Little Springs area are limited, data from pedestrian survey indicate a moderate site density (Moffitt and Chang 1978:199) and, extrapolating from this data, it is possible that as many as 35 prehistoric habitation sites were covered by the lava flow. Although prehistoric demography is a difficult endeavor, if each habitation site contained 1-2 households, with each household containing 5-6 people, then around 300 people (+/- 50%) may have been displaced by the eruption. This is significantly fewer than the 1,800 people estimated to have been impacted by Sunset Crater, clearly showing the differences in magnitude between the two eruptions.

Unlike Sunset Crater, where the thick cinder deposit made living anywhere near the lava flow untenable, occupation at Little Springs continued on and near arable land right up to the flow edge. Masonry structures, built out of lava blocks, were constructed abutting the lava face at the base of the flow and on top of the flow itself. Our preliminary archaeological survey of just the southern lava lobe recorded 16 sites containing a total of around 150 structures on the flow top and 48 structures at the base (see Elson and Ort 2006). The largest sites contained structures on both the flow top and at the base; for example, AZ A:12:183 had over 45 structures on top of the lava, with another 10 or so structures at the base. While structures around the base of the flow had associated low-density artifact scatters, only a small number of artifacts were found with the structures on top of the flow, suggesting they were not long-term habitations and may have been used largely for defensive purposes.

The defensive nature of the top of the flow is further supported by the intricate and extensive network of trails that trend both north-south and east-west across the lava (see Figure 4). The trails were constructed by using small lava blocks to fill in holes and smooth the rough surfaces, which remain very difficult to traverse without trails today. Many of the trails are still smooth enough to run on. The building of these trails suggests a concern with rapid movement, which might be necessary in defensive situations. The trails could not be seen from the base of the flow and all had relatively rough, and somewhat hidden, ground level access: someone who knew the lava flow and the trails and fortifications would have a tremendous advantage over any invader. The utility of lava flows as defensive retreats is amply demonstrated by the Modoc Indian War in the early 1870s, where the U.S. Army estimated they would need 1,000 troops to defeat the 100-200 Modoc hiding in the lava beds along the shores of Tule Lake in northern California (Beck and Hasse 2004).

Six prehistoric ceramic sherds embedded in Little Springs lava spatter agglutinate were recovered from the Lightning site (AZ A:12:74), a small 7-room masonry pueblo situated about

0.9 km east of the northern lobe of the lava flow (see Figures 2 and 5). Diagnostic artifacts and the site architecture suggest the site dates between ca. A.D. 1075-1150 (Altschul and Fairley 1989; Elson and Ort 2006:Table 7). The lava-embedded sherds, which represent at least two different ceramic types, were found clustered on the surface of the site, most within a single room (Feature 2), and may represent pieces of the collapsed room walls. The largest piece of spatter is approximately 25 cm by 25 cm by 10 cm, requiring a moderate amount of determination on the part of the carrier to bring it to the site from the place of origin. As suggested above, we believe that sherds, or possibly whole vessels, were placed on the spatter rampart of an *hornito* (spatter cone). Spatter then covered the ceramics, which were later retrieved and carried at least 0.9 km to the habitation site, where they were possibly placed in the walls of the structures. The reasons for this behavior are unknown, but the effort required to make and transport the "sherd-rocks" suggest they were more than just a curiosity or volcano souvenir. Because the site has not been excavated, it is quite possible that other sherd-embedded pieces remain subsurface that could provide more information on their origin.

The eruption of two volcanoes at about the same time and situated only 200 km apart may have had great significance to the inhabitants of the northern Southwest. Digital elevational modeling indicates the Sunset Crater ash plume (and maybe the fire fountain) was clearly visible from the Little Springs area and much of the American Southwest (Elson et al. 2006). Although Little Springs did not disperse much ash, and its plume was probably low and not visible much beyond the immediate area, it is likely that the occurrence of this event was rapidly communicated throughout the Southwest. The prehistoric behavioral response to these events is not yet understood, although throughout the Southwest the eleventh and early twelfth centuries A.D. were troubled times, attested to by the demise or retraction of two dominant cultural systems: Chaco Canyon in northern New Mexico and the Hohokam of central and southern Arizona. Whether the eruptions of Little Springs and Sunset Crater volcanoes played a role in these events remains to be seen.

In conclusion, volcanic eruptions are almost always incorporated into local traditional histories, and ritual behavior on the part of affected groups should be expected (Kirch 1985; Nolan 1979; Plunket and Uruñuela 1998a, 1998b; Sigurdsson 1999). Eruptions are commonly seen as signs of spiritual transgressions and offerings are made in an attempt to rectify these "sins" and avert the ongoing destruction (Scarth 1999). Hopi accounts of the Sunset Crater eruption, for example, cite various offenses, including gambling, immoral behavior, and the cuckolding of a katsina (Colton 1932b; Ferguson and Loma'omvaya 2006; Malotki and Lomatuway'ma 1987). Perhaps most important for understanding prehistoric (and modern) eruptions, studies of catastrophic events have shown that religious or cultural mechanisms for coping with a natural disaster, such as a volcanic eruption, can be highly adaptive, enabling affected individuals and groups to more readily accept the event and begin the recovery process (Nolan 1979:331). Although we do not yet have modern or ethnohistoric accounts of the Little Springs eruption, it is considered part of the sacred landscape of Southern Paiute groups, who see the lava flows as "evidence that the mountains are alive and contain puha [sacred power or energy], and that these locations have to be treated with the highest level of respect" (Stoffle et al. 2004:114).

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