Using 3D Laser Scanning Technology to Document the Sand Cliff Signatures Site Historic Inscriptions, Iron County, Utah

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This article reports the results from the Sand Cliff Signatures Public Archaeology project conducted by USU Archeological Services. Here we employed terrestrial LiDAR scanning technology to document what remains of the historic inscriptions left by participants of the 1849–1850 southern expedition of Parley P. Pratt in Fremont Canyon, Iron County, Utah. By using LiDAR we were able to produce a high resolution digital surface model of the historic inscriptions. The model preserves the spatial context of the panels and allowed us to isolate historic names and dates related to the 1849 expedition from subsequent inscriptions. This project highlights the benefits of using LiDAR and photogrammetry in documenting historic sites and provides a summary of our results.

INTRODUCTION

Rock art researchers employ a variety of methods to document and depict pictographs and petroglyphs, ranging from the traditional hand-drawn sketches accompanied by written descriptions to three-dimensional digital models aided by high resolution photogrammetry and topographic laser scanning. Three-dimensional digital documentation, particularly laser scanning technology, offers clear advantages over more traditional approaches such as photo journals, rubbings, tracings, or castings. Comparatively quick and inexpensive, laser scanning methods generate high resolution, quantifiable, objective, and replicable data sets with negligible impacts to the physical integrity of rock art panels (Haynes and McCarthy 2006; Trinks et al. 2005).

Slowly, archaeologists and, notably, cultural resource managers are adopting these new technologies to document, monitor, and interpret rock art sites (Eklund and Fowles 2003; Haines and McCarthy 2006; Hurst et al. 2009; Simpson et al. 2004; Trinks et al. 2005). For example, Gonzalez-Anguilera et al. (2009) employed non-invasive three-dimensional survey methods to build integral and multi-scalar models of Paleolithic Caves in Northern Spain. The digital models incorporated natural (chambers, walls, and tunnels) and cultural features (rock art panels) that produced high resolution photo realistic virtual animations. This newly rendered three-dimensional perspective facilitated new research into artistic element placement, use of space, and other anthropological research issues (Gonzalez-Aguilera et al. 2009).

Not only can LiDAR (light detection and ranging) data generate new methods of interpretation and visualization; those data can be used to monitor impacts to rock art. Barnett et al. (2005) and Vogt and Edsall (2010) employed scanning LiDAR data converted for use in geographic information systems (GIS) software packages to locate types and extent of various weathering processes on rock art panels. In both cases, the researchers identified a host of weathering types including fissures, disintegration, salt leaching, lichen growth, and even paintball residue (Barnett et al. 2005; Vogt and Edsall 2010). These research projects indicated that spatially-referenced, high-

Figure 1. Overview of the Sand Cliff Signatures Site with terrestrial LiDAR equipment.

resolution LiDAR data taken over a period of time can be used to identify sub-millimeter scale levels of surface material loss or accumulation on surfaces.

In 2011, USU Archeological Services (USUAS) conducted the Sand Cliff Public Archaeology Project. Here we employed terrestrial LiDAR scanning technology to document what remains of the historic inscriptions left by participants of the 1849–1850 southern expedition of Parley P. Pratt in Fremont Canyon, Iron County, Utah (Figure 1). However many of the inscriptions left by Pratt's expedition are illegible due to erosion and more recent superimposed graffiti (Peart et al. 2012). Recording the panels with LiDAR produced digital, high-density topographic surfaces with point spacing of less than 1 mm. Overlain with projected and draped high-resolution digital images we created three-dimensional depictions of the inscription panels. High resolution documentation allowed us to isolate historic names and dates related to the 1849 expedition from subsequent inscriptions. This project highlights the benefits of using LiDAR and photogrammetry in documenting historic sites and provides a summary of our results.

SOUTHERN EXPEDITION OF PARLEY P. PRATT (1849–1850)

The following historical summary of the Southern Expedition of Parley P. Pratt (1849–1850) borrows from the more detailed historical accounts provided by Smart and Smart (1999a) and Fish (1992). Following colonization of the Salt Lake Valley by the Mormon Pioneer Company in 1847, it became apparent to Brigham Young that with several tens of thousands of converts on their way to the territory, he needed a comprehensive colonization program. Identifying new settlement locations, discovering economic resources, and spreading out the population to alleviate resource strain within the Salt Lake Valley became key operating principles of Young's strategy (Fish 1992).

At the November 1849 meeting of the Legislative Assembly of the Provisional Government of the State of Deseret, Young requested that Parley P. Pratt lead an expedition to explore the region to the south of Salt Lake City (Fish 1992). Following Young's command, the committee commissioned Pratt to lead the expedition. Pratt (1964:365) wrote in his autobiography:

> I now received a commission from the Governor and Legislative Assembly of the State of Deseret to raise fifty men, with the necessary teams and outfit, and go at their head on an exploring tour to the southward . . . This company was soon raised, armed and equipped and ready for a march into the dreary and almost unknown regions of southern Utah.

Events transpired rather quickly. By 22 November, Pratt had gathered most of the necessary supplies, equipment, and the majority of the company at the home of John Brown near Salt Lake City (Smart and Smart 1999b). Among the provisions and equipment, Pratt (1964:366) lists

> 12 wagons; 1 carriage; 24 yokes of cattle; 7 beeves; number of horses and mules, 38; average in flour, 150 lbs to each man; besides crackers, bread and meal. One brass field piece; firearms; ammunition in proportions.

As was customary for Mormon groups at the time they organized in a company of fifty men, with five groups of ten, each with their own captain (Pratt 1964). The assembled group voted Pratt as president of the company with William W. Phelps and David Fulmer as his counselors. The company also voted John Brown as Captain of the Fifty, William W. Phelps as Topographical Engineer and Ephraim Green as Chief Gunner (Pratt 1964). Table 1 contains the names of the men in the party when they departed the Salt Lake Valley.

On the morning of 24 November 1849, the party headed south from Brown's home (Brown 1941). Hampered by winter storms and deep snows, the company passed Fort Utah, present-day Provo, and camped at Hobble Creek. Over the next week the company travelled on established wagon roads into Juab Valley and then to the newly established settlement at Sanpitch by 3 December 1849. Before departing the settlement, on 5 December, the company added two wagons and five men: Madison D. Hamilton, Gordon G. Potter, Sylvester Hewlit, Edward Everet and John Lowry (Brown 1941).

For the next two weeks, the party endured sub-zero temperatures and nearly continuous winter storms as they traveled along the Sevier River to present-day Marysville. From here, the party continued south to Circleville Valley. Robert Campbell wrote, "The valley terminated in an impassable canyon, and abrupt chain of mountains sweeping before and on each hand, and the river rushing like a torrent between perpendicular rocks" (Fish 1992:72). The company remained in the valley while scouts searched for a pass over the mountains to the west connecting to the Little Salt Lake Valley. Arriving at camp after a day of scouting, Captain John Brown and Robert Campbell reported finding "a route very difficult, but not impassable, winding over a succession of canyons with steep ascents and descents, nearly perpendicular in places, with rocks and cobblestones all the way" (Fish 1992:80). The group decided to take this route over the mountains in the hope that they would find passage to the Little Salt Lake Valley. This route proved to be very arduous as historian Rick J. Fish (1992:81–82) explained:

> The company descended and ascended these steep rocky passes, while much of the way, shoveling snow as high as 4–6 foot in order to make the trail. Occasionally they dismounted their horses and stamped a double track where the animals and wagons would follow. In some places twenty men would use axes, spades and picks to open up narrow gaps in the trail.

On 20 December, Pratt and Brown rode into camp after finding a pass leading into the Little Salt Lake Valley. Although they named the pass, Brown's Pass, after its discoverer John Brown, the area is now known as Fremont Pass and Fremont Canyon after John C. Frémont who famously explored the area a few years later. While passing through Fremont Canyon on 21 December 1849, several members of the party inscribed their names on a rock face they named "Cornish Rock" now known as the Sand Cliff Signatures site (42IN418). John C. Armstrong (Armstrong 1848–1849, emphasis added) wrote in his journal:

> After passing through the canyon . . . the rocks at some sides very much like theramparts of some ancient Baronial castle such as was used in feudal times . . . there was a range of stupendous rocks, one was named Cornish rock on account of its resemblance to a cornice work done by stone mason and cut to put over doors. *I cut my name on the face of these rocks, and many more had I the time*.

John C. Armstrong's deeply incised name remains the most prominent at the site. Smart and Smart (1999a) identified inscriptions made by Henry Heath and possibly Homer Duncan, William Wadsworth, Christopher Williams, John Holladay, and John and William Matthews at the Sand Cliffs Signature Site. Local ranchers claim other historic signatures, including those made by John C. Frémont and his party, were formerly visible at the site (Peart et al. 2012).

Continuing west through Fremont Canyon, the party reached Red Creek, present-day Paragonah, on 23 December. Here they decided to split up. Pratt led a group on horseback to explore the Virgin River region, while the remaining balance of the company continued to explore the Parowan and Cedar Valleys. The party reassembled near Parowan and started back towards Salt Lake City on 10 January 1850. They made it as far north as present-day Fillmore where the combined effects of bitterly cold temperatures, deep snows, and limited feed for their animals made it impossible for the oxen and wagons to continue.

Again, they decided to split up. Pratt and about half of the men departed north on horseback while the others remained with the wagons. Pratt's mounted group made it to about 50 miles south of Fort Utah before exhaustion, lack of food, and inclement weather halted the party. Pratt and Chauncey West took the strongest horses and headed north to Fort Utah. The returning rescue party helped the mounted group return to Salt Lake by the end of January 1850. The wagon party remained snow-bound for the next seven weeks but eventually made it to Salt Lake City by the end of March (Smart and Smart 1999a).

In total, the group traversed about 536 miles, with an additional 190 miles travelled by the group that explored the Virgin River region on horseback (Smart and Smart 1999a; Figure 2). The official report produced by the party listed 26 places south of the Salt Lake Valley desirable for settlement (Pratt 1964; Smart and Smart 1999a). Within 15 years, Brigham Young sent settlers to all of these locations including Payson (Peteeneet Creek), Juab Valley (Yohab), Nephi, Salina, Richfield, areas near St. George, Parowan, Cedar City, Fillmore, Harmony, and Santa Clara (Smart and Smart 1999a, 1999b).

3D LASER SCANNING METHODS

LiDAR documentation for the project employed a Leica ScanStation2 terrestrial laser scanner (TLS or ground-based LiDAR) to capture high-density, topographic data points on the outcrop surfaces that contain the historic inscriptions. The Leica ScanStation2 equipment employs a high-speed, pulse laser (scan rate up to 50k points per second) integrated with a high-resolution digital camera. The equipment delivers survey-grade, locational point data with single positions accurate to 6 mm and distance measurements to 4 mm (one sigma accuracy at 50 m). We established five instrument setup locations (101–105) to minimize the effect of shadowing from different perspectives while

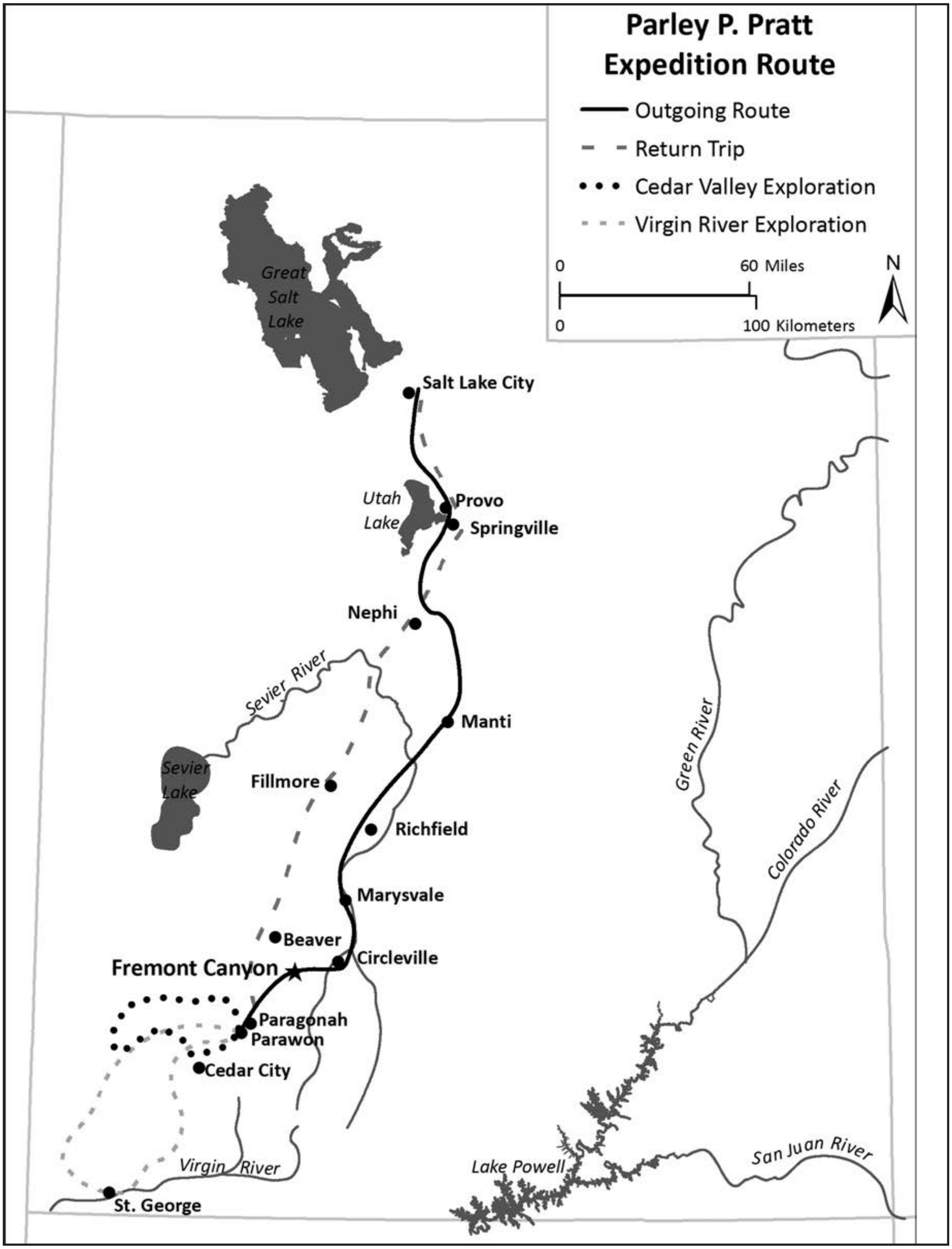

Figure 2. Overview map showing the route of the southern expedition of Parley P. Pratt (1849-1850). Adapted from Smart and Smart (1999:x).

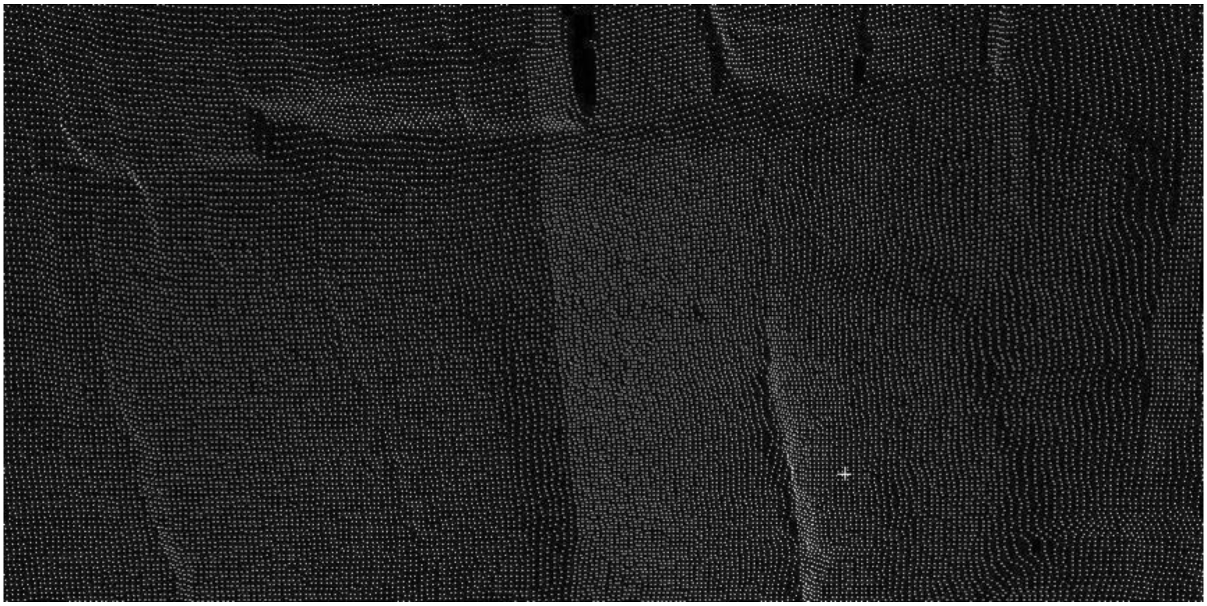

Figure 3. Raw LiDAR point cloud data generated from the main signature panel, reduced point sample for visual effect.

maintaining point spacing of 1 mm or less within the core area of inscriptions (one million points per square meter). Collected raw LiDAR data was downloaded and post-processed with Cyclone Scan and Leica TruView software suites. The LiDAR documentation of the panels generated well over 20 million X, Y, Z and intensity value individual data points (Figure 3). The documented area measures about 12 m long by 3 m tall with a core area about 4.5 m in length.

We also produced written descriptions and photographed the core area of inscriptions using a series of digital cameras equipped with a range of lenses and from multiple angles. With Cyclone Scan software, mosaicked high-resolution digital images were draped over the LiDAR point cloud data which produced three-dimensional virtual walk-through animations of the entire documented outcrop in QuickTime user navigable file formats (Figure 4). LiDAR and digital photographic documentation of the site produced a high-resolution record that preserves the spatial context of the rock surface with an inventory of discernible historic inscriptions.

PROJECT RESULTS AND DISCUSSION

By implementing LiDAR scanning and digital photography we were able to accomplish two primary project goals. Our first goal was to create a quantifiable and replicable digital model of the historic signature panels that inventories all inscriptions and preserves their spatial context. The second goal was to use this digital model to explore data manipulation (e.g., geospatial statistics, map algebra, spatial filtering) and visualization techniques to indentify inscriptions and possibly rock art not readily apparent to the unaided eye.

To accomplish our first goal, we mosaicked orthorectified digital photographs to produce a panoramic image of the entire rock surface (Figure 5). We digitized all visually recognizable inscriptions on the panoramic image using Adobe Illustrator and cross-checked the results with our field descriptions of the panels and existing site documentation (Figure 6). Of the 1849 party members, we were only able to visually identify John C. Armstrong's and the barely decipherable Henry Heath's inscriptions. The

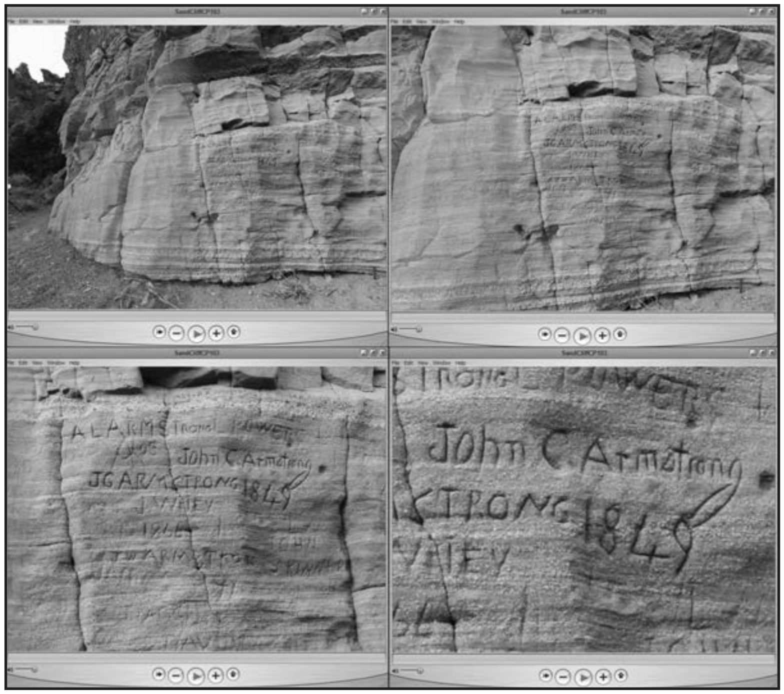

Figure 4. Selection of screen shots generated from QuickTime walk-through animation.

Figure 5. Panoramic image of the Sand Cliff Signatures main historic inscription panel, produced from mosaicked digital photographs.

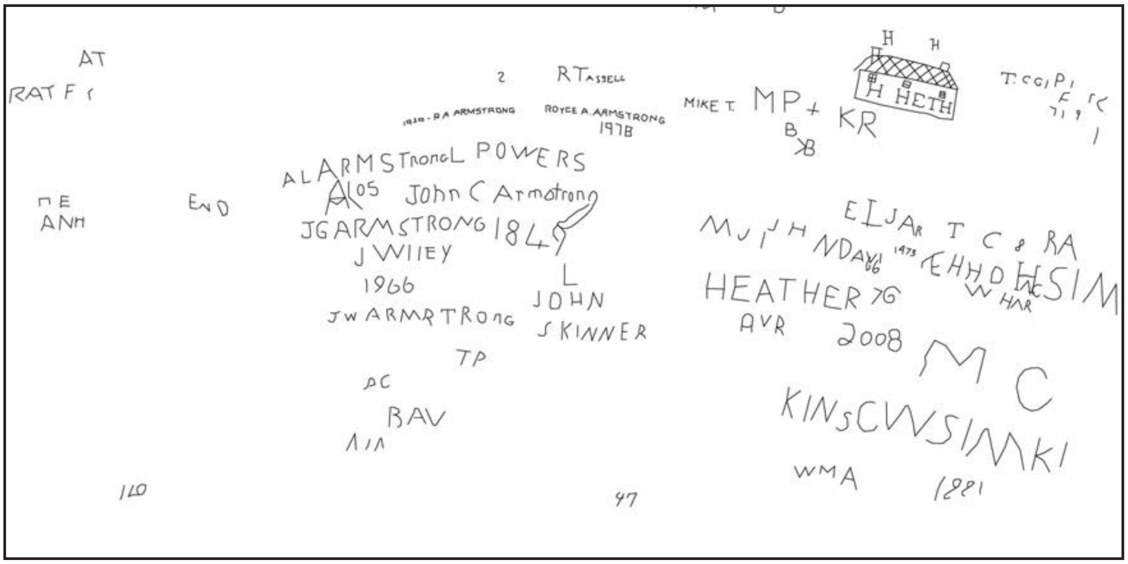

Figure 6. Overview sketch depicting visually identified inscriptions at the Sand Cliff Signatures Site.

other inscriptions tentatively identified by Smart and Smart (1999a) were not identified probably due to erosion and superimposed graffiti.

John C. Armstrong's name remains the most prominent inscription at the site and is encircled with several of his descendants' engravings (Figure 7). These include his son, John G. Armstrong, to the left; two of his sons, Arthur Leroy (L.A.) Armstrong and John W. Armstrong; and John G. Armstrong's wife, Mary Ann Jane Simkins's brothers, Hezekiah Simkins and Charles Simkins Jr. More recently, another descendent, Royce A. Armstrong appears to have visited Sand Cliff twice, once in 1959 and again in 1978, leaving his signature both times. Evidently, the Sand Cliff Signatures Site remains an important traditional landmark for the descendants of John C. Armstrong. The prominence of John C. Armstrong's inscription may indicate the signature is periodically maintained by his descendants.

To fulfill the second project goal, topographic point data were exported from selected areas of the panels as comma-delineated files compatible with ArcGIS software. We converted the raw point data using ArcGIS Versions 9.3.1 and 10.1 into ESRI shapefiles and with ArcGIS Spatial Analyst toolkit generated two-dimensional raster datasets. Raster data represents a matrix of identically-sized square cells where each cell stands for a spatial location and stores a value (e.g., elevation or intensity). Our field methods generated data with sub-millimeter point density allowing us to produce high resolution rasters with about 1 mm cell dimensions. Due to the irregular shape of the outcrop surface, inevitably some grid cells remained unsampled due to shadowing. We used the ArcGIS Spatial Analyst raster interpolation function, in this case Natural Neighbor, to estimate the values of these unsampled cells thereby filling in the gaps and producing continuous raster representations of selected areas of the rock surface containing the historic inscriptions.

We tested a host of different visualization strategies and geostatistical surface manipulation techniques (e.g., interpolation, map algebra, spatial filtering) primarily available within the ArcGIS Spatial Analyst suite of functions to investigate which methods generated the best results. We consulted previously–conducted, LiDAR-based studies of rock art inscriptions (Eklund and Fowles 2003; Haines and McCarthy 2006; Hurst et al. 2009; Simpson et al. 2004; Trinks et al. 2005) and tested a number of techniques including surface derivatives (e.g., slope and aspect),

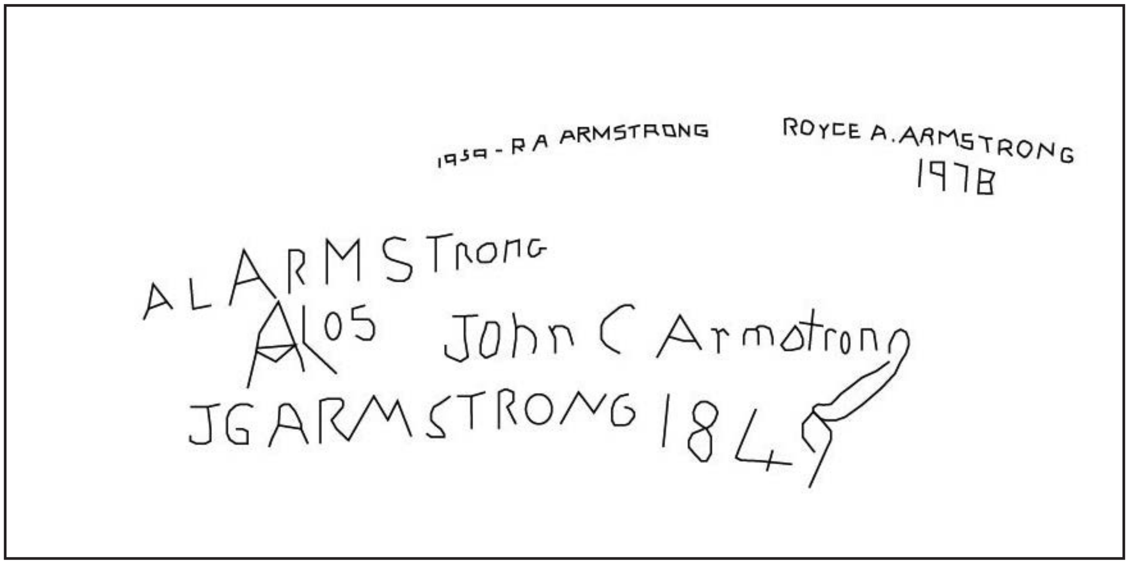

Figure 7. Close-up sketch of John C Armstrong's inscription surrounded by those of his descendants.

spatial filtering (e.g., high and low pass filtering, Krigging), triangulated irregular network (TIN) surfaces, and a series of map algebra techniques to highlight local topographic variability (e.g., logarithmic and exponential map algebra). Through trial and error, we discovered that two techniques, high-pass filtering (also called edge detection) and hillshade visualization generated the most useful results considering our dataset and research goals.

Hillshade uses an artificial light source to illuminate a raster and generates the appearance of a three-dimensional topographic surface due to the combined effects of light and shadow. By adjusting two parameters, light source altitude and azimuth angle, different topographic features (e.g., inscriptions) can be visually enhanced. For this project we employed the hillshade function within ArcGIS Spatial Analyst in an attempt to identify traces of faint historic inscriptions not readily apparent to the naked eye. Unfortunately, the irregular rock surface of the outcrop proved too coarse-grained for the discrimination between cultural and natural surface features based on any of the visualization techniques tried (e.g., hillshade, graduated/ramped raster symbology) or simple surface derivatives (e.g., slope, aspect). Even so, hillshade raster provides a simple visualization technique that produces the aesthetic illusion of three-dimensions and is shown to effectively highlight identified historic inscriptions (Figure 8).

In order to highlight the signatures, we determined that the surface topography of the rock needed to be eliminated. High-pass filters sharpen local raster surface topographic variability also called spatial autocorrelation (Conolly and Lake 2006). One of the ancillary benefits of using a high-pass filter is that it removes large scale trends and orients the panel squarely in two-dimensional space. Low-pass filters smooth out or blur surface variability using a process called spatial filtering where cell values are calculated as a function of a weighted average within a defined spatial extent (e.g., cell neighborhood). We found the ArcGIS software Spatial Analyst toolkit's preloaded "filter" tool simple to use, but unsuccessful in highlighting signatures within our specific dataset. Instead, we calculated the high-pass filter using map algebra by subtracting a low-pass filter from the original surface raster (Conolly and Lake 2006).

The specific spatial filtering technique used to generate the most effective filter depends on

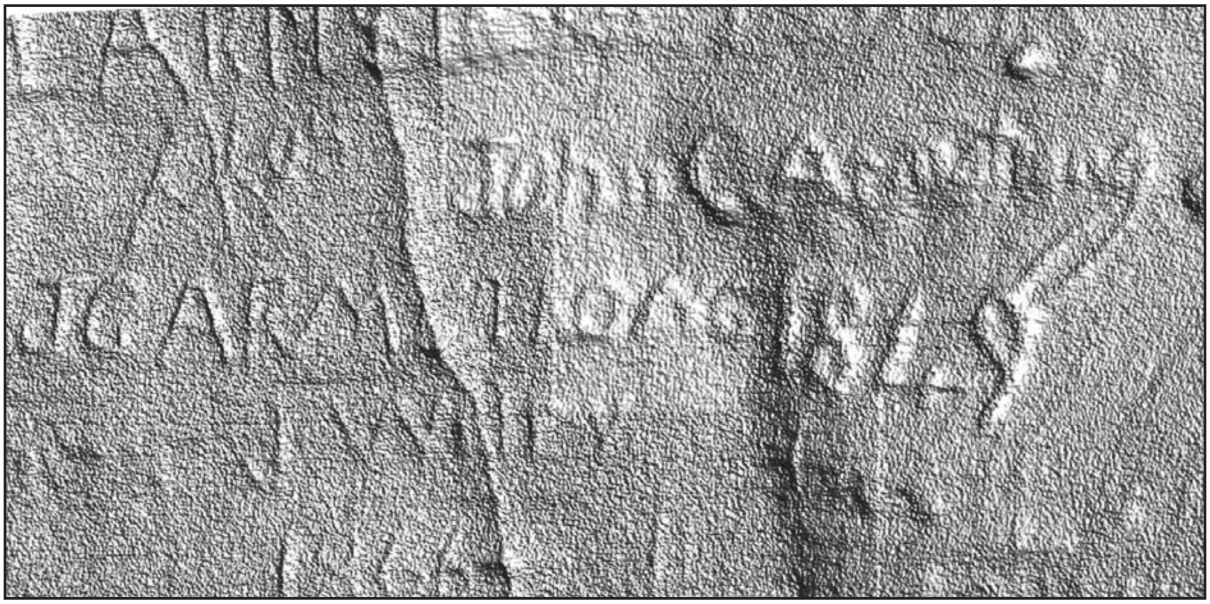

Figure 8. Example of a hillshade raster centered on John C. Armstrong's inscription.

the resolution and nature of the individual dataset (Conolly and Lake 2006). For our project, we found that the Natural Neighbor function set to populate a new raster with cell sizes ten times larger than the original raster (original cell size = .00015) generated the most applicable low-pass filter. To perform the map algebra both rasters (original and low-pass filter) must be at the same resolution. Therefore, we resampled the low-pass filter with Cubic Resampling to populate a higher–resolution, cell-size, low-pass filter. Using map algebra we generated the high-pass filter by subtracting the low-pass filter from the original raster. The resulting high-pass filter (Figure 9) produced a flat depiction of the rock face that accentuates areas of high topographic variability. These quantitatively derived areas represent possible historic inscriptions.

Concluding Comments

By implementing high resolution LiDAR and consistent digital photograph methods we were able to produce an accurate and replicable digital model that preserves the entire context of the Sand Cliff Signatures Site. In the future, these data can be used to track impacts to the surface of the panels (Barnett et al. 2005; Vogt and Edsall 2010). We were also able to explore quantitative surface manipulations and visualization techniques to select for locations on the rock surfaces with high topographic variability while also creating clear visual enhancements. This project highlights both the interpretive and cultural resource management value of three-dimensional high-resolution documentation of historic inscriptions. While archaeologists practice similar research methods to document prehistoric rock art, this study shows that these same methods can be effectively applied to sites containing historic inscriptions. ■

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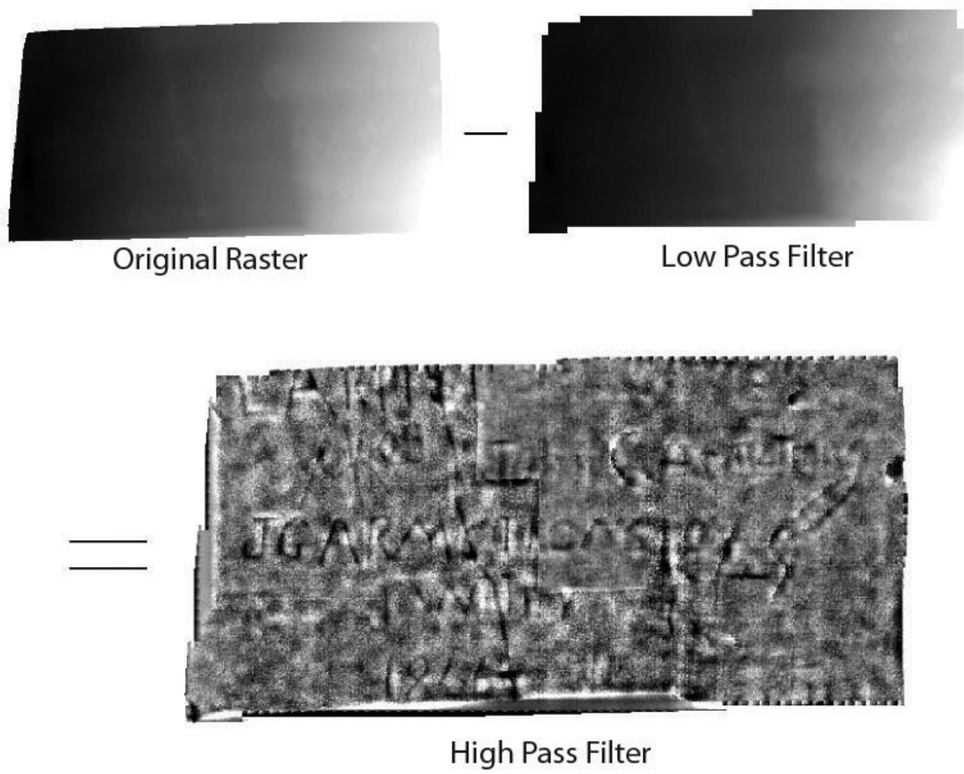

Figure 9. Series of rasters showing the original raster (1), followed by a generalized raster used to recreate the natural surface of the rock (2), reclassified version of raster 2 used in raster math calculation that resulted in the final product that shows signatures quite clearly (3).

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