Assessing Early Spanish Explorer Routes Through Authentication of Rock Inscriptions*

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Rock inscriptions containing both names and calendar dates provide place-specific data on travels of explorers, if those inscriptions are truly authentic. We exemplify here a new strategy for determining the authenticity of inscriptions in arid environments in two case studies. One is an inscription purportedly created during the Marcos de Niza expedition of 1539 through Arizona. The other might have been made by the Dominguez–Escalante expedition of 1776 through the Colorado Plateau and Great Basin. The rock inscription in Phoenix, Arizona, "Fr Marcos de Niza corona todo el nuebo Mexico a su costa ano de 1539," is likely not authentic. Although the Marcos de Niza petroglyph was manufactured before the use of leaded gasoline about 1922, it was made after the Little Ice Age ended in the mid-nineteenth century. In contrast, the engraving "Paso Por Aqui—Año 1776" near Lake Powell's Padre Bay in Glen Canyon National Recreation Area has a lead profile indicating that the engraving predates twentieth-century pollution and also contains a Little Ice Age signal, evidence that the engraving is likely authentic. Nearby graffiti and natural weathering often endangers rock inscriptions, necessitating conservation efforts of authentic engravings. Conservation efforts to protect the delicate condition of the Lake Powell engraving are justified by these findings. In contrast, unnecessary expenditures and effort can result from work on engravings that are not authentic. **Key Words: authenticate, Marcos de Niza, petroglyph, rock art, Spanish explorers.**

包含名字和日历日期的岩石雕刻能提供探险者所旅行之地的具体数据，如果这些铭文是真实的。我们在此的两个研究案例中，体现一个新的确定干旱环境中铭文的真实性的策略。一个据说是在马科斯·尼杂 1539 远征通过亚利桑那州时故意建造的一个岩石铭文。另一个可能是在 1776 年多明格斯埃斯·卡兰特通过科罗拉多高原和大盆地探险时刻的。亚利桑那州凤凰城的岩石题词，“Fr Marcos de Niza corona todo el nuebo Mexico a su costa ano de 1539,”，很可能不是真的。尽管马科斯·尼杂的岩石雕刻在约 1922 年使用含铅汽油前建造，但它是在十九世纪中叶小冰期结束之后出现的。相比之下，在雕刻“Paso Por Aqui—Año 1776” 铭文的格伦峡谷国家景区里，鲍威尔湖的帕德雷湾附近，有一个主要资料表明该雕刻早于二十世纪的污染，并包含一个小冰河时代的符号，证明雕刻可能是真实的。附近的涂鸦和自然风化常常危及岩石铭文，需要作出保护真实岩画的努力。研究结果证明，对这些

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保护鲍威尔湖岩刻的细腻条件的保护工作是合理的。反之，则可能导致源于非真实岩刻的不必要的开支和努力。**关键词：验证，马科斯·尼杂，岩石雕刻，岩画，西班牙探险家。**

Las inscripciones en rocas que contienen nombres y fechas del calendario proveen datos de lugares específicos en los viajes de exploradores, si dichas inscripciones son realmente auténticas. Ejemplificamos aquí una nueva estrategia para determinar la autenticidad de las inscripciones en los ambientes áridos de dos casos de estudio. Uno de ellos es una inscripción aparentemente creada durante la expedición de Marcos de Niza a través de Arizona en 1539. La otra inscripción puede haber sido hecha por la expedición de 1776 de Domínguez-Escalante a través de la meseta de Colorado y la gran cuenca. La inscripción en roca en Phoenix, Arizona: "Fr Padre Marcos de Niza corona todo el nuebo Mexico a su costa año de 1539", es probable no sea auténtica. Aunque el petroglifo de Marcos de Niza fue hecho antes de la utilización de la gasolina con plomo alrededor de 1922, fue hecho después de la Pequeña Edad de Hielo que terminó a mediados del siglo XIX. Por el contrario, el grabado "Paso Por Aqui—Año 1776", cerca del Lago Powell de Padre Bay en el Área Recreativa Nacional del Cañón de Glen, tiene un contorno de plomo que indica que el grabado es anterior a la contaminación del siglo XX y también contiene un rastro de la Pequeña Edad de Hielo, evidencia de que el grabado es probablemente auténtico. La meteorización natural y los grafiti cercanos suelen poner en peligro las inscripciones hechas en las rocas, requiriendo así de esfuerzos de conservación para los grabados auténticos. Justificándose con estos resultados los esfuerzos de conservación para proteger el delicado estado del grabado del Lago Powell. Por el contrario, trabajos en grabados que no son auténticos pueden resultar en innecesarios gastos y esfuerzos. **Palabras Claves: autenticar, Marcos de Niza, petroglifo, arte rupestre, exploradores españoles.**

The routes and impact of early Spanish explorers have long been of interest to geographers (Sauer 1937, 1941; Comeaux 1981; Meinig 1986; Allen 1992; Nostrand 1996; Barrett 1997). Rock inscriptions providing names and dates offer the potential to provide locational constraints on routes that are often ambiguously described and sometimes heavily debated. A major difficulty in interpreting the importance of historic inscriptions rests in not knowing whether an inscription is a twentieth-century hoax or whether it was engraved centuries ago.

This article brings together two simple methods of analyzing rock coatings to carry out authentication testing of possible early Spanish explorer inscriptions. This new strategy is tried on two inscriptions: one purportedly made by Fray Marcos de Niza along a possible route that passes by what is now Phoenix, Arizona, and one possibly made by the Dominguez–Escalante expedition of 1776 that, if authentic, identifies the famous fording of the Colorado River. This article starts by presenting contextual and site-specific background information on these two inscriptions and their sampling. The second section explains how two simple methods were combined to test the authenticity of early Spanish inscriptions in arid North America. The results section details why one engraving is likely authentic, whereas the other is likely not. The last section explores the broader implications of these findings for the handling of other purported historic inscriptions by heritage managers.

Context of Two Spanish Explorer Inscriptions

Marcos de Niza Petroglyph, Phoenix, Arizona

In December 1526, King Charles V granted license to Pánfilo de Narváez to claim the Gulf Coast for Spain, as long as the king's trusted advisors accompanied Narváez. Among them was Álvar Núñez Cabeza de Vaca, who served as treasurer of the enterprise. The Narváez expedition left Spain in 1527 with 450 soldiers, officers, and slaves and 150 sailors, wives, and servants. In the New World, the mission suffered hurricanes and Indian attacks until everyone of the expedition died except Cabeza de Vaca, a North African slave Estéban de Dorantes, and two other Spaniards, Alonso del Castillo and Andres Dorantes. For ten years, the four wandered overland in search of a Spanish outpost. Surviving periods of enslavement by various American Indian tribes along the coast, they wandered on foot through what is now Louisiana, Texas, New Mexico, and Arizona. Finally, after being discovered by Spanish slave raiders north of Culiacán, near present-day Sinaloa, Mexico, they traveled back to Mexico City and eventually returned to Spain.

The report to the king was later published as *La Relación* in 1542 (Cabeza de Vaca 1542), including descriptions of gifts of emerald arrowheads that came from a people who lived in very high mountains to the north and who lived in large dwellings and large towns. He also described seeing gold, silver, copper, and other precious metals along his journey. Cabeza de Vaca's report of untapped wealth inspired the crown to fund an expedition to explore the country in the northern territories of New Spain.

After a thorough investigation, the Viceroy of New Spain in Mexico City, Antonio de Mendoza, asked Cabeza de Vaca to lead an expedition north to further explore these unknown lands (Flint 2008). De Vaca refused. The Viceroy then purchased Estéban and asked Andres Dorantes if he would venture north, but he also declined. Mendoza then chose a native of Italian-controlled Nice, France, Fray Marco da Nizza (who is more commonly known today as Marcos de Niza), to journey north from Culiacán into the unknown land. Marcos was about forty years of age and was well traveled, having already been to Guatemala and Peru. Because of his scholarly writings and his sympathy to Indians, Marcos was nominated for the journey by the Franciscan Provincial in Mexico City. Mendoza also sent along Estéban to serve as his guide.

On 7 March 1539, Marcos departed Culiacán with a group of Indians who were to act as native emissaries on his behalf. On Easter break at the present-day Sinaloa–Sonora border, Marcos sent Estéban ahead to scout the countryside. When Marcos resumed his journey north in mid-May, Estéban was more than two weeks' travel ahead of him. After several days of travel, Marcos met Indians returning from Cibola who told him that Estéban had been killed by the Indians of Cibola (very likely the Zuni Pueblos of west-central New Mexico). Marcos later reported to Mendoza that he and his Indian companions had walked on to the edge of Cibola and then hastily returned to Mexico City, arriving in August (da Nizza 1539).

In his report to the Viceroy (da Nizza 1539), Marcos called Cibola "extraordinary," but he did not specifically mention the presence of gold or silver (Flint 2008). In private conversations afterward, however, he apparently exaggerated the wealth of Cibola, and rumors spread that Cibola was the seven cities of gold, an often repeated medieval tale about the seven cities of Antilia that persisted in Spanish legends in the New World. Mendoza was skeptical of Marcos but worried that others, including the English, would claim Cibola before he could. He sent Francisco Vasquez de Coronado on his infamous 1540–1542 expedition to find Cibola. Marcos was sent along to guide Coronado's large group of some 300 Spaniards and more than 1,000 Indians. When Coronado's party encountered Cibola, they did not find seven cities of gold but rather several impoverished Pueblo towns, and Marcos quickly fled back to Mexico City in fear of being killed by members of the expedition. He lived a lonely and broken life after Coronado's failed expedition, dying on 25 March 1558 in Veracruz (Hartmann 1997).

Historians and geographers have long debated what route Marcos traveled on his journey into the American Southwest (Bancroft 1889; Bolton 1916; Sauer 1937; Oblasser 1939; Hammond and Rey 1940; Bloom 1941; Sauer 1941; Undreiner 1947; Hallenbeck 1949; Di Peso, Rinaldo, and Fenner 1974; Bandelier 1981; Rinaldo et al. 1995; Hartmann 1997; Flint 2008). Because Marcos's own account of his visit to Cibola is questionable, retracing his route has been the subject of considerable controversy. Hallenbeck (1949) called Marcos a lying monk and one of the Munchausens of history. Other historians have been more generous and claim that Marcos's "written description of Cibola from a distance is curt, sober, and can be credited as literally accurate" (Hartmann 1997, 64). Nonetheless, the exact locations of his routes to and from Cibola are still in question.

Most historians today argue that it is likely that Marcos traveled through eastern Arizona along the San Pedro River on his way to west-central New Mexico. Few reconstructions of his routes take him through the Phoenix, Arizona, area. An exception is a translation of Marcos's report by Father Oblasser containing purported maps of Marcos's routes (Oblasser 1939), one of which was influenced by the Marcos de Niza inscription rock in Phoenix's South Mountain Park (Figure 1). It is important to note that Marcos had been instructed by Viceroy Mendoza to explore possible sea ports located to the west during his trip with Estéban, and his whereabouts during the Easter break while Estéban forged ahead remain ambiguous.

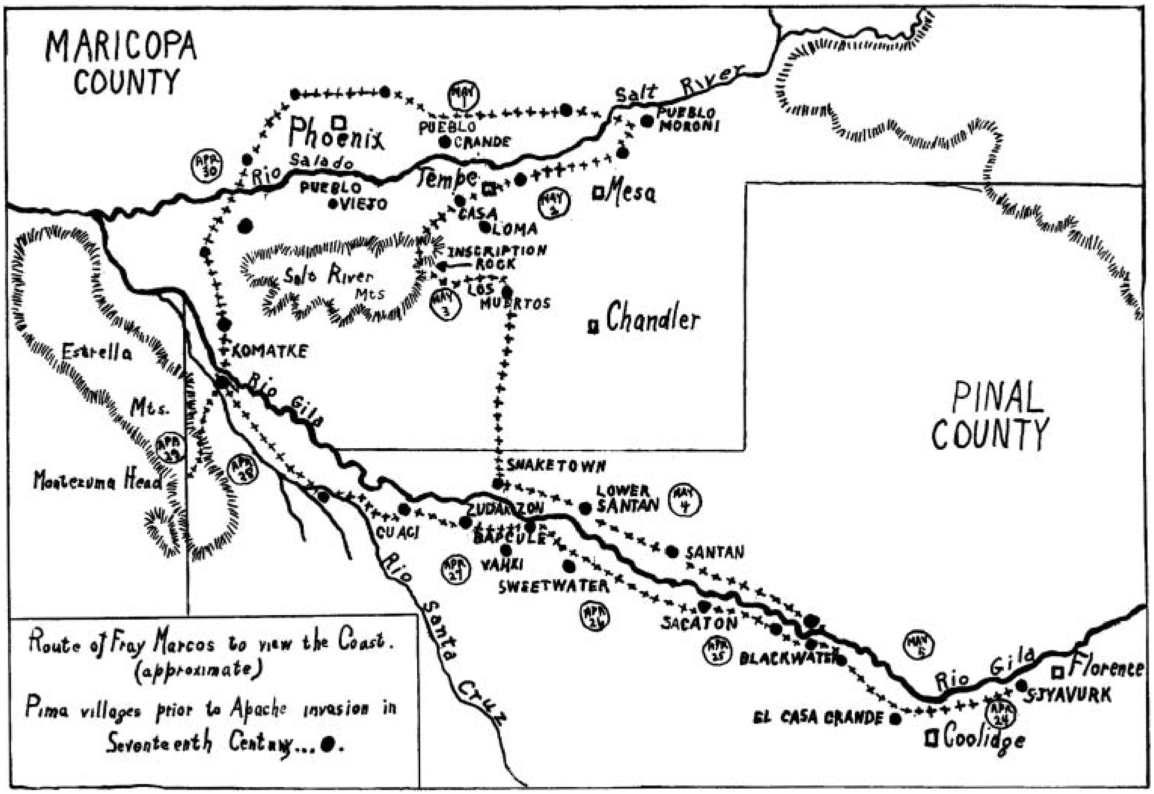

Figure 1 *Father Oblasser's 1939 map of the purported route of Marcos de Niza through the Phoenix region—with a special notation of inscription rock at the eastern end of what is now called the South Mountains.*

Another possible reason for Marcos to have ventured into the Phoenix region was to look for gold and silver, and high-grade gold ore has been found in the South Mountains (Bostwick 2001). The Marcos de Niza petroglyph is located in a rock alcove at the easternmost end of the South Mountains. Similar to the numerous prehistoric petroglyphs in these mountains (Bostwick 2002), this inscription is pecked into the dark, rock varnish that covers the granodiorite bedrock. The inscription revealed a lighter colored interior, providing a contrast that made the writing very visible. The Marcos de Niza petroglyph was apparently not found until the 1920s, when Matthew E. Bellew announced its discovery. At the time, that portion of the South Mountains was on private land owned by Bellew. This inscription reads "Fr Marcos de Niza Corona to Do el nuebo Mexico a su costa ano de 1539," which translates to "Fray Marcos de Niza crowned all of New Mexico at his expense in the year of 1539." Marcos's name is located on a vertical rock face, with the remaining portion of the inscription on an adjacent horizontal rock face.

The Marcos de Niza inscription has long been a subject of controversy. In 1925, James H. McClintock, the Arizona State Historian, wrote a letter to F. W. Hodge of the Museum of the American Indian in New York, asking for his opinion (McClintock 1925). McClintock (1925) also mentions another, more recent-looking, petroglyph with "Marcos de Niza" and "Estavanico" names located in the same general vicinity. This petroglyph also had the Roman numeral date, "MCXXXIX," which was clearly a fraud, as it was off by a century.

Hodge responded that he believed that the 1539 inscription was a forgery in part because Spanish priests were not likely to leave their own names in public places and the phrase translated as "at his own expense" was not true because many people contributed funding to support Coronado's expedition in 1540 (F. W. Hodge 1925). Hodge noted that the phrase was not uncommon in Spanish inscriptions at El Morro National Monument in New Mexico,

Figure 2 *Marcos de Niza inscription surrounded by metal bars in the City of Phoenix South Mountains Park.*

suggesting that "whoever made the inscription had gained a smattering of the character of the inscriptions on El Morro, and made use of it, but failed to avoid the pitfalls."

Park ranger and archaeologist Frank Mitalsky (a.k.a. Midvalle) also thought the inscription was a fraud (Mitalsky 1936). Mitalsky wrote that historian Herbert E. Bolton examined the inscription with him and concluded that it was "a forgery but undoubtably an old one." Bolton noted that the script was not typical of that period and the words *Mexico* and *New Mexico* were not established at that time. Nonetheless, he felt its authenticity was still a subject of debate. Katherine Bartlett and Harold Colton of the Museum of Northern Arizona echoed Bolton's and Hodge's opinions in an article published a few years later (Bartlett and Colton 1940).

Local citizens were not convinced that the inscription was a fake, especially because Marcos de Niza's exact routes were unclear, and its preservation became an issue for the City of Phoenix. Because there was no clear evidence that it was a fraud, a set of heavy metal bars were placed around the inscription in the 1930s to prevent it from being stolen. Those bars remain today (Figure 2).

Determining whether or not the Marcos de Niza inscription is a fraud is a significant research question for two reasons: First, if it is authentic it would be the earliest known Spanish inscription in North America and, second, it would provide important information about the route taken by Marcos de Niza.

The opportunity to apply a new analytical approach to test the authenticity of the Marcos de Niza inscription occurred in January 2009 when Aaron Wright contacted the PBS television show *History Detectives* to consider the inscription for one of its programs. Aaron is a doctoral student at Washington State University studying the petroglyphs of the South Mountains. Oregon Public Broadcasting agreed to produce a *History Detectives* show on the inscription and assembled a team of scholars, including one of its hosts, Professor Eduardo Pagán.

To access the inscription, the metal bars had to be temporarily removed with a welding torch, an effort that would not have happened without interest in the television show.

Figure 3 *"Fr Marcos de Niza corona to do el nuebo Mexico a su costa ano de 1539" petroglyph where arrows indicate the location of samples from letters M and d and two locations from the number 5. Control samples were collected from the upper left of the letter F. (Color figure available online.)*

Millimeter-sized rock chips were then removed from several locations on the inscription. Multiple chips were removed in a pattern that mimics the pattern of natural erosion (Figure 3) to create a minimal amount of damage to the inscription. In addition, centimeter-sized rock chips were removed from natural, nonpecked surfaces to the upper left of the petroglyph. Rock chip samples were entombed with epoxy and oriented in a fashion such that polishing would generate a cross section for electron microprobe analysis.

Crossing of the Fathers Engraving, Glen Canyon National Recreation Area, Utah

In 2006, a group of volunteers removing graffiti in Glen Canyon National Recreation Area reported an inscription that reads "Paso Por Aqui—Año 1776." This phrase, "passed by here," was in common use during the period of Spanish exploration as evidenced by the 1605 inscription by Governor Don Juan de Onate at El Morro National Monument that begins with this phrase. Onate was returning from an expedition to the Gulf of California with thirty soldiers when they camped at El Morro because of the reliable water source that was present below the towering mesa (Simmons 1991). Onate's inscription at El Morro reads: "Paso por aqui, el adelantado Don Juan de Onate del descrubimiento de la mar del sur a 16 de Abril de 1605," which translates to "Passed by here, the Governor Don Juan de Onate from the discovery of the seas of the south the 16th of April of 1605."

The Dominguez–Escalante expedition of 1776 is widely considered one of the great explorations in Western U.S. history because the 1,700-mile and 158-day journey on horseback represents the first comprehensive effort of the Spanish Empire to officially traverse the Plateau Province of the Colorado River and portions of the Great Basin (Bolton 1950; E. B. Adams and Chavez 1956; Briggs 1976; Warner 1976).

Franciscans Atanascio Domínquez and Silvetre Vélez de Escalante had been assigned the task of finding a route to California from the missions in New Mexico and to establish new missions among the Ute Indians. They were accompanied by a group of eight men, including their guide, Andre Muníz, a mixed-blood Hispano-Ute Indian. The diary kept by the twenty-five-year old Vélez de Escalante and the maps created by topographer Bernardo Miera y Pacheco represent today some of the best historical documents for the Colorado Plateau and Great Basin, providing detailed information about the geography, plants, animals, and Indian tribes of the region.

Thwarted in an attempt to reach Monterey, California, by an early October snowfall in western Utah and facing dwindling food supplies, the group decided to cast lots and subject themselves to the will of God. The drawn lot redirected the party toward the Hopi Villages in Arizona. Over the next three weeks the party traversed the area north of the Grand Canyon in search of a suitable crossing of the Colorado River.

After two failed attempts to cross the river at the mouth of the Little Colorado River and Navajo Canyon, the expedition finally forded the main course of the Colorado River on 7 November 1776. With time, this crossing of the Colorado River became known as the "El Vado de los Padres" or "The Crossing of the Fathers." Unfortunately, the famous ford was

Figure 4 *"Paso Por Aqui—Año 1776" engraving and sample collection vial after collection of the rock chips. The arrow indicates the location of the Año inscription in relation to the 1776 date. (Color figure available online.)*

covered by the waters of Lake Powell in 1964 after construction of Glen Canyon Dam.

It is possible that the "Paso Por Aqui 1776" inscription is related to the previous day when on 6 November the diary indicated that the party "stopped for a long time by a strong blizzard and tempest consisting of rain and thick hailstones amid horrendous thunder claps and lightning. We chanted the Litany of the Virgin in order that She might ask some relief for us and God was pleased that the storm should cease."

The 1776 inscription in the Glen Canyon Recreation Area was engraved relatively deep into the soft sandstone rock with a sharp tool. Over time it has darkened from rock varnish and other rock coatings so that it is now much darker than more recent graffiti (Figure 4). Millimeter-sized rock chips were collected from the 1776 motif. The chips were removed in a pattern that mimicked the texture of natural erosion (Figure 4). For comparison, millimeter-sized samples were removed from a nearby 1980 graffiti ("Boyce 1980") and an adjacent portion of the same rock face. These rock chips were placed in epoxy and oriented to generate cross-sections for electron microprobe analysis.

Methods of Authenticity Testing

Two different methods are used in combination to place arid-region inscriptions in three possible time groupings: (1) carved during the period of twentieth-century automotive lead and other heavy metal pollution; (2) engraved in the late nineteenth or earliest twentieth century before lead and other heavy metal pollution but after the Little Ice Age ended by ca. 1850; or (3) inscribed during the Little Ice Age that started in the mid-fourteenth century and ended by the middle of the nineteenth century.

Each testing starts by measuring lead profiles of rock coatings formed on top of the engravings. If the profile only shows contamination from twentieth-century automotive lead pollution, then the authentication effort need go no further. The varnish microlamination (VML) technique is used to assess whether the engraving formed during the Little Ice Age only if lead concentrations drop to natural low levels underneath a contaminated surface layer.

Lead Profiles Assess Twentieth-Century Manufacturing

> Lead accumulates in rock varnishes and dust films on desert surfaces. Electron microprobe profiles reveal that lead is a contaminant in the uppermost surfaces of rock varnishes, but these concentrations drop to background levels below the very surface of natural rock coatings that have formed since lead additives were introduced into gasoline in 1922. (Dorn 1998, 139)

Multiple researchers have since confirmed this observation that lead and other anthropogenic pollutants contaminate the very surface of rock varnish and other iron-rich rock coatings. Radioactive cesium from nuclear bomb tests, lead released from automobiles, and zinc from smelters were found in the surface-most layer of varnish (Fleisher et al. 1999), including in eastern California distant from cities (Broecker and Liu 2001). Another study (Wayne, Diaz, and Orndorff 2004) noted that "the surface layers of all varnish samples studied display an extreme enrichment in Pb that is not always reflected in the abundances of most other trace elements. Varnish Pb isotope signatures contain a distinct atmospheric Pb component, relative to those of the substrate rock." Still others reported similar surficial contamination by lead and other heavy metal contaminants (Thiagarajan and Lee 2004; V. F. Hodge et al. 2005; Wayne et al. 2006; Spilde, Boston, and Northup 2007; Nowinski et al. 2010).

Twentieth-century industrial activities spread lead pollution around the globe, even in areas distant from major lead-pollution sources (Andersen 1994; Getty et al. 1999).

Because the manganese found in rock varnish and iron found in iron films scavenge lead from the surrounding environment (Dong, Hua, and Zhonghua 2002; Hassellöv and von der Kammer 2006; J. P. Adams et al. 2009), it is not surprising that a twentieth-century "spike" in lead is detected in chemical profiles from the surface-most layers of rock varnish and iron films. Lead profiles have been used previously to authenticate prehistoric petroglyphs (Dorn 2006; Merrell and Dorn 2009) as well as reveal that ground figures (geoglyphs) of a fisherman and a snake in western Arizona are likely not authentic (Dorn 1998).

There are several different ways of measuring a lead profile from the surface down into a rock coating with enough spatial precision to analyze a depth profile from the surface micrometer down through the entire rock coating. We employ in this study a technique that is reasonably accessible: wavelength-dispersive electron microprobe analyses (Reed 1993). The approach starts with embedding a rock chip sampled from the engraving and adjacent control samples such as natural rock faces or clear examples of graffiti in epoxy. The rock chips are positioned in the hardening epoxy with an orientation normal to the coating surface. This positioning allows polishing of a flat surface that provides a cross-section of the rock coating. We used electron microprobe operating conditions of 20 nA, a take-off angle of 40°, accelerating voltage of 15 kV, and a 300-second counting time to increase sensitivity to a detection limit of about 0.03 percent weight PbO.

Varnish Microlaminations Assess Little Ice Age Manufacturing

If lead profiles reveal a surface layer that is contaminated with lead on top of rock coating that is not contaminated, then the engraving predates the period of lead contamination. Such a result implies that the coating and the underlying engraving would be earliest twentieth century or older and thus possibly authentic. Thus, in these cases, the same sample used in the electron microprobe testing is polished further into an ultrathin section where rock VMLs can be observed optically.

The study of VML dating (Liu 2003, 2011; Marston 2003; Liu and Broecker 2007, 2008a, 2008b) is based on observations of more than 10,000 microsedimentary basins that have distinctive layering patterns in rock varnishes produced by climatic changes. The VML dating method does not give a distinct age, such as radiocarbon dating or tree-ring dating. Instead, matching varnish layers with the established calibrations generates age categories. At the present time, calibrations exist for the late Pleistocene and Holocene only in the Western United States. However, additional work being completed globally will expand the method's utility into other deserts (Liu 2011).

The Little Ice Age is the calibrated Holocene lamination used in authenticity testing. This wetter period in the Western United States started in the mid-fourteenth century and ended in the mid-nineteenth century and resulted in the deposition of a black layer of rock varnish, underneath a surface orange layer. If a sample is collected from a wetter microenvironment where varnish grows especially fast, the Little Ice Age signal in rock varnish results in accretion of three very narrow secondary black bands that together comprise this Little Ice Age signal (Liu and Broecker 2007).

Results

Marcos de Niza Petroglyph Is Likely Not Authentic

The letter M in Marcos, the letter d in de Niza, two spots on the number 5 in 1539, and a control sample all showed lead contamination in the surface-most micrometer. Contaminated concentrations were 0.21 percent, 0.25 percent, 0.39 percent, 1.20 percent, and 0.26 percent PbO, respectively. PbO measurements underneath this surface layer, however, dropped to 0.04 percent or less where the limit of detection was about 0.03 percent. These results reveal that the petroglyph predates the use of automobiles, which began in earnest in the mid-1920s in the area of South Mountains, Phoenix, Arizona. This finding then led to the need to make and analyze ultrathin sections of these samples for VML analyses.

The control sample (Figure 5), collected from near the inscription, matches the VML pattern for late Holocene varnishes (Liu and Broecker 2007). Of particular note, there is a yellow-orange surface-most microlaminae that postdates the Little Ice Age (Wet Holocene 1

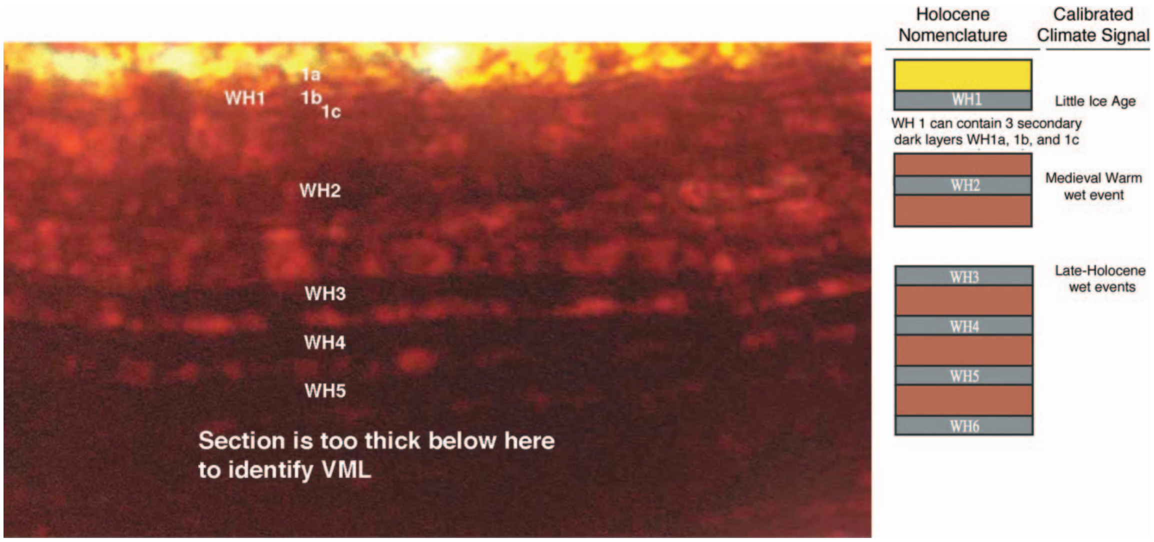

Figure 5 *Ultrathin section of the control sample collected near the Marcos de Niza petroglyph next to the Holocene calibration (Liu and Broecker 2007). Wet Holocene (WH) events before WH5 cannot be identified, because the ultrathin section was too thick. This is because the section was made to accentuate the finer laminae of the Little Ice Age (WH1) signal. This section is approximately 35 μm from top to bottom. (Color figure available online.)*

[WH1] event). With the fastest growing varnishes, the WH1 layer often contains three secondary dark layers called WH1a, WH1b, and WH1c (Liu and Broecker 2007). These secondary layers can be seen in the control sample of Figure 5. Then, there is the orange layer underneath WH1 that is the end of the Medieval Warm event, with WH2 being a wet period inside the Medieval Warm event. WH3, WH4, and WH5 are wet events during the late Holocene. The details of the control sample are important, because none of the rock coatings analyzed from the engraving show any evidence of the Little Ice Age event (Figure 6).

Each sample analyzed from the inscription is (Figure 6) similar to the surface-most layer seen in the control sample (Figure 5). This layer consists of clay minerals cemented by about 10 percent iron oxyhydroxides, and this type of rock coating formed after Little Ice Age dark varnish microlaminae accreted. Thus, there is no evidence of the WH1 Little Ice Age signal in any of the coatings formed on the engraving.

Three events likely led to the observed results obtained here for the Marcos de Niza petroglyph:

1. Inscribing the petroglyph. Pecking exposed the quartz and feldspar minerals seen underneath rock coating (Figure 6).
2. Formation of post-WH1 yellow-orange microlaminae. When the climate of the Western United States dried after the Little Ice Age, the post-WH1 coating formed (Figure 6). Lead concentrations underneath the very surface micron reflect natural background levels of PbO.
3. Lead contamination during the twentieth century. In each of the profiles where PbO was measured (lines in Figure 6), the surface-most micrometer shows contamination with lead, likely from automobiles that generated lead pollution in the area after the mid-1920s.

In summary, the Marcos de Niza inscription likely predates growing use of automobiles in Phoenix in the mid-1920s, but it is younger than the Little Ice Age that ended in the mid-nineteenth century. These analyses suggest that the petroglyph is not authentic and could have been inscribed about the same time it was first reported, in the early 1920s.

Crossing of the Fathers Engraving Is Likely Authentic

Three separate control samples were analyzed for their PbO content from the surface-most micron down into rock varnishes that were 12,

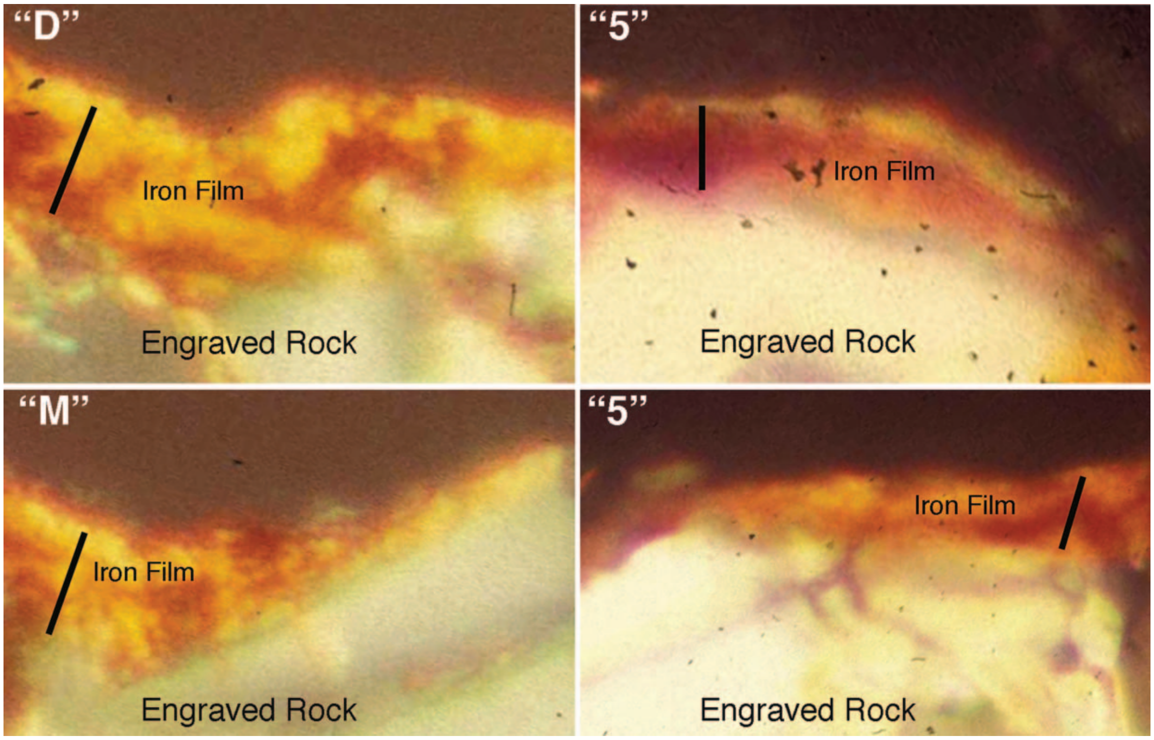

Figure 6 *Rock coatings formed on top of the Marcos de Niza inscription. Each of the lines indicates the location of electron microprobe measurements. The lines are about 5 μm long. (Color figure available online.)*

15, and 20 μm thick. The surface-most analyses revealed lead contamination of 0.15 percent, 0.26 percent, and 0.33 percent PbO. Then, just underneath this contaminated later, lead concentrations were at or just above the limit of detection of 0.03 percent PbO. The modern graffiti carved in 1980 hosted a film of from 1 to 3 μm consisting of clays cemented to the sandstone surface by iron oxyhydroxides. Wavelength-dispersive analyses revealed only PbO contamination of between 0.20 percent and 0.25 percent.

Three chips from the 1776 inscription showed rapid formation of rock varnish. This rapid formation allowed fairly lengthy lead profiles from the surface-most micron down into the rock varnish. In all profiles, the surface-most analysis revealed contamination that dropped down to background levels right around the limit of detection (Figure 7). Thus, the most reasonable interpretation is that the 1776 "paso por aqui" inscription is older than the period of lead contamination in the twentieth century. This result then led to repolishing of the samples for VML analyses.

The VML analyses revealed that the 1776 engraving was likely made in the Little Ice Age during a wetter climate that would have deposited the WH1 layer seen in ultrathin cross sections (Figures 8 and 9). VML analyses were carried out on three samples from the 1776 engraving, and all showed the same signal of a thin basal layer of the WH1 microlaminae. Given that we only see one microlaminae in the WH1 layer, the engraving was likely made at the end of the Little Ice Age.

Four different events explain the observations for the 1776 inscription:

1. Carving the engraving. Carving exposed the weathering rind of the sandstone seen at the "bottom" of the ultrathin sections (Figures 8 and 9). Then, rock varnish started to form on the quartz grains of the sandstone.
2. Formation of WH1 varnish microlaminae at the end of the Little Ice Age. The very lowest layer of varnish is a very thin black layer. The interpretation is that this microlaminae was deposited at the end of the

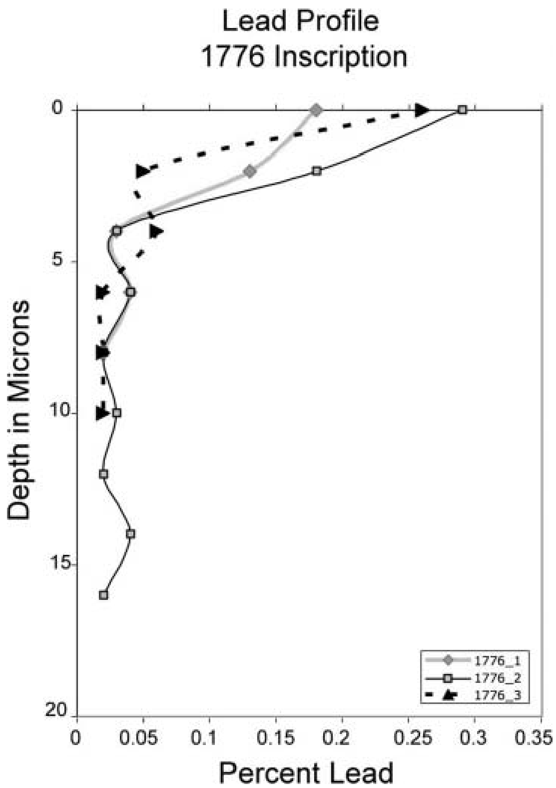

Figure 7 *Lead profiles in three different subsamples from the inscription all show that "background" levels in lead concentration occur underneath the twentieth-century surface layer. The best explanation for these profiles is that the iron film rock coating formed on top of the carving started to accrete well before the start of twentieth-century lead contamination.*

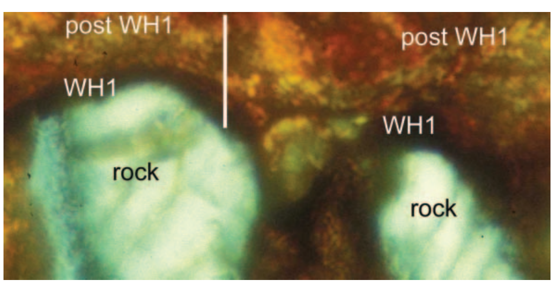

Figure 8 *Ultrathin section of rock varnish formed on top of the 1776 "pasa por aqui" rock coating. Two weathered quartz grains in the sandstone can be seen in this cross section. The lowest layer of the varnish displays a black lamination diagnostic of the WH1 (Little Ice Age) interval that ended about 300 calendar years ago (Liu and Broecker 2007). Above the WH1 interval is varnish accreted during the last 300 years. The 15-μm-long line indicates the approximate position of the lead profile analysis of 1776. (Color figure available online.)*

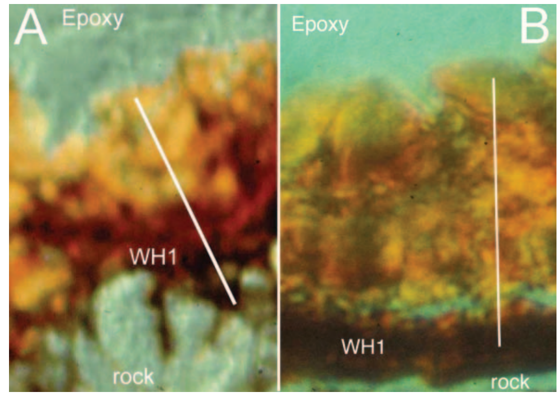

Figure 9 *Ultrathin sections of two different samples collected from the 1776 engraving. Like Figure 8, the lowest layer of the varnish displays a black lamination diagnostic of the WH1 (Little Ice Age) interval that ended about 300 calendar years ago (Liu and Broecker 2007). The line in the left section is about 8 μm long, and the line in the right section is about 10 μm long, indicating the approximate position of the lead profile analyses. (Color figure available online.)*

Little Ice Age. Thus, VML dating is consistent with the inscription being made in 1776.

3. Formation of post-WH1 varnish microlaminae. When the climate of the Western United States dried after the Little Ice Age, the post-WH1 orange layer formed (Figures 8 and 9). Lead concentrations in the varnish underneath the very surface micron are in the range of 0.05 percent PbO or less, consistent with formation in the time before twentieth-century lead contamination.
4. Lead contamination during the twentieth century. The uppermost micron of iron-rich coating shows a jump in lead concentration at the very top of the varnish stratigraphy. The increase is almost an order of magnitude more lead than the varnish underneath. The best interpretation of this "spike" is that it took place from pollution contamination. The existence of a surface lead-contaminated layer is seen in other varnish samples from the region (Wayne et al. 2006).

Discussion and Conclusion

Rock inscriptions and other petroglyphs have long been an important concern of heritage managers (Clarke 1976; Dolanski 1978; Elvidge and Moore 1980; Watchman 1990; Ford, Macleod, and Haydock 1994; Laver and Wainwright 1995; Price 1995; Young and Wainwright 1995; Griswold 1999; Russ et al. 1999; Loubser 2001; Scott, Scheerer, and Reeves 2002; Brink, Campbell, and Peterson 2003; Whitley 2004; Clottes 2006; Deacon and Agnew 2006; Hall et al. 2007; Mol and Viles 2010). Notably, considerable conservation activity has been focused at sites where vandalism has disturbed rock art (Higgins 1992; Chaffee, Hyman, and Rowe 1994; Loubser 2001).

Less attention has been given to determining whether the rock art in need of conservation is actually authentic. Although authenticity is clearly not an issue in many circumstances, there can be an assumption of authenticity that might not be valid. For example, a signature of W. F. Cody is presumed to have been carved when he was stationed at nearby Fort Harker in 1871. Without any means of testing authenticity, conservation efforts entombed the signature in ethyl silicate (Grisafe 2000). In another example, engravings at abandoned sites in Mustang, Nepal, are being used to understand cultural history and cultural geography, where ongoing conservation efforts also presume authenticity without any evidence (Pohle 2000).

The concern addressed here is the assumption of authenticity, specifically to illustrate a new strategy to determine the authenticity of rock engravings in arid and semiarid environments. The issue is not trivial, given the time and costs involved in repairing vandalism damage or in helping to conserve cultural resources that are rare traces of the past. The two simple tests exemplified here can prevent unnecessary efforts to conserve inscriptions that are simply twentieth-century graffiti. Because these two tests can be conducted on millimeter-sized samples, the minimal aesthetic effects of sampling and low cost of these tests can enable authentication of historic engravings prior to conservation efforts.

Limited fiscal resources are available to conserve authentic historic inscriptions that are found commonly in arid and semiarid regions. The decision to expend such resources should not rely on assumptions of authenticity but on solid evidence. Two simple tests, lead profiles and VMLs, can be used to assess whether inscriptions were made (1) in the period that postdates twentieth-century lead and other heavy metal pollution, (2) in the period that postdates the Little Ice Age but predates heavy metal pollution, or (3) during the Little Ice Age.

Two simple tests were used on two purported Spanish explorer engravings and the resulting data reveal contrasting findings. The 1776 “pasa por aqui” engraving from Crossing of the Fathers, Glen Canyon National Recreation Area, Utah, was likely made during the Dominguez–Escalante expedition and identifies the location of the famous fording of the Colorado River, but data reveal that the “Fr Marcos de Niza corona todo el nuebo Mexico a su costa ano de 1539” petroglyph at South Mountain Park, Phoenix, Arizona, was made more than three centuries after this expedition. ■

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