ARCHAEOLOGY SOUTHWEST *magazine*

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Although Preservation Archaeology begins with the active protection of archaeological sites, it doesn't end there. We utilize holistic, low-impact investigation methods in order to pursue big-picture questions about what life was like long ago. As a part of our mission to help foster advocacy and appreciation for the special places of our past, we share our discoveries with the public. This free back issue of *Archaeology Southwest Magazine* is one of many ways we connect people with the Southwest's rich past. **Enjoy!**

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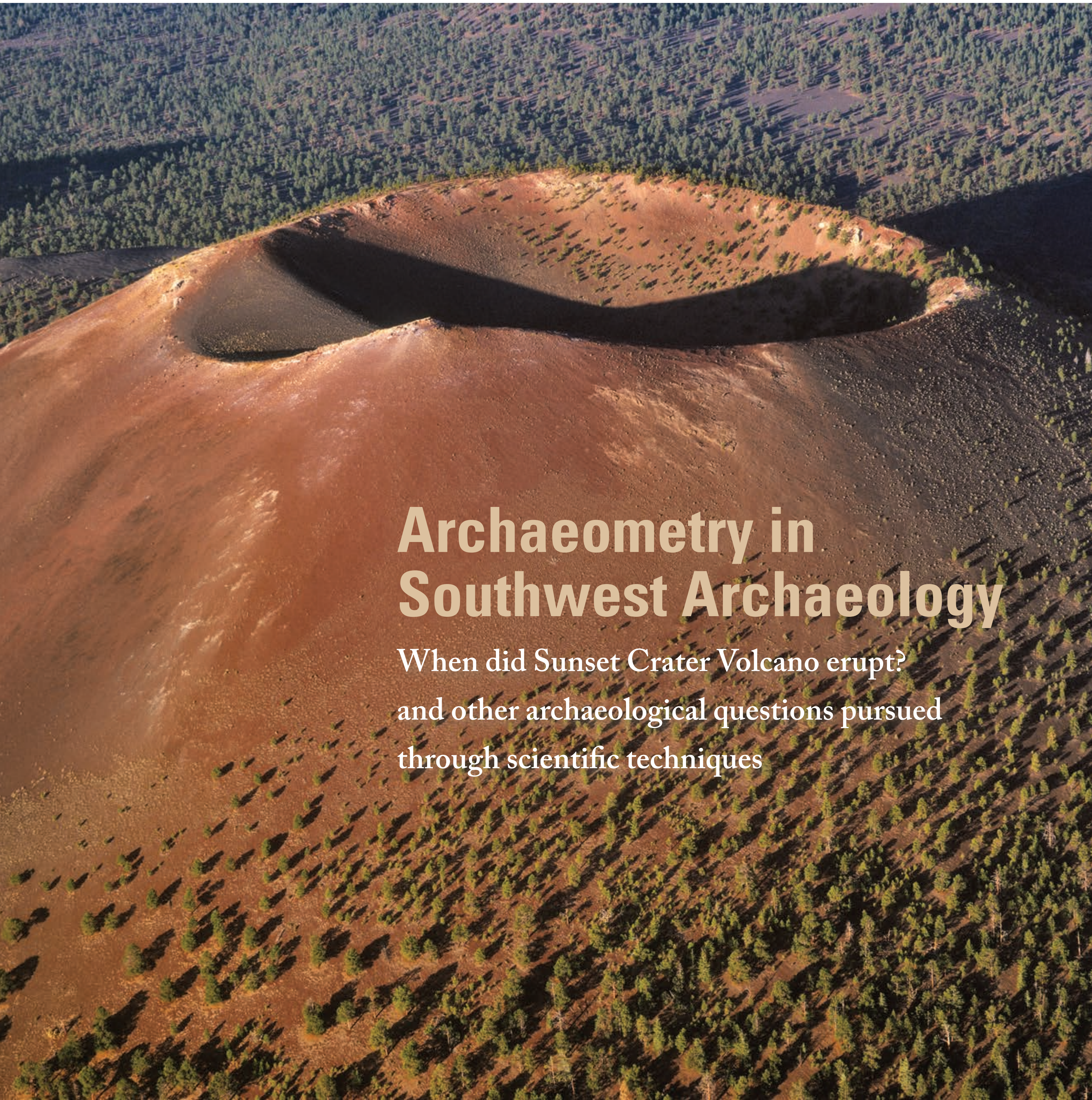

Archaeometry in Southwest Archaeology

When did Sunset Crater Volcano erupt? and other archaeological questions pursued through scientific techniques

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For a glossary of terms and techniques, additional reading, links, and special essays on the proper use of portable X-ray fluorescence spectrometry to analyze obsidian and ceramics, visit **www.archaeologysouthwest.org/asw26-2.**

about us

Archaeology Southwest explores and protects the places of our past across the American Southwest and Mexican Northwest. We have developed a holistic, conservation-based approach known as Preservation Archaeology. By looking forward and acting now, we are achieving protections and creating meaningful connections between people and history that will benefit generations to come. **Learn more at www.archaeologysouthwest.org.**

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Archaeology Southwest

Exploring and protecting the places of our past

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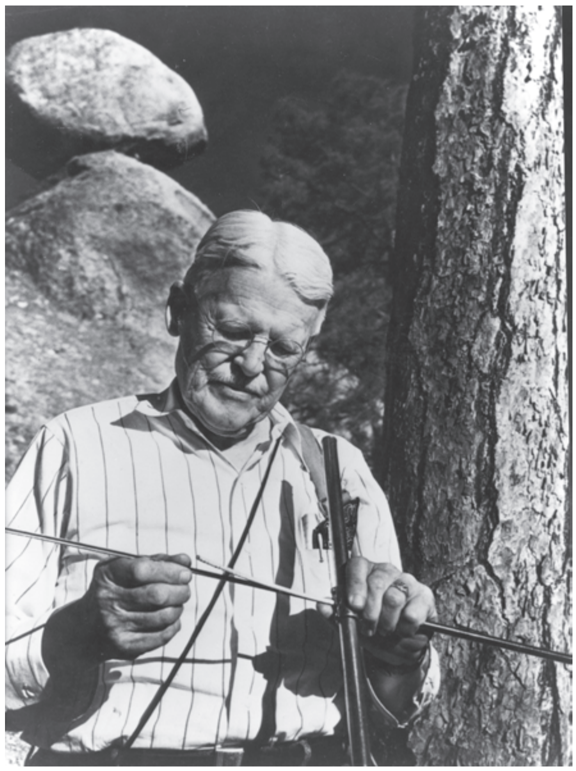
Archaeometry in Southwest Archaeology: Pursuing Archaeological Questions through Scientific Techniques

MARY F. OWNBY, DESERT ARCHAEOLOGY, INC.
MARK D. ELSON, DESERT ARCHAEOLOGY, INC.

In the United States, archaeology is a subfield of anthropology, which is concerned with the study of human evolution and behavior. Archaeology is unique among the social sciences, however, in its considerable adoption of techniques developed in the physical sciences. Today, use of these methods is so pervasive in archaeological research that the field has its own name—archaeometry, or archaeological science—and two eponymous scholarly journals.

Through the integration of science and anthropological theory, we have gained a richer understanding of the past. For several decades now, archaeologists have applied physical science methods toward two of our most basic questions: "How old is it?" and "Where was it made?" Yet, as authors in this issue demonstrate, recent advances are illuminating past human behavior in ways that, even twenty years ago, we would have thought were impossible.

Archaeometry's history is longer than one might expect. Scientific analysis of artifacts began in the early nineteenth century, when scholars sought to discover the compositions of pigments and bronze objects through chemistry. In 1888, the first laboratory devoted to studying and conserving archaeological artifacts opened at Berlin's Königliche Museum. The concept of a laboratory dedicated to analyses of archaeological materials soon spread to other institutions. In the 1930s, continued development of specialized instruments for determining chemical signatures prompted investigations into the origins and production of artifacts. Provenance studies developed around understanding ancient trade and interaction networks. Radiocarbon dating became standard practice in the 1960s, revolutionizing our knowledge of past events and cultural change. In the next decade, archaeologists began using electrical resistivity and magnetometry to explore buried sites. And it almost goes without saying that the most notable contribution science has made to archaeology is computer technology. Without it, we could not identify significant patterns within the vast quantities of information we record.

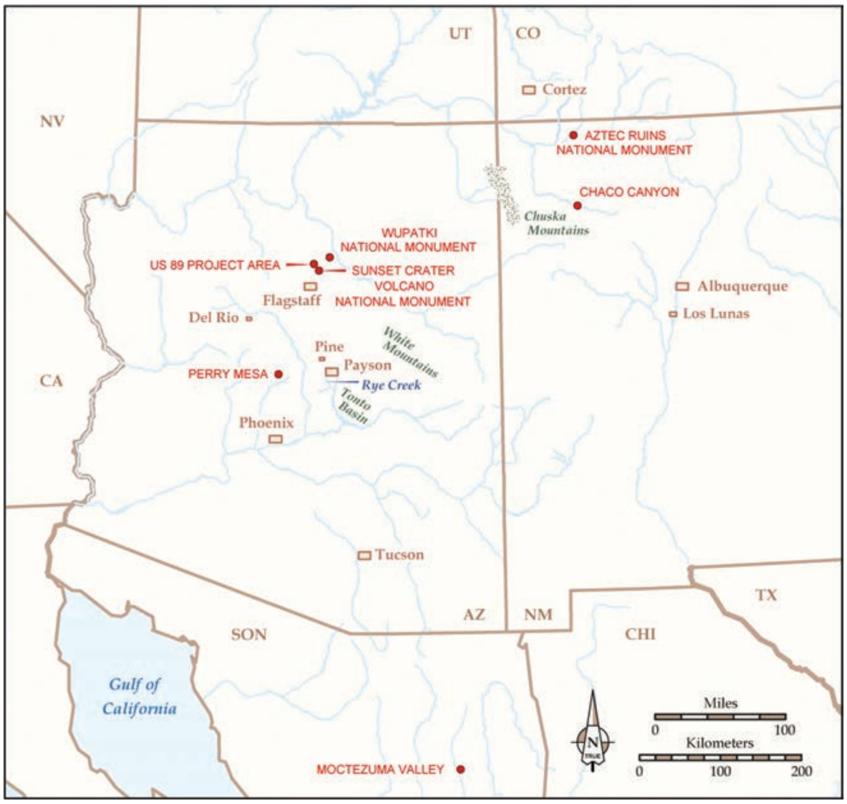


Andrew Ellicott Douglass (1867–1962), the founder of dendrochronology, collecting tree-ring samples in 1946. Douglass, a prominent astronomer, began studying tree rings early in the twentieth century as a proxy record of sunspot activity. He established the principle of crossdating, in which patterns of ring growth from an archaeological wood sample are visually compared and matched to a dated tree-ring sequence, thereby providing a single-year date for the sample. Through the 1910s and 1920s, Douglass worked with southwestern archaeologists to collect archaeological tree-ring samples and develop a tree-ring chronology that helped date sites in relation to each other. Calendrical dating of many sites became possible in 1929, when a famous archaeological specimen, HH-39, bridged an established historical ring series and the archaeological ring series. This achievement had, and continues to have, a profound impact on Southwest archaeology. COURTESY OF THE LABORATORY OF TREE-RING RESEARCH, UNIVERSITY OF ARIZONA

How old is it? When did it happen?

Dating sites and objects remains a primary focus of archaeological research, and scientific dating methods are important tools for understanding cultural interaction and change over time. Archaeologists working in the Southwest have consistently employed radiocarbon dating, and they have taken advantage of a well-developed dendrochronology program at the University of Arizona that uses tree rings for dating.

Other, more recently developed dating methods include potassium-argon dating, which is similar to radiocarbon dating in the use of isotope quantities, although it can be used for much older samples. Thermoluminescence and optically stimulated luminescence date a sample based on the time elapsed since it was exposed to heat or light. Paleomagnetic dating records the alignment of magnetic particles at the time they cooled and stopped moving, and then compares these alignments to past locations of the magnetic pole. In this issue, Mark Elson and Michael Ort (page 5) discuss their pioneering approach, which combines dendrochronology and geochemistry to more accurately date Sunset Crater Volcano's eleventh-century eruption.



Major places mentioned in this issue. MAP: CATHERINE GILMAN

What is it made of?

Science also contributes to the identification of archaeological materials. Several methods play a role in determining what artifacts are made of, including basic binocular microscopy and scanning electron microscopy, which achieves high-magnification images. Mary Ownby and Jenny Adams (page 7) describe how Ownby used imaging and chemistry to determine the material types of some very tiny beads.

Where did it come from? Where was it made?

The ability to ascertain the source of an object and track its movement is perhaps archaeometry's most significant contribution to the study of the past. Knowledge about the source of an object enables archaeologists to reconstruct exchange networks and patterns of social contact. Analysts apply sourcing methods primarily to stone, metal, ceramic, and glass.

Petrographers use a geologic microscope to identify the clay and mineral inclusions in pottery as an important step in studying ceramic exchange. Matthew Pailes (page 8) shares how his use of petrography is illuminating pottery production and distribution in northern Mexico.

Researchers also employ methods that provide chemical data on ceramics and stone, including X-ray fluorescence (XRF), X-ray diffraction (XRD), inductively coupled plasma mass spectrometry (ICP-MS), and neutron activation analysis (NAA). Stacy Ryan and Steven Shackley (page 9) explain how they used XRF to identify the origins of obsidian found at two Tucson Basin sites. Mark Elson (page 11) describes how XRD helped him determine source areas for argillite, a red mudstone used to make ornaments and effigies.

Particular isotopes can also be significant for identifying the provenance of some objects. Through Alyson Marie Thibodeau and colleagues' work with lead and strontium isotopic ratios (page 12), archaeologists will be able to more accurately examine turquoise mining and exchange in the Southwest and Mexico. Linda Cordell (page 14) presents a novel use of strontium isotopes to track the movement of corn into Chaco Canyon.

How have people altered the land? Why did they do that?

Archaeology also benefits from recent advances in remote sensing and satellite imagery technology, which help us locate and map sites. Geophysical methods allow us to examine how a site developed over time and the effects of climate change. Such techniques enhance our understanding of human settlement patterns and impacts on the landscape. Melissa Kruse-Peeples (page 15) shares what soil science methods reveal about past farming on Arizona's Perry Mesa.

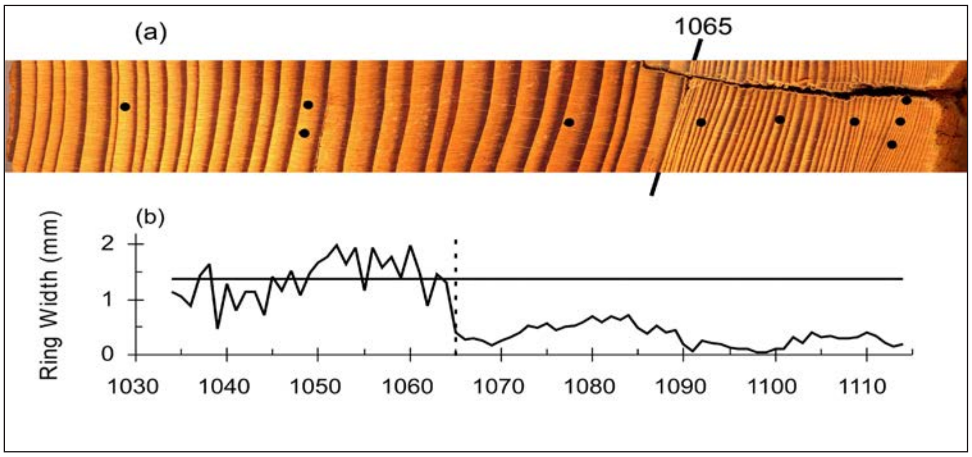
Integration with science has been positive for nearly every aspect of archaeology. Conversely, archaeologists' demands to answer increasingly specific questions have spurred scientific developments. Funding for much of this vital work comes from the National Science Foundation's Archaeology and Archaeometry programs, which recognize the paramount role scientific development plays in archaeological research. Likewise, funding and opportunity come through the field of cultural resource management (CRM), which employs analysts and helps develop these scientific techniques.

When Did It Happen? (Re)Dating the Eruption of Sunset Crater Volcano

MARK D. ELSON, DESERT ARCHAEOLOGY, INC.
MICHAEL H. ORT, NORTHERN ARIZONA UNIVERSITY

In 1997, archaeologists from Desert Archaeology began excavations of forty precontact sites north of Flagstaff. The sites were in the path of road improvements along US 89, and work occurred on behalf of the Arizona Department of Transportation. All of the sites were within fifteen miles of Sunset Crater Volcano, and some were within just four miles (see map on page 4). Excavators found volcanic ash and cinders on the floors of some structures and in outdoor areas where people would have gone about daily activities.

There is no doubt that people witnessed the eruption of Sunset Crater. We have known this since 1930, when archaeologists from the Museum of Northern Arizona (MNA) uncovered a pit structure sealed beneath a thick layer of black cinders. Although that project did not recover directly dateable materials, associated pottery indicated that the eruption had occurred within the past millennium. Its impact on local populations must have been significant—catastrophic, even. But when, exactly, did the eruption happen? And how long did it last?



Sample of beam wood from Wupatki Ruin studied by Terah Smiley (a), and its ring-width series showing abrupt suppression at A.D. 1064–1065, followed by ring complacency (b). COURTESY OF PAUL R. SHEPPARD

Because of the number of sites in the US 89 sample, their varied elevations, and their locations relative to Sunset Crater, Desert Archaeology's work presented an opportunity to revisit the dating of the eruption and quantify its duration. To understand why we began this long-term investigation, which involved close collaboration between archaeologists, volcanologists, and dendrochronologists, it helps to consider previous approaches.

Not long after MNA's discovery, Dr. Harold S. Colton applied archaeological dating methods to sites with and without Sunset Crater cinders, narrowing the eruptive range to the mid- to late-eleventh century. In 1958, University of Arizona dendrochronologist Terah Smiley noted a series of thin and then complacent (or unchanging) tree rings in several beams from Wupatki Pueblo, a precontact village about fifteen miles north of Sunset Crater. Using the thin rings as a marker of volcano-inflicted damage, Smiley proposed a date of A.D. 1064, which accorded fairly well with Colton's estimate. In the 1970s, Duane Champion and Eugene Shoemaker undertook paleomagnetic analysis of Sunset lava flows. Their work suggested that the volcano might have erupted around 1064 and could have remained active for nearly 200 years. Scholarly literature soon reflected general acceptance of this date range, and it formed the basis for archaeological interpretations of Wupatki and Sunset Crater Volcano National Monuments.

Those early attempts to date the eruption were important, because they represented the world's first calendrical dating of prehistoric volcanic activity. Still, we decided to revisit the dating for several reasons. First, the pine and fir trees Smiley dated could not have grown at the elevation at which Wupatki sits, so one cannot be certain where the trees used for the architectural beams originated. Second, of the hundreds of Wupatki specimens Smiley examined, only a few showed the thin-ring/complacency signature. Moreover, since Smiley's work, and despite the dating of hundreds of additional tree-ring samples, no one had ever again observed the unambiguous presence of thin rings at 1064. Finally, no known cinder-cone volcano has been active for as long as 200 years; half of all cinder-cone eruptions cease within three months, and they seldom last more than a year.

Top: Parícutin Volcano in Michoacán, Mexico, is considered a "twin" of Sunset Crater. The volcano's 1943–1952 eruption is one of the longest cinder-cone eruptions on record. This photograph was taken early in the eruptive period, when the cinder cone was still forming. COURTESY OF U.S. GEOLOGICAL SURVEY
Left: Volcanologist Michael Ort coring a tree at Parícutin Volcano, with Mark Elson looking on. PHOTO: WENDELL DUFFIELD

Although we suspected that the 1064 date was inaccurate, we knew it would take several lines of evidence to convince the scientific community, and ourselves, that our suspicions were true. Our multidisciplinary team followed four avenues of inquiry: paleomagnetic analysis, comparative analysis of chemicals in eruption-affected trees, strontium isotope analysis, and dendrochronological analysis.

First, we recovered additional paleomagnetic samples from Sunset Crater lava flows and combined these data with the previous collection by Champion and Shoemaker. This enabled us to bracket the eruption between 1040 and 1100 and rule out the possibility that it lasted 200 years.

We then traveled to Parícutin Volcano, south of Guadalajara, Mexico, where we sampled four trees that had lived through an unusually long cinder-cone eruption (1943–1952). We reasoned that evidence of elevated levels of specific chemicals might provide clues as to which chemicals to look for in samples of trees that had lived through the Sunset Crater eruption. We found elevated levels of phosphorus and sulfur in the Parícutin eruption period. When we applied the same method to several Wupatki-area trees, we found elevated phosphorus in the mid-1080s, but not at 1064.

Next, we used strontium isotopes to assess whether isotope ratios had changed. In this case, we reasoned that volcanic cinders might have provided a different source of strontium for the trees, one that we might identify by its strontium-isotopic "fingerprint." Again, several of our samples showed a change in strontium ratios around 1085, but not at 1064. Only the arrival of a new strontium source could cause such a difference.

Finally, reexamination of about forty tree-ring samples from the Wupatki area and from higher elevations closer to Sunset Crater supported an eruption date in the mid-1080s. Indications of tree-ring narrowing were most prevalent in the mid-1080s, particularly among samples recovered from areas closer to the crater, where volcano-related damage should be more apparent. Moreover, although the 1064 ring narrowing was present in a few of our samples, we did not find the robust pattern that Smiley had seen among his samples. The 1060s narrowing we observed might have resulted from local environmental conditions, rather than the eruption.

To date, then, we have found multiple lines of evidence that suggest Sunset Crater erupted in the mid-1080s, and we think the eruption lasted less than a year. Although our sample sizes for each method are small, taken together, they strongly support this new date. Revising the dating of the eruption has important implications for reconstructing the precontact history of the northern Southwest. For one, adapting to a long-term periodic event is very different than adapting to a single event of limited duration. For another, a mid-1080s eruption shortens the period between the eruption and the occupation of the lower elevations north and south of Sunset Crater, supporting our hypothesis that these areas were settled largely by volcano refugees and not by outside migrants, as previous models have proposed. We are pursuing additional funding to increase our sample size and definitively date the Sunset Crater eruption.

What Is It Made Of?
Scanning Electronic Microscopy of Minuscule Beads

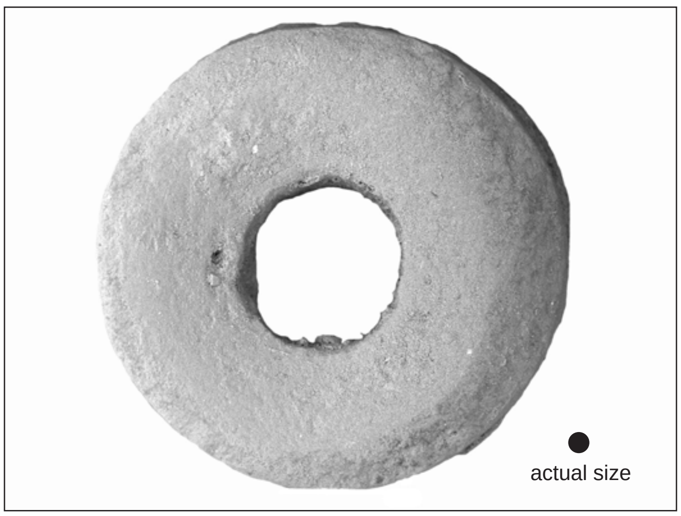
MARY F. OWNBY, DESERT ARCHAEOLOGY, INC.
JENNY L. ADAMS, DESERT ARCHAEOLOGY, INC.

A unique analytical challenge arose from the discovery of more than 6,000 tiny beads in a Late Rincon phase (A.D. 1100–1150) Hohokam burial within the Santa Cruz River floodplain of the Tucson Basin. Probably originally part of a garment, the beads were almost as small as the proverbial head of a pin—on average, about two millimeters from outside edge to outside edge. We could see that some were turquoise or mudstone and some appeared to be clay, but we could not easily distinguish others with the naked eye or a binocular microscope. What were these beads made of? How many were clay, and how many were stone?

There are several well-established techniques for determining material type. Because the collection was associated with human remains, however, we were required to find a nondestructive means of identification. Scanning electron microscopy (SEM) enabled viewing of the beads at very high magnifications, and it provided data on the chemistry of the materials used to make the beads. For analysis, we selected twenty beads representing the range of colors and shapes observed through a binocular microscope.

The high-magnification images captured through SEM facilitated identification of technological features related to bead manufacture, which, by extension, helped us determine material types. Subtle chemical differences between stone and clay detected through SEM supported these identifications. Together, data showed that half of the SEM analyzed beads were clay and half were stone. We then used these results to characterize the rest of the bead assemblage, and found that 5,712 beads were clay and 715 were stone.

Clearly, it was important to the people who made the beads that they look alike, even if they were made of different materials. Because the manufacture of stone beads required considerable effort, the artisans supplemented stone beads with clay beads produced through a more efficient method.



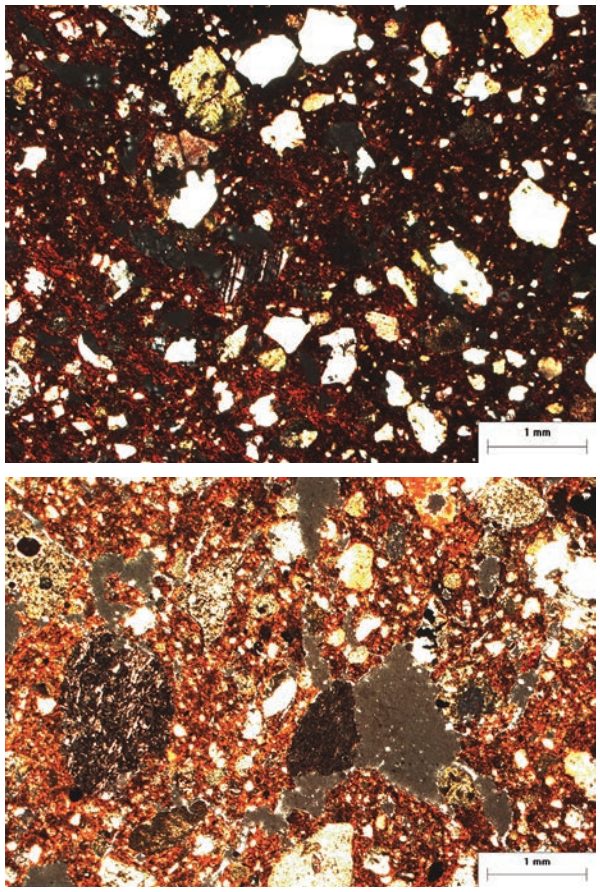
Left: Clay bead viewed through a scanning electron microscope, magnified 32x. Note the beveled exterior edge and the irregular hole, which are both features of manufacture. The clay is more consistently fine-grained, but the surface topography is rougher than the stone bead. Actual size is 2.8 mm in diameter and 1.0 mm thick, as shown in the lower right corner of the image.
Right: Stone bead viewed through a scanning electron microscope, magnified 32x. Note the sharp exterior edge, as well as the circular abrasions in the hole, all of which are features of manufacture. The stone is more granular with mineral inclusions, but the surface topography is smoother than the clay bead. Actual size is 3.7 mm in diameter and 1.5 mm thick, as shown in the lower right corner of the image.

Where Was It Made? Using Petrography to Reconstruct Trade in Eastern Sonora

MATTHEW PAILES, UNIVERSITY OF ARIZONA

Connections between precontact Mesoamerica and the regions now known as Northwest Mexico and the American Southwest are of great interest to archaeologists working on both sides of the border. My research in the Moctezuma valley of eastern Sonora (see map on page 4) aims to understand how the valley's settlements were organized and to what extent this and neighboring valleys might have acted as conduits between Mesoamerica and the Southwest. One aspect of this work examines trade networks in the valley through pottery recovered on archaeological surveys. Where were certain kinds of pottery made? Where did they end up? Who was interacting with whom—and what does that mean?

One way to determine where pottery was made, or its provenance, is to look at the rocks and minerals mixed into the clay. Through petrography, a technique developed for geologic samples, analysts can identify materials or describe their properties using a special microscope. In ceramic petrography, the analyst slices a pottery sherd three times thinner than a piece of paper and places it on a slide, creating a thin section, which is then examined with a petrographic microscope. Analysts then compare their observations with geologic maps of the study area and samples collected from possible source areas—places where potters might have collected the materials they mixed into the clay. The technique works best for studying pots traded within a single river valley or in areas with high geologic diversity, where it is easier to identify distinct source areas.



Views of petrographic thin sections of Moctezuma valley pottery sherds. On the top, pottery with granitic inclusions; on the bottom, pottery with mafic inclusions. Scale is 1 mm.
COURTESY OF MATTHEW PAILES

Most of the Moctezuma valley's hills are volcanic, made of light-colored lava rocks, such as tuff and rhyolite, with an occasional dark outcrop of basalt. Fortunately—at least for my research—within this volcanic landscape lies an island of granite, a very different rock made of large blocky crystals. As the granite eroded, the resulting sand washed down the mountains, accumulating next to just a few of the village sites I am studying. Because potters usually collected raw materials from nearby sources, it is likely that most of the vessels containing granite sands were made in these villages.

Petrographic analysis of surface pottery collected at twenty-five valley sites indicated that most of the plain brown pottery bears sands from the granite area. This, in turn, suggests that people living near the granite-sand sources exchanged or gifted brown ware pots up and down the valley. For example, around twenty-five percent of the pottery found at a large site about twenty miles north of the granite source contains granite sand. Because there is also good evidence that most villages made their own pots, it is notable that people so intensively traded pots with granite sand.

When I compared pottery from different houses within a single village, however, I found evidence that each household obtained pots in its own way. Some households used local vessels almost exclusively, but others received most of their pots from villages near the granite area. This suggests to me that families traded and gifted independently, rather than participating in a regular exchange system, such as a market.

Although there is more work to do, my data show that, in general, Moctezuma valley sites occur in small clusters. Evidence of large-scale political organization is lacking. As such, it makes sense that individual families might have found their own trading partners.

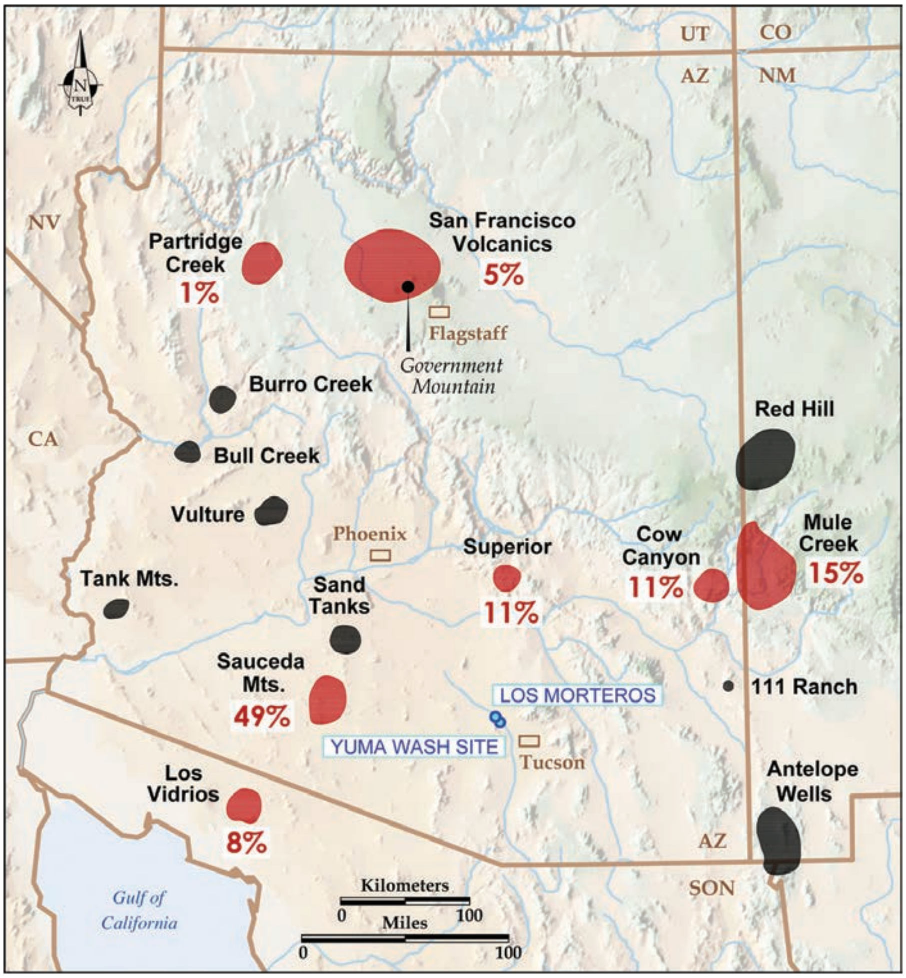
Where Did It Come From? Source Analysis of Obsidian Found at the Yuma Wash Site

STACY L. RYAN, DESERT ARCHAEOLOGY, INC.
M. STEVEN SHACKLEY, UNIVERSITY OF CALIFORNIA, BERKELEY

For centuries, across the Southwest, people used and traded obsidian, a volcanic glass with excellent tool-making properties. In 2008, Desert Archaeology recovered a sizable collection of obsidian artifacts from the Yuma Wash site, a large Hohokam village northwest of Tucson. The Town of Marana sponsored excavations at the site, which dates primarily to the Classic period (A.D. 1150–1450).

Because obsidian comes from specific sources, none of which is in the Tucson Basin, we knew the material must have originated somewhere else. But where exactly? How did people living at the site procure this obsidian, and in what form? Did those patterns change over time? What might those patterns reveal about social networks?

X-ray fluorescence spectrometry (XRF) has been helping southwestern archaeologists identify the provenance, or origin, of certain kinds of artifacts, particularly those made of obsidian, since the 1970s. Energy-dispersive XRF (EDXRF) is the best and most commonly used nondestructive technique for analyzing stone artifacts. After primary X-rays excite the electrons in a sample, secondary X-rays (fluorescence) are emitted. Through those emissions, analysts are able to determine which chemical elements are present and in what amounts, which, in turn, enables differentiation of source areas. Over time, researchers have developed a comprehensive database of archaeological obsidian sources in the region.



Map of known regional obsidian sources. The origins of the 89 artifacts in the analyzed Yuma Wash sample are indicated in red; for example, 49 percent of the sample found at Yuma Wash was sourced to the Sauceda Mountains. Obsidian points from two early Classic period cremations at Los Morteros, located just a few miles north of Yuma Wash, were mostly from the Superior source. MAP: CATHERINE GILMAN

By analyzing the Yuma Wash obsidian with EDXRF, we were able to determine its origins. We supplemented a sample of projectile points and flaked stone from the 2008 excavations with obsidian artifacts recovered during Old Pueblo Archaeology Center's earlier work at the site. Analysis showed that, together, the artifacts represented seven different reliably identified obsidian sources.

Distinct patterns provide clues about ties beyond the community. Nearly half of the sample originated in the Sauceda Mountains and arrived at Yuma Wash as raw material for making stone tools. The site's residents may have acquired this obsidian through exchange with people living to the west, and it may have circulated along with other trade goods from that region. In contrast, material from the Cow Canyon and Mule Creek sources may have come to Yuma Wash as finished arrow points. The points made of Cow Canyon obsidian are stylistically similar, and archaeologists recovered almost all of them in one cemetery area, suggesting that people interred there had relationships with groups to the east.

Interesting changes in distribution occurred over time. Areas of the site that were inhabited in the later part

A Late Classic Side-notched point found at Yuma Wash. The point is made of obsidian from the Sauceda source. PHOTO: STACY RYAN

of the Classic period, after A.D. 1300, yielded greater amounts of obsidian. Many of the projectile points from the site that are markers of this later time are obsidian, as well. When we analyzed those points, we found that the obsidian came from five of the seven sources represented by the total site sample. Moreover, it is in late Classic times that Yuma Wash residents appear to have acquired most of the material from the distant Government Mountain and Los Vidrios sources. The community must have maintained exchange networks well beyond the Tucson Basin at this time, ensuring access to obsidian from a wide variety of sources. Our findings are consistent with observations by others studying obsidian distribution in the late Classic period.

Portable XRF Analysis of a Special Collection from Los Morteros

To learn more about Classic period obsidian distribution in the Tucson Basin, we recently examined a collection of projectile points currently housed at the Arizona State Museum (ASM). Desert Archaeology recovered these obsidian points from two early Classic period cremations at the Los Morteros site in the late 1980s.

Because the projectile points had been associated with human remains, we could not remove them from ASM. Instead, we undertook analyses at ASM using a Bruker portable XRF spectrometer. When properly calibrated for precision and accuracy, this handheld device returns reliable results nondestructively. Funded by a National Science Foundation award (NSF Grant No. 0827011) to Archaeology Southwest, we analyzed fifty projectile points.

A portable XRF spectrometer.

The results surprised us. Forty-three (eighty-six percent) of the points were made of obsidian from Picketpost Mountain in Superior, Arizona—a stark contrast to the variety of sources identified in the Yuma Wash sample. Although Superior is the closest source, it usually is not predominant in Classic period assemblages from the Tucson Basin. Did a few people collect obsidian directly from the source and produce these points? Did Los Morteros residents acquire the points through exchange with groups in the Superior area? We do not have answers at present. Even so, we were fortunate to obtain these data through this portable analytical technology while the artifacts were still available for study. *Stacy L. Ryan and M. Steven Shackley.*

ONLINE EXCLUSIVES

Essays by M. Steven Shackley and Mary F. Ownby on the proper use of portable XRF spectrometry for analyzing obsidian and ceramics, respectively, are available at: www.archaeologysouthwest.org/asw26-2.

Where Did It Come From? Using X-ray Diffraction to Track Argillite Sources and Artifacts

MARK D. ELSON, DESERT ARCHAEOLOGY, INC.

Argillite is a soft, usually reddish mudstone or claystone that is also known as pipestone. The soft stone is easy to carve, and argillite objects are found throughout the world. In the Southwest, archaeologists find them in residential and mortuary contexts. Argillite artifacts are most abundant in northern Arizona.

In the late 1930s, Katharine Bartlett of the Museum of Northern Arizona documented an argillite source near the town of Del Rio, north of Prescott, Arizona (see map on page 4). In one of the first mineral characterization studies in the Southwest, Bartlett used atomic absorption spectroscopy to match argillite artifacts from precontact sites in central and northern Arizona to argillite "mines" at Del Rio.

My interest in argillite stems from Desert Archaeology's 1989 Rye Creek Project, where we excavated thirteen precontact sites just south of Payson, Arizona. During the excavations, we encountered several sites containing hundreds of argillite artifacts in many forms, as well as raw material and flakes indicating that artisans had created argillite objects there. It turned out that an argillite source area lies within the project area, on the terraces above Deer Creek, a tributary of Rye Creek. Where might other sources be? Among argillite artifacts recovered across Arizona, how well were various known and unknown sources represented? Did any source predominate?

To begin to answer these questions, I collaborated with the late James Gundersen of Wichita State University, who had extensively studied Midwest pipestone. We used X-ray diffraction (XRD) analysis to characterize 714 potential source area samples, including some from the Deer Creek source, and 179 artifacts. Most of the artifacts (131) were from the Rye Creek Project. The others came from ten sites in central, southern, and eastern Arizona, and I chose them because they were readily available for analysis. Because XRD enables analysts to determine a unique mineralogical fingerprint, we were able to pin almost all the artifacts in our sample (95%) to four sources: the Del Rio and Deer Creek sources, a source north of Payson near the town of Pine, and a source west of Tucson. We identified five additional distinct sources that have not yet been located on the ground.

Top: A whole argillite, shell, and turquoise necklace recovered from the entrance of a pithouse at Eagle Ridge, a Sedentary period site in the Tonto Basin. The beads at the top are steatite (left two) and argillite (right two). COURTESY OF DESERT ARCHAEOLOGY, INC.
Bottom: Argillite-turquoise artifact, perhaps a representation of a rattlesnake rattle, recovered from the floor of a platform mound room at the Pyramid Point site. COURTESY OF DESERT ARCHAEOLOGY, INC.

Significantly, our analysis showed that the locations of the argillite artifacts did not follow a simple fall-off distribution curve, with proximity to the source correlated with frequency of occurrence. This is what we would expect if source area access was unrestricted and if source areas were equivalent in value and desirability. Instead, artifacts from Del Rio occurred throughout Arizona, including at sites in the Tucson and Phoenix Basins, the Flagstaff area, and the White Mountains. Artifacts from other sources tended to be locally distributed.

This preliminary study raised questions requiring further investigation. Did people prefer Del Rio argillite? Did it move through a more efficient distribution network? Our study provides a foundation for addressing these topics.

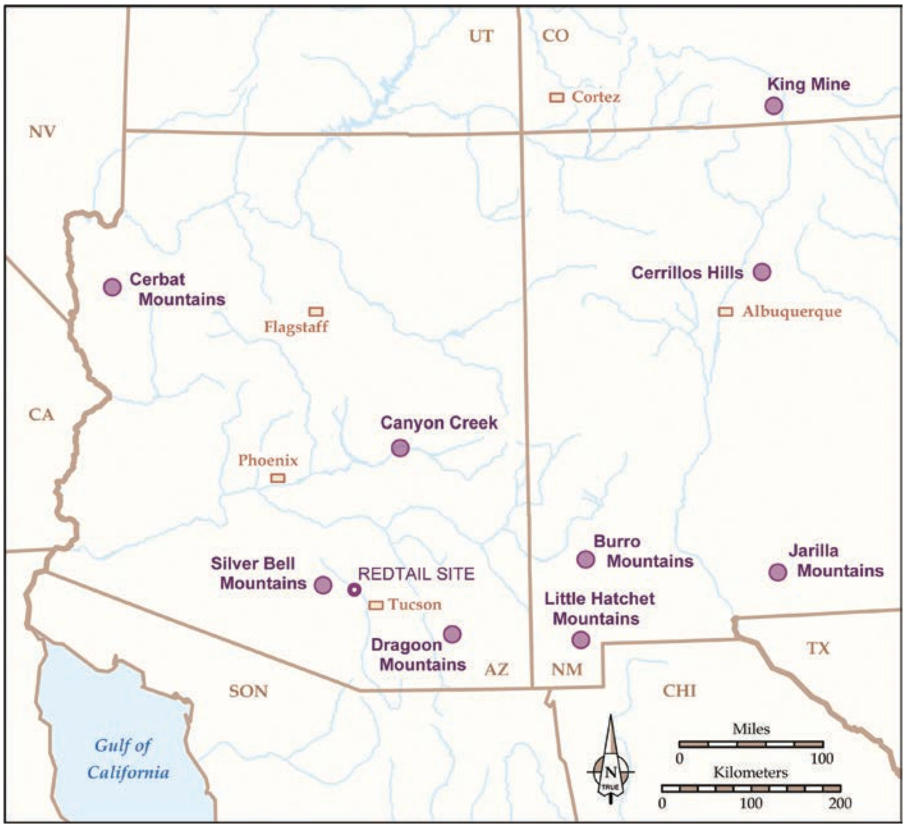
Where Did It Come From? A New Method for Learning about Ancient Turquoise Mining and Trade

ALYSON MARIE THIBODEAU, UNIVERSITY OF ARIZONA

Turquoise was highly valued, intensively mined, and widely exchanged by precontact societies in the American Southwest and Mexico. Researchers have documented ancient turquoise mining in Arizona, New Mexico, Nevada, California, and Colorado, and in the Mexican states of Sonora and Zacatecas. Because turquoise artifacts appear in archaeological sites distant from known mines, we can infer that people may have exchanged turquoise down the line or transported it across long distances, or both. Due to little evidence of turquoise mining in Mesoamerica, some archaeologists speculate that Mesoamerican groups may have acquired turquoise through trade with southwestern peoples.

Where did any given piece of archaeological turquoise originate? In most cases, the sources of archaeological turquoise remain unknown, greatly limiting our knowledge of its acquisition and exchange. From the 1970s through the 1990s, many studies attempted to trace the sources of turquoise artifacts by measuring the concentrations of certain trace and major elements in archaeological and geological samples of turquoise. It was hoped that measurements of elemental concentrations would make it possible to "match" turquoise artifacts to the source from which they came. Turquoise can vary greatly in its chemical composition within a single deposit or mine, however, and it is often closely associated with a variety of mineral impurities. This variability, and the common presence of impurities, has confounded efforts to use elemental concentrations to trace turquoise. If we could determine a method for identifying the sources of turquoise artifacts that works with—or despite—these characteristics, what might we learn about patterns of exchange and social interaction in and beyond the ancient Southwest?

Together with my colleagues at the University of Arizona, I am working to trace the source of turquoise artifacts using a different approach. This approach utilizes two geochemical tracers, called lead and strontium isotopes, to differentiate turquoise from different deposits and link turquoise artifacts to their source. For a variety of geological reasons, lead and strontium isotopic ratios are not significantly affected by variations in elemental concentrations or by the presence of most impurities in turquoise. This makes them ideal tracers for the mineral, and eliminates many of the problems encountered by previous researchers. At the University of Arizona, we are measuring strontium isotopes with thermal ionization mass spectrometry (TIMS), and lead isotopes with multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS).



Turquoise found at the Redtail site originated in the Silver Bell Mountains. Other known sources in the region are marked. MAP: CATHERINE GILMAN

In a recent case study, I was able to test the efficacy of these methods by identifying the source of turquoise artifacts excavated from the Redtail (Coachline) site, a medium-sized village located in the northern Tucson Basin and inhabited between

Left: *View of Ragged Top Mountain, Silver Bell Mountains in the Ironwood Forest National Monument.*
Bottom: Turquoise recovered from pithouses (except as noted) at the Redtail site, except as noted. Clockwise from upper left: chunk of turquoise found on the site surface (FN 1839); three views of a bead preform (FN 266); two views of a finished bead (FN 3345A); two views of a pendant (FN 3709); two tesserae (small, FN 444; medium, FN 4020); a finished oblong pendant or bead (FN 4063); two views of a faceted rectangular pendant (FN 4079); two views of a large bead in progress, made of very low grade material (FN 513). COURTESY OF ARIZONA STATE MUSEUM, ACCESSION NO. AP-2007-46, UNIVERSITY OF ARIZONA. PHOTO: ROB CIACCIO

A.D. 750 and 850. More than 3,000 fragments of turquoise were recovered at Redtail, most of it in raw form or as debris related to the manufacture of turquoise objects. Moreover, archaeologists working at the site in the 1980s identified artisans' workshops. I analyzed a total of seventeen samples of turquoise from Redtail. For comparison, I also analyzed ten turquoise artifacts from Scorpion Village, a small Hohokam site located near ancient turquoise mines in the Silver Bell Mountains and inhabited at the same time as the Redtail site. Because the Silver Bells are not far from Redtail, archaeologists Arthur Vokes and David Gregory have hypothesized that the turquoise at Redtail was mined there.

The results of my analyses support their hypothesis; the lead and strontium isotopic ratios of turquoise from the Redtail site closely match those of turquoise from Scorpion Village. From a geochemical perspective, we can conclude that the turquoise at the Redtail site probably did originate in the Silver Bell Mountains. Future analyses of archaeological samples should be able to reveal the extent to which turquoise from the Silver Bell Mountains circulated across the Southwest. Lead and strontium isotopes are thus providing quantitative information about the source of turquoise artifacts, and offering a new opportunity to address big-picture questions about turquoise acquisition and exchange in the Southwest and beyond.

This study is described in detail in the forthcoming paper: Thibodeau, A. M., J. T. Chesley, J. Ruiz, D. J. Killick, and A. Vokes. An Alternative Approach to the Prehispanic Turquoise Trade. In Turquoise in Mexico and North America: Science, Conservation, Culture, and Collections, *edited by J. C. H. King, C. R. Cartwright, R. Stacey, C. McEwan, and M. Carocci. Archetype, London.*

Food for Thought...

Prehistoric? Precontact? Prehispanic?

As a result of changes in anthropological thinking that reflect a deepening awareness of diverse viewpoints, archaeologists working in the Southwest are moving away from use of the term "prehistoric." The term has generally referred to "the time before written records." Some Native American groups and other indigenous peoples have pointed out that using this term for the time in which their ancestors lived implies that they do not have history, when, in fact, their histories have been transmitted orally, rather than in writing. Some scholars favor the term "prehispanic," meaning "the time before the Spaniards arrived." When it is appropriate to do so, *Archaeology Southwest Magazine* has decided to use the term "precontact," meaning "before contact with Europeans, before Europeans arrived."

Where Was It Grown? Biogeochemical Markers and Chaco's Corn

LINDA S. CORDELL, UNIVERSITY OF COLORADO BOULDER & SCHOOL FOR ADVANCED RESEARCH

During the eleventh and twelfth centuries, fourteen multistory great houses and dozens of small villages stood along a ten-mile-long stretch of Chaco Wash. Archaeologists have recovered maize, or corn, from these sites, and it must have been a staple food there, as it was for Native Americans throughout the Southwest.

Researchers have long debated how the barren environment of Chaco Canyon could have supplied enough food for the builders of these structures. Today, the climate is marginal for corn. The length of the growing season and amount of available moisture are unpredictable, often falling below what would ensure a successful crop. Paleoenvironmental studies suggest eleventh-century Chaco was not much different than today. Did the ancestral Pueblo peoples of Chaco Canyon actually grow corn there, or was it imported?

A plot of Tohono O'odham 60-day corn (not one of the gardens in this study). COURTESY OF NATIVE SEEDS/SEARCH

To address these questions, my colleagues and I turned to methods used in biogeochemical prospecting. The methods rely on identification of mineral elements drawn into a plant's tissue through its roots. These elements reflect the sediments in which the plant grew. Most applications use trees, because their deep roots carry a signature of the underlying bedrock. A team of geologists and archaeologists has employed this technique to show that trees used in Chacoan buildings came from forests up to forty-five miles away. In contrast, corn is an annual plant with shallow roots. For our research, we first had to determine whether we could differentiate chemical signatures of different gardens and of varieties of corn grown in them.

We took soil and corn samples from experimental gardens in three locations: Chaco Canyon, Crow Canyon Archaeological Research Center near Cortez, Colorado, and New Mexico State University Agricultural Science Center near Los Lunas (see map on page 4). The Crow Canyon garden sat near the postulated northern extent of the Chaco system. We experimented with Hopi Blue corn and Tohono O'odham 60-day corn. Using inductively coupled plasma mass spectrometry (ICP-MS), we analyzed fifty paired samples of corn and soils. We tested nineteen elements, four of which differentiated both the corn and soil samples. This experiment paved the way for testing archaeological corn.

We then analyzed seven ancient corncobs from Pueblo Bonito, Chaco's most famous great house. We also analyzed nine excavated corncobs from Aztec Ruins, a large Chacoan site on the Animas River (see map on page 4). To avoid contamination, we selected only unburned cobs that were less likely to have absorbed minerals from the ground in which they were buried. We collected soil and stream-water samples from several potential field areas in Chaco Canyon, from Aztec Ruins' environs, and from the Chuska slope, where Chaco residents obtained timber and chert. After cleaning and processing, we used ICP-MS to analyze chemical elements from these samples. We also analyzed samples for two isotopes of strontium, ^{87}Sr and ^{86}Sr. Finally, we obtained radiocarbon dates for the seven corncobs from Pueblo Bonito.

We learned that six of the cobs from Pueblo Bonito had grown outside Chaco Canyon, either along the Chuska slope or further upstream from the canyon on the Chaco Wash. One cob from Pueblo Bonito had grown far to the north, near Aztec Ruins. Archaeologists found five of these cobs together in one room in Pueblo Bonito; their radiocarbon ages range from A.D. 879 to 1170. The cob matching soil samples from near Aztec Ruins came from a different room in Pueblo Bonito, and that cob dates to 1010. All of these cobs are larger than most ancient corn from Chaco Canyon, and, being unburned, they differ from most corn recovered by archaeologists.

We propose that people likely imported some corn to Chaco, but we also think the analyzed corn was not ordinary food.

People may have brought this corn to Chaco Canyon as a physical link to particular, perhaps ancestral, locations. It might be of a much different variety than what Chacoans usually ate, or perhaps it grew in irrigated and well-tended fields. Other analyses—of the DNA of the ancient maize, for example—could help resolve these questions. Although our present sample sizes are small and more work needs to be done, our methods show great promise.

Why Did They Do That? Soil Science and Ancient Agriculture on Perry Mesa

MELISSA KRUSE-PEEPLES, ARIZONA STATE UNIVERSITY & NATIVE SEEDS/SEARCH

Between about A.D. 1275 and 1450, a few thousand people lived in the Perry Mesa area of central Arizona, where they resided in masonry pueblos ranging from a dozen to more than 100 rooms. Because the dramatic, canyon-incised terrain made irrigation and floodwater farming impractical, these communities practiced dry farming on the upland mesa tops, growing maize, squash, beans, and agave, as well as small amounts of little barley. How did Perry Mesa's farmers grow enough, or at least some, food to support such a large population?

We know these farmers built extensive rock alignments, or terraces, perpendicular to gentle hillslopes. Usually one or two stones high, these terraces maximized water resources, built up soil, and minimized erosion. They also slowed the surface flow of water and sediment that would have crossed these slopes during intense rains. This, in turn, allowed water to percolate into the soil and deposited organic debris and sediments above the rock features. Did these terraces effectively increase agricultural productivity?

In my research, the soil itself is an artifact of human activity. By applying methods from soil science, I have been able to characterize the productivity of these terraced agricultural fields and assess the impact of ancient farming on soils. To do this, I compared data from terraced fields with data from uncultivated areas in similar environmental settings. With the help of student volunteers, I excavated trenches that enabled me to document soil profiles in each setting. We also installed a series of experimental flumes along hillslopes. The flumes collected water, sediments, and debris mobilized by intense rainstorms over the course of two years. Runoff collected in these flumes approximated the types of surface flows that occurred in the distant past.

I evaluated the physical and chemical properties of each set of soils. Compared to unmodified areas, agricultural terraces have thinner profiles and coarser surface soil texture. My soil collections indicate that this results from preferential removal of clay and silt particles during runoff events. Terraces experience more frequent runoff with greater sediment transport. Moreover, the elevated position of the rocks relative to the present position of the soil implies that the terrace surfaces were much higher at one time. After people left the area, the terraces experienced small-scale erosion, rather than deposition.

Agricultural stone terraces on Perry Mesa. PHOTO: MELISSA KRUSE-PEEPLES

When I analyzed surface runoff from the experimental flume system, I found that it was rich in nutrients and organic material. As such, runoff helped renew the soil with nutrients. Simulations of soil fertility under maize cultivation suggest that Perry Mesa soils were only marginally fertile, and supplemental nutrients obtained as a result of terracing would have been essential for long-term agricultural productivity.

Perry Mesa's ancient farmers knew how to improve their soil. Without these field systems, it might not have been possible for so many people to inhabit Perry Mesa.

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back sight

At Archaeology Southwest, Preservation Archaeology entails a commitment to the pursuit of big-picture research questions. I find it intriguing that the scientific techniques highlighted in this issue illustrate the importance of "the small" on the road to "the big." We cannot see a strontium isotope. We need a special microscope to examine the temper inclusions in pottery. We cannot measure or even perceive so many of the details relevant to the big picture without these highly specialized tools and techniques.

Reading about these remarkable tools leads me to two observations. First, the tools and the information they generate are not ends in themselves. For example, counting strontium isotopes does not produce an answer to an important archaeological question on its own. That count becomes data. An archaeologist must put those data into an interpretive context that addresses the kinds of basic questions that Ownby and Elson identify in their introductory article. The archaeologist must work closely with one or more specialists trained in a different discipline. Together, they must ensure that they communicate across the boundaries of their home disciplines. So, although the road from the small to the big is not an easy one, the potential payoff in new insights justifies the effort to make that journey.

Archaeology Southwest uses archaeometry methods to explore population movement between A.D. 1250 and 1450. For example, ceramic petrography and Instrumental Neutron Activation Analysis help us establish where potters were making Salado polychrome pottery. Kayenta immigrants from the northern Southwest produced this pottery in their new communities across the southern Southwest. Many of the ceramics we study are in museum collections. This Tonto Polychrome vessel at Eastern Arizona College represents a late Salado polychrome type. PHOTO: MAT DEVITT

My second observation is that these scientific tools are often essential to the practice of Preservation Archaeology. Preservation archaeologists seek to optimize what remains for future exploration and discovery. That means leaving as much of the archaeological record intact and in place as is feasible. The availability of a battery of ever-developing scientific techniques often means that the archaeologist who does consume the resource through excavation can get by with a smaller sample. Or, in many cases, it means that collections already in museums may be tapped, making new excavations unnecessary.

In summary, scientific techniques can expand the information that archaeologists may derive from the archaeological record, while also conserving that record. These dual aspects of present and future scientific techniques underscore their importance to Preservation Archaeology.

William H. Doelle

back sight (băk sīt)
n. 1. a reading used by surveyors to check the accuracy of their work. 2. an opportunity to reflect on and evaluate Archaeology Southwest's mission.