PERMIAN QUARTERLY

Permian Basin Programmatic Agreement Quarterly Newsletter

Volume 2, Number 2, June 2014 - Bureau of Land Management, Carlsbad Field Office
New Mexico

This view of a rock ring midden shows its characteristic "doughnut" shape. Read more about rock ring middens and an aerial survey for these types of sites inside this newsletter.

The *Permian Quarterly* is a newsletter for participants in the Permian Basin Programmatic Agreement (PA) and for other interested persons. Its purpose is to provide information in a timely manner about implementation of the PA and to disseminate that information to a wide audience.

Introduction to the Permian Basin Programmatic Agreement

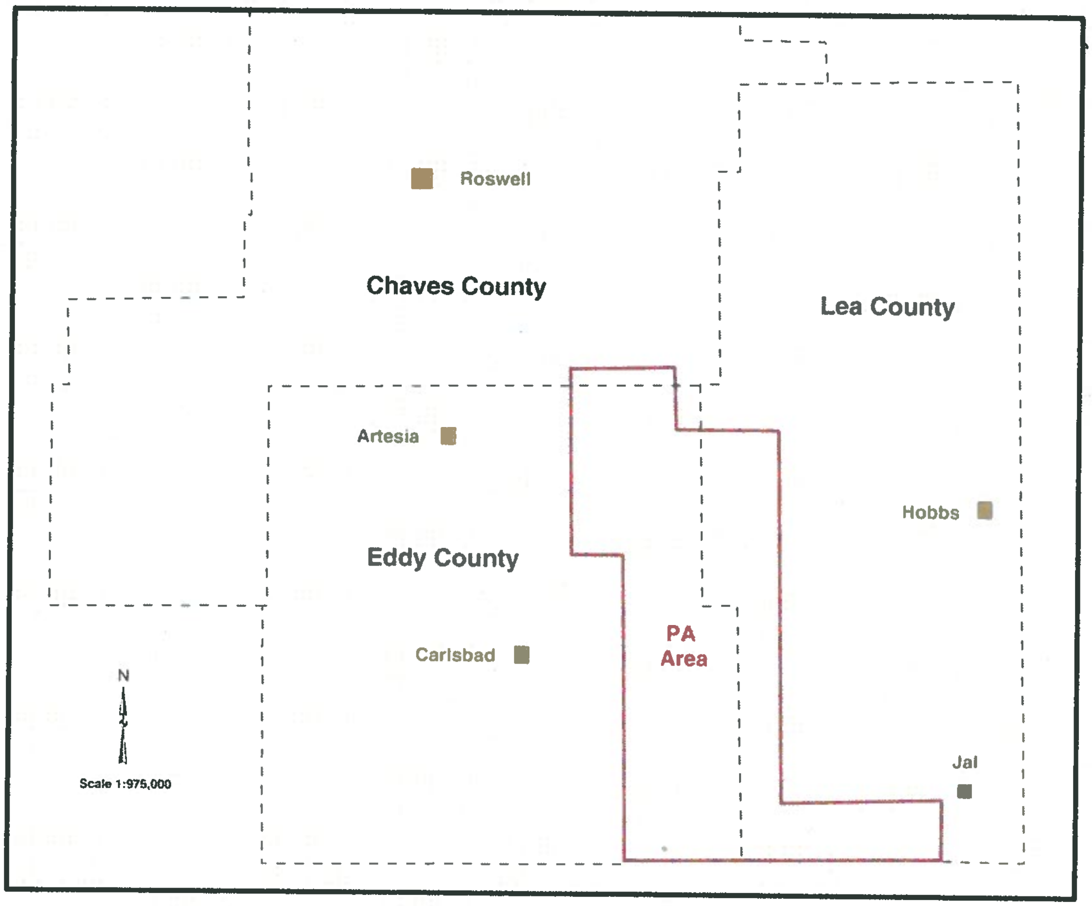


Figure 1. Map showing the Permian Basin PA Area.

The PA is an alternate form of compliance with Section 106 of the National Historic Preservation Act of 1966, as amended, that is offered to the oil and gas industry, potash mining companies, and local governments in southeastern New Mexico for federal projects located on Bureau of Land Management (BLM) land or private property. Formerly called the Permian Basin MOA, it was extended for a period of three years in April 2013 as a Programmatic Agreement. The PA area, noted above in red, is located partially in Chaves, Eddy, and Lea counties and generally coincides with a physiographic region in southeastern New Mexico called the Mescalero Plain. Proponents of projects within the PA area may contribute to a dedicated archeological research fund in lieu of contracting for project specific archeological surveys, provided their proposed projects avoid recorded archeological sites. This dedicated fund is then used to study the archeology and history of southeastern New Mexico.

Current PA News

Research Update

Approximately the western one-fourth of the Carlsbad Field Office (CFO) is comprised of the foothills of the Guadalupe Mountains in Eddy County and the Sacramento Mountains in Chaves County. This region, generally corresponding to the Sacramento Section as defined in the Southeastern New Mexico Regional Research Design, is dramatically different from the Permian Basin Programmatic Agreement (PA) area in geology, topography, elevation above sea level and in the composition of its flora (Hogan, et.al. 2006). This region is one of rugged topography with many canyons and draws ranging from approximately 3200 feet (975 m) to approximately 6500 feet (1981 m) above mean sea level. Limestone and dolomite bedrock covered with a thin topsoil support a variety of plants, notably stands of sotol and agave that were important food sources in historic and prehistoric times.

Figure 2. *Agave neomexicana* or mescal plant.

The most common and prominent site type within this region is the rock ring midden (see newsletter cover). Rock rings are also referred to as mescal pits, midden circles or midden rings (Applegarth 1976:153), as well as ring middens, annular thermal features, agave roasters (Wiseman 2006), and communal baking facilities (Wiseman 2007). Some site forms refer to these features as roasting pits. As some of the names imply these features were created by cooking plant or animal foods, in particular, crowns from succulent plants such as agave. Historic accounts of baking various species of sotol or agave describe digging large shallow pits, which were then lined with large flat stones. A fire heated the rocks and after the fire died down a moist grass layer was added, then the agave or other plants to be baked were placed on the grass. The plants were then covered with more grass and finally sealed with a layer of earth to prevent heat from escaping. The baking plants were left for an extended period of time and then removed for further processing (Katz and Katz 1985:40-43). Historic or ethnographic accounts most often mention cooking agave ("mescal") or sotol, but cattails and banana yucca plants were also baked (Applegarth 1976:158). Small pieces of animal bone (jack rabbit and cottontail rabbit have been identified), and fresh water mussel shell fragments have been found within the rocks of some rings, but it is not certain that these were baked in the features or if they were incidentally incorporated into the earth that was heaped on top (Applegarth 1976:161).

Figure 3. Agave crown removed from base.

Figure 4. Trimming leaves from crown.

Removing the plants involved raking back the earth and rocks forming the oven. The repeated use of an individual oven and the continued raking out of its contents over time produced a circular heap of heat-fractured rocks, with a depressed center composed of burned material mixed with rock and earth. Rock rings are typically circular or oval shapes composed of fist-size rock fragments. Rings may be solitary or intersecting and the height of the piled rocks varies, but may be three to four feet (1 m) high or higher. Ring diameter varies also ranging from six feet to 78 feet (2 m to 26 m) in diameter (Katz and Katz 1985:40).

Figure 5. A truck load of agave crowns or mescal "heads."

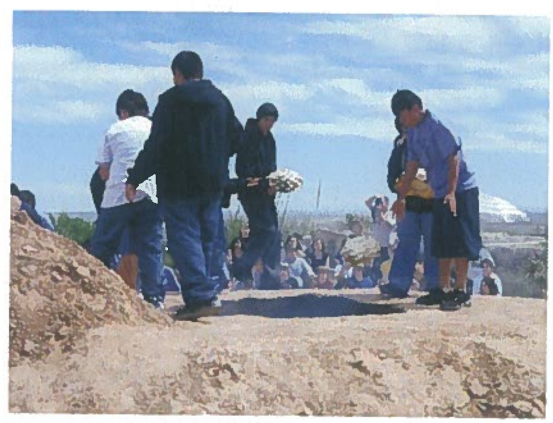


Figure 6. Loading mescal into a pit at the 2012 Mescal Roast at the Living Desert Zoo and Gardens, Carlsbad, N.M.

Excavated rock rings show that some of them have pits in their centers, but others are level with the ground surface. It is assumed that digging a pit partly depends upon the local topography, because some rings are located in places where bedrock is visible at the surface, or where bedrock is covered by only a few inches of soil (Applegarth 1976:159). These surface rings are assumed to have baked food equally as well as those with pits. Few artifacts have been found in association with rock rings (Applegarth 1976:159-160), but diagnostic projectile points and potsherds have been discovered at some sites.

Figure 7. Baked mescal from the pit. 2012 Mescal Roast.

Figure 8. Baked mescal leaf with edible pulp.

Although rock rings are the most obvious features at these sites, other accumulations of burned rock may also be present. Sometimes occurring as amorphous sheet deposits, this rock may also appear as loosely aggregated or tightly clustered features adjacent to the rock rings. Some clusters of burned rock may have charred material within them similar to the rock rings.

One explanation for the abundance of ring midden sites is that they reflect the increased use of plant resources by the region's inhabitants in order to increase the production of food per unit area, termed "intensification." As noted in the Southeastern New Mexico Regional Research Design, "The best evidence for intensification may therefore be the appearance of ring middens which, on the basis of indirect evidence are presumed to be associated with the processing of succulents. Except for one very early assay, the radiocarbon dates for ring middens in southeastern New Mexico (Condon 2002; Katz and Katz 2001:Table III-35) suggest that the exploitation of mescal and other succulents may have begun as early as 3500 radiocarbon years before present (BP), became more common after about 2500 BP, and increased sharply during the Ceramic period. At least in the southern part of the region, this intensification of wild resource procurement may have been a successful enough response to population packing to obviate the need to adopt cultigens." (Hogan 2006:4-33).

The foothills region of the CFO provided unique food resources for the inhabitants of what later became southeastern New Mexico for a period of several thousand years. Given the characterization of these people as mobile hunter/gatherers it is important to take into account the archeological record of this region as it relates to sites located within the Permian Basin PA area (Sebastian and Larralde1989:82).

Conventional archeological survey is done by walking transects at consistent intervals across the area to be inspected while looking for indications of an archeological site. Most archeological sites in southeastern New Mexico are buried beneath the ground surface and clues to their existence - usually in the form of burned rock, stone waste flakes, stone tools, or pottery - are revealed through natural erosion or by the archeologist digging small exploratory tests to see what is below. Ring middens, however, exist above the ground surface and are readily visible to an archeological surveyor.

They can also be seen from above and this makes them good candidates for using an aerial survey technique called Lidar (Light Detecting and Ranging) to record them. Lidar uses laser beams to measure the distance from an airplane mounted instrument to the ground surface. The resulting data is then processed to produce a visible map of the ground surface showing hills and valleys and various irregularities present on the landscape. Man-made alterations, such as roads and buildings can be seen, as well as ring middens.

A preliminary Lidar survey of three localities northwest of Carlsbad, New Mexico is currently underway. The Azotea Mesa study area is approximately 54 square miles (140 square km), the Box Canyon study area is 64 square miles (166 square km) and the Upper Rio Felix study area is 254 square miles (658 square km) in size. These study areas encompass complete drainages, including named and unnamed tributaries to the Rio Felix, Box Canyon, and the West Fork Little McKittrick Draw. The study areas also include portions of other stream basins that will produce partial data for those drainages. Factors that went into the selection of the three areas included a consideration of the amount of previous archeological survey, the number of acres under BLM administration, the height of the land surface above sea level, the number of previously recorded sites, and that the study area be located within the portion of the Carlsbad Field Office in which rock ring middens occur.

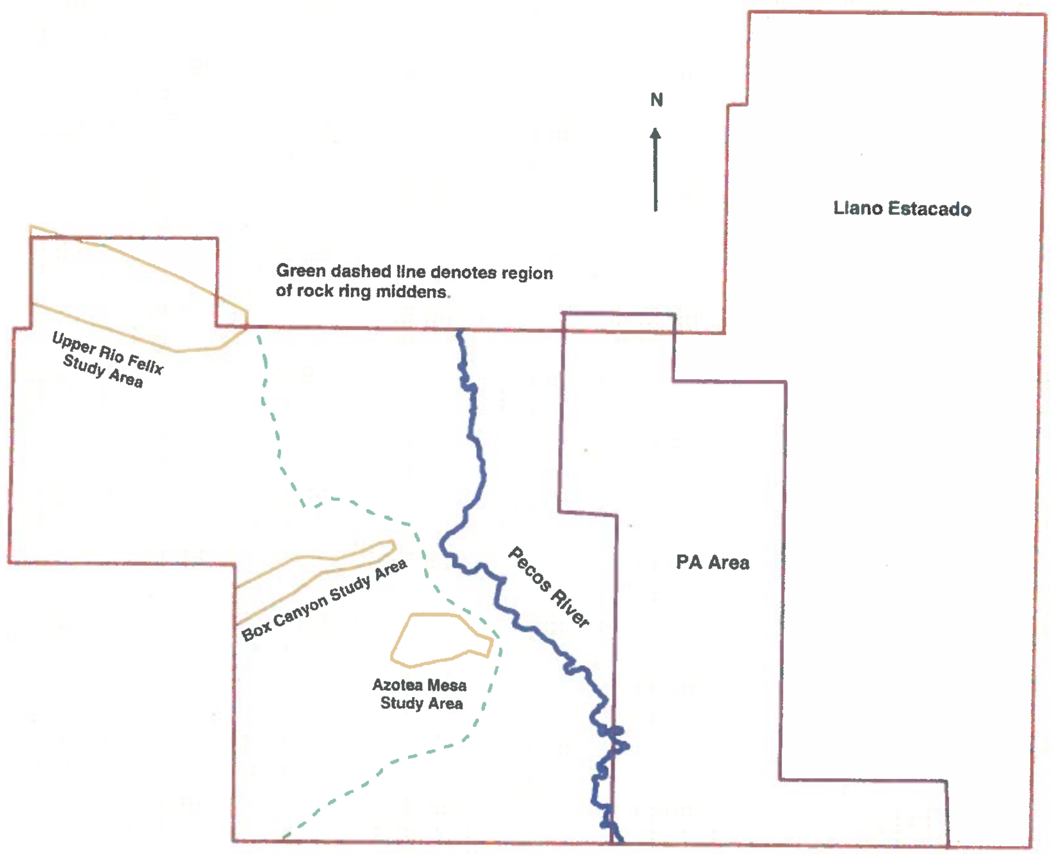


Figure 9. Location map showing three study areas for the Lidar aerial survey. Red outline is the Carlsbad Field Office boundary.

The Azotea Mesa study area was chosen as a control. It contains 38,108 acres (14,422 ha) of which 81 percent is BLM land. It has the most area surveyed of the three study areas; 2,996 acres (1212 ha) or eight percent of the whole. A review of the site forms found that of 127 prehistoric sites, 84 had rock rings, 34 were composed of small fire-cracked rock features, either aggregated or dispersed, three were caves, and six were rockshelters. Rock ring midden sites represent 66 percent of all recorded sites and these sites have more than 273 rings in total. Thirty-one of the sites had a single ring, but one site LA 139107 had 18, the most within the Azotea Mesa study area. Figures for the Box Canyon study area generally parallel those for Azotea Mesa in terms of land administration, 80 percent is BLM, and six percent of the 41,225 acres (16, 683 ha) have been surveyed. The number of sites recorded within this unit is considerably fewer, 24 prehistoric sites, of which 15 have rock rings (63 percent). Nine of the sites have a single ring, but one, LA 129599, has 31 rings. The Upper Rio Felix study area is unique in not having a single ring midden among the eight previously recorded prehistoric sites. This is the largest study area, totaling 162,639 acres (65,818 ha), but only one percent of this unit has been surveyed for archeological sites. Sites with fire cracked rock concentrations are the most numerous, totaling six, while the remaining two are characterized as lithic scatters.

A review of these statistics indicates ring middens comprise the majority of the site types (over 60 percent) and that some sites can have multiple rings, up to a maximum of 31 rings in the recorded site inventory. Using a rate of 30 acres (12 ha) per day for one surveyor, found in State of New Mexico guidelines, and a crew of five it would take over four years to examine the three study areas using traditional survey techniques. One advantage, however, is that other site types would potentially be found.

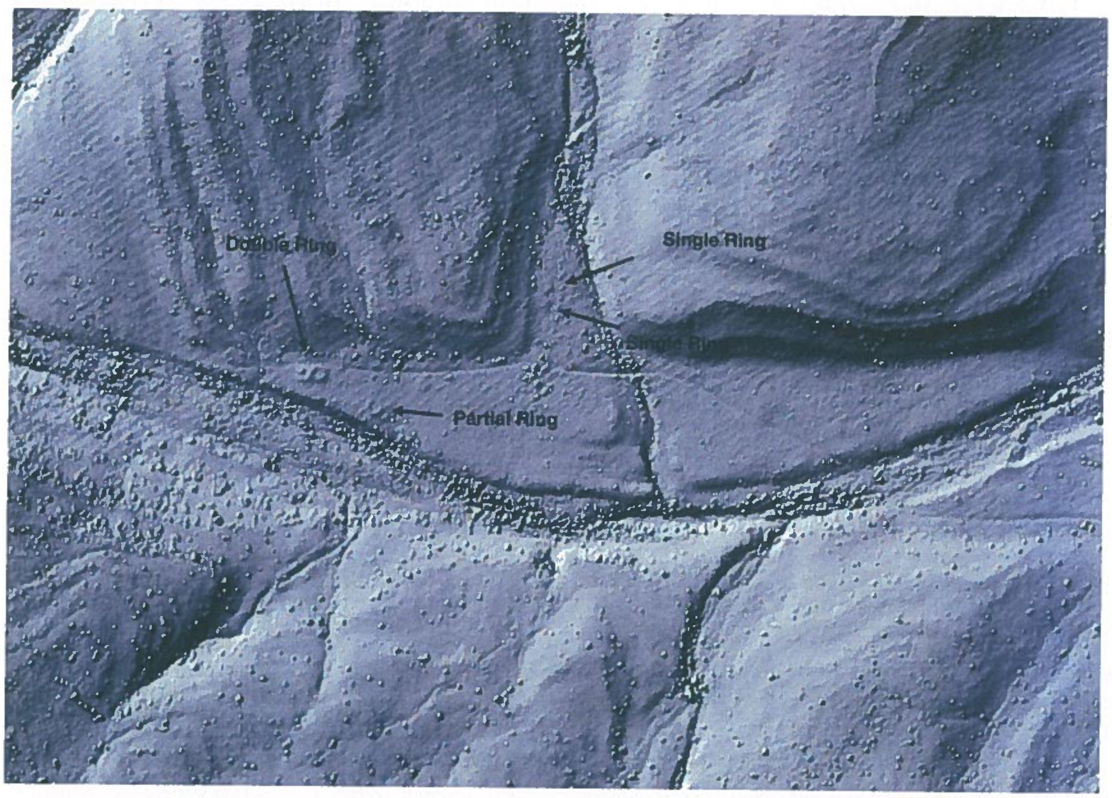


Figure 10. A sample image from the Azotea Mesa Lidar data showing rings found at the juncture of a side arroyo in the Boyd's canyon drainage. The double rings measure 20 m x 9.7 m x .8 m high (approximately 72 feet x 31 feet x 2.6 feet high). The single rings measure approximately 8.5 m in diameter x .48 m high (approximately 28 feet in diameter x 1.5 feet high). The partial ring is 9.6 m across x .49 m high (approximately 31.5 feet x 1.6 feet high).

The goals of the Lidar survey are to locate ring midden sites, to determine the number of rings at each site, and to describe the distribution of the rings on the landscape in order to define any patterns that occur in each of the drainages. Information on the placement of sites within topographic features of the drainages will be described and quantified, for example, sites within a specific drainage that occur at the junctures of side canyons or tributary arroyos. A preliminary evaluation of rock ring midden sites as an index to other types of sites that are invisible to the Lidar technology will also be done. The results of this study will be published in future editions of the *Permian Quarterly* newsletter.

References Cited

Applegarth, Susan M.

1976 Prehistoric Utilization of the Environment of the Eastern Slopes of the Guadalupe Mountains, Southeastern New Mexico. Ph.D. dissertation, Department of Anthropology, University of Wisconsin, Madison.

Condon, Peter

2002 A Data Recovery of Two Burned Rock Midden Sites Near Sheep Draw Canyon, Eddy County, New Mexico. Mesa Field Services Report No. 495M. Carlsbad, New Mexico.

Hogan, Patrick F., Richard Chapman, Glenna Dean, Peggy Gerow, Stephen Hall, Cynthia Herhahn, John Speth, and Regge Wiseman

2006 Southeast New Mexico Regional Research Design and Resource Management Strategy. Office of Contract Archeology, University of New Mexico, Contract NAC000002, UNM Report No. 185-849, Albuquerque.

Katz, Susana R. and Paul Katz

1985 The Prehistory of the Carlsbad Basin, Southeastern New Mexico. Contract No. 3-CS-57-01690, Bureau of Reclamation, Amarillo, Texas.

Sebastian, Lynne and Signa Larralde

1989 Living on the Land: 11,000 Years of Human Adaptation in Southeastern New Mexico. BLM Contract No. RDO YA551-CTS-340042-01 and 02. Bureau of Land Management, Roswell District.

Wiseman, Regge N.

2006 News from the Field. T-PAS Times 6:2 (1)

2007 News from the Office. T-PAS Times 6:2 (2)

HPD Grants are Completed

The Permian Basin PA funded a small grants program in 2013 administered by the Historic Preservation Division of the New Mexico Department of Cultural Affairs. The purpose of the program is to provide funds for small-scale, but important research projects that could be accomplished in a relatively short period of time. Six applications were approved (see *Permian Quarterly* Vol. 1, No. 2) and to date reports have been received for three of the projects, which are summarized below:

Composition Analysis, Nutt Mountain Obsidian Source, Sierra County, NM

Obsidian does not naturally occur in the Permian Basin or elsewhere within the CFO boundary, but obsidian artifacts are found at sites in this region and determining the origin of the obsidian used for the artifacts provides opportunities for research. The following abstract by Jeff Ferguson, University of Missouri and Steve Shackley, Archaeological XRF Laboratory, Albuquerque, New Mexico, describes this project.

The compositional analysis of prehistoric stone tools is one of the best measures of population movements and social interaction routinely preserved in the archaeological record. Obsidian, in particular, presents the most ideal material to link human behavior to a specific point on the landscape. Geologic sources of obsidian are relatively rare, compositionally distinct, and highly prized by makers of stone tools. By determining the chemistry of a particular obsidian artifact it is possible to link it to a particular geologic outcrop, assuming the geologic source has been sampled and analyzed.

The vast majority of the obsidian artifacts at sites in New Mexico come from three primary source areas (the Jemez Mountains, Mount Taylor, and Mule Creek) that have all been extensively studied and sampled. Smaller sources represent interesting cases for the local use of obsidian and how that material is integrated into larger-scale patterns of regional exchange. Most minor sources are also known, but there are still at least a few recurring chemical signatures that are not yet linked to known geologic outcrops. One such signature is common in sites in SW New Mexico near the Black Range. This project involves survey and sample collection at the Nutt Mountain Obsidian source near Hatch, NM. Our survey located abundant small pebbles of obsidian on the ground surface along with large cobbles of flakable dacite. The dacite was most likely the primary target of the stone tool makers but it is clear that some obsidian was also flaked at the site and some was transported to sites in the region.

The obsidian samples from Nutt Mountain reveal a single chemical signature; however, it is very similar to another minor source (Ewe/Gwynn Canyon) located 90 miles to the northwest, near the Plains of San Agustin. This project incorporated a survey of the Ewe and Gwynn Canyons in order to determine the primary outcrop for this source a well as examine any possible chemical differences with the Nutt Mountain obsidian. We located workable obsidian in both Ewe and Gwynn Canyons along with a primary perlite deposit in Gwynn Canyon.

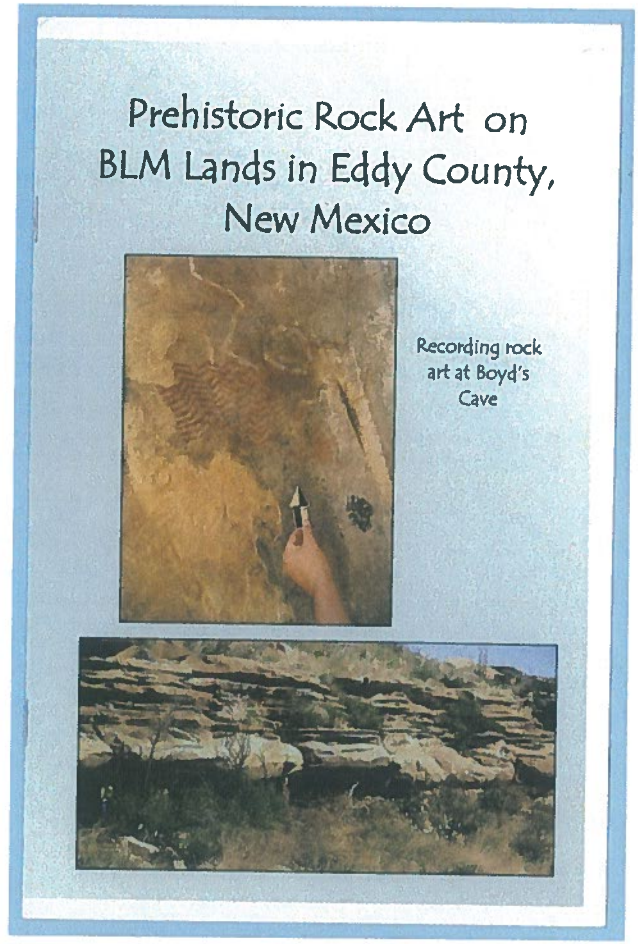
While it is still difficult to differentiate Ewe/Gwynn obsidian from Nutt Mountain obsidian using the five elements commonly measured by X-ray fluorescence (Rb, Sr, Y, Zr, Nb) it is possible to use neutron activation analysis and perhaps barium analysis by X-ray fluorescence to differentiate these sources. This project has clarified the surprising (and now mostly erroneous) assignment of artifacts in southern New Mexico to the Ewe/Gwynn source. This research has helped to improve our understanding of obsidian movement throughout southern and western New Mexico.

Survey and Documentation of Four Rock Art Sites in Eddy County

Consulting firm Geo-Marine, Inc., Sacred Sites Research, Inc., of Albuquerque, and Mark Willis Archaeology of Austin, Texas documented rock art panels at four sites using state-of-the-art digital photography, which can also be enhanced to bring out faded portions of the rock art, supplemented by measurements, drawings, and written descriptions. Detailed assessment sheets were filled out noting damage or potential problems. They thus created a detailed archive for each of the sites. Comparisons of the age and iconography of the rock art elements and motifs were made to other sites in southern New Mexico and within a larger region. This analysis resulted in the definition of a new descriptive type for some of the motifs, termed *Jornada Abstract*. A booklet for the general public describing the sites and presenting interpretations of the rock art was also prepared.

Figure 11 (right). This is the cover of a booklet describing the rock art at four sites in Eddy County, New Mexico. This booklet is available as a pdf file or as a printed copy. Readers wishing a copy should contact the *Permian Quarterly* editor (cstein@blm.gov). For paper copies provide a U.S. postal mailing address.

.



Detection of Buried Archaeological Features in the Mescalero Sand Plain Using Geophysical Survey Methods

Archaeo-Physics, LLC , the Institute for Rock Magnetism, and the Archaeological Sciences Group at the University of Minnesota conducted fieldwork at five sites in the PA area, supplemented by laboratory analysis of the magnetic properties of eolian sand, the Berino paleosol (natural and heated), and caliche (natural and heated). This combined work was an attempt to determine if man-made features can be identified through non-invasive magnetic field gradient surveys. Unfortunately, there is a limited magnetic contrast between the soil in archeological features and the soil that surrounds them for sites located in the Mescalero Plain and it was not possible to discern these features. A more detailed explanation of the project and its results are included as an appendix to this newsletter.

Permian Basin Publications in Regional Libraries

Copies of reports, booklets, or other publications for the public resulting from Permian Basin PA studies are being sent to 22 high schools, junior colleges, and public libraries located in 12 villages, towns, and cities in southeastern New Mexico. These communities are: Artesia, Carlsbad, Dexter, Eunice, Hagerman, Hobbs, Jal, Lake Arthur, Loving, Lovington, Roswell, and Tatum. It is our hope that students and patrons will use this material and thereby develop a fuller appreciation for the history and prehistory of the region.

Other Archeology News from the Permian Basin

Archeologists from SWCA Environmental Consultants completed excavations at two prehistoric sites in Eddy County this spring. One site, LA 171726, was affected by an oil and saltwater spill. The affected areas were excavated and 94 features, primarily the remains of hearths, recorded. This site is notable also for having an adjacent arroyo some four meters (13 ft.) deep that has produced a series of optically stimulated luminescence (OSL) dates that help to place the site in time.

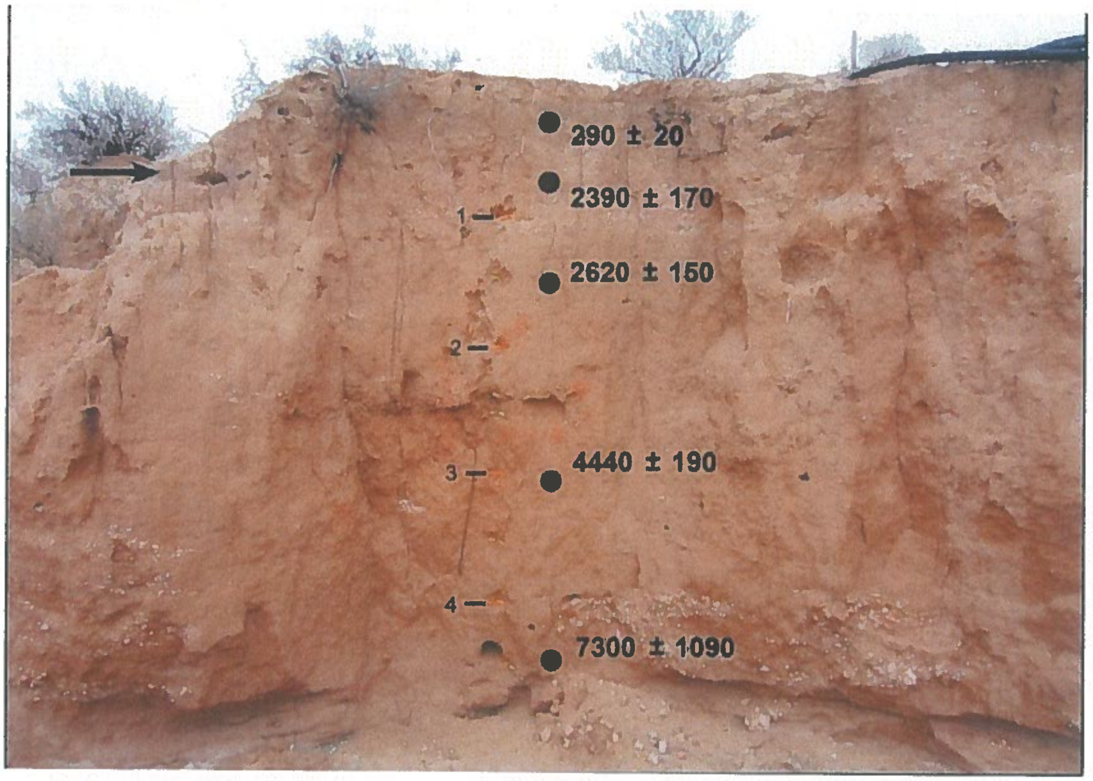


Figure 12. A series of OSL dates from an arroyo adjacent to site LA 171726. The dates are expressed in years before 2014, with an associated error factor. The arrow in the left upper corner points to a prehistoric hearth that was sampled.

The other site, LA 43257, was partially excavated prior to constructing a large diameter natural gas pipeline. Features defined at this site included four bell-shaped storage pits, a type that is extremely rare within the CFO. Although small in size, ranging from 26 cm to 64 cm in maximum diameter, their presence (along with grinding and pounding tools) indicates food caching or storage at the site.

More details about these two sites will be available when the final reports are written. The analysis of these two sites will be more fully described in future editions of the *Permian Quarterly* .

Newsletter Contact Information

Questions or comments about this newsletter or the Permian Basin PA may be directed to Martin Stein, Permian Basin PA Coordinator, BLM Carlsbad Field Office, 620 East Greene Street, Carlsbad, New Mexico 88220. Phone: (575) 234-5967; E-mail address: cstein@blm.gov.

Magnetic Studies of Archaeological Sites and Materials from the Mescalero Sand Plain, Eddy County, New Mexico

By David Maki, Archaeo-Physics, LLC, and Joshua Feinberg , Institute for Rock Magnetism, University of Minnesota.

Introduction

In January of 2014 a geoarchaeological investigation was conducted at archaeological sites located within the Mescalero Sand Plain located west of Carlsbad in Eddy County, New Mexico. The investigation was conducted by Archaeo-Physics, LLC, a private consulting firm specializing in non-invasive archaeological prospection, and the Institute for Rock Magnetism (IRM), a state-of-the-art facility located at the University of Minnesota dedicated to the study of naturally occurring magnetic materials and their use in addressing outstanding research problems in Earth and planetary sciences and archaeological and anthropological studies.

The objective of the investigation was to assess the effectiveness of magnetic survey methods for detecting buried archaeological features in this region, where the formation of relatively young sand dunes is thought to have obscured the locations of many archaeological features. Magnetic survey is one of the most commonly used archaeological prospection methods due to its speed, reliability, and cost effectiveness. Magnetic surveys have had sporadic success in the arid southwest however, with some very successful results and numerous failures. This study was unique in that it sought not only to determine whether magnetic survey could be used to map archaeological sites in this region, but also to more fully understand the magnetic properties of natural soils and sediments as well as those modified by human activity. Many of the archaeological features in the area also contain blocks of caliche, a sedimentary rock formed in semi-arid environments that is cemented together by calcium carbonate minerals. Blocks of caliche are sometimes the only coherent rock type available in the Mescalero Sand Plains and were frequently used to form hearths and line cooking pits. The laboratory component of this study analyzed the magnetic properties of unaltered and altered soil and caliche from the sites.

Magnetic surveys work by detecting small changes in the magnetic field measured at the surface of the Earth. These changes are caused by two interrelated factors, induced magnetization and remanent magnetization. Induced magnetization is caused by a contrast in a soil property known as magnetic susceptibility. A good analogy to help understand induced magnetization is soil porosity. Water will flow readily through a porous soil, but will tend to flow around a less porous soil. In like manner, the earth's magnetic field will tend to flow through an archaeological feature with higher magnetic susceptibility than surrounding soils, but will flow around a feature with lower magnetic susceptibility. Induced fields occur only in the presence of the earth's naturally occurring magnetic field.

Remanent magnetic fields are already familiar to most readers. This is the form of magnetism that occurs in a common everyday magnet such as you might have on your refrigerator. Remanent magnetization of archaeological features typically occurs when a feature is heated in a fire to above a certain threshold known as the Curie temperature. As the material cools from above this temperature, the magnetic moments of certain iron-bearing minerals align with the earth's magnetic field and remain permanently locked in that orientation. The end result is a form of remanence known as 'thermoremanent magnetization'. The intensity of this magnetic field is proportional to both the intensity of the earth's magnetic field at the time the sample is heated, and the type and concentration of magnetic minerals in the sample.

Another important point to remember when discussing magnetism is that magnetic fields have both a magnitude (or intensity) and a direction. In other words, they are vector fields. Both the intensity and direction of the earth's magnetic field varies through time, and these variables are permanently recorded in archaeological materials that have been heated. Vector fields are additive, meaning fields with the same direction will combine together to make an even stronger field, and fields opposing one another will cancel each other out, assuming they have the same intensity. Oftentimes archaeological features will possess both an induced and remanent magnetization component, each of which are noticeably different from those of the surrounding natural soils and rocks. This contrast between the magnetization of natural and human-modified materials is what allows magnetic surveys to successfully map out the locations of archaeological sites, but the underlying mineral physics behind this contrast is complicated and makes the creation of accurate models of archeological features a challenge.

Investigation Results

Magnetic data were collected over five archaeological sites covering a total area of just over 10,000 square meters (the area of approximately two football fields). Sites with known features were selected so we could observe changes in the magnetic field (referred to as 'magnetic anomalies') over these features, then look for similar anomalies in other areas where archaeological features may be buried under shallow sand dunes. We collected our data using an instrument called a Geoscan Research FM256 fluxgate gradiometer (Figure 1). Because the types of archaeological features we were looking for are rather small (< 1 m diameter) our data sample density was quite high at 16 magnetic reading per square meter.

An example of our survey results is shown in Figure 2. This figure shows the results of the magnetic survey as a grey-scale image, with increases in the local field strength depicted as darker shades and decreases in field strength depicted as lighter shades. The range of magnetic field values in this example is ±2 nanoTesla (nT), which is exceedingly small given that the strength of Earth's magnetic field in this region is ~50,000 nT. The location of a known fire hearth is shown, as are the locations of soil and rock samples collected from the site for testing. Unfortunately, the known feature did not create a detectable magnetic anomaly at this, or any of the other sites surveyed during this study. The magnetic contrast between the features and their natural surroundings was simply too low. In an effort to understand why, we collected soil and caliche samples from archaeological features and compared their magnetic properties to control samples that were not modified by humans.

Our analysis showed there was very little contrast in magnetic susceptibility between samples from the archaeological features versus the surrounding soils (Figure 3). What little contrast there was tended to be negative, that is the features had lower magnetic susceptibility values than surrounding soils (and hence contained less magnetic material). This is the opposite of what is normally observed at sites in more temperate regions, where a positive anomaly is associated with hearths due to the formation of the mineral magnetite during heating of soils with more iron-rich organic material. The negative contrast between the features and the surrounding natural soils in the Mescalero Plain was too small to create a detectable magnetic field, and this is the reason the features were "invisible" to our magnetic gradiometer. Experimental heating of Mescalero Series soils in the lab confirmed a small reduction in magnetic susceptibility values, again the opposite of what normally occurs when soils are heated in more temperate regions.

Looking at Figure 2, readers will note that although the known feature at LA20241 did not create a visible magnetic anomaly, there are strong magnetic anomalies over large portions of the site that typically appear as adjacent zones of contrasting black and white. Similarly intense magnetic anomalies were visible in most of the other sites investigated. We suspect these magnetic anomalies may represent the locations of lightning strikes. Lightning strikes can create strong remanent magnetizations in soil and rock samples, both at the location of the strike and along electrical current pathways radiating from the strike. This phenomena produces what is known as a 'lightning induced remanent magnetization' (LIRM). Despite the low odds of a person being struck by lightning, such magnetizations are frequently found during paleomagnetic studies, especially at elevated points in an area (e.g., peaks, ridge lines, canyon rims, etc.). Contrary to popular belief LIRMs are not generally associated with heating of the soil or the creation of fulgurites, but are caused by a very strong electromagnetic pulse radiating from the electric current pathway. The magnetic component of this pulse can permanently re-magnetize iron-bearing minerals in soil and rocks, oftentimes with an intensity that is much, much larger than the thermoremanent magnetization imparted by the earth's magnetic field. Researchers who specialize in the study of the Earth's ancient magnetic field behavior have devised methods to identify when a rock's magnetization is likely to be a LIRM.

The magnetic remanence of caliche samples was measured at the IRM. Results showed that samples collected from suspected lightning strikes had much higher magnetizations than control samples (Figure 3). This confirmed that the source of the numerous intense magnetic anomalies observed in our survey results was LIRM.

These tests also detected elevated magnetic remanence in samples of burned caliche collected from archaeological features. These are examples of thermoremanence acquired when the samples cooled after being heated in archaeological hearths or were used as boiling stones. Note that the burned caliche sample from the archaeological hearth in Figure 2 possesses an unusually large remanence with an intensity more in-line with an LIRM than a thermoremanent magnetization. We initially found this confusing until we noticed that the hearth at LA 20241 is located along an arcing magnetic anomaly that was likely caused by a lightning discharge current. This sample's final magnetization was a combination of magnetic remanence imparted by both heating (thermoremanence) and lightning (LIRM).

Some of the burned caliche samples from features displayed a multicomponent demagnetization path that was inconsistent with other forms of remanance (Figure 4). We interpret these multicomponent demagnetization paths as evidence that certain caliche blocks were reheated, possibly multiple times, as parts of hearths or as boiling stones. Future research may exploit these characteristics to examine the "use history" of caliche stones (for example, to establish a minimum number of times that a stone has been heated), or to determine the age of last heating using paleomagnetic field intensity methods.

The results of this investigation suggest that magnetic field gradient survey is not an effective method for detecting buried archaeological features in the Mescalero Sand Plain, largely due to limited magnetic contrast between features and surrounding soils. This lack of magnetic contrast is primarily due to negligible magnetic mineral enhancement during heating. Additional contributing factors include a very low concentration of iron in the soil parent material and low soil organic and moisture contents. These latter two factors likely result in a paucity of iron-bearing minerals in the soil, which are typically more abundant in less arid environments.

One of the more successful outcomes of this study is the recognition that simple, inexpensive laboratory-based tests of the magnetic properties of local soils (and their propensity to change during heating) are a smart means for determining whether a magnetic survey is an appropriate prospection tool for archaeological features in arid environments. If these tests can be completed before a magnetic survey is commissioned, then everyone will benefit in the end.

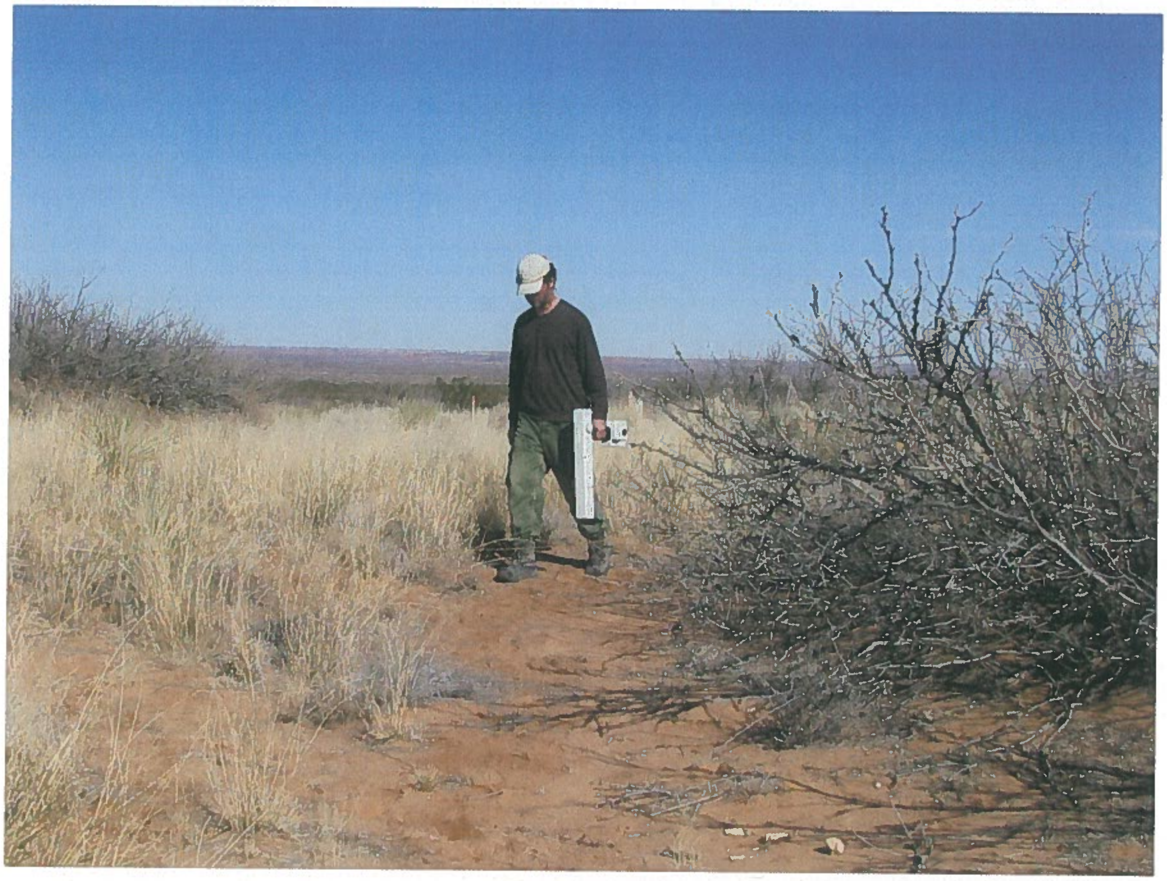


Figure 1: Magnetic field gradient survey using the FM256 fluxgate gradiometer at the Bopco Road site (LA179156). Sand dunes on the Mescalero Sand Plains have obscured many of the archaeological features in the area.

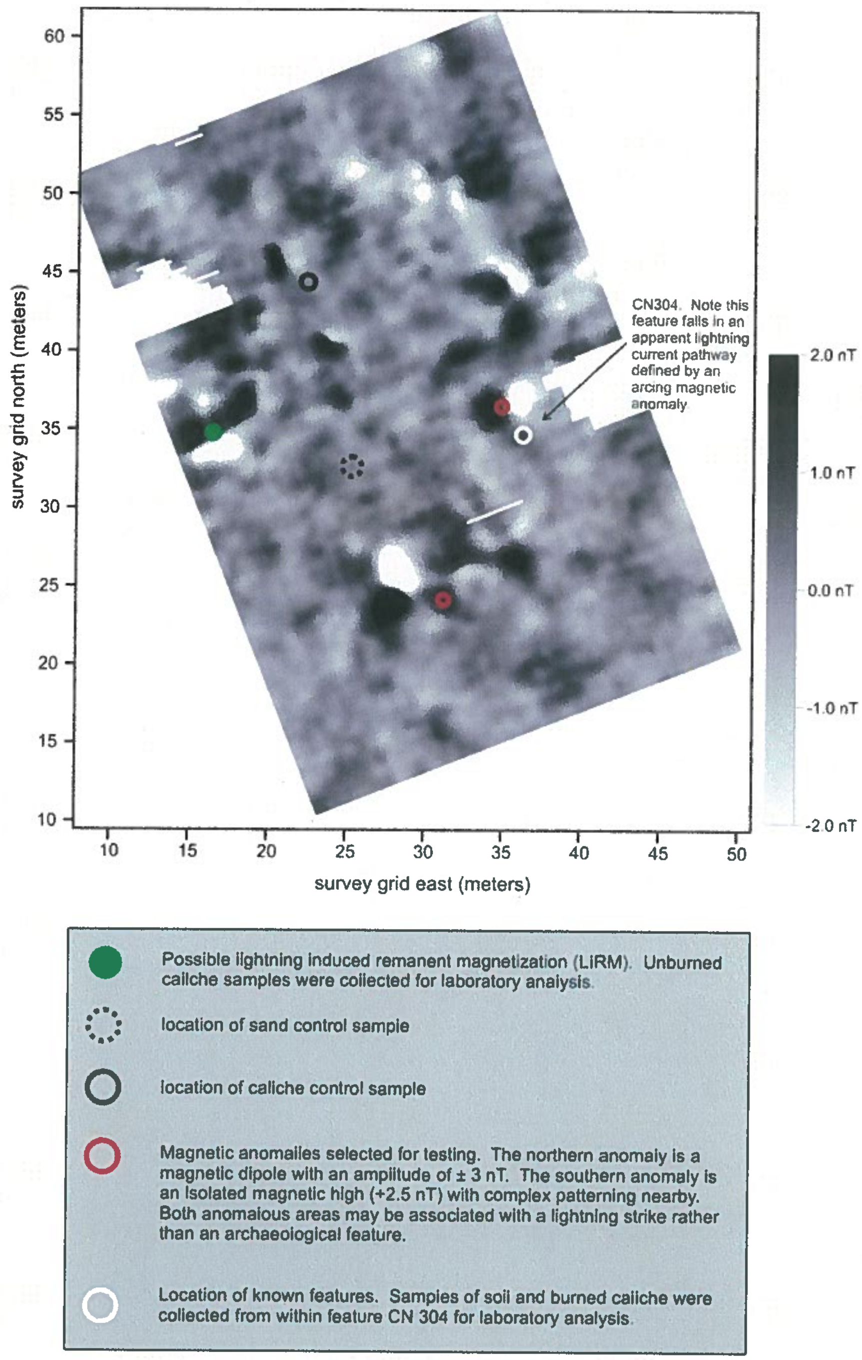


Figure 2: Magnetic survey results from LA 20241. Archaeological testing of the magnetic anomalies (red) was negative. These anomalies are most likely caused by lightning strikes (LIRM).

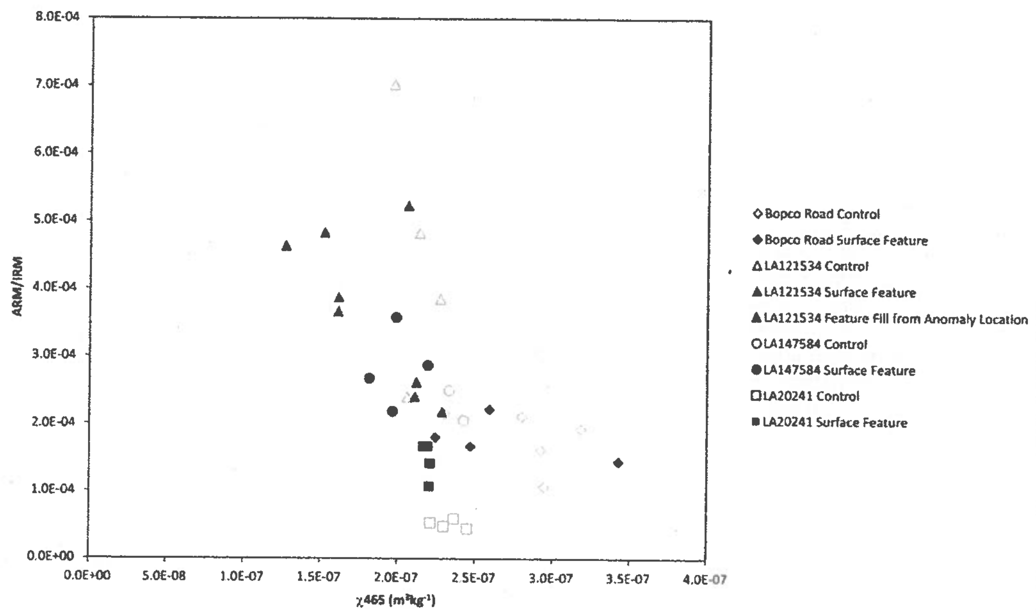


Figure 3: In this figure magnetic susceptibility (χ_{465}) is shown along the x-axis and can be interpreted as a measure of the concentration of magnetic minerals in sand samples from Mescalero Plains. The ARM/IRM ratio is shown along the y-axis and can be understood as an indicator of the average grain size of the magnetic minerals in a sample. Solid symbols represent samples from archaeological features, while hollow symbols represent control samples of natural, unmodified sands. Feature sands tend to have lower magnetic susceptibility values (shifted left on x-axis) and smaller magnetic mineral grain sizes (shifted up on y-axis).

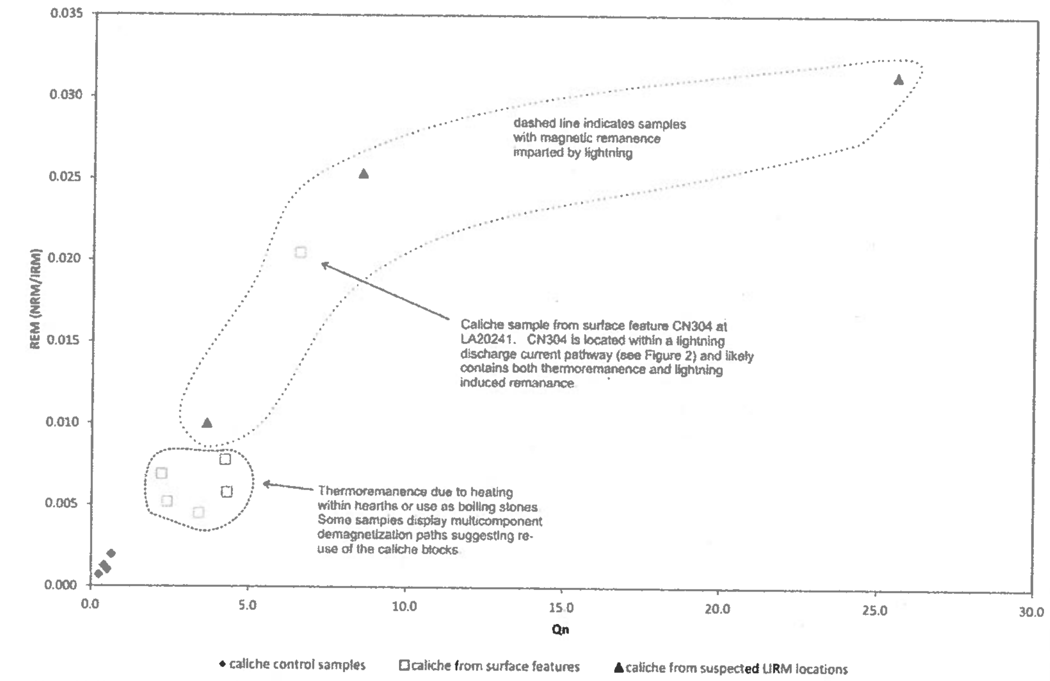


Figure 3: This figure shows the magnetic properties of caliche samples collected from the Mescalero Sand Plains. The x-axis of the plot shows the caliche's Koenigsberger ratio (Qn), where larger values correspond to samples with greater magnetizations. The y-axis of the plot shows the 'Ratio of Equivalent Magnetizations' (REM), where higher values indicate that the sample is more efficiently magnetized (as would be expected from a lightning strike). Samples collected from anomalies in the magnetic survey appear in the upper right of the figure (filled triangles), and are thus likely to be affected by lightning, whereas the unmodified, control samples appear in the lower left of the image (filled diamonds). Interestingly, caliche samples from known features display intermediate values (open squares).

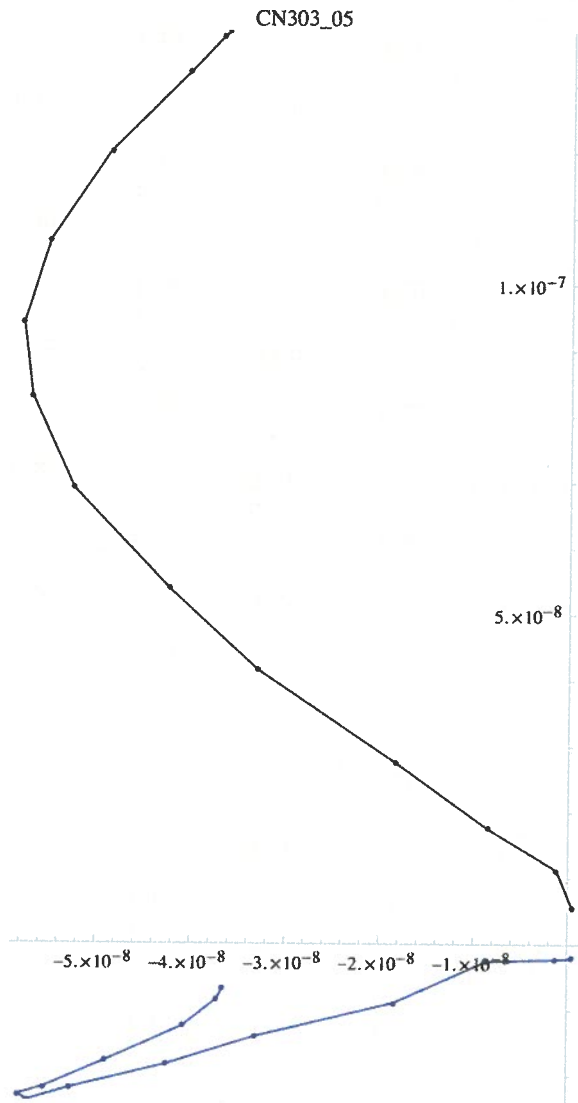


Figure 4: This figure is an example of an 'orthogonal vector endpoint diagram' that shows the evolution of a sample's magnetization during demagnetization experiments. The caliche sample was collected from an archaeological fire hearth. Black points show the endpoint of the magnetic vector in map view (where the x-axis goes from west (left) to east (right) and the y-axis goes from north (up) to south (down)). The blue points show the endpoint of the vector in cross-sectional view (where the x-axis goes from west (left) to east (right) and the y-axis goes from up to down). The sharp elbow in both the black and blue points indicates the field strength (25-30 mT) at which the weakest magnetic component is removed. Thus, this figure indicates that this particular caliche sample was heated at least twice in its past. Units along both axes are in Am^2.