NewsMAC

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New Technologies in Archaeology

Contents

Welcome……2
Modeling in Southwestern Archaeology……2
Modeling of Archaeological Site Location in Southern New Mexico……4
Google Earth and Landscape Archaeology……6
Mapping Archaeological Sites Using an Unmanned Aerial Vehicle……8
Spatial Analysis and Survey in South-Central New Mexico……10
PaleoWest Archaeology's Digital Recordation On the Navajo-Gallup Water Supply Project, Northwest, New Mexico……12
Data Management……14

WELCOME

I would like to wish everyone a happy and prosperous 2013. This year we will have four topic-oriented issues of NewsMac. The first issue is entitled New Technologies in Archaeology.

We are constantly faced with TV commercials that market an array of new hi-tech solutions to our daily life. Should I buy an IPhone, Samsung, or Droid cell phone, what about a tablet, or a tablet/laptop? Some of us still remember the days when we took those key punched cards over to the computer center and waited 24 hours for the output. Then we were alerted of a typo on one of the cards and had to go through the whole process again. Thank god those days are long over. But, what about all the new technologies that are currently being developed, and what aspects of this technology can we productively and efficiently integrate into our archaeological research? Well, I probably canôt answer that question. But, I can offer a series of brief reports on the status of several techniques that are currently being used by archaeologists working in New Mexico. These generally fall into four categories: modeling, survey, excavation and data management. Yes, you can do more than find your house or look at Pueblo Bonito with google earth, and yes, you can use a drone for other activities besides hunting down terrorists. I hope the following articles provide some food for thought, and opens up other possibilities for innovative and new techniques while exploring the past.

Bradley Vierra, Editor
Statistical Research Inc.

Modeling in Southwestern Archaeology

Tim Kohler
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Given the current and presumed future dominance of CRM in archaeology, what should be the role of archaeologists in academia? I think there are three: *training*, of course; and also *services to the field* such as building repositories for archaeological data (see, e.g., http://www.digitalantiquity.org/) or editing journals. Finally, academic archaeologists are uniquely placed to undertake the kinds of *research* that typically donôt get done in the CRM world. Among other things such research includes comparative archaeology on large spatial scales (Smith 2012); middle-range research to strengthen the connections between the sorts of things we find in the archaeological record and how we interpret them (Verhagen and Whitley 2011); and building methods to ground new (or more secure) inferences about what happened in prehistory. Modeling can contribute to all three of these research aims simultaneously.

Every time we regress one variable on another we engage in modeling, but here Iôm not talking about this sort of statistical (inferential) modeling to identify patterning in our data. Statistical models are our main analytic tools and will continue to be; they have been taught in archaeology curricula for decades. Within the last 15 years, however, we have seen increasing experimentation with deductive modeling. The essence of deductive modeling is to begin from some set of premises (model) and to deduce their consequences through space and/or time. This exercise not only forces us to be explicit about the model in questionð a useful remedy for fuzzy thinkingð but also, for all but the simplest models, yields some serendipitous results that force us to reexamine our prior beliefs about how the processes we model produce patterns in the archaeological record.

Early simulation models in archaeology usually focused on variables (such as ñlaborò or ñworker housingò) and their relationships, described in a series of differential or difference equations, iterated through time via computer (simulated). An example is Ezra Zubrowôs (1981) use of Forresterôs (1969) model of urban dynamics to study Roman cities.

A newer approach to simulation, called agent-based modeling (ABM), focuses instead on entities (ñagentsò) such as households or villages, and studies their patterns of behavior through time, given some model. I was inspired to try my hand at ABM in the early 1990s when I happened to be in residence at the Santa Fe Institute just as a group led by Chris Langton was developing one of the first ABM platforms, Swarm. Since then, with help from a wide range of researchers in various disciplines and institutions, the Village Ecodynamics Project (which I coordinate) has been developing a suite of models and examining them against the archaeological record of the central Mesa Verde region between AD 600 and 1280. The most basic model asks, ñwhat would be the distribution of households through time on this landscape if households sought to distribute themselves to maximize their access to maize, water, fuelwood, and hunting prospects for deer, hare, and rabbit?ò

Not a very interesting question, perhaps, but in fact the results, detailed in Kohler and Varien (2012), are sometimes surprising. I wonôt spoil the suspense; the book is available from better bookstores everywhere! Since then weôve used the virtual sandbox of simulation to examine the process of turkey domestication (Bocinsky 2011), the effects of exchange on aggregation (Crabtree 2012), and the effects of specialization and barter on population size and settlement practices (Cockburn et al. 2013). Kohler et al. (2012) provide a general overview of the history and uses of simulation in this project, which we are currently expanding to include the northern Rio Grande.

Other proven or promising modeling work oriented towards the Southwest could include very focused questions (what for example are the expected distributions for locally available lithic raw materials in sites under the null hypothesis that there was no selection for specific types of stoneð Brantingham 2003) or to explore big questions, such as how water management interacted with the long-term trajectory of Hohokam rise and decline (Murphy 2012).

In general, simulation helps us to build expectations about what the archaeological record should look like, given efficacy for the processes modeled. Many scenarios modeled are counterfactual: they didnôt happen. For example, the scenarios built in Kohler and Varien (2012) explore a version of prehispanic southwestern Colorado unaffected by low-frequency climate change, in which no immigration or emigration was possible. The importance of specific processes in the real world can be assessed by building models lacking those processes, if we are willing to make the inference that the main reasons for the differences between the simulation output and the real world can be attributed to the processes omitted in the model.

It is our tendency as humans to naturalize what we see. For example, once we learn that Classic towns in the northern Rio Grande can be very large and long-lived, we rapidly forget to ask *why* that is. Building models of prehistory reminds us that the prehistory that happened is not the only possible prehistory. This rekindles our capacity to have the reality of the archaeological record astound us: it could have been otherwise.

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Modeling of Archaeological Site Location in Southern New Mexico

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Statistical Research Inc.

Only a small portion of the millions of acres of BLM Land in New Mexico has been surveyed for archaeological sites. In addition, many of the data from the surveys that have been conducted are not yet available in the statewide database used for tracking these resources. Yet, to fulfill its legal obligations under the National Environmental Policy Act (NEPA) and the National Historic Preservation Act (NHPA), the BLM New Mexico needs reliable and objective information for a vast land base about where survey has been conducted and where archaeological sites of different types are located. The BLM NM is thus faced with the daunting challenge of having to make decisions about land uses that could adversely affect archaeological sites, but based only on limited and incomplete information about the cultural resources under their jurisdiction.

Given this challenge, the BLM New Mexico (BLM NM) decided to create models of archaeological site location that could be used to project where in southern New Mexico archaeological sites of different types are likely to be found. These models were to use data in the statewide database about where (within surveyed areas) sites have and have not been found to estimate where sites are likely to be found in areas that have not been surveyed. The BLM NM also decided that it needed to develop a series of software tools for updating models as new data become available and for evaluating the extent and quality of survey for any area where cultural resource data are available in a geographic information system (GIS).

To develop the models and software tools, the BLM New Mexico hired Statistical Research, Inc. (SRI) in 2010 to 1) develop a series of archaeological sensitivity models, according to site type, for lands contained within the jurisdiction of the Las Cruces and Pecos District Offices and 2) develop a series of GIS software tools for revising archaeological sensitivity models and assessing survey reliability (Heilen et al. 2012). Because the association between sites and their environmental or cultural setting varies according to geographic context, the BLM New Mexico requested that the project

area be divided into a manageable series of geographically distinctive areas. The BLM also specified that the data used in modeling were to come from the New Mexico Cultural Resources Information System (NMCRIS). This was to ensure that the models are based on the official source for digital CRM data in the state of New Mexico and that the modeling approach developed for the project can be consistently applied across a wide array of archaeological contexts.

To create the models, a series of site types that are readily identifiable from NMCRIS tabular data also had to be identified. Site types were expected to reflect core human behavior and to be distinguishable in terms of potential mitigation costs and NRHP eligibility status. Based in part on the availability and distribution of attribute data in NMCRIS and on variation in settlement pattern and culture history, a series of seven site types was developed for the project using information in the database on site function and temporal and cultural affiliation.

The models developed for the project are empirical models that identify statistical associations between site location and measurable characteristics of the environmental and cultural context in which sites have (or have not) been found (Altschul 1988; Kvamme 1988a,b; Mehrer and Wescott 2006). An advantage of these kinds of models is that they provide a spatially explicit and testable estimation of archaeological site location based on transparent and systematic use of the existing data. A disadvantage is that, although these kinds of models can perform better than other kinds of models, they do not explain why sites are located where they are; they simply identify where sites tend to be located based on the relationship of site location to a set of spatial variables.

To develop the models, a diverse set of more than 60 variables were used to analyze the relationship between site location and environmental setting. These included variables related to topography, soil attributes, water resources, historical-period resources, and vegetation. Variables were conceptualized as proxies for factors that affected how people have moved through and used the landscape. Software tools developed for the project used query language to identify sites in the statewide database, according to type, and then randomly generated a sample of points in a GIS representing site and non-site locations. Using another software tool developed for the project, these samples of site and non-site locations were then attributed in a GIS with the values of environmental variables, thus providing a series of cases for statistically generating each model.

The statistical approach used to develop the locational models is an innovative new technique referred to as Random Forests (Breiman 2001; Prasad et al. 2006). Random Forests is a nonparametric decision-tree statistical-learning technique that is widely considered to result in statistically robust models that overcome problems associated with other commonly-used modeling techniques. The Random Forests algorithm generates a series of rules for classifying a variable, such as the presence or absence of an archaeological site, according to other variables, such as distance to water or elevation. It does so by sampling both the modeling variables and the individual site and non-site cases thousands of times to generate hundreds or thousands of decision trees; these trees are then combined to form a final model based on which variables and rules performed best in predicting site location. During the process of calculating a model, the Random Forest algorithm reserves a sample of cases from model development that are used to test model performance. Models can also be tested using additional survey data not used in model development (Kvamme 1988b). Locational models were developed for each modeling unit and site type for which at least 50 sites of a given type had been identified, resulting in the development of a total of 35 site-type sensitivity models (out of a possible 49 models) for the project. Validation statistics show that the models work well, although it is expected that models will improve substantially when new CRM data become available and software tools developed for the project are used to update the models.

The BLM needs to know not only about where sites are likely to be found at the surface, but also where sites may potentially be encountered below the ground surface during excavation or construction. Because the locational models developed by the project were derived primarily from surface survey data, they cannot predict where buried sites are located. Though, a model of buried site potential was also developed for the project. Rather than being created through statistical associations between site location and environmental or cultural variables, the model was created by means of expert geoarchaeological knowledge of geomorphology and soil attributes. For any given location in the project area, the model estimates the likelihood for buried deposits to occur below ground. To create the model, project geoarchaeologist Dr. Jeffrey Homburg examined and interpreted information on more than 700 soil series present in the project area and estimated the buried-site potential of each soil series. These estimates were then combined systematically in a GIS to derive a series of maps depicting buried-site potential across the project area according to five sensitivity categories, ranging from very low to very high buried-site potential.

Models are only as good as the data, methods, and assumptions used to create them. It is important to recognize that the locational and buried-sites models discussed above are simply depictions of the *potential* distribution of cultural resources that are based on current knowledge, including the data and methods used to create a model. The models developed for the project can certainly be improved using new data and techniques. This is something that the BLM NM fully recognized in requesting GIS software tools that would allow models to improve with new data.

In situations where knowledge about cultural resources is limited, locational models help land managers anticipate the kinds of resources likely to be found in the areas they manage; they can also be used to estimate the potential cost of inventory, the risk of unanticipated discovery, prioritize areas for survey, design projects, and to devise methods for

protecting sites or conducting field investigations. As such, they allow us to leverage the data we have to understand something about areas for where cultural resources data are not yet available.

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Google Earth in Landscape Archaeology

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The first time I used Google Earth I remember saying to myself, ñwhat a wonderful time to be alive!ò My task at the time was quite simpleð to create some interesting overview slides for a presentation I was working onð and anyone who has attended an archaeology conference in recent years knows that this is now commonplace. The sheer popularity of Google Earth screen shots demonstrates just how convenient the application is for depicting the locations of archaeological sites from the air, or study areas from outer space. Thereôs no doubt about it, Google Earth is a fun and effective visualization tool.

The initial applications of Google Earth in archaeology tended to focus on these sorts of ñgee whizò visualizations. But as with other technologies, researchers are beginning to discover things they can do using Google Earth that they couldnôt do before. I wouldnôt claim to know all the interesting new ideas that are being tried out, but I can share some of the ways Iôve been using Google Earth to help me in my studies of cultural landscapes.

One of the things Iôve been interested in for a long time is how the people who built the archaeological sites we study perceived the world around themð what it consisted of, how it worked, and why it worked as it

did. And Iôve also been interested in how people appropriated these understandings and perceptions in the service of their social and political goals. In my view, people donôt make material statements about the world just to make themð they have reasons for making them. So by placing important buildings or settlements in particular places, people in the past werenôt just expressing worldview, they were deploying it to accomplish somethingð whether that be control of the weather, strengthening a community, establishing authority or rank, or simply changing peoplesô minds.

What all of this means for me is that, if one wishes to learn more about past peoplesô goals, itôs not enough to merely reconstruct worldviewsð one also needs to look at expressions of worldview from place to place and over time. This is where Google Earth comes in. One of the remarkable things you can do with Google Earth is ñfly downò to the ground and look around at the horizon, as viewed from a particular spot. A compass at the top of the screen helps you keep track of which direction you are facing as you look around, and you can determine where the sun would be, with respect to a given observation point on the ground, at any date and time. You can even make time-elapse movies at various speeds to observe the sunôs position as you move around on the landscape. Iôve been using these features to hypothesize interactions between important structures, landforms, and solar cycles in ancestral Tewa sites. And on a few occasions Iôve verified these hypotheses through site visits. Google Earth will never be a replacement for direct observation, but it can help one determine which sites should be visited, and when.

Let me illustrate this using a concrete example. For the past year or so Iôve been collaborating with Bob Bernhart, an avocational archaeologist who lives in Cortez, on a study of a 13th century Mesa Verde region village known as Jacksonôs Castle, which was recently added to Canyons of the Ancients National Monument. One of the remarkable things Bob noticed there was that, around the time of the equinox, the sun rises from directly behind a hill to the east of the site when viewed from a D-shaped building in the village. And on the top of this hill there is a partly-buried stone circle shrine that is strikingly reminiscent of an ancestral Tewa world-quarter shrine (see Ortman 2008 for more on this point). Importantly, due to the vertical angle up to the hill from the site, and the daily path of the sun, the sunrise is actually about 10 degrees south of east on the morning closest to the equinox, when viewed from the D-shaped building. So it seems that the buildingôs location was chosen by someone who watched the equinox sunrise from the top of the hill and then turned around to watch the shadow of the crest of the hill move across the area below. This would be the only way to create an orientation between the rising sun at equinox, the shrine hill, and the D-shaped building.

While Bob and I were writing up this information I happened to visit Lamy Junction Ruin, a 13th century ancestral Tewa site in the Galisteo Basin. At this site the most prominent building is a C-shaped adobe mound with a kiva in the center, and which opens toward the center of a prominent hill to the east. I visited the site during mid-summer and found myself wondering where the sun came up around the equinox, when viewed from the C-shaped building. Later, in my office in Santa Fe, I checked it out on Google Earth. I was able to find the C-shaped mound on an aerial photo, zoom down to the ground, and then set the time slider to the morning of the equinox. Google Earth suggested the sun would rise right behind the center of this hill that day, but again at a certain angle south of east due to the vertical angle to the top of the hill. I even made a movie of the simulated event so I would remember the details. Based on this result, I made arrangements to visit the site the morning of the Autumnal equinox in 2011, and low and behold, the sun did exactly as Google Earth predicted.

I think this is a remarkable finding because it shows that people living in Jacksonôs Castle in the mid-1200s marked the equinox in precisely the same way as the people who built Lamy Junction Ruin in the late-1200s. To Bob and I these data indicate the dual organization characteristic of contemporary Tewa communities actually originated in the Mesa Verde region. As such, this adds to the range of evidence which suggests a historical relationship between Mesa Verde and ancestral Tewa society (see Ortman 2012). We also hypothesize that public marking of the equinox was one of the ways community leaders promoted and sanctified the seasonal change of leadership. The paper Bob and I wrote about these findings will appear in print soon (Bernhart and Ortman, in press), but the paper itself doesnôt mention the important role Google Earth played in the discovery. Iôm busy enough these days that Iôm not sure I would have made this discovery if Google Earth hadnôt encouraged me to invest the time in it. And I suspect there are many other discoveries waiting to be made using a similar approach. I hope to hear about some of them!

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Mapping Archaeological Sites Using an Unmanned Aerial Vehicle

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The words ñUnmanned Aerial Vehicleò are probably more likely to evoke scenes of combat in hostile foreign terrain than of archaeologists in northern New Mexico. But UAVs, more popularly known as drones, are not used exclusively for military incursions in the mountains of Afghanistan and deserts in Iraq. In recent years, drones have been widely used in civilian contexts across the globe in the aid of wildlife conservation efforts, Environmental Sciences, forest fire detection, Search and Rescue operations, Meteorology, construction, and Geology. Archaeology is one of the more recent disciplines to join that list, with drone technology serving as a rapid and comparatively inexpensive technique for the large-scale mapping and spatial analysis of archaeological sites. In June 2012, we used a drone to map Ancestral Pueblo archaeological sites in and around the Jemez Valley in the Santa Fe National Forest. The drone is mounted with a standard, off-the-shelf digital camera that captures low-level aerial images of the landscape. These two-dimensional images are then processed to produce three-dimensional textured digital elevation models (DEMs), taking advantage of recent advances in photogrammetric software technology. The final result is a series of remarkably precise and accurate topographic maps, produced in a fraction of the time it typically takes to capture these data using traditional survey methods.

What Exactly is a "Drone"?

A UAV is simply an aircraft with no pilot on board. UAVs come in a variety of shapes and sizes, with wingspans ranging from those comparable to a Boeing 737 down to those more like the average turkey buzzard. They can either be remotely controlled by a human pilot at a ground control station or they can fly ñon their ownò (following a previously prepared flight plan and controlled by an onboard computer). For typical archaeological applications, however, when we use the term ñaircraftò we are not talking about full-sized airplanes flying miles above the ground. Rather, these drones are more along the lines of remote-controlled toy planes. The drone we use is a deceptively simple-looking craft, consisting of a v-shaped wing made of black industrial foam (the same type of material found inside modern automobile bumpers), with a wingspan of about 1 meter (FIG. 1). In laymanôs terms, it looks like a black styrofoam replica of a stealth bomber. A small, battery-operated propeller at the rear of the craft powers the drone. The model we use is equipped with a standard 12 megapixel Canon IXUS 220HS digital camera mounted in the nose of the drone, with its lens protruding through a hole cut through the bottom of the aircraft. Also embedded in the drone is a small GPS receiver used for navigation. Despite all this the craft is remarkably lightweight; even with the camera, propeller engine, and GPS receiver, it weighs in at under 1 kilogram.

The Federal Aviation Administration prefers the acronym UAS (Unmanned Aircraft System) to UAV to reflect the fact that these aircraft include vital components that remain on the ground in addition to the parts that fly. The drone we use is capable of both autonomous flight and can be piloted by an individual via a standard laptop computer or a remote control device. It typically follows a pre-programmed flight plan that is plotted prior to each takeoff. A portable antenna erected on-site communicates between the laptop and the aircraft in real time, sending signals to the drone to keep it on course or to return it to its correct trajectory when it is blown off-course by the occasional gust of wind.

How does it work?

Once on-site, a two-meter antenna is mounted on a standard portable tripod in order to establish communication between the (on-the-ground) laptop with the drone (in the air). The laptop is used to program the flight pattern and an onboard computer carries out the plan. It is important to note that while the UAV can operate autonomously, a pilot always maintains control and line-of-sight with the aircraft and can take full control of the craft if the need arises. A series of 2 x 2 meter aerial photo targets are laid out across the site, which are later used to georectify the aerial imagery during the post-processing stage. To launch the drone, the operator simply starts the propeller, initiates communication with the base computer, and lets go of the aircraft in an open area free of trees or other standing structures. The computer directs the UAV to climb to a specified altitude, typically about 400 feet above the ground (in order to avoid the tree canopy) and stay below the altitude ceiling set by the FAA and the Academy of Model Aeronautics (AMA) for recreational remote control air craft. The computer also directs the digital camera to trip its shutter at regularly specified intervals. If the drone is out of position at the time specified to capture an image, the computer ñabortsò that photo and continues on course to the next target. Typically the drone flies along series of parallel north-south vectors, snapping a new image every 10-30 seconds. In order to maintain the light weight of the drone, the batteries used to power the propeller are small, limiting flights to no more than 24 minutes. However, we found this to be more than ample for mapping large pueblo sites and the surrounding landscape with areas of 10 hectares. The most harrowing part of any flight is the landing. While the operator is able to specify a general landing area for the craft in the pre-flight programming, unless that area is completely denuded, there is always the danger that the drone could crash into or become stuck in the branches of a tree. For this reason, take-offs and landings are always performed in the most open area of any site.

Following the flight, we use RTK surveying equipment to establish the precise UTM locations of 12 control points, located in the center of each aerial photo target. These coordinates are used to georectify the digital images, establishing the precise location of the imagery to within +/- 10 centimeters under optimal conditions. The images are downloaded from the digital camera and processed using Agisoft Photoscan software. This software works by searching for common points in the digital images and matching them (much the same as standard photo-merging software, such as Adobe Photoshop and Canon Photostitch), but it also crucially goes on to calculate the position of the camera when each image was taken. Photoscan then uses the estimated camera positions in concert with the images to derive a 3D polygonal mesh of the ground surface. Following this step, Photoscan orthorectifies the images, establishing a uniform scale and removing any distortion, producing digital orthophotos and DEMs that can be used in any GIS.

Limitations and Benefits of Drone Mapping

While this method of mapping large areas may seem too good to be true to anyone who has ever labored at the business end of a prism pole for long hours under the New Mexico sun, there are some limitations to drone mapping. First and foremost, this is a passive method of data collection. That is, unlike active mapping technologies such as LIDAR, digital photography does not penetrate the tree canopy. It can only map the ground that is visible from the air. That said, it is possible to supplement the drone imagery using additional ground-based photography or good old-fashioned XYZ data captured using a total station to fill in any areas obscured by trees. It is also possible to remove trees from the model in the post-processing phase, and then ñfilling inò the resulting holes in the imagery with interpolated data projected across the void. However, if trees cover much of the surface in which you are interested, drone mapping is impractical. A less permanent (but no

less persistent) problem is the wind. Optimal wind speeds are less than 7 mph. Anything more than a slight breeze blows the lightweight drone off-course, so you need a calm day to gather reliable data.

Yet even with these drawbacks, the benefits of drone mapping are significant. Under optimal conditions, it is possible to collect up to 50 hectares of data in a single day. We were able to map four large sites in the Jemez District in just two days. Mapping these sites using a traditional total station or RTK mapping equipment would conservatively take 4-8 months of fieldwork (using a 40 hour work week). Drone mapping is therefore a rapid, relatively inexpensive method of data collection that can produce LIDAR-like resolution at a fraction of the cost and time. For all these reasons, we recommend it to anyone working in relatively tree-free rural areas of New Mexico.

Figure 1: Chet Walker holding the drone prior to takeoff at an Ancestral Jemez site in the Santa Fe National Forest, June 2012.

Spatial Analysis and Survey in South-Central New Mexico

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Dominated by large swathes of land managed by the Department of Defense, southern New Mexicoôs Tularosa Basin has long been a crucible for innovative approaches to collecting and analyzing archaeological survey data. Experimentation with innovative survey methods in this region got underway in the late 1970s and early 1980s, when large projects on the U.S. Armyôs Fort Bliss and White Sands Missile Range like the GBFEL-TIE and Borderstar 85 surveys began to explore the potential for dividing the regionôs broad dunal expanses into consistently gridded spaces and then conducting survey, site definition and analysis in terms of these regularized grids.

Today, the linear descendant of these early innovations remains in use at Fort Bliss, where for the last fifteen years pedestrian archaeological survey has been conducted using the Transect Recording Unit (TRU) method. When an archaeological survey area is identified at the Fort, space within the survey boundaries is

divided into a regular grid of fifteen-meter cells tied to local UTM coordinate intervals. Archaeological survey is conducted within this TRU grid, and all artifacts, features and other cultural manifestations observed during the survey are recorded within the TRU cells where they occur.

Unlike some of the earlier approaches to survey mentioned above, the TRU method does not represent non-site archaeology in the strict sense. Instead, the Fortôs site definition criteria are designed to be operationalized at the TRU level, allowing individual TRU cells to be identified as ñsite-positive.ò Sites are then built by aggregation, with all TRUs adjacent to site-positive cells assembled and daisy-chained together to generate final site boundaries. The resulting boundaries thus meet the needs of land managers, SHPOs and agencies accustomed to managing data at the site level.

TRU Survey and Spatial Analysis

On the other hand, TRUs afford many of the same resource and management advantages touted by advocates of siteless survey. They allow cultural resources to be documented at the same level of detail across an entire survey area and tie all data ï artifact counts and types, observations about ground disturbance and vegetation cover, and so on ï to a single fifteen-by-fifteen meter cell. Because all TRU grids at Fort Bliss are tied into the UTM system within the same parameters, data can thus be easily and straightforwardly verified and updated anywhere on the installation. Datasets and observations can be compared between contractors and projects, or used as a proxy for estimating changes in disturbance or visibility over time.

Most importantly, though, the spatially precise, relatively detailed grid of archaeological observations that results from a TRU survey is extremely well-suited for a wide range of spatial analyses at a variety of spatial scales. At the site level, TRU data can be used to map artifact or feature density or identify significant patterns of clustering across various material classes or feature types. Such data may be invaluable to resource managers, allowing them to pinpoint concentrations of cultural materials and delineate areas with good preservation or high potential significance. They also provide rich data for archaeological interpretation, suggesting zones where particular activities were carried out or delineating the locations of possible occupational clusters.

If anything, however, it is at the regional scale where the research and interpretive potential of TRU data really becomes evident. At the scale of a 5 or 10,000-acre survey ï or even better, if data from multiple surveys are pooled ï the thousands of individual observations making up a TRU dataset are exceptionally well-suited for GIS-based spatial analysis. Over the past decade, archaeologists from the four CRM firms that have worked at the Fort in recent years have used a variety of geospatial analytical methods to shed new light on the Tularosa Basinôs shifting patterns of prehistoric occupation. These analyses have delineated the foci of prehistoric landscape use over time, revealed ancient corridors of travel and movement, and even, to a certain degree, provided insight into the beliefs and culture of the Basinôs prehistoric inhabitants.

Current TRU Research at Fort Bliss

Among the most straightforward ways methods of spatial analysis can be applied to TRU datasets is the study of associations between TRUs and landscape features, whether these are the alternating, linear fault troughs and rises that run roughly north-to-south across the southwestern Tularosa Basin or the broad alluvial fans that spill from adjacent mountain ranges onto the basin floor. While previous research suggested that both landforms were important foci for prehistoric hunters, gatherers, and farmers, recent archaeologists have used goodness-of-fit tests with TRU data to precisely map the changing importance of fault troughs and alluvial fans to human populations over time. Briefly, these tests consider the distribution of TRUs within a particular area in terms of the percentage of that area occupied by a particular landform or landscape feature. If the proportion of cultural materials of a particular type or class occurring in association with a given landform far outstrips the percentage of the study area that landform occupies, this suggests that area may have been of particular importance. By contrast, areas occupied by small proportions of artifacts or features relative to their area were likely less important for the regionôs prehistoric occupants.

Beginning with work by Trevor Kludt and other Lone Mountain archaeologists in the mid-2000s and continuing via ongoing research conducted by Statistical Research, Inc. (SRI), GMI, and TRC, these analyses demonstrate a significant correlation between fault trough margins and evidence for human occupation

beginning during the Mesilla phase (AD 200-1000) or earlier, far outstripping the use of surrounding basin areas. Densely concentrated lithic artifacts along fault-trough margins suggest these areas were important resources for prehistoric hunting, but the presence of large quantities of ground stone and ceramic debris suggest they may have been used for seasonal camps or floodwater farming as well. The use of these areas declined later in the Formative period, however: TRU datasets from several areas document marked decreases in the extent and intensity of fault-trough-margin use during the later Doña Ana (AD 1000-1300) and El Paso phases (AD 1300-1450). At the same time, TRU datasets from alluvial fan areas around the basinôs edges display exceptionally strong correlations between El Paso-phase ceramic types and distal alluvial fans, indicating the presence of relatively dense occupations in these areas compared to surrounding zones. These occupations likely represent evidence for seasonal campsites associated with the use of alluvial fans for farming.

While the use of the basin floor for habitation and resource procurement declined during the later Formative Period, however, its use for other purposes continued. Recent TRU-based research has documented the presence of relatively high concentrations of ceramics arrayed in extensive linear patterns across the basin floor. Interpreted as clear evidence for prehistoric trails and transit corridors, these features were first examined in detail by Lone Mountain archaeologists along the eastern margins of the basin but have now been documented in all areas of the southern Tularosa Basin. Recent analyses by SRI archaeologists have demonstrated that these trails tend not to follow the routes of lowest effort, instead traveling in straight lines between large habitation sites, water sources, and other important resources. GIS-based viewshed analysis suggests that line of sight was as important for route-finding as any other variable, with a seeming preference for routes with clear intervisibility to habitation areas or major horizon features like prominent peaks or hilltops. Additionally, our examination of ceramic types associated with basin-floor trails has documented a clear pattern of association between these trails and later-period ceramics, suggesting that favored routes across the basin remained in use even as the use of the surrounding landscape for occupation or intensive hunting declined. We are currently investigating one of a series of massive, heavily used trails first identified by TRC archaeologists that converge at the Old Coe Lake playa in the western basin. Preliminary analysis indicates that a sizeable majority of the ceramic rim sherds identified in the vicinity of the trail were found along the trail corridor, suggesting it may have been an important route for water transfer across the basin.

PaleoWest Archaeology's Digital Recordation on the Navajo-Gallup Water Supply Project, Northwest, New Mexico

Jason Chuipka (PaleoWest Archaeology)
Shawn Fehrenbach (PaleoWest Archaeology)

Introduction

The Bureau of Reclamationôs $1.3 billion Navajo-Gallup Water Supply Project involves drawing water from the San Juan River in northwestern New Mexico and delivering it to communities of the San Juan Basin, including a large portion of the Navajo Nation, via a 280-mile-long pipeline system. It crosses hundreds of prehistoric and historic cultural resources, and is presently the largest public archaeology contract in the United States. To support it, PaleoWest Archaeology has developed digital data collection methods that are used in the field for survey, testing, and data recovery. These methods are intended reduce data collection redundancy and gather information so that it can be immediately shared among the PaleoWest research team members as well as with the Bureau of Reclamation, the Navajo Nation and other consulting native American tribes, and land management agencies for at least the next decade.

The move away from paper to digital data collection methods needs to be viewed in historic context. All fields of science rely on establishing an agreed upon vocabulary and system of classification. That was the goal of the first meeting at Pecos in 1927, during which leading archaeologists working the region at the time formulated the Pecos Classification that defined prehistoric periods in the northern Southwest. However, it was not until the rise of professional contract archaeology in the 1960s that the need for standardized data became most critical. Rather than a handful of archaeologists working on a few archaeological investigations across the American Southwest, archaeologists were now involved in numerous construction and development projects ï dams, roads, powerlines, timber sales ï prompted by the mandates of Section 106 of the National Historic Preservation Act. Consequently, a huge amount of data was being generated and there needed to be a way to collect this information, analyze it, and produce reports. These reports not only needed to satisfy academic research questions, but also provided the mechanism by which development projects could legally move forward. And as many archaeologists working in the Southwest know, completion of archaeological investigations more often than not follows timelines established by construction schedules and budgets.

By the early 1970s, computers began to play a larger role in archaeological studies, as they offered a means to conduct analysis of data and produce complex, multivariate models. It is at this point that it became apparent that data needed to be collected in the field in a standardized manner that would facilitate more efficient entry into a computer database after the completion of fieldwork. Although it is easy to forget the time before the desktop PC, these early computers lacked software that could be easily used for data entry and analysis. Programming was required, and computers were specialized pieces of equipment often times operated by serious men in white lab coats carrying handfuls of punch cards.

PaleoWest Digital Database

Over a period of several months prior to the start of the Navajo-Gallup Water Supply Project, PaleoWest developed a digital data collection system for use in the field that uses a variety of networked devices, including tablets, smartphones, and laptops. The guiding principles were simple. First, the system needed to be adaptive and alterations to parts of the system needed to be possible without redesigning the whole system. Second, the use of digital technology is intended to free up time in the field rather than hinder data collection. This second principle is a means to focus on the archaeology, address research questions more thoroughly, and allow project data to be viewed by all members of the research team from anywhere with an internet connection and access to the PaleoWest server.

All data on the Navajo-Gallup project is collected on digital forms. Artifacts and samples are tracked using Quick Response (QR) codes ï those patterned square matrix codes that are similar to UPC bar codes -- that are scanned into the project database in the field. This allows project staff to manage the items from the field to the lab, from the lab to the analyst, and from the analyst through the curation process. The analysis data is tied to these QR codes and they are also used to organize materials for curation. Plan maps and profiles are completed in the field using a total station and programs loaded onto tablets. Digital photographs are immediately captioned and saved in the database as well.

Discussion

The summer of 2012 was the first implementation of PaleoWestôs digital data collection system on an excavation project. The successes of the first go around include the reduction of redundancy and transcription; streamlining of artifact bag tracking, once the bane of any crew chief or lab director; immediate data sharing and backup; and nearly complete field maps that can be included in status reports.

The biggest challenge remaining for PaleoWestôs digital data recovery system is not harsh desert conditions or the cost of re-tooling with digital devices. Rather, the biggest challenge has been resistance to going paperless. This is partially rooted in the fact that many archaeologists are rather dogmatic when it comes to fieldwork processes ï ñthis is the way I learned to do it, and therefore it is the one and true wayò. Minor panic attacks have occurred when there is no stack of forms and field logs in sight. It has been conceptually difficult to transition to using a database in the field, even though the underlying processes have not changed. You just cannot physically quantify your efforts by measuring the stack of paper generated.

Granted, some methodological touchstones learned at field schools have been the primary means by which data consistency has been managed in the past ï keeping field logs, cross-checking master lists, etc. This has not changed much with the methods implemented in 2012. Rather than replacing the old with the new, PaleoWest is looking at how technology can be used to advance these tried-and-true methods.

Data Management

Robert Heckman (Statistical Research Inc.)

Data management is a critical component of every project regardless of size and complexity. At SRI, the goals for data management are to facilitate the descriptive, analytical, and curation needs of a project. To that end, SRI developed a relational database (SRID) that is a reflection of our fieldwork recording system for surveys, evaluations, and data recovery projects. The core of SRIôs recording system is space. In our system, we code space with a unique identifier and then associate artifacts, samples, observations, photographs, contextual attributes as well as a host of other data with that space. SRID, by design, is scalable and agile and used for small surveys as well as large, complex data recovery projects. The number and suites of attributes measured, observed, and entered into SRID are entirely dependent on the project goals and needs. Project principals at the onset of a project define the variables that will be recorded and define the workflow and procedures for data entry into SRID. The key to success in developing and using a centralized-relational database is developing a User Interface that enables people to access the data easily. This has been a real challenge at SRI and we are still refining the tools.

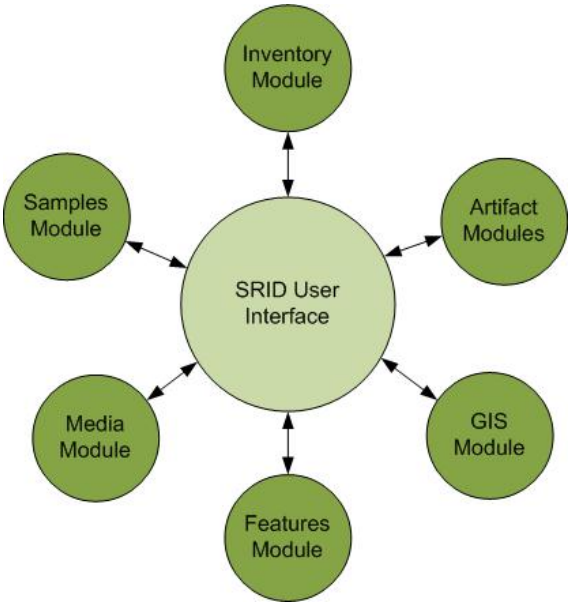

Figure 1. Schematic overview of SRID

Figure 1 presents a simplistic diagram showing the various modules in SRID. A SRID Module is essentially a coherent suite of data, for example, the Artifacts Module contains the various analytical environments for ceramics, lithics, and fauna. The Features Module contains the metric, morphological, and other attribute data recorded for each feature.

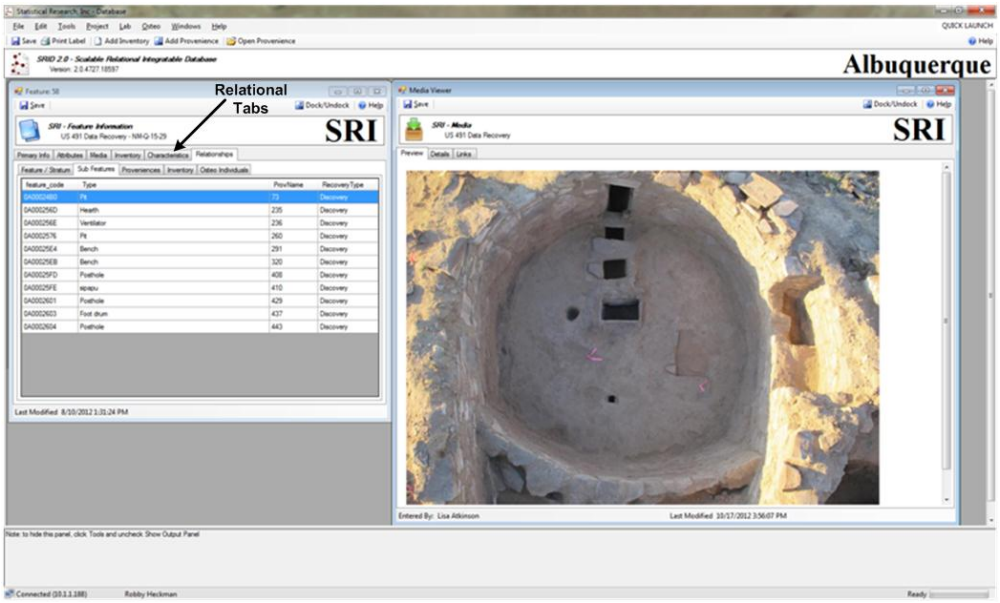

Figure 2. Example of SRID User Interface showing feature-data relationships and the Media Viewer

The primary advantage to centralized-data management in a relational database is the ability to quickly access information and get consistent results for perfunctory questions like how many features at a site or complex queries that combine variables and observations and provide synthetic results. The SRID user interface allows users to interact with the data and quickly get descriptive or tabular information, or view the photographs of the feature (Figure 2). The interface was designed to bring important relational data together and allow the user to explore and drill down on specific sets of data. For example, the user can easily find out what artifacts and samples were collected from the feature without having to write a query (Figure 3). The panel on the right hand side in Figure 3 displays the tabular data and allows the user to easily drag and drop other variables into the pivot table for viewing.

The User Interface allows members of the project team to access the data in a controlled manner that ensures consistent results. The component of the User Interface shown in Figure 2 and 3 is used routinely to quickly and efficiently write descriptive summaries for sites and features. In addition to displaying relationally linked photographs, the Media Module can also display any kind of document or file that is relationally linked to the feature or site. For example, a site form, quality assurance forms, hand drawn and line-drawn maps, and any other documents or files relevant to the feature or site can be relationally linked and easily accessed.
The ultimate goal in using SRID at SRI is to have project personnel move quickly and efficiently through the purely descriptive tasks and have the ability to spend more time interpreting the data and designing analyses. Collecting data in a systematic manner project to project also allows researchers to easily use data collected for one project and compare it to another project as appropriate. SRI is very fortunate to work for clients that manage large tracks of land where we conduct multiple surveys and excavations within the same basin or valley. Collecting the data for each of these projects in SRID allows a cumulative data set that provides a much boarder context than the data collected for the immediate project. After all, archaeology is all about context and with powerful tools like relational databases that are dynamically linked to GIS data researchers can ask questions at various scales more easily.

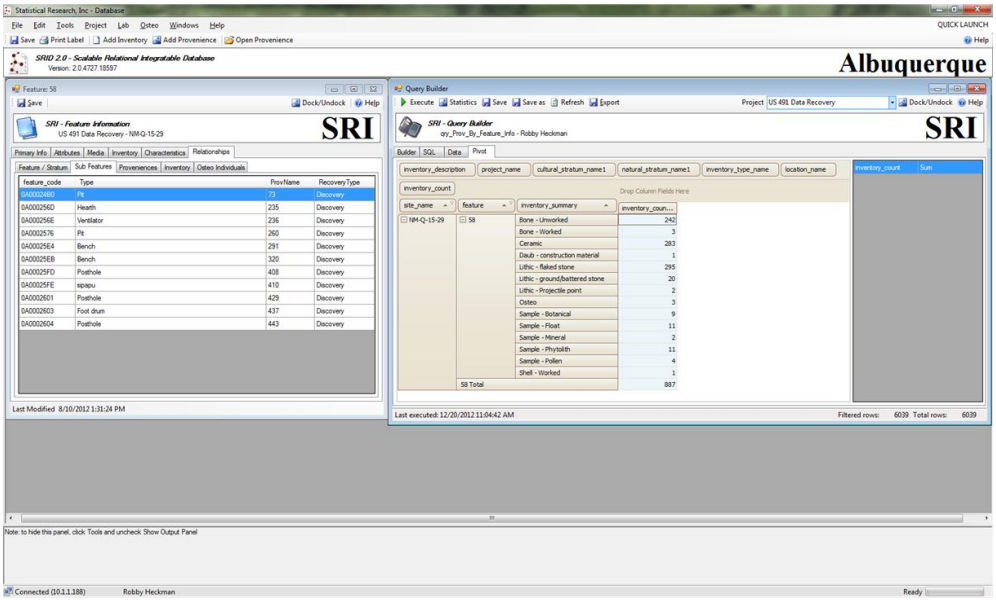

Figure 3. Example of SRID User Interface showing tabular output using the Pivot Table Builder

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