ARCHAEOLOGY SOUTHWEST *magazine*

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Social Networks in the Distant Past

Seven centuries ago, foot travel, powerful ideas, and long-distance relationships connected people across the Southwest

inside this issue

ISSUE EDITOR:

Matthew A. Peeples

ONLINE EXCLUSIVES:

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Cover images: Twill-plaited H-strap sandal made of agave fiber (Catalog No. GP 6439). Archaeologists recovered this sandal from the Hog Hill Ruin, a site in the upper Verde River valley of north-central Arizona. Similar examples came from the Tonto Cliff Dwellings, Canyon Creek Ruin, and the Red Bow site in the Point of Pines region. All date between A.D. 1300 and about 1400. Experts believe this style of sandal may reflect a more southerly tradition, and similar examples seem to be depicted in sixteenth-century Mesoamerican codices. Image: Jannelle Weakly, courtesy of the Arizona State Museum, University of Arizona. Consultants: Laurie D. Webster and G. M. Jacobs. Trail and landscape at Quail Point, a rock art site in the lower Gila River valley. Image: Andy Laurenzi. Cover design: Kathleen Bader.

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

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Archaeology Southwest

Exploring and protecting the places of our past

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Social Networks in the Distant Past: The Late Precontact Southwest

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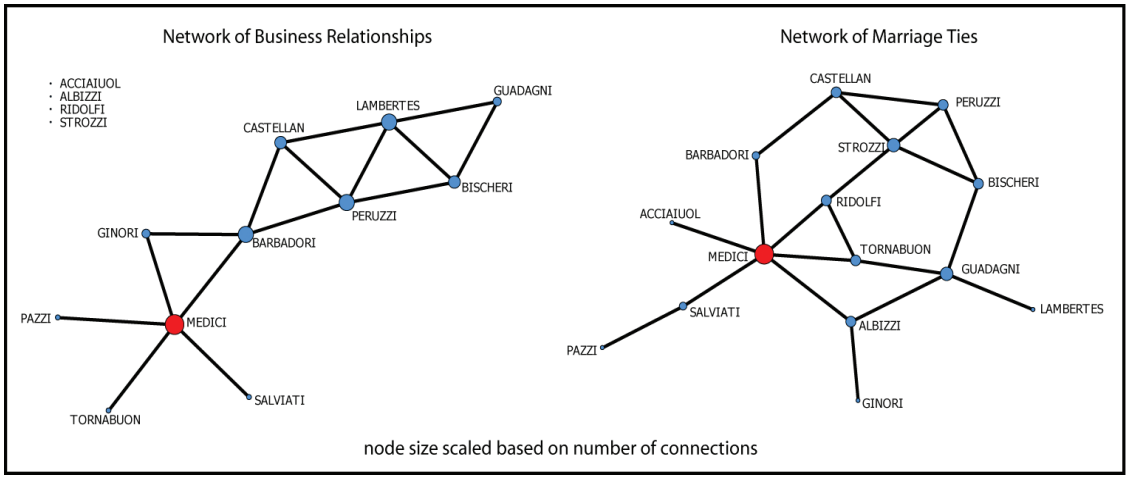
In the age of Facebook and Twitter, "social network" is a phrase heard or read almost daily. Most of our readers will have a general concept of social networks through their familiarity with these communication tools. Yet, social networks are a mainstay of the human experience, not a product of new technologies.

In the simplest terms, a social network consists of a set of actors—individuals, communities, or even organizations—and the connections among them. "Connections" may represent any number of relationships between pairs of actors: familial ties, friendship, acquaintance, frequent interaction, exchange partnerships, or political alliances, among others.

Based in network theory, social network analysis (SNA) is a developing field that most often evaluates these kinds of connections in today's world, as a means of systematically exploring interaction. The work presented in this issue of *Archaeology Southwest Magazine* represents one of the first comprehensive and large-scale attempts to apply SNA to relationships in the distant past.

The Southwest Social Networks project team met at the School for Advanced Research in Santa Fe, New Mexico, for a seminar in which they reviewed interim findings. Of course, the team represents a social network unto itself, reflecting ties among professors, colleagues, former and current graduate students, and experts who inspired the project (see pages 22–23). Standing, from left to right: Ronald Breiger, John Roberts, Matt Peeples, Aaron Clauset, Lewis Borck, Steven Shackley, Randy Haas, and Brett Hill. Seated, from left to right: Barbara Mills, Jeffery Clark, and Deb Huntley. PHOTO: JASON S. ORDAZ, COURTESY OF THE SCHOOL FOR ADVANCED RESEARCH

One tenet of SNA is that if you know something about the structure of relationships and interactions among some set of actors, you may be able to better understand their motivations for interaction, or even assess probable outcomes for that network. For example, network studies have shown that if you are friends with two people who do not know each other, they are considerably more likely to become friends themselves than they would be if you did not know both of them. Further, individuals or organizations who are connected to diverse individuals—or located in key intermediate positions—often enjoy greater long-term success than those who are peripheral to the interactions represented in that network. An instructive historical example of this is the famed Medici dynasty (see graphic below).



Top: The Medici family of Renaissance Florence rose to prominence during the 1400s. Sociologist John Padgett examined historical documents of marriage, trade, and business relations among prominent Florentine families. As these graphs illustrate, the House of Medici was located in a key position characterized by more connections than any other family. This was true for business relationships, such as loans or co-ventures (left), as well as marriage (right). Padgett argues that such structural positions were important to the success of the dynasty. GRAPHIC: ADAPTED BY MATTHEW PEEPLES FROM PADGETT'S DATA. *Left: Lorenzo de' Medici (the "Magnificent") as an adolescent.* SOURCE: WIKIMEDIA COMMONS

Social network analysis enables formal, quantitative consideration of the social processes at work in a given setting. Researchers illustrate networks using diagrams or graphs, with individuals or groups depicted as nodes, and the connections between them depicted with lines. Creation of these representations tells us much about the relative importance or influence of specific actors, or about the nature of social groups. However, SNA methods can also lead to unexpected realizations about the relationships between local and regional-scale interactions, the centrality of specific sets of nodes, or the processes behind significant changes in interaction over time.

Applying SNA methods to archaeological data pushes us to consider the importance of *relationships* in driving cultural or demographic change, in addition to the external factors we more often examine, such as population pressure or environmental change. The models and methods of SNA show great potential for helping archaeologists understand social processes occurring at regional scales, such as the entire Southwest.

The Southwest in the Last Centuries before European Contact

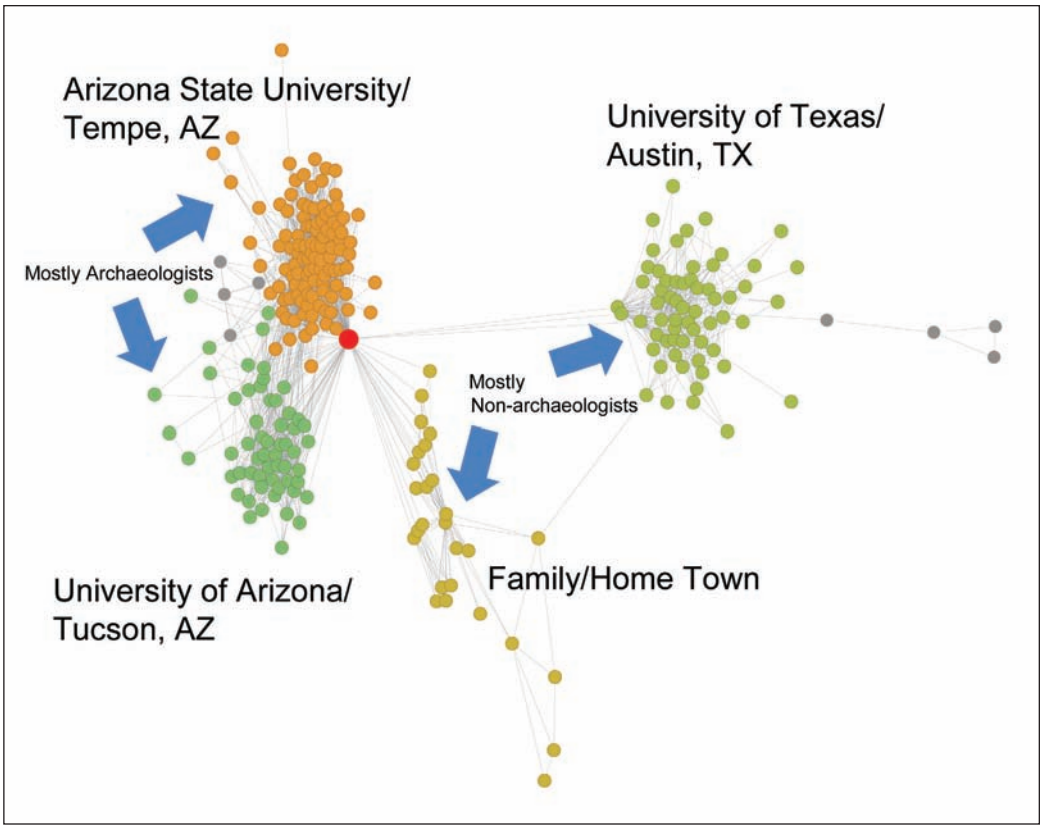
Emil Haury's classic 1958 study of social dynamics at a settlement now known as Point of Pines used multiple lines of evidence to show that, in the late A.D. 1200s, a small number of people from what is now northeastern Arizona migrated to this established community in east-central Arizona. The immigrants settled alongside the resident population, building houses in the style of their homeland, which were very different from the locals' dwellings. As it turns out, Point of Pines was one among many contemporaneous communities in which northern immigrants of various origins and local southern populations resided together.

For more than a decade, Archaeology Southwest and its partners have sought to characterize the impact of these ancestral Pueblo immigrants and their descendants across the Southwest. To date, evidence suggests that significant developments in the last centuries before European contact, or the late precontact period (A.D. 1200–1500), arose from this social and cultural mixing. The emergence and spread of Salado polychrome pottery, which we argue represents a social and religious movement, is one such development during this time (see *Archaeology Southwest Magazine* 26:3/4).

Though immigrant populations were relatively small, they seem to have had a considerable impact on many important changes marking this era. Investigations in specific parts of the southern Southwest indicate that patterns of interaction, exchange, and mobility were transformed in the late 1200s and early 1300s, in the wake of the immigrants' arrival. One trend we see is the establishment of strong connections among several areas that were not closely linked before immigrants settled there (see *Archaeology Southwest Magazine* 22:4).

Beyond this, the nature and timing of major demographic changes across the Southwest suggest that, in some places, immigration probably spurred people to leave smaller, more dispersed settlements and move to larger, more populous settlements. This, in turn, probably contributed to a decline in regional population over about 150 years.

Before the advent of SNA and related tools, it was difficult to track how the networks of interaction, exchange, and mobility implicated in these transformations might play out at broader regional scales. Now, our work is showing that these tools may help us understand the past in new ways.

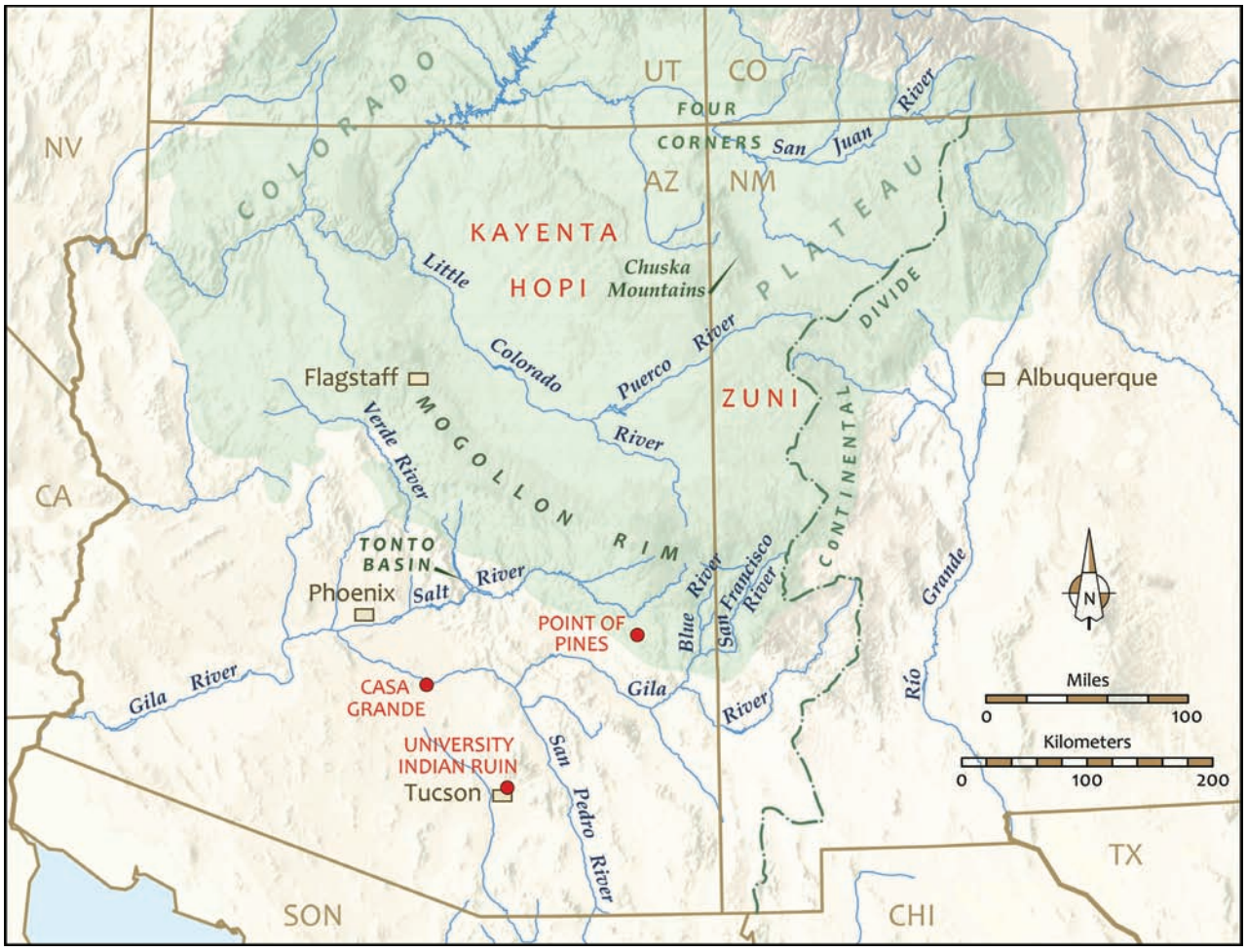


By observing network graphs, we can learn quite a bit about a person's or a group's interactions and history. This graph shows issue editor Matt Peeples's Facebook network. Several distinct clusters relate to places Matt has worked and lived. We can also see a clear distinction between archaeologists and non-archaeologists. The red node in the center is Matt's wife Melissa, the most central node in the network ("As I should be," according to Melissa). You can make a network graph of your own Facebook network by visiting www.wolframalpha.com and searching for "Facebook Report." To view Matt's Archaeology Café presentation about social networks and the research presented in this issue, visit www.archaeologysouthwest.org/asw27-2.

The Southwest Social Networks Project

In 2008, the University of Arizona's School of Anthropology and Archaeology Southwest received a grant from the National Science Foundation to use SNA to explore regional networks of interaction and exchange across the western Southwest between 1200 and 1500. The Southwest Social Networks (SWSN) project, as we call it, builds on a long history of big-picture research into this turbulent period by formally examining how previously identified demographic and social trends may have influenced, or been influenced by, changing patterns of interaction among the region's inhabitants. The SWSN project is interdisciplinary, involving archaeologists with various areas of expertise, sociologists, a geochemist, and a computer scientist (see pages 22–23).

Archaeologists interpret patterns of social interaction primarily through material culture—the things people built, made, and used. To track and describe networks of interaction among settlements and regions, we had to compile a massive body of data about sites and artifacts. To do this, the SWSN project expanded the Coalescent Communities Database (CCD), which contained information about the size and habitation span of every documented southwestern settlement with more than twelve rooms that dates between 1200 and 1700. The CCD was derived from collaborative research conducted by Archaeology Southwest, the Museum of Northern Arizona, and Western Mapping Company (see *Archaeology Southwest Magazine* 22:4 for discussion of the demographic processes the CCD helped elucidate). Our project added information about pottery wares and counts and obsidian source determinations for 715 sites



Places mentioned in this issue. GRAPHIC: CATHERINE GILMAN

west of the Continental Divide. We gathered these data from many sources, including published reports and unpublished field notes, and through our own analyses of museum collections. In a few areas where data were particularly sparse, project members went into the field to document surface artifacts (see photo on page 22).

At present, the expanded database—now known as the Southwest Social Networks Database—contains information about more than 4.3 million ceramic artifacts from more than 700 sites, and more than 6,000 sourced obsidian objects from about 150 sites. Data collected for this project represent the results of more than a century of archaeological research in the Southwest. This rich compilation allows us to leverage new and existing information at a scale never before possible. Our project also reflects the values and practice of Preservation Archaeology, in that the SWSN Database facilitates access to a considerable amount of information, with no adverse impacts to archaeological resources.

Articles in this issue describe analyses conducted by project team members using the SWSN Database and SNA methods. Although these analyses draw on somewhat different techniques and evidence, they all center on related questions. How did patterns of interaction and exchange change through time at local and regional scales? How might the structure and organization of networks of interaction among settlements have influenced the long-term success or failure of settlements or regions? How did the arrival of a relatively small number of northern immigrants to the mountains and deserts of the southern Southwest affect the network landscape of the region as a whole?

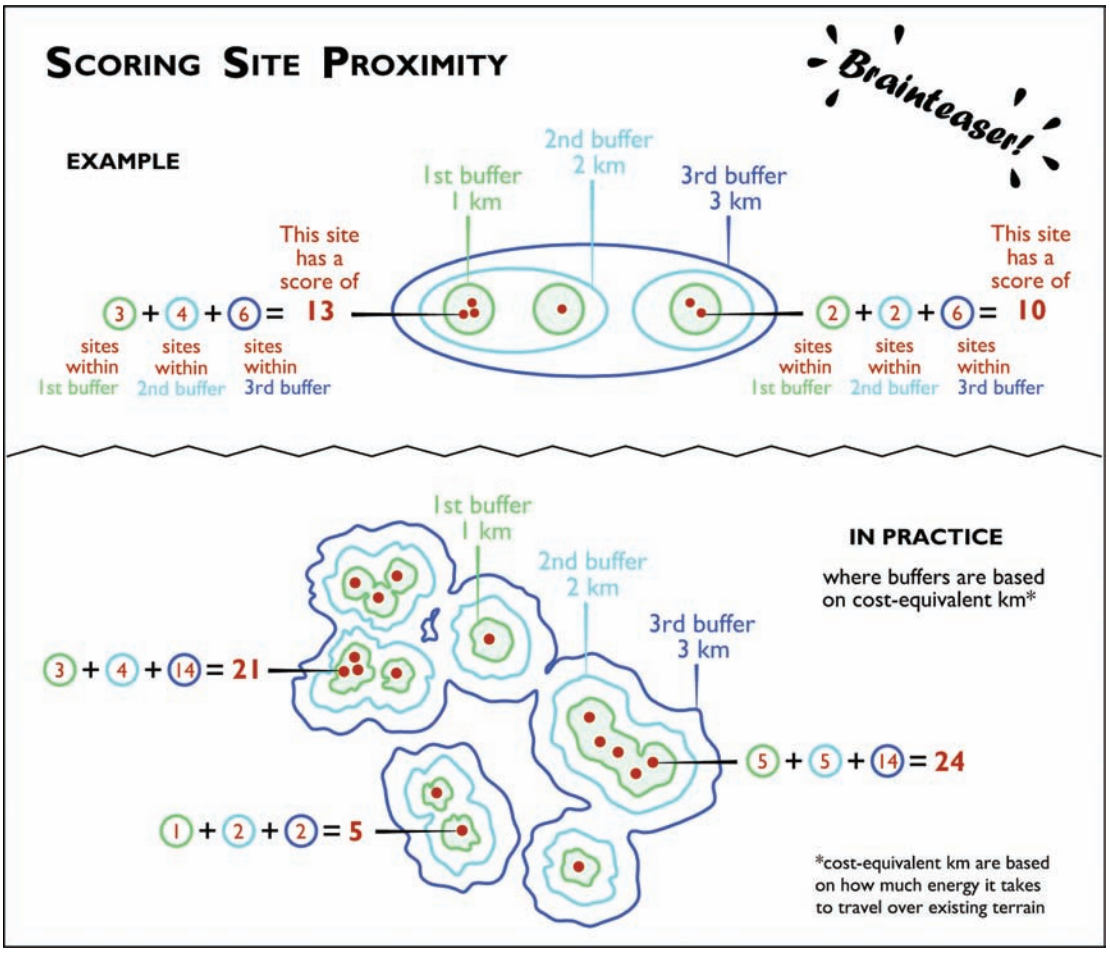
We conclude with a discussion of some of the themes that pervade individual analyses, and we consider how migration might have contributed to remarkable changes in people's lives and communities in the three centuries before Europeans arrived. We also share the story of how our collaboration unfolded and how our own networks led to a prestigious publication.

Proximity:
What Role Did Nearness Play in Creating Social Networks?

From real estate to physics, location and distance guide our understanding of the world. In anthropology, too, we typically hold spatial relationships to be among the most influential factors affecting cultural dynamics. We usually expect proximity to determine the likelihood of interaction with other people, especially for societies in which people travel solely on foot, as they did in the late precontact Southwest. What was the relationship between proximity and interaction at that time?

Methodology

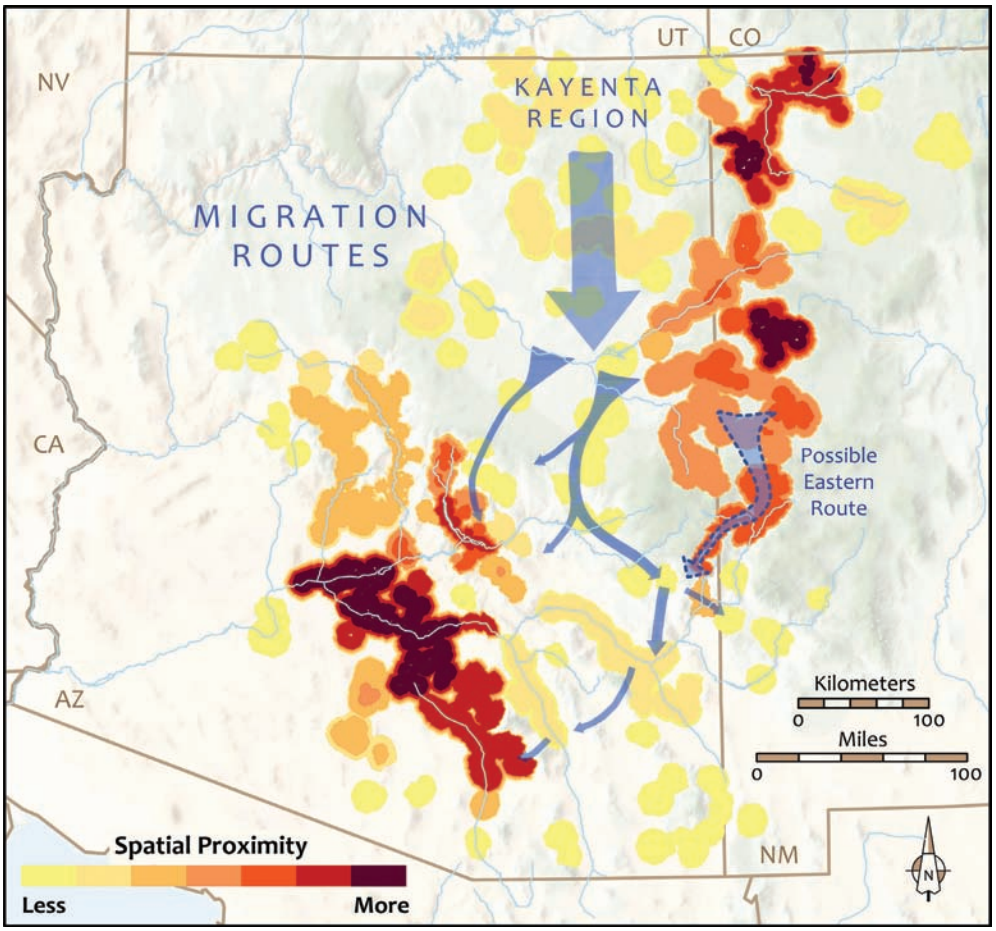
To examine how the potential for pedestrian travel in mountainous terrain shapes social networks, we turn to Geographic Information Systems (GIS). Combining digital terrain data and information about archaeological site locations and habitation spans enables us to create maps of likely interaction zones around ancient communities in our study area. We scale these interaction zones to reflect the decreasing likelihood of interaction as distance increases from less than a mile to about twenty miles (one to thirty-six kilometers). The latter reflects the maximum distance typically considered to be traversable on foot in one day.



Our measure of spatial proximity assigns higher values to sites characterized by higher local site densities across shorter distances; that is, to sites that are clustered together on the landscape at short distances. The example here shows three calculations of this measure based on three buffer levels. Our final measure of proximity is defined as the sum of the number of sites within each buffer level, from 1 cost-equivalent kilometer (less than a mile away) to 9 cost-equivalent kilometers (almost six miles away, or half a day of foot travel out and back). GRAPHIC: CATHERINE GILMAN

Calculating the number of neighboring sites within each zone allows us to identify areas of high potential for social interaction. If proximity is, in fact, an important determinant of such interaction, social network analyses should find evidence for greater connectivity in areas of high potential.

A central goal of the SWSN project is to understand how social upheaval and migration played out across the Southwest over a span of centuries. Such disruption and change in the distances between and among various groups of people and their social relations should result in interaction



How does mountainous terrain affect the formation and structure of social networks among people who travel solely on foot? For the period just before migration out of the Four Corners, our calculations predict certain corridors of connectivity based on proximity. As it happens, most of these corridors correspond to migration routes archaeologists have already proposed. Our calculations also predict a corridor of connectivity from west-central New Mexico into Arizona's Safford Valley. We look forward to exploring this zone in future research. GRAPHIC: CATHERINE GILMAN

patterns that differ from what proximity predicts. Ours is the first large-scale archaeological study to integrate GIS and social network analyses in this way, and the results illustrate several interesting and related phenomena.

Patterns and Inferences

The first stage of our GIS calculations demonstrates two dominant areas of potential social interaction in the study area, in the northern and southern Southwest. One centers on the southern portion of the Colorado Plateau, the homeland of ancestral Pueblo people. The other surrounds modern-day Phoenix, the homeland of people whom archaeologists call the Hohokam.

When we examine the correlation between potential for social interaction and measures of actual interaction in the two areas, such as those indicated by similarities in decorated pottery (see pages 9–13), we find striking differences. These disparities underscore cultural differences between the two areas and begin to explain their divergent paths of survival and decline (see pages 17–19). In general, the northern Southwest shows a strong correlation between proximity and potential social connectedness in the early through mid-1200s and 1300s, which then intensifies in the 1400s, as regional population declines and populations become increasingly concentrated. By contrast, the southern Southwest exhibits little correlation between proximity and potential social connectedness overall, followed by a precipitous decline during the 1400s.

In addition, there appears to be relatively close correspondence between zones of high potential connectivity based on proximity and previously hypothesized migration corridors (see map at left). We see this especially in the Tonto Basin and along the lower Salt River and middle Gila River valleys of southeastern Arizona between about 1250 and 1400. During the 1200s, there is also a zone of high potential connectivity in what is now west-central New Mexico—from the southern Zuni/Cibola region down through the San Francisco/Blue River area and into the Safford Valley—that our research has not yet examined.

Finally, our analysis suggests that the most isolated sites are located along the Mogollon Rim and in the Upper Gila region. Based on potential connectivity alone, we would expect communities in these areas to be relatively socially isolated, as well. Similarities in ceramic wares indicate that these communities maintained quite diverse social connections, however (see pages 9–13). Newcomers arriving in the late 1200s and 1300s may have taken advantage of, or even expanded, those connections, rather than interacting solely with their closest neighbors. This disparity illustrates that proximity is not the only factor affecting social networks, and that long-distance interactions in the precontact Southwest were dynamic and complex.

Pottery:

How Do Decorated Ceramics Enable Us to Reconstruct Social Networks?

There are several reasons why pottery, especially decorated pottery, is one of our best means of exploring social relationships among individuals, settlements, and regions in the precontact Southwest.

First, the high degree of variation in technology provides a basis for systematically distinguishing different varieties of ceramics, particularly those categories that archaeologists define as *wares* (see page 11). In other words, we can see that people living in different regions or working in different traditions learned to make and paint pottery in specific ways.

Second, the decoration on painted pottery is often ideologically charged. People actively used imagery to mark social relationships among themselves, although we cannot discern the exact nature of those relationships.

Third, because pottery was a part of daily life, it was continually broken and discarded. Broken pottery is ubiquitous at settlements in the Southwest.

Finally, a tremendous amount of existing data informs our research. Generations of archaeologists have been recording variations in ceramic assemblages, the collections of pottery found at a site. This has resulted in the classification and dating of millions of objects.

Our approach to defining social networks using ceramic data relies on similarities in the *consumption* of different kinds of ceramics—that is, in the patterns of how people used and discarded pottery.

Similarities in ceramic assemblages result from a number of social processes, including trade, population movement, and the transmission of knowledge about how to make pottery, as well as other learned behaviors, such as the socially appropriate ways to cook, serve, and store food and other goods. Top: A Zuni potter (1903) forms a vessel using a coiling method. Subsequently, the potter would thin the vessel walls with a scraper. Bottom: Tohono O'odham potter Rupert Angea (1980) uses a wooden paddle in his right hand and stone anvil in his left hand to form and thin vessel walls. The rectangular paddle on the table was his grandmother's. Each of these potters has learned the craft according to different traditions. Such technological differences are detectable in archaeological ceramics. IMAGES: TOP: EDWARD S. CURTIS, COURTESY OF THE LIBRARY OF CONGRESS, NO. 112233. BOTTOM: HELGA TEIWES, COURTESY OF THE ARIZONA STATE MUSEUM, UNIVERSITY OF ARIZONA, NO. 53166

Major pottery traditions (ceramic wares) documented in our study area, dating circa A.D. 1200–1450. Examples are shown in the regions where they are most commonly found. Left to right, top to bottom: Tusayan White Ware jar, Mesa Verde White Ware bowl, Jeddito Yellow Ware bowl, Late White Mountain Red Ware bowl, Early White Mountain Red Ware bowl, Middle Gila Buff Ware jar, Roosevelt Red Ware (Salado polychrome) jar, Mogollon Brown Ware (McDonald Painted Corrugated) bowl, Cibola White Ware jar, Tucson Basin Brown Ware jar, Roosevelt Red Ware (Salado polychrome) bowl, Chihuahuan Series (Ramos) jar. For ceramic types, catalog numbers, provenience information, and photo credits, visit www.archaeologysouthwest.org/asw27-2. GRAPHIC: CATHERINE GILMAN AND MATTHEW PEEPLES

Methodology

To capture the effects of all of these processes in a systematic manner, we define the strength of connections between pairs of sites in our database using quantitative measures of similarity in the proportions of different ceramic wares present at each site. We do not mean to suggest that individuals within every settlement interacted directly with all other individuals who shared general consumption practices. But we do argue that, at a community level, the inhabitants of settlements with similar frequencies of wares were more likely to have interacted with one another than with those who used and discarded quite different sets of wares. We focus here on the strongest connections among sites, though weaker connections also play an important part in regional networks of interaction (see pages 16–17).

To maintain consistent data quality, we rely only on ceramic assemblages that archaeologists have systematically recorded and described. To ensure comparability, we further standardize various ceramic type and ware names and assignments made by different researchers over the years. Using these standardized assignments and estimated dates of production, we mathematically split each site's ceramic assemblage into each of the six fifty-year intervals between 1200 and 1500 in which people inhabited that site. Next, in order to quantify the relationships among sites, we calculate similarity scores by comparing the proportions of different ceramic wares from every site to every other site in the database for all periods.

Using these similarity scores, we are able to determine which sites were strongly connected to each other—that is, very similar in terms of ceramic consumption—and which were not. We can also ascertain how ceramic networks developed and changed through time.

The maps presented here (see pages 12–13) show network ties among sites for each fifty-year period between 1200 and 1500. Each line represents a tie between a pair of sites in our database. In order to ease display of these complex data, we display only those ties between sites that have at least 75 percent of their ceramic assemblages in common. The ties are color-coded based on the spatial distance between sites, with the shortest-distance connections (less than twenty-five kilometers, or about fifteen miles) in white and the longest (greater than 250 kilometers, or about 150 miles) in dark blue.

Patterns and Inferences

One of the most striking trends in these network maps is the number of long-distance ties, expressed in dark blue. As these maps illustrate, a number of settlements shared remarkably strong similarities in terms of the proportions of different ceramic wares, even though these settlements were quite distant from one another.

Additionally, these maps show well-defined subgroups, which network analysts call components, within the overall regional network. For example, in the earliest period (1200–1250), several portions of the northern Southwest, as well as many major river valleys in the Hohokam region of southern Arizona, were all largely disconnected from one another. At the same time, a large cluster of sites in the central and eastern portion of the study area represents strong ceramic similarities across vast distances.

This series of maps also illustrates a major transformation in network structure that occurred sometime between 1250 and 1300. This corresponds with a period of long-distance population movement, including the depopulation of much of the Four Corners region and the arrival of northern immigrants in the southern Southwest (see pages 4–5). Within our study area, some of the most important population movements involved the migration of thousands of people from the Kayenta region in northeastern Arizona into central and southern Arizona. Dramatic changes in network structure in the north and in the south mark this migration. Many of the destination areas for northern immigrants in the southern Southwest became increasingly connected during this period, whereas the northern Southwest was increasingly characterized by small, inwardly focused subgroups (see pages 17–19).

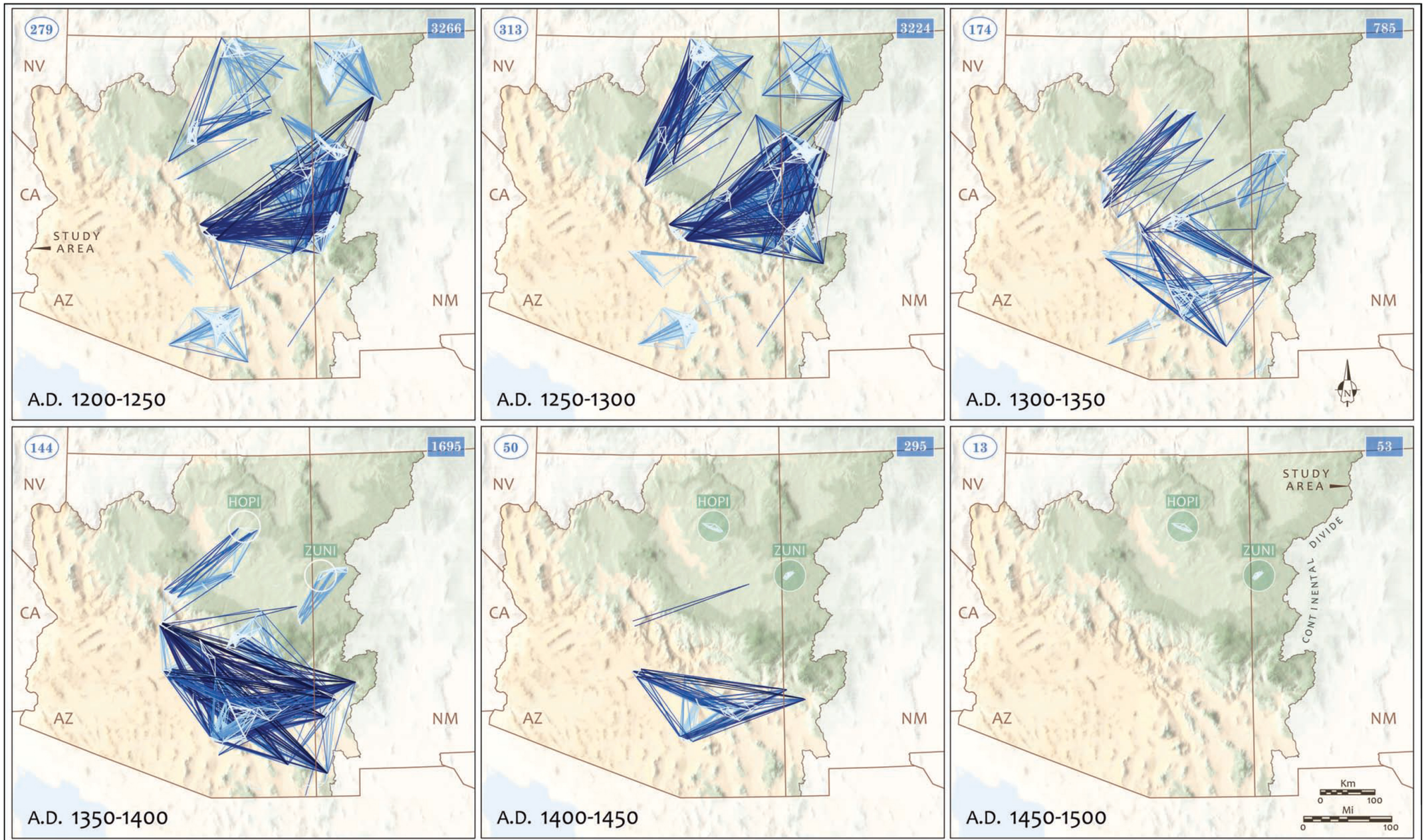
The period after this migration is also associated with a significant increase in the number of long-distance ties across the region. The locations of ties changed significantly, as well. One ceramic ware is largely responsible for the high degree of long-distance connectivity in the southern Southwest: Salado polychrome pottery. Archaeologist Patricia Crown and others have pointed out the ideological importance of Salado polychromes (see *Archaeology Southwest Magazine* 26:3/4). The vivid slip and paint combinations and bold iconographic content on Salado pottery make it some of the most striking ever produced in the region. It appears to have connected multiethnic communities—those in which northerners and their descendants lived among people of local southern heritage—across great distances.

By about 1400–1450, however, the dense connections among these southern sites began to break up. As populations declined, long-distance connections must have been more difficult to maintain. The expansive networks of the south dissolved, but the more inwardly focused networks of the northern Southwest around Hopi and Zuni persist to this day.

Food for Thought...

To facilitate comparisons, archaeologists use standardized terms to classify southwestern pottery. One of the broadest classifications is **ware**. Wares represent technological traditions associated with groups of people in different places. Each ware name has two parts. The first indicates where archaeologists first identified it, and the second describes the ware's color scheme or some aspect of technology. For examples of ware names, see the caption on the facing page.

Practical applications of social network analyses include counterterrorism and the detection of financial crimes, such as money laundering and insurance fraud.



These maps show networks of ceramic similarity (consumption of similar pottery wares) among sites across our study area for six fifty-year periods between A.D. 1200 and 1500. Each line represents a pair of sites in our database that have in common at least seventy-five percent of the ceramic wares recovered at both sites for the period in question. The color of the lines from white to dark blue indicates the distance between the pair of sites in question. As these maps show, regions of the northern Southwest, especially the areas along the Arizona-New Mexico border, were marked by many strong similarities among sites spanning great distances in the period before about 1300. After 1300 (after the migration of people out of the Kayenta region [see pages 4–5]), the longest distances between pairs of sites shift to the southern Southwest, with many connections linking areas that had been distinct for more than a century prior. By 1400, we see further consolidation of northern networks and a decline in the total number of connections in the southern Southwest as the number of sites declines and population decreases. Finally, by 1450, only the tight-knit and short-distance networks of ceramic similarity in the Hopi and Zuni areas remain. GRAPHIC: CATHERINE GILMAN

Obsidian:

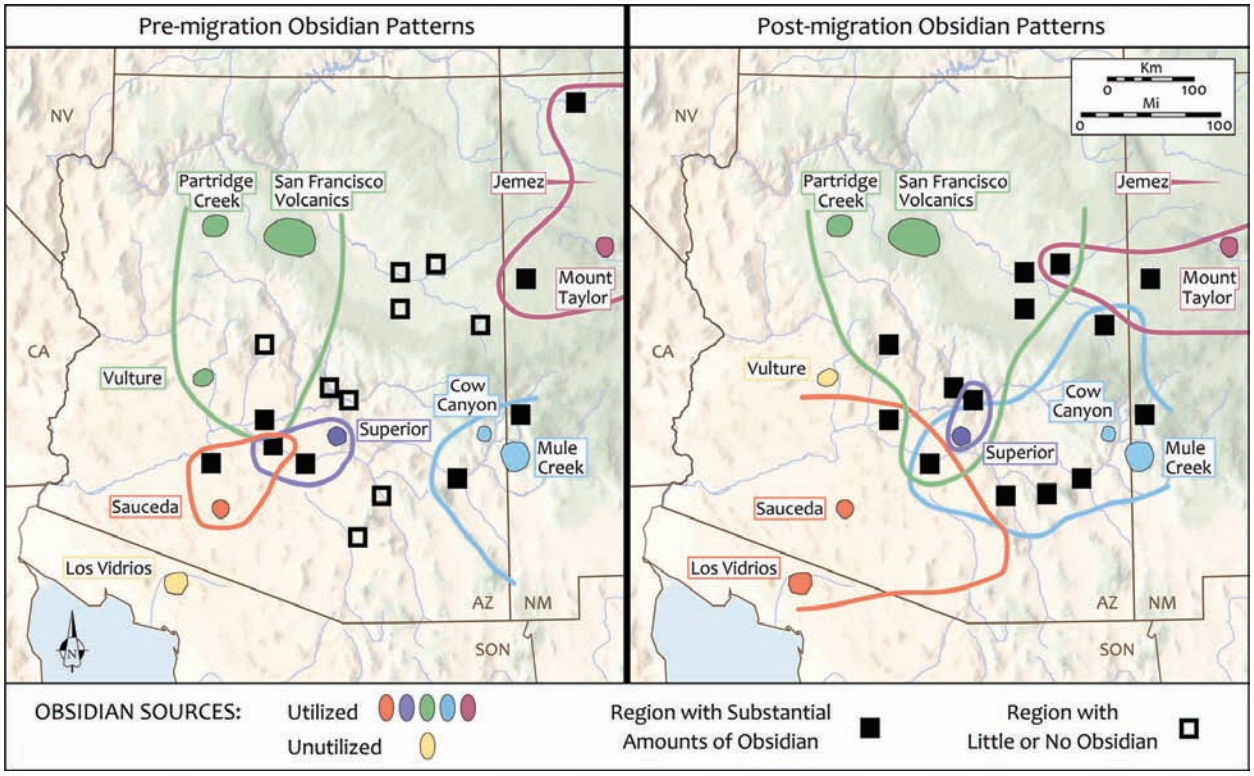
What Does a Sudden Expansion in Its Distribution Imply?

Residents of the precontact Southwest obtained faraway materials and conducted astoundingly extensive trade with only their own feet and very limited transportation technology. Did they expend minimum effort for maximum economic gain—like choosing a grocery store based on how close it is to your home? Or did social factors, such as kinship, ethnicity, or religion, drive their economic decisions—like shopping a little farther from your home because a friend or family member manages the store, or avoiding a nearby store because you do not care for the owner or the products?

Obsidian, or volcanic glass, was a common trade good in the late precontact Southwest. If people had sought to minimize effort, they would have selected the closest sources, given comparable quality. Substantial differences from such a pattern would suggest that other factors, particularly social relationships, outweighed purely economic considerations.

Largely through M. Steven Shackley's work, we now know the trace element fingerprints of almost all of the roughly forty deposits of tool-grade obsidian in the Greater Southwest. X-ray fluorescence spectrometry (XRF) (see *Archaeology Southwest Magazine* 26:2) allows us to determine, with high accuracy, the source of nearly all obsidian artifacts found at consumer settlements.

Between A.D. 1200 and 1500, the most intensively exploited sources were the San Francisco Volcanic Field near Flagstaff, Arizona, and the Mule Creek and Cow Canyon sources in the Upper Gila River valley. People also commonly used obsidian from the Superior source in central Arizona, the Jemez source



Left: Prior to the widespread migration and disruption of the late 1200s, obsidian assemblages at most sites follow distance decay expectations: many settlements used the closest source. Right: Obsidian use throughout much of the Southwest increased significantly after 1300, when most sites also deviate from distance decay expectations. Over- and underrepresented sources and site locations shifted from the northern to the southern Southwest. The primary overrepresented sources include Mule Creek, Cow Canyon, and the San Francisco Volcanic Field. GRAPHIC: CATHERINE GILMAN

in northern New Mexico, the Sauceda source in southwestern Arizona, and the Los Vidrios source in northwestern Sonora.

Angular nodules of obsidian on the ground surface at RS Hill, one of the obsidian sources within the San Francisco Volcanic Field. PHOTO: WILLIAM BRYCE

Methodology

To determine if residents of late precontact settlements primarily used the most convenient obsidian sources, we use a standard distance decay model (in which frequency declines relative to the square of the distance) to generate expected source frequencies. To account for differences in terrain, we calculate distance in terms of the energy costs required to travel from each site to each obsidian source. For example, as the crow flies, Point of Pines is about twenty miles from the Cow Canyon obsidian source; however, because of intervening mountains, this trip requires the energy equivalent of walking almost thirty-four miles over flat terrain.

We compare the actual, XRF-determined sources of the obsidian assemblages with expected source assemblages derived from our distance decay model. If analyzed assemblages conform to the pattern generated by the model, we consider them to follow the rule of minimum effort for maximum gain based solely on economic considerations. Where assemblages deviate greatly from distance decay expectations, we consider the influence of other factors, including social connections.

Patterns and Inferences

Prior to the widespread migration and disruption of the late 1200s, obsidian assemblages at most sites follow distance decay expectations: many settlements used the closest source. In most areas where a local source was not available, obsidian was extremely rare and limited to finished tools, primarily projectile points.

Obsidian use throughout much of the Southwest increased significantly after 1300—as much as tenfold in the San Pedro River valley and the Tonto Basin, for example. Although people continued to use obsidian almost exclusively for projectile points, people in the southern Southwest increasingly traded nodules of raw material (today sometimes called "Apache Tears"), rather than finished tools and points.

Moreover, most sites dating after 1300 also deviate from distance decay expectations. Over- and underrepresented sources and site locations shifted from the northern to the southern Southwest. The primary overrepresented sources include Mule Creek, Cow Canyon, and the San Francisco Volcanic Field. People traded substantial quantities of San Francisco Volcanic obsidian far into southern Arizona, reaching University Indian Ruin and Casa Grande in high frequencies (see map on page 6). Superior and Vulture are the major underrepresented sources.

After 1300, decorated ceramic assemblages from sites in which specific obsidian sources are overrepresented are more similar to each other than the average similarity among other sites for each fifty-year period (see pages 9–13). This suggests that social networks measured through ceramic similarity also influenced obsidian trade. In particular, Mule Creek and Cow Canyon obsidian are overrepresented at many sites dominated by Salado polychrome pottery, with the Phoenix Basin and the lower Verde Valley being notable exceptions (see *Archaeology Southwest Magazine* 26:3/4). Obsidian from the San Francisco Volcanic Field is the only commonly overrepresented source that crosses ceramic ware boundaries in substantial quantities: we find it at sites where Hopi Yellow Ware predominates and at sites where Salado polychrome pottery predominates.

Because obsidian trade intensified after 1300 and does not seem to conform to a distance decay model, we argue that powerful social forces were involved. These forces were also associated with the production and exchange of specific kinds of decorated pottery. The new social institutions and ideologies that emerged during this era apparently overshadowed purely economic considerations.

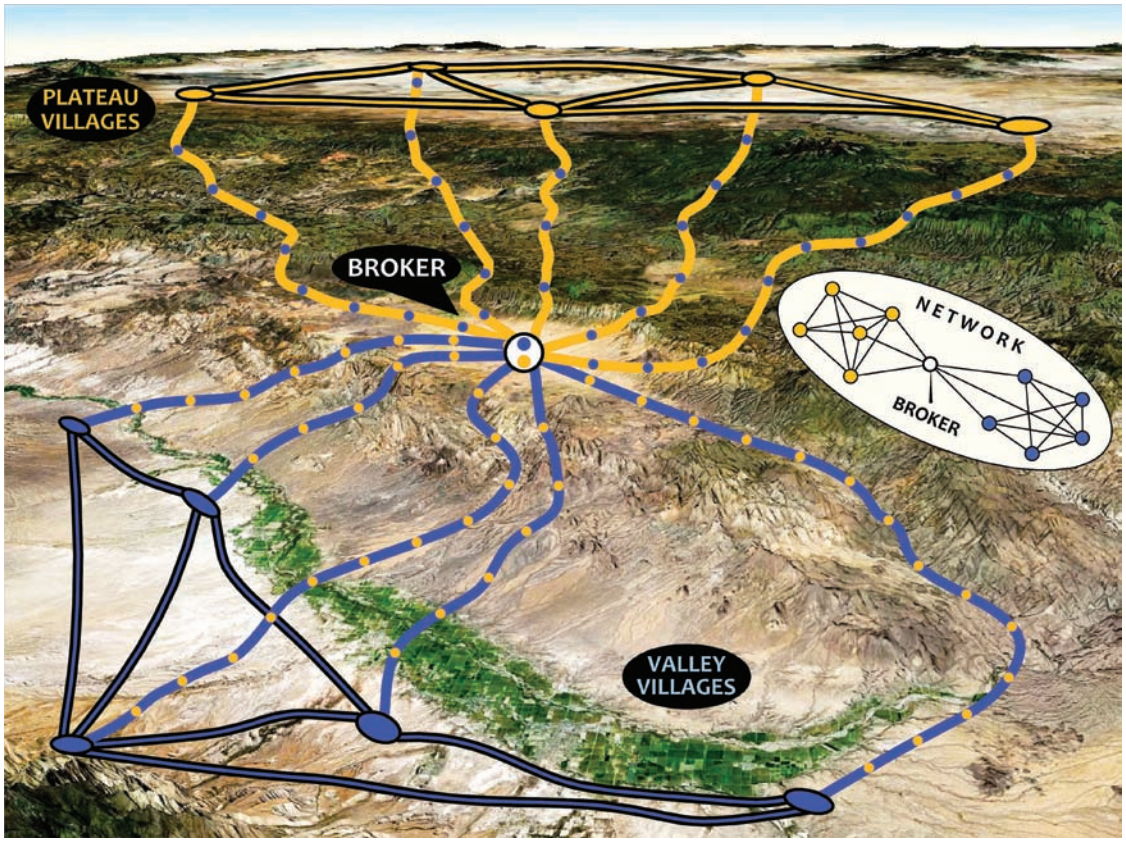
Identifying the specific social factors responsible for the post-1300 obsidian explosion is the next step. We are currently considering the role that dispersed Kayenta immigrants and their descendants might have played in circulating Mule Creek obsidian throughout what is now southeastern Arizona and southwestern New Mexico, to settlements that, in many cases, could have exploited a geographically closer source. In the San Pedro River valley, Kayenta enclave settlements had much more obsidian than local settlements (see *Archaeology Southwest Magazine* 22:4), and almost all of it came from Upper Gila sources. Tellingly, Archaeology Southwest's recent fieldwork identified a Kayenta enclave in the only fourteenth-century village located near the Mule Creek source. At present, we interpret these patterns of obsidian trade as evidence of a Kayenta immigrant community in diaspora (see *Archaeology Southwest Magazine* 26:3/4).

Brokers:
Where Were the Middlemen? What Was Their Role?

In social network analysis, a broker is an actor who links individuals or groups who would not be directly connected otherwise. These middlemen bridge gaps in the structure of networks and often play key roles in mediating connections among others.

Because brokers' intermediary positions confer access to diverse information and resources, brokers are often able to control the flow of information or resources through a network. This can result in considerable power and advantage over time. In social settings in which cooperation is highly valued, however, brokers may be at a disadvantage, in that they are not fully immersed in either social group, and may be distrusted by actors on either side of the boundary they span.

In this study, we identify and characterize settlements that probably served as brokers in late precontact networks across our study area (see page 6). We then compare the long-term outcomes for broker settlements with those of other settlements. If being a broker offered considerable advantages, as many contemporary models suggest, this might translate into settlement growth, and perhaps longevity. Archaeologists have documented similar patterns in other regional and cultural contexts.



Schematic representation of a brokerage relationship. Broker settlements occupy an intermediary position that confers special access to diverse information and resources. GRAPHIC: CATHERINE GILMAN, ADAPTED FROM AN ORIGINAL BY MATTHEW PEEPLES

Methodology

To test our proposition, we create a new measure of brokerage. We base it on similarities in ceramic assemblages among settlements in our study area (see pages 12–13). In general, we define sites as brokers when they consistently show strong connections to pairs of other sites that are not strongly connected to each other.

Patterns and Inferences

We find that broker settlements share a number of demographic characteristics: they are typically smaller than other contemporaneous settlements; they are located in areas of low population density; and they are relatively short-lived. Overall, this suggests brokerage did not convey a major advantage, at least in ways that directly contributed to settlement growth or longevity. Indeed, brokerage appears to have been a fleeting position. Settlements connected by broker communities tend to strengthen their mutual connection over time, suggesting that integration may have been valued over deference to intermediary positions.

Brokers in our networks also tend to be spatially concentrated during any given period. After about 1300, settlements characterized by a relatively high degree of brokerage fall almost entirely along a line running east–west along the Mogollon Rim and the southern edge of the Colorado Plateau. Archaeologists have documented a number of multiethnic communities composed of immigrants, their descendants, and people of local heritage in these same areas.

Reproduction of a late fourteenth- to fifteenth-century kiva mural found at the Hopi village of Kawaika'a. Murals such as this one, which shows several figures with cloud-terrace headdresses, appear to have been closely associated with the spread of katsina religion. Katsina ceremonies may have helped to build and strengthen social ties among diverse populations that had only recently come together. IMAGE: COURTESY OF THE PEABODY MUSEUM OF ARCHAEOLOGY AND ETHNOLOGY, HARVARD UNIVERSITY, NO. 39-97-10/23026C

Intriguingly, this is also where we see some of the earliest archaeological evidence of several widespread social transformations of the late precontact time, including developments related to Salado (see pages 4–5) and the emergence of the katsina religion still practiced among many contemporary Pueblos. Because katsina ceremonies and similar practices intentionally cut across clans and lineages, they may have been a powerful force for creating and maintaining tenuous social connections among diverse populations that had only recently come together.

Although broker settlements may have been smaller and more ephemeral than settlements in nearby areas, they were socially creative. People negotiated differences and created new institutions that fostered cooperation and integration. Because these broker communities held diverse social connections, they may have facilitated the swift spread of new institutions and practices across the Southwest.

Internal and External Relations:

Why Were Some Groups Less Vulnerable to Crises?

Are social networks also survival networks? Some studies suggest social groups are more likely to endure a crisis if their members maintain contacts outside of their own immediate social groups. External relations function as a safety net, allowing people to draw upon social or economic resources that would otherwise be inaccessible. These studies also imply that groups with fewer external connections may be vulnerable to crises, because most of their contacts are, essentially, in the same boat.

Social network analysis (SNA) helps researchers understand the degree to which network interactions primarily occur either *within* or *between* distinct social groups. Through SNA methods, we can identify and quantify the relative frequencies of internal and external social ties. These measures yield insights into why groups succeed or fail in the face of major crises.

In this study, we explore internal and external social connections and assess their role in determining outcomes for different portions of our study area. Long-distance migration was a recurring response to environmental crises in the precontact Southwest. Previous archaeological research on migration has tended to emphasize local economic drivers for migration—poor environmental conditions or local population pressure, for example. Social network analysis highlights the potential role of

interaction in determining why some populations persisted in place while others moved on.

Methodology

To measure the relative frequencies of within-group and between-group social ties, we must first define what we mean by "group." Here, we delineate groups geographically, using established archaeological classifications for regional culture areas. Within-group ties represent strong social connections that are local. Between-group ties represent strong social relations across geographic and cultural boundaries.

For each site in our study, we tabulate the proportion of within-group and between-group ties as defined by strong ceramic similarities (see pages 9–13). This enables us to identify differences in how embedded each site is within the larger regional ceramic network. We can then measure outcomes in terms of the longevity of communities within each cultural-geographic division.

Patterns and Inferences

For our study area as a whole, we see major differences among regions in terms of their emphasis on either internal (within-group) or external (between-group) social ties. These differences are apparent across space and through time.

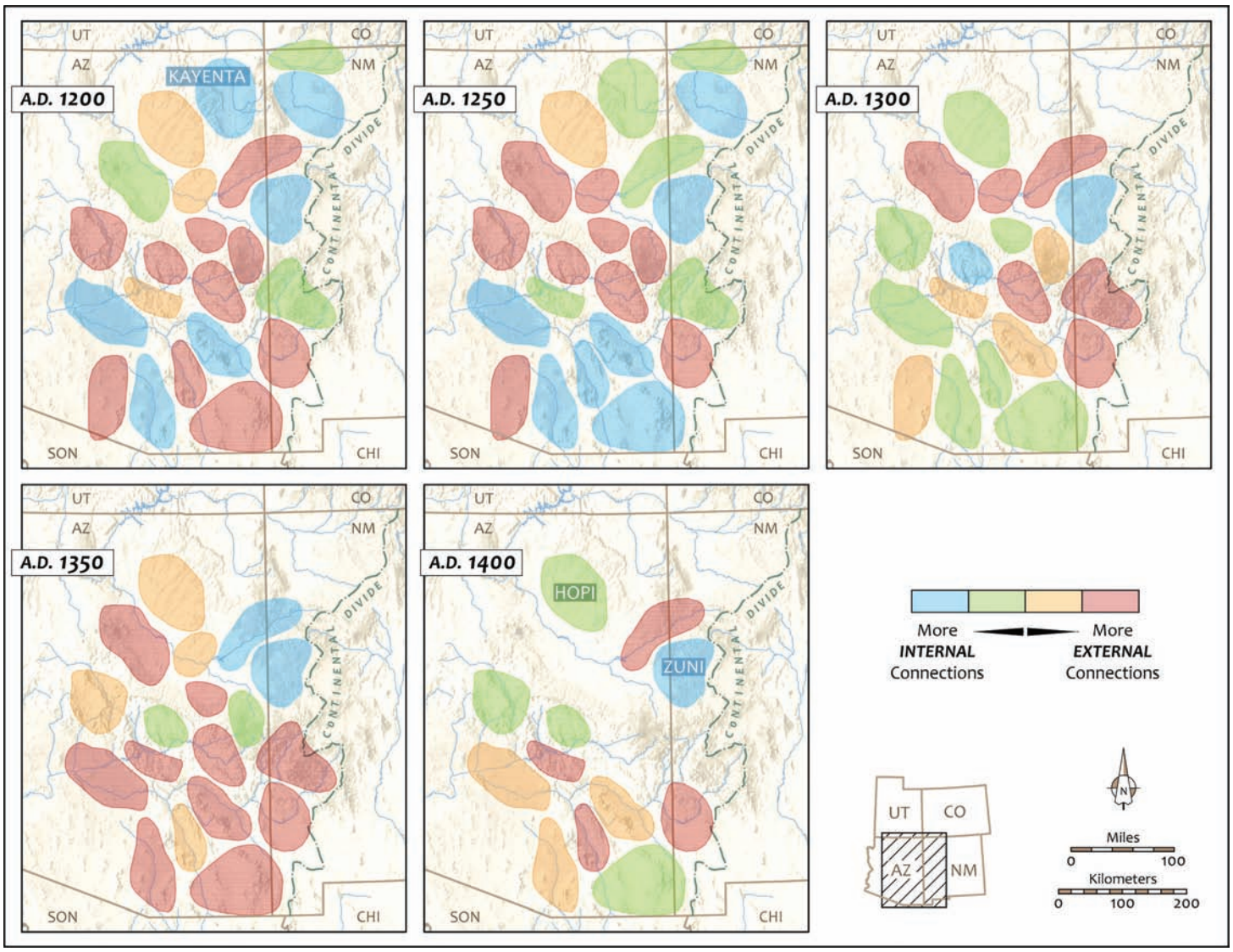
In general, before 1300, the most densely populated portions of our study area exhibit far greater internal connections. Portions of the study area with fewer sites, such as places along the Mogollon Rim, show strong external connections.

This pattern changes abruptly after about 1300. By 1350, the typical community in our study area was more likely to be externally oriented. Moreover, by this time, the vast majority of people from our study area were living in what is now southern Arizona. Prior to depopulation of the Four Corners and the associated southward migration of northern groups, groups living in the southern portion of our study area were, for the most part, fairly insular. A few southern regions had an external focus, but most were moderate at best. This striking change from an internal to an external focus probably resulted from the influx of northern immigrants and the subsequent development and spread of Salado ideology, which Archaeology Southwest and others argue facilitated the integration of disparate peoples.

When we investigate this trend of expanding external connections at a smaller scale, we are able to parse some of the cultural processes that might have been at work. At this smaller scale, our interaction measures indicate that almost none of the internally focused groups in the northern Southwest continued in place after the environmental crisis brought on by the drought of the late 1200s. People left previously internally focused areas such as the Kayenta, Chuska, and Middle San Juan regions.

In fact, of all the internally focused northern regions, only Zuni endured. This may be because, from the onset of the

One of the most common responses to severe and prolonged drought among small-scale farmers past and present is migration. The Dust Bowl of the 1930s displaced hundreds of thousands of people, many of whom headed west, following leads on job opportunities obtained through networks of family members, friends, and neighbors who had already made the journey. Photographer Dorothea Lange noted, "[I] passed twenty-eight cars of this type (drought refugees) between Bakersfield and Famoso, thirty-five miles, between 9:00 and 9:45 in the morning." Inset: Lange commented on this photo: "Corn, drought-stricken and eaten off by grasshoppers." PHOTOS: DOROTHEA LANGE, COURTESY OF THE LIBRARY OF CONGRESS



These maps illustrate the changing degree of internal and external connections by region through time. Note the dramatic shift toward external connections in the southern Southwest following the depopulation of the Kayenta region and the Four Corners (circa 1275). GRAPHIC: CATHERINE GILMAN

drought, they maintained a high degree of short-distance mobility, moving among areas offering better access to food and water sources at any given time. Population size may have been a factor, as well: because the Zuni region had a larger population than many neighboring areas, its residents may have been able to draw upon resources from within their own group. Studies do suggest that population size is a factor in withstanding a crisis.

Interestingly, Hopi was the only region of the Colorado Plateau that sustained many external connections before the drought, and it, too, persevered. Ties to outside groups probably enabled Hopi to secure precious resources that were increasingly scarce in the Hopi homeland.

A thousand fibres connect you with your fellow-men, and along those fibres, as along sympathetic threads, run your actions as causes, and return to you as effects.

—The Reverend Henry Melvill (1855)

Interactions in Turbulent Times:
Insights Revealed by Social Network Analyses

Together, the studies presented in this issue are a window on the extremely dynamic centuries immediately preceding the Spaniards' arrival. Over a period of about 300 years, people in our study area experienced the creation and dissolution of new and widespread networks spanning hundreds of miles. Social connections changed dramatically in nature and scale. Moreover, these transformations occurred in the context of a major demographic decline: by 1450, population in our study area had diminished to about one-quarter of what it had been 150 years earlier. Most of the loss occurred in the southern Southwest.

Previous research by Archaeology Southwest and its partners suggests that the southward migration of northern immigrants played a significant role in initiating or accelerating these changes in specific places (see *Archaeology Southwest Magazine* 22:4). Data and analyses presented here provide an unparalleled opportunity to assess migration's role in demographic and social transformations at a broad regional scale. Beyond this, our network analyses suggest that the nature and structure of relationships among settlements and regions may account for the divergent long-term outcomes experienced by different regions of the Southwest, at least in part.

A major theme of our analyses is the rapid increase in the size and density of ceramic and obsidian social networks in the southern Southwest beginning at about 1300. The expansion of these southern networks involved the establishment of strong connections among almost all of the major river valleys south of the Mogollon Rim. Notably, these connections spanned areas that had not consistently interacted in the preceding century. These connections involved long-distance transport of obsidian objects and raw materials (particularly from sources near a large immigrant enclave along Mule Creek), as well as production and exchange of a new ceramic ware, Salado polychrome. Indeed, during the 1300s and early 1400s, the robust connections among southern settlements—some quite distant from one another—were driven almost exclusively by Salado pottery.

This historic photograph of Zuni Pueblo (Halona:wa) was taken in 1873, as part of a documentation mission conducted by the U.S. Army Corps of Engineers. PHOTO: TIMOTHY H. O'SULLIVAN, COURTESY OF THE LIBRARY OF CONGRESS

Mineralogical and chemical compositional studies have shown that potters made Salado polychrome vessels in most places where we find them in the southern Southwest, and even in a few places on the Colorado Plateau. Despite such extensive production, this bold, vibrant pottery is remarkably uniform across a seemingly diverse cultural landscape. Understanding

the social meaning of Salado polychrome pottery has been challenging, in part because we find it across an area that otherwise exhibits great variability in architecture and other aspects of material culture. Our regional-scale network analyses suggest that this pottery tradition spread quickly—within two generations—and eventually replaced local decorated ceramic traditions in many places where it arrived.

Several archaeologists have attributed this phenomenon to the emergence of a new ideology or religious movement that united people of local heritage and northern heritage across the southern Southwest. Because the region's inhabitants traveled on foot, we were somewhat surprised to find that relatively sudden network expansions and long-distance movement of materials did not depend heavily on the spatial proximity of settlements, despite distances of more than 150 miles and major topographic features, such as the Mogollon Rim.

Despite its rapid rise and spread, this expansive network was short-lived. By about 1400, the dense social connections among settlements in the south began to dissolve as regional population declined, perhaps making long-distance ties harder to maintain. By 1450, those populations remaining in areas south of the Mogollon Rim are difficult to detect, at least archaeologically.

The trajectory of the Colorado Plateau was quite different. Unlike those in the south, ceramic networks in the northern Southwest saw a dramatic contraction over the course of the 1300s and early 1400s. Northern populations were increasingly concentrated in two clusters of settlements, in the Hopi and Zuni areas, and communities at a greater distance were depopulated. Social interactions in each cluster increasingly focused inwardly, and ceramic evidence suggests that pottery circulation between Hopi and Zuni was limited. These small, self-contained settlement clusters—in network terms, "distinct components"—persist to the present day.

Some researchers have suggested that the historical persistence of populations in the Hopi and Zuni areas probably relates to the fact that these two areas were major population centers at least as early as A.D. 1000. Similarities between the two regions in terms of network characteristics and in terms of trajectories of network change suggest that the organization of interactions within and outside of these regions also played a role in their endurance.

As this overview suggests, network analyses have great potential in archaeological research, particularly at regional scales. We are confident that network methods and models will help us find new answers to old questions and develop new questions from old data. Furthermore, as archaeologists use SNA to address archaeological problems, we will also be contributing new tools and perspectives to the broader interdisciplinary field of network science. Indeed, archaeologists are uniquely positioned to offer perspectives on how networks develop over the long term. As a result, we anticipate that network analyses will continue to grow in importance in archaeology over the coming years.

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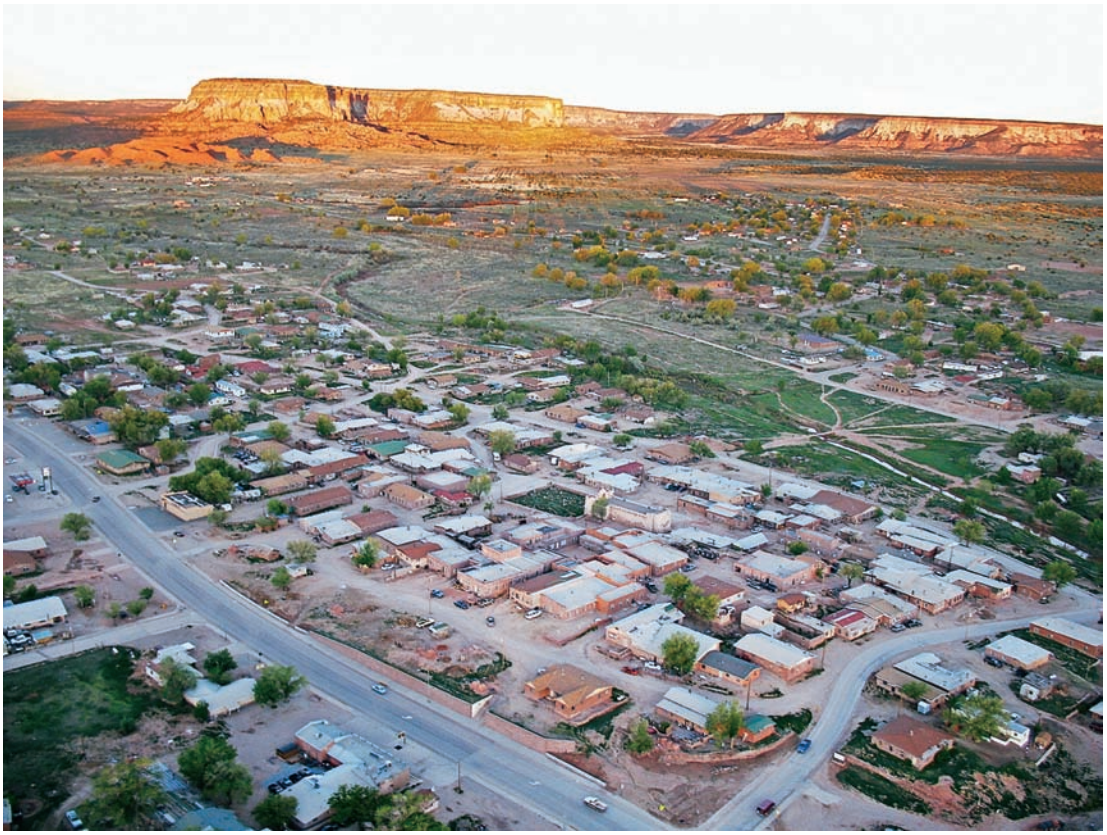

This photograph shows the central portion of Zuni Pueblo along the banks of the Zuni River in 1990. The striking banded sandstone mesa in the background is Dowa Yalanne (Corn Mountain).

Collaborations:
More than the Sum of Their Parts

Archaeologists working in the U.S. Southwest and northern Mexico have always been a friendly bunch. There is a long tradition of visiting each other's sites during the summer field season and trading stories over beer. Over the last few decades, another tradition has emerged: increasingly, archaeologists are moving beyond simply cultivating connections with colleagues, and forming research teams, often including non-archaeologists. Such teams engage in research that is interdisciplinary and collaborative from its inception. More than the sum of their parts, these collectives enable members to address large-scale questions no single researcher could ever tackle alone.

Meaghan Trowbridge and Barbara Mills wade through the San Francisco River on their way to count sherds at sites along its banks (and thus fill some gaps in our database). PHOTO: DEBORAH HUNTLEY

The SWSN project is a prime example: quite simply, it could not have happened without collaboration. Our team includes professional researchers and university faculty members, along with many graduate and undergraduate students. All have brought ideas and expertise to the table. This open environment allowed us to expand our research in the many directions discussed in this issue, and beyond.

As many projects do, the SWSN project began through a series of conversations. Upon becoming interested in the potential of SNA for archaeology, Barbara Mills met with Archaeology Southwest's Bill Doelle and Jeff Clark. Bill and Jeff had access to regional-scale data and expertise in the creation and management of large databases (see page 24). Barbara then spoke with Ronald Breiger, a colleague in the University of Arizona's Department of Sociology, about the benefits and challenges of applying SNA to archaeological data. From there, the team grew to more than twenty members. Our group has also benefitted greatly from connections to others pursuing archaeological network research, including members of the Connected Past, an international interest group and conference.

In March 2012, we held a working retreat at the School for Advanced Research (SAR) in Santa Fe. After several years of data gathering and initial analyses, this meeting provided an opportunity to present to each other, reflect on our ongoing research, and develop a plan for publication. This seminar also provided a chance for us to discuss our research with members of the SAR staff, including Vice President John Kantner and Senior Scholar Linda Cordell (see tribute on page 23).

Linda had already become interested in our SNA work through poster presentations we made at academic symposia. As a member of the prestigious National Academy of Sciences of the United States of America, a national organization promoting and rewarding excellence in all branches of science since 1863, Linda encouraged us to seek publication in the widely circulated *Proceedings of the National Academy of Sciences*. Several

short months later, we submitted our work for peer review, and this past spring, with Linda's help as our editor, we published an article covering much of the work discussed in this issue. We are thankful that she was able to celebrate its online release with us just before her unexpected passing.

The collaboration that began with the SWSN project is not over. Our group is continuing to work together to push network methods further using archaeological data. We also plan to welcome new collaborators, and to expand the spatial and temporal scope of our database and analyses to new times and places across the Southwest. Our experience as a research team has enriched each of our own perspectives on archaeological data and network methods. We expect it to drive our future research efforts, too.

Dr. Linda Cordell (1943–2013) was a central node in the network of southwestern archaeologists, linking people together across the region and across generations. Her influential research spanned many topics, and her encouragement of new ways of thinking about Southwest archaeology—including network approaches—is especially celebrated. Linda's impact, both personal and professional, was immeasurable. She is truly missed. PHOTO: JAMES E. SNEAD

Food for Thought...

The foundations of many of the basic methods for analyzing and visualizing network data have their origins in a brainteaser from the early eighteenth century. The town of Königsberg, Prussia (modern-day Kaliningrad, Russia), sat along the banks of the Pregel River, as well as on two islands within the river. The segments of the town were connected by a series of seven bridges. According to folklore, a local debate arose as to whether a person could walk across all of Königsberg while crossing each of the seven bridges exactly once. Word of this challenge eventually reached the famous Swiss mathematician Leonhard Euler.

In 1735, Euler proved that such a walk across Königsberg was impossible. Euler's key realization was that the path within each segment of the town was irrelevant, and the only important feature was the total number of segments (nodes) and the number of bridges (ties) entering each segment. Euler's solution to the Königsberg bridge problem is widely regarded as the first theorem of graph theory, the basis of modern network analysis. Interestingly, the modern city of Kaliningrad, Russia, has only five bridges connecting the same land segments, and it is now possible to walk across each segment of the city crossing each bridge only once.

To see an illustration of the problem, visit www.archaeologysouthwest.org/asw27-2.

Acronyms Used in This Issue

CCD: Coalescent Communities Database (see page 5), a precursor to the SWSN Database.

GIS: Geographic Information System (see pages 7–8), an integrated computerized system for storing, mapping, and analyzing geographic data. In practice, GIS can refer to a database itself, or to analyses performed on the data therein, as in "a GIS database" or "using GIS techniques."

SNA: Social network analysis (see pages 3–4), a group of tools derived from the mathematical field of graph theory and used to systematically examine social interactions.

SWSN: Southwest Social Networks (project and database), the subject of this issue.

XRF: X-ray fluorescence spectrometry (see pages 14–15), a technique that uses a special instrument to acquire elemental data in artifacts, providing information about the provenance of analyzed samples.

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back sight

Big research questions demand "big data."

The tedium of converting millions of material items—whole pots, broken pots, arrow points, the waste from making points—into DATA is not a story people clamor to hear. (An observer of the SWSN project remarked that this work was the equivalent of one person working forty hours per week for twenty-seven weeks, looking at one artifact every five seconds—and that is only for the decorated pottery.) Monotonous, maybe, but without good data tied to reliable location information over a vast spatial scale, archaeologists cannot tackle truly big research questions. This issue of *Archaeology Southwest Magazine* illustrates what can happen when creative researchers bring sophisticated new analytical strategies to a robust, high-quality database.

As "large collections of data organized for rapid search and retrieval" (Merriam-Webster), databases have a longer history than one might think. One example is the quipu *("talking knots"), a device the Inca and their forebears in the Andean region used to record information through a series of knots. This illustration from an early seventeenth-century chronicle shows a* Quipucamayoc *(accountant) wielding the device. A* yupana *(calculator) is depicted in the lower left.* SOURCE: WIKIMEDIA COMMONS

The origins of the SWSN database date to the 1990s. By the early 2000s, the Coalescent Communities Database (CCD) emerged from collaboration among Archaeology Southwest, the Museum of Northern Arizona, and Western Mapping Company. It is a surprisingly simple database, containing site names or numbers (or both), room counts, habitation spans, and locations. The CCD allowed us to estimate the Southwest's precontact population in fifty-year intervals. The dramatic demographic changes we documented have guided a decade of subsequent research by us and others—and that research raises yet more questions.

A useful database is dynamic, requiring constant "care and feeding." The database-building phase of the SWSN project greatly enhanced the richness of the CCD. Millions of artifacts now enable profound insights regarding technology, exchange, cultural identity, ideology, and social interaction. In these realms, the stories become exciting, and offer deeper understanding of the past.

Archaeology Southwest continues to build our regional database, which we call the Heritage Southwest Database. It contains the CCD, the SWSN, and several other, smaller databases. These data are available through a simple application process [www.archaeologysouthwest.org/hswdb]. Preserving, enhancing, and facilitating use of existing regional data is an important part of our Preservation Archaeology mission.

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