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Droughts, Floods, and Social Infrastructure in the Pre-Hispanic US Southwest

Nicolas Gauthier, PhD
Florida Museum of Natural History

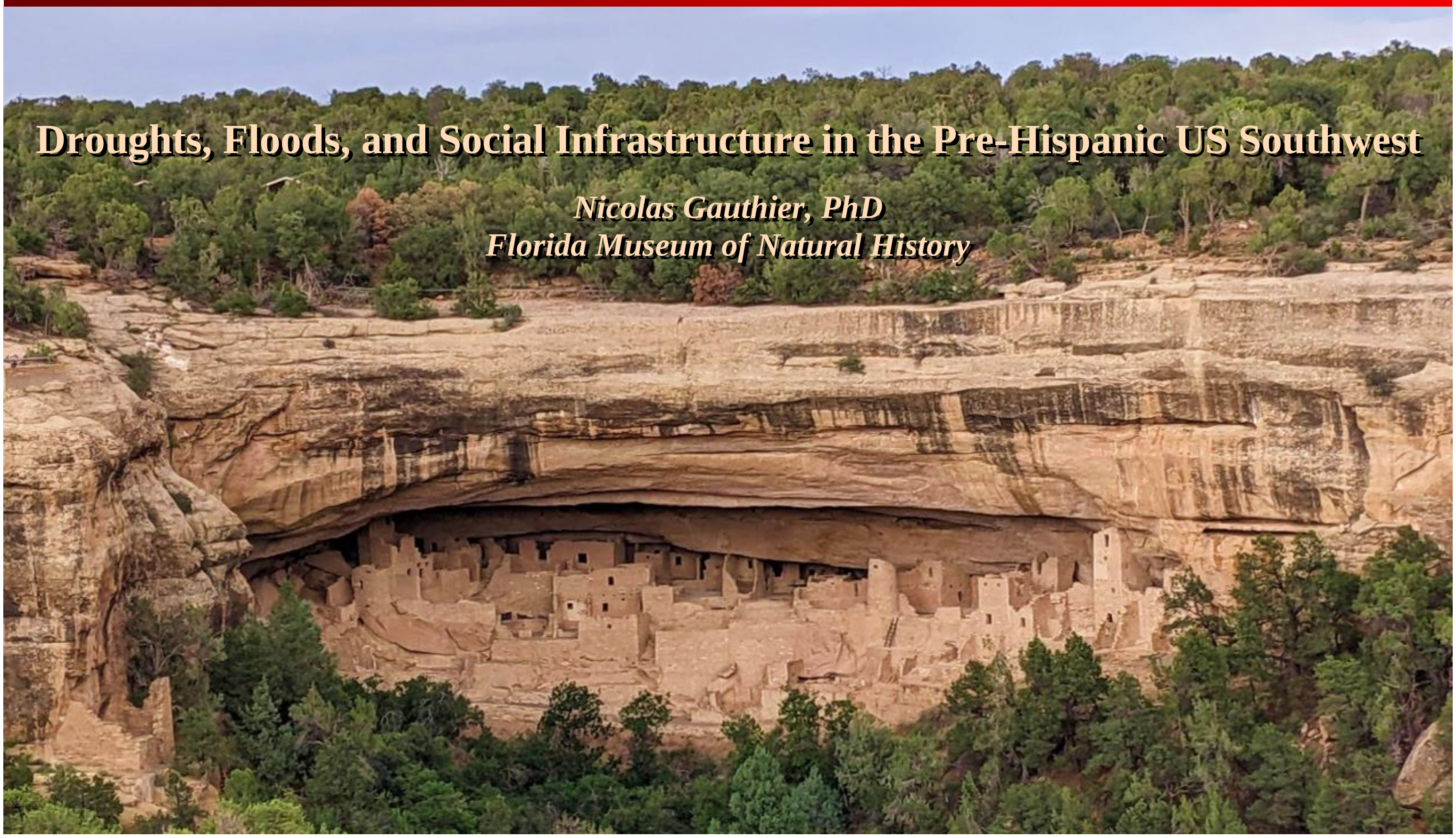


Figure 1. Remains of cliff dwellings constructed by the Ancestral Pueblo people around 1200 CE in what is today the Four Corners region of the US Southwest (Photo by Nicolas Gauthier)

Disasters and Infrastructure

What would you do if a natural disaster like a fire, flood, or heatwave struck your town? Would you shelter in place or evacuate? Where would you go and how would you get there?

Although it's easy to ignore in our everyday life, infrastructure is central to our survival in these disaster situations. We rely on networks of pipes and power lines to get water and energy into our homes. When they fail, we rely on our telecommunications networks to find out what's happening and our road networks to get to safety.

Less obvious, but equally important, is our social infrastructure. In times of need, we rely on our social networks – our friends, family, and acquaintances – to find out where the trouble is, what we should do about it, and who can help. Although social infrastructure is not tangible like a road or sewer system, it operates in much the same way as physical infrastructure. All types of infrastructure enable the flow of information and resources we need to survive over large distances. Roads allow for flows of goods and people, canals for flows of water, power lines for flows of energy, and social networks for flows of information. Our social networks let us know what the situation is like in other places and

Also in this issue:

whether it's a good idea to leave, or help us get in touch with others who can help bring resources like food, water, and clothing.

Even though the people of the distant past didn't have their social networks as well defined as we do today with modern telecommunications systems and the internet, they were equally reliant on social infrastructure to adapt to the threat of natural disasters. Modern technology may have superficially sped up the rate at which information moves from person to person in today's social networks, but it hasn't changed their fundamental nature. Information is information, whether it comes to you through a TV, cell phone, or a face-to-face conversation. Indeed, prior to the benefit of modern technology, social infrastructure was one of the few reliable ways to adapt to the threats of natural disaster.

Social Infrastructure in the Past

So how did the people of the past use social infrastructure to adapt to recurring natural disasters? For ancient farmers who had to grow their own food each year, droughts and floods were a critical threat to their livelihood. Not enough water meant crops would die and streams dry up, but too much could destroy homes, fields, and physical infrastructure like canals.

Luckily, although the next year's rainfall was impossible to predict, ancient farmers could still recognize weather patterns that tended to reoccur over several years. They could recognize different types of drought and flood that tended to occur, even if they couldn't predict any one event. But the information available to a single person is inherently limited. An individual farmer will only experience a few decades of weather variability, and only in their local landscape. A large and diverse social network would allow a farmer to learn about conditions in distant locations year after year and to gain a working knowledge of climate variability on a scale beyond their limited personal experience. In times of extreme drought or flood, farmers could mobilize these networks to access food and any other resources they desperately needed and, if conditions got bad enough, find a new destination to migrate to.

But the benefits of a large and diverse social network wouldn't have come for free. Traveling long distances on foot takes significant time and energy – especially without the benefit of pack animals, carts, or roads to make the journey easier. These costs don't just apply to rare, long-distance migrations, but also to the day-to-day and months-to-months trips that are required to maintain strong relationships.

So, did ancient farmers prefer to invest in social relationships – through friendship, trade, or marriage – in ways that made their social networks more resilient to these recurring drought and flood patterns? Would the benefits of interacting with someone who experiences different weather outweigh the costs of traveling to see them over long distances and rough terrain?

To answer these questions, I turned to the archaeological record of the pre-Hispanic (ca. 1200-1450 CE) US Southwest – the material remains of the Hohokam, Mogollon, and Ancestral Pueblo peoples (Figure 1 on page 1). This time and place is ideal for exploring connections between the past and present. It was a time of high population, complex culture, and long-distance exchange – wracked by compounding threats of climate change, warfare, inequality, and migration. (Sound familiar?) Luckily for us, this region and period are unparalleled in the quality and quantity of information available to archaeologists in the form of archaeological sites, artifacts, and paleoclimate records like tree rings.

Droughts and Floods in the US Southwest

My first goal was to identify reoccurring drought and flood patterns in the past climate of the US Southwest. To do so, I looked at detailed maps of drought and flood patterns over the last 100 and 1,000 years. For each year, these maps showed how unusually wet or dry were the previous twelve months leading up to the summer growing season. Then, I used a technique for extracting important patterns from "noisy" climate data to calculate these key patterns of variability.

It turns out that just six spatial patterns can explain nearly 90 percent of the year-to-year drought and flood changes over the past 100 years (Figure 2). These same patterns also appear in climate reconstructions of the last 1,000 years, indicating that they are long-term recurring patterns.

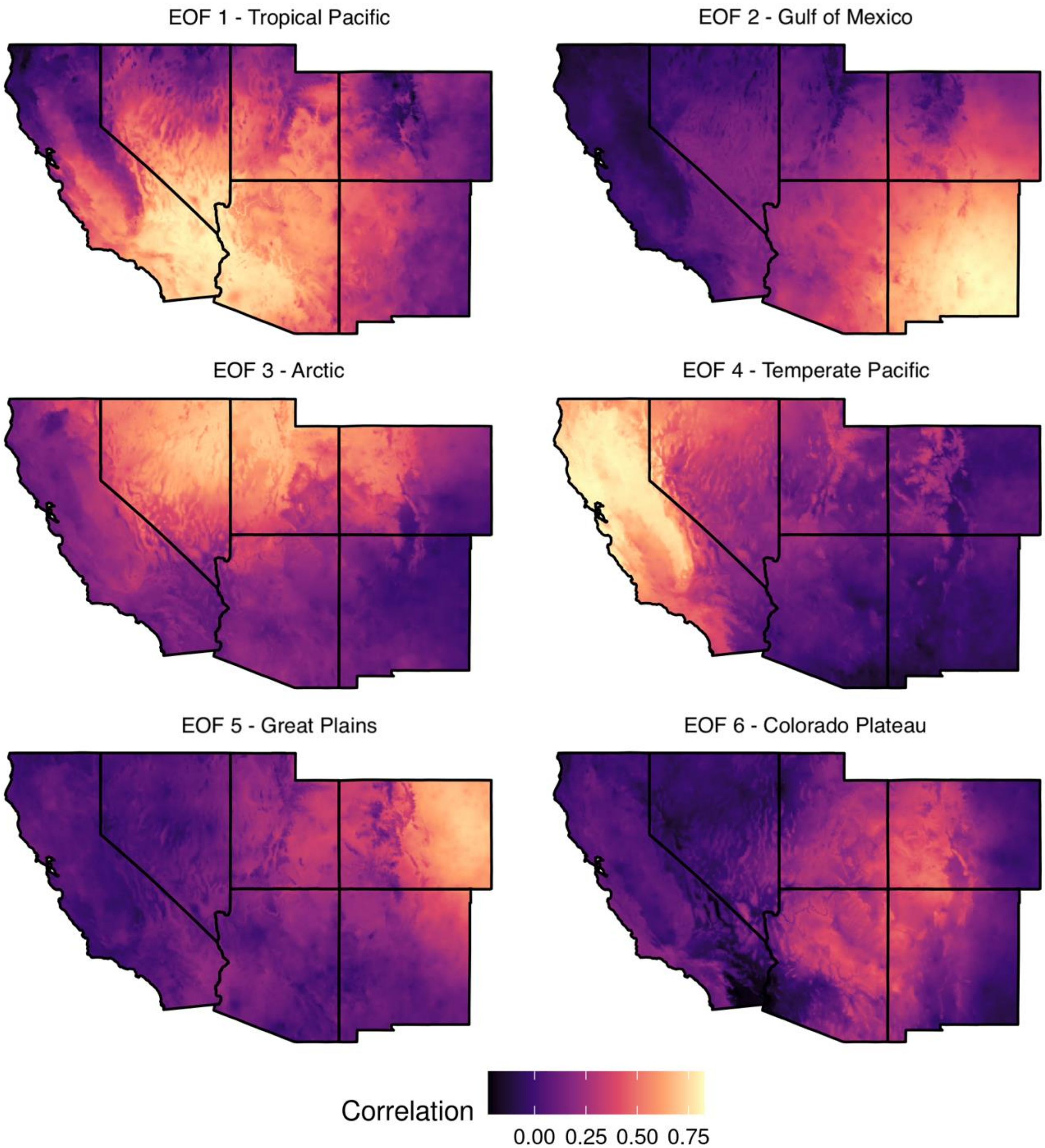


Figure 2. The six leading spatial patterns of observed droughts and floods over the past 100 years; although these patterns do not represent specific years or ranges of years, the weather of any given year will always resemble some combination of these six patterns. Only the relative intensity of each pattern varies from year to year. These kinds of patterns are known as "empirical orthogonal functions" or EOFs in the climate sciences. Each pattern is labeled by the geographic region from which each climatic influence originates. The color of each pixel reflects the strength of its association with each climatic influence, with higher correlations indicating stronger associations.

These patterns represent distinct regions of drought variability affected by specific influences from the oceans, continents, and mountain ranges. For example, the leading pattern represents droughts and floods caused by unusually dry or moist air coming from the tropical Pacific Ocean and the second pattern represents air masses coming from the Gulf of Mexico. The weather in any given year will represent some mix of each of these patterns (Figure 3).

Figure 3. Summer rainfall in western New Mexico, driven by a mix of climate influences from the tropical Pacific Ocean and Gulf of Mexico (Photo by Nicolas Gauthier)

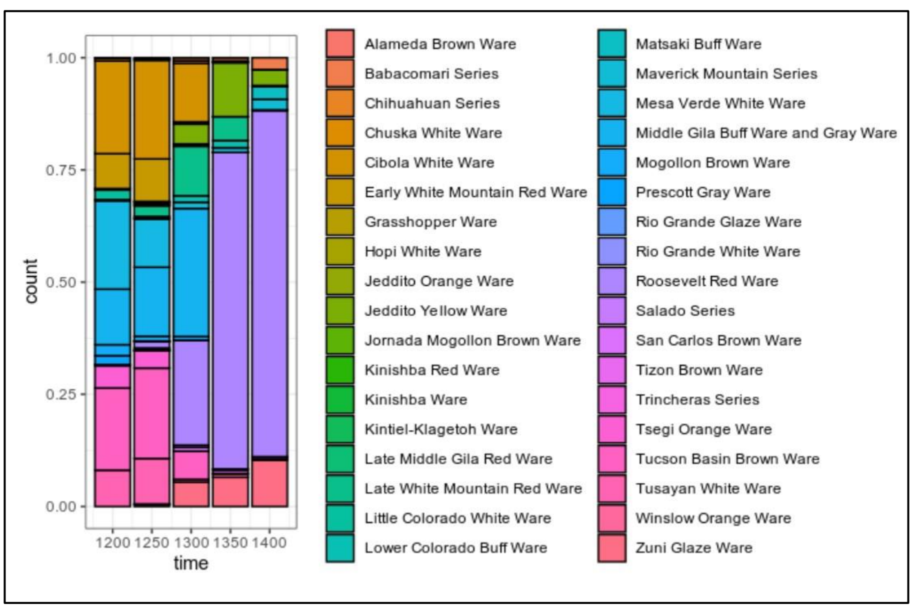


Figure 4. Example of an assemblage of artifacts and its change through time; each vertical bar represents an assemblage for a specific time period, and the relative size of each color section in each bar tells us the relative proportion of that artifact type among the entire assemblage for that time period.

Ancient Social Networks

The next task was to reconstruct the social networks of the pre-Hispanic farming peoples of the Southwest, to see how well they were adapted to the six drought and flood patterns. I compared these climate patterns to archaeological data from Arizona and New Mexico, an area of high population and social interaction of the last 1,000 years. I used a dataset compiled by researchers at the University of Arizona and Tucson's Archaeology Southwest, a nonprofit organization, recording all decorated ceramic artifacts recovered from nearly all archaeological sites west of the Continental Divide, for a total 4.3 million artifacts across nearly 500 sites.

At each of these sites I looked at the assemblage of artifacts, that is, the relative distribution of different artifact types (Figure 4). I then estimated how similar the assemblages of artifacts were among every pair of sites. This measure tells us something about the information flow between those two sites in the past. In other words, the more similar the artifacts were at a pair of sites, the closer the contact and stronger the social interaction between those two sites must have been. We don't know exactly what form that interaction took – such as migration, trade, intermarriage, or shared culture – only how strong was the combination of all these factors. This ambiguity is useful, however, as it lets us average over much of the small-scale differences to see the bigger picture: the past social network.

This isn't a social network exactly like we see on Facebook or Twitter, but the underlying logic is the same. It's the large-scale pattern of who-knows-whom across an entire region, and it lets us trace cultural change through time. We can clearly see the effects of climate change and migration (Figure 5). The stable cultural clusters in 1200 and 1250 CE are disrupted by drought (starting 1275 CE) causing a large-scale reorganization of the network as people migrate from the drought-afflicted north to the irrigated societies of the southern Southwest. At the 1400 CE time step in the reconstruction, these irrigated societies were themselves disrupted by large-scale floods, leading to another wave of migration and depopulation in later generations. There are no free lunches when it comes to climate adaptation, and infrastructure systems like irrigation networks that are helpful in one year can become liabilities in the next.

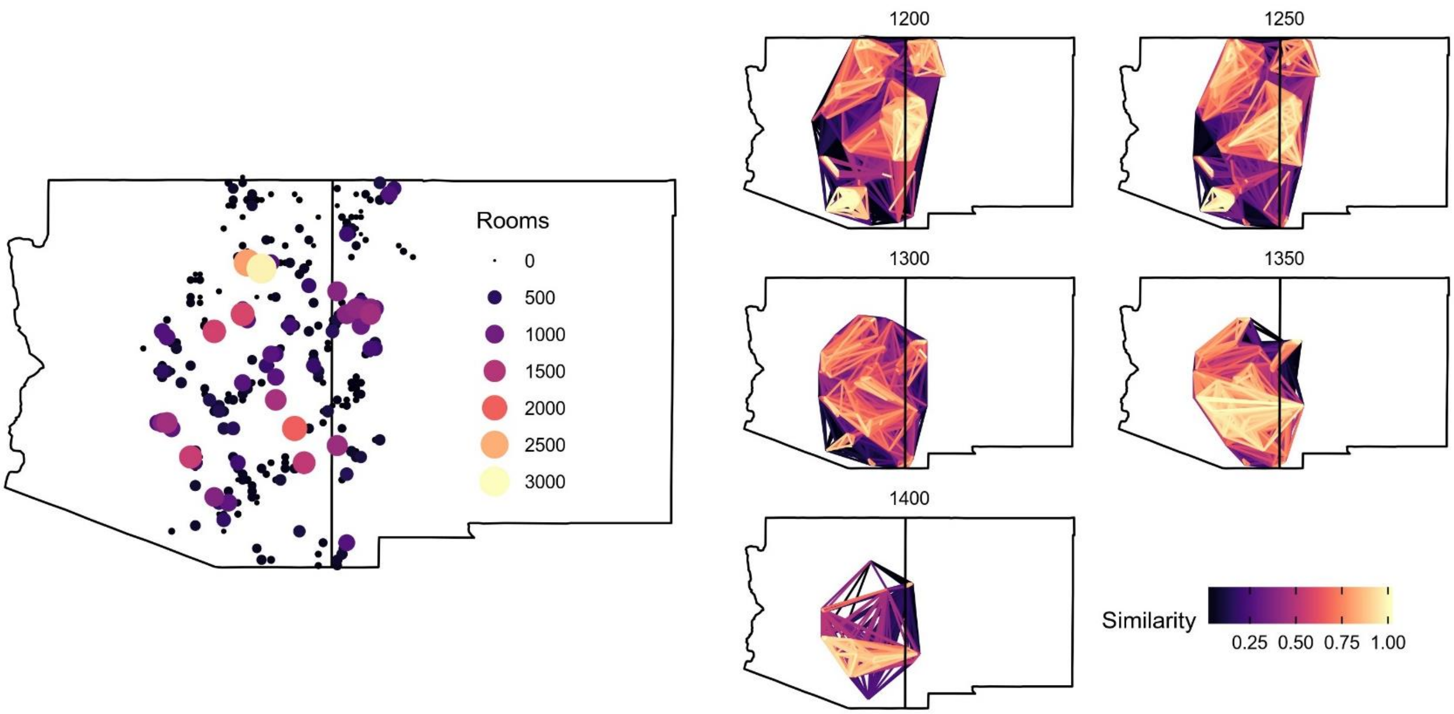


Figure 5. Left, the size and location of all archaeological sites in the database (aggregated to 10 km x 10 km grid cells to hide sensitive site locations); right, estimated social networks at five time steps, as measured by the similarity of the ceramic assemblages at each pair of sites.

The Costs and Benefits of Social Interaction

Finally, I needed to assess the role of social infrastructure in ancient societies' responses to climate disasters. A key challenge for all infrastructure systems is that they will inevitably degrade over time without continued investment of time and energy in maintaining them. You wouldn't want to use a poorly maintained road or rely on a casual acquaintance in a time of need, nor would you build a road that didn't lead anywhere or maintain a friendship with someone you didn't benefit from knowing. All infrastructure – whether it be physical or social – must also adapt to fit its environment to be effective. Over time, we can expect social networks to develop that balance out the costs of their continued maintenance with the benefits of their continued existence and are able to change in response to shifting environmental and social conditions.

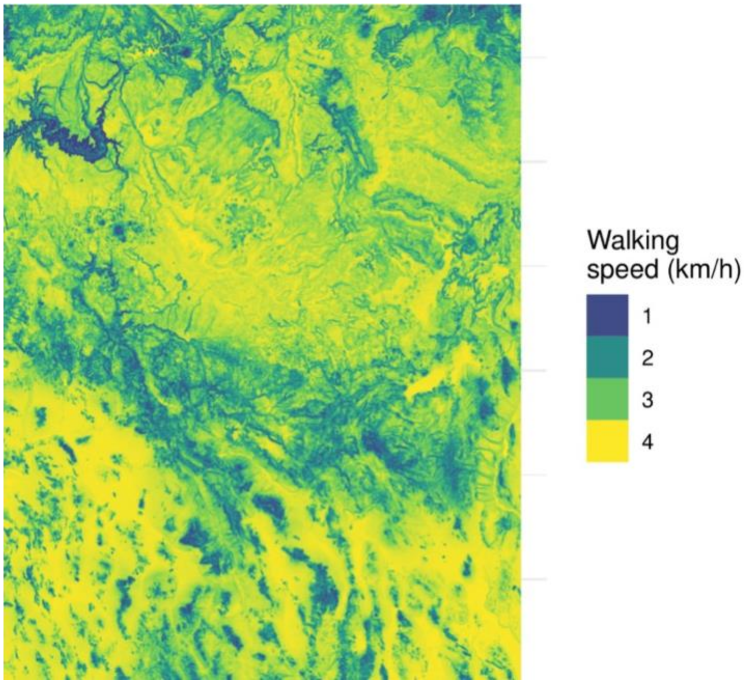


Figure 6. Estimated walking speeds of a foot traveler over the terrain of eastern Arizona and western New Mexico; lighter colors indicate shallower slopes and thus faster potential walking speeds, darker colors indicate steeper slopes and slower potential walking speeds. Note the Grand Canyon in the top left corner of the map.

The primary cost of maintaining a social network in the ancient Southwest was distance. To determine the role of distance in shaping these network patterns, I had to estimate how long it would take a traveler on foot to move between each pair of sites. To do so, I used a digital representation of the topography in the study area to estimate the average walking speed of a hiker over the terrain (Figure 6). By assuming people can walk fastest moving down moderate slopes, but must slow down for steeper slopes or when moving uphill, we can calculate the typical hiking speed across the landscape. Then we can use this map to estimate the time it would have taken to travel between each pair of sites, assuming travelers are moving as fast as they can while avoiding steep slopes.

We can use these data to factor out the influence of distance on our social network – the "costs" of maintaining the social infrastructure (Figure 7). After doing so we can compare the remaining network relationships to the six drought and flood patterns (Figure 8). These climate patterns explain a moderate but clear proportion of the network structure not accounted for by travel distance. In other words, social interaction was stronger among sites in different drought and flood regimes than would be expected by chance and distance alone. Interestingly, which patterns are important change through time. In the beginning, the Tropical Pacific patterns predominate. Then, during the period of migration, no pattern predominates. When the network reforms in the south, the Gulf of Mexico pattern predominates. This tells us that the infrastructure network is adapting and changing in response to different climate patterns as they become more or less influential.

As climatic difference (that is, the degree to which a pair of sites is influenced by the same climate pattern) increases, so too does the intensity of social interaction – but only for specific time periods and climate patterns. For example, in 1200 CE the Tropical Pacific (EOF1), Temperate Pacific (EOF4), and Great Plains (EOF5) patterns show clear relationships to social interaction (indicated by the upward slope of the lines), but the others do not. During the period centered on 1300, one of large-scale migration and social reorganization, these relationships decline (all lines are flat). As the network settles around a new configuration in 1350-1400, we find that the Gulf of Mexico pattern now predominates (EOF2).

While maintaining a diverse social network was crucial for past populations to avoid the risk of climate disaster, it apparently was easier for some settlements than others. Locations that had easy access to multiple climate regimes were most able to survive these turbulent times. Hopi and Zuni pueblos (the two northernmost points in the network after 1300 CE in Figure 5b) are two of only a handful of

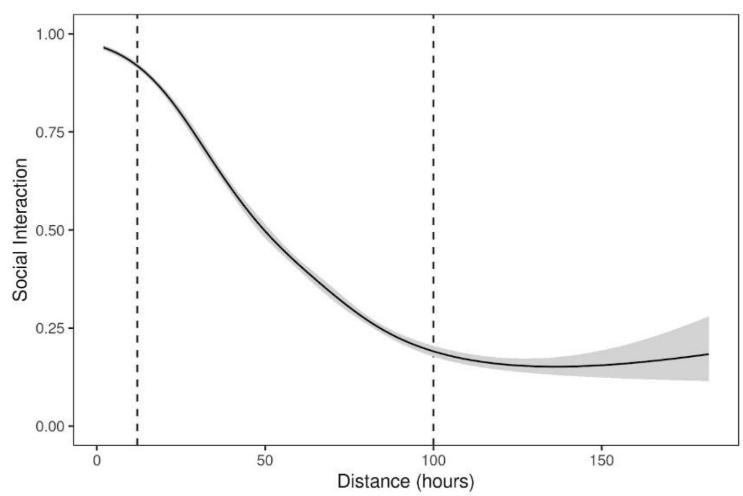


Figure 7. Influence of distance on the intensity of social interaction; social interaction between a pair of archaeological sites decreases as distance increases. This relationship is nonlinear – within about a day's travel, distance doesn't decrease social interaction too much (first dashed line), but beyond 100 hours social interaction is already at its lowest.

sites in the database that survived past this period of major collapse, migration, and reorganization to continue until the present day. Both have favorable positions with respect to regional terrain and climate patterns that appear to have allowed them to persist longer than many of their neighbors. Zuni Pueblo seems to be especially well positioned with respect to regional drought and flood patterns. It is located at the precise boundary between the zones where Tropical Pacific (EOF1) or Gulf of Mexico (EOF2) influences are more strongly expressed – down to the exact pixels on the maps in Figure 2!

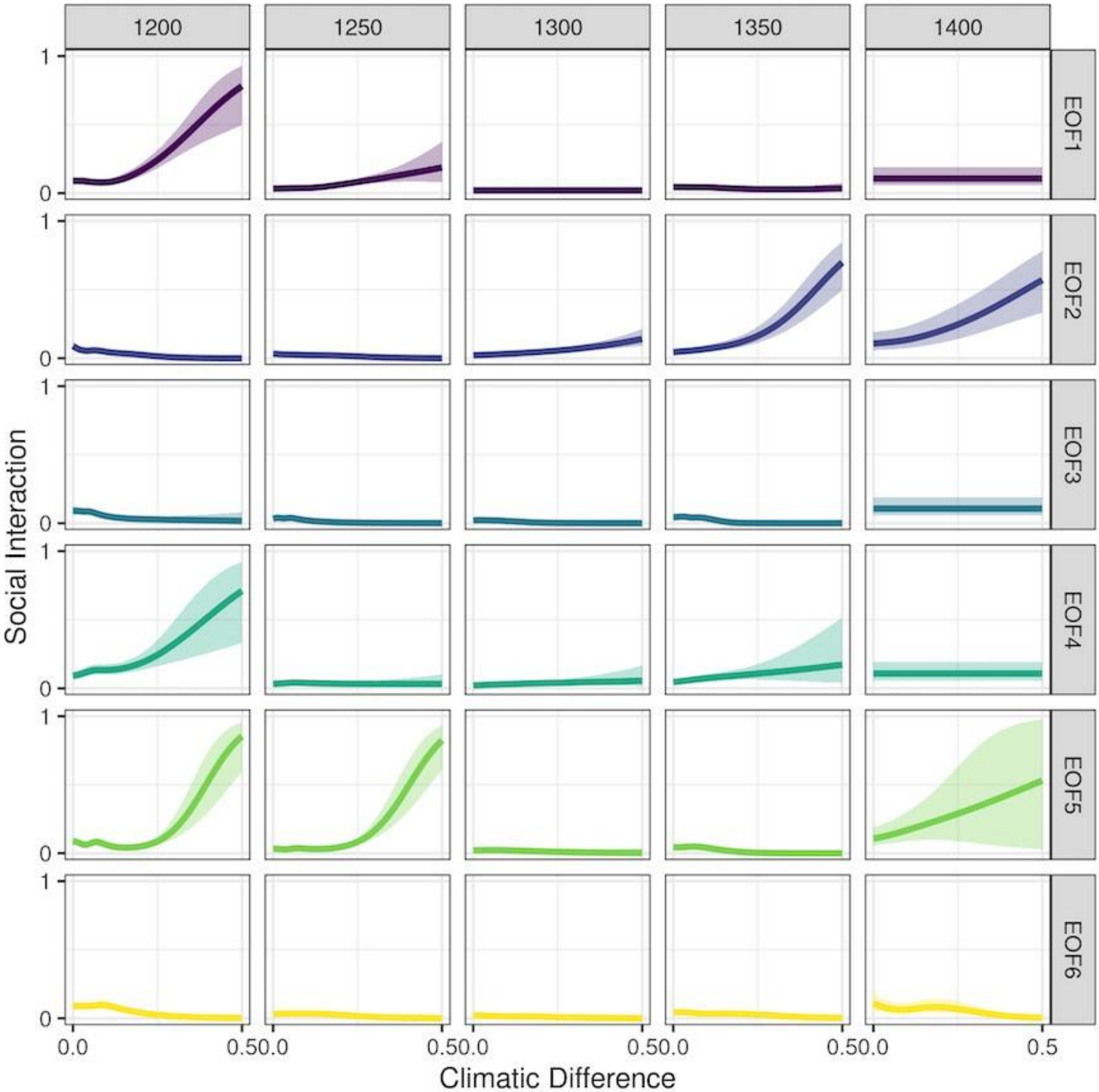
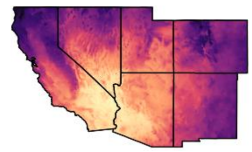


Figure 8. Relationships between climatic dissimilarity and social interaction over time; rows represent each of the six drought/flood patterns (i.e., the EOFs from Figure 2), and columns represent each of the five time steps in the study. Lines that increase from left to right indicate an increase of social interaction with increasing climate dissimilarity, flat lines indicate no relationship. The shaded areas around each line indicate the degree of uncertainty in the estimated relationship.

Lessons for Today

What do the successes and failures of ancient social infrastructure have to do with the challenges we face today? These same six climate patterns influence our climate today, since they reflect unchanging factors such as the size and position of the oceans and mountains. Thus, shifts in the global climate will be translated into local environmental impacts via these recurring regional climate patterns.

For example, droughts and floods in Arizona are influenced by three competing climate patterns – the Tropical Pacific, Gulf of Mexico, and Colorado Plateau. Each of these patterns can bring different extreme weather, and it's important that our infrastructure networks like food supply chains, power lines, and regional evacuation routes account for these different sources of variability.



More broadly, we must remember that infrastructure is crucial to our survival, and continuing investment in it is crucial to adapting to changing climates. As the pre-Hispanic peoples of the Southwest have shown us, our social relationships, though they are difficult to see, are just as important as roads and bridges when adapting to challenging climates.

About the Author

Nicolas Gauthier, PhD, is the Assistant Curator for Artificial Intelligence in the Florida Museum of Natural History at the University of Florida, where he uses supercomputers to better understand how people in the past interacted with their natural environments. He was previously a postdoctoral researcher at the University of Arizona Laboratory of Tree-Ring Research and Scripps Institution of Oceanography, where he worked to reconstruct past climates in Asia and western North America. More information about his research is available at https://nick-gauthier.github.io.

Acknowledgments. Archaeology Southwest and the Southwest Social Networks project kindly provided access to the archaeological data used in this study. Lawrence Fatica and Allen Dart provided helpful comments on previous versions of this article. This article is adapted from a peer-reviewed scientific paper published in *Frontiers in Earth Science*, freely available at https://doi.org/10.3389/feart.2020.620856.

Introductory Paths to Get into Field Sciences Like Archaeology

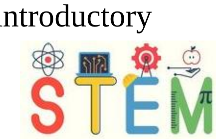
Brian W. Kenny

Editor's note: Brian Kenny is an archaeologist who had a long career in Arizona and in federal service before he retired to Flagstaff, Arizona. In late 2013 he posted on the New Mexico Archaeological Council's listserve some advice he had given to a student who had asked what it takes to become an archaeologist, and in March 2014 he expanded on his earlier post to list a dozen points of advice to anyone seeking a career in field sciences, including archaeology. Since I often receive similar inquiries from students asking for advice on how to get into archaeology, I copied Brian's 2014 post to my files, and in January 2018 I asked his permission to include it in a future issue of the *Old Pueblo Archaeology* bulletin either as-is or revised if he wanted to make any changes. He replied, "Five years is a longtime for advice to remain valid, but if it has merit, please go ahead and modify it or use it as it is." I believe it has a lot of merit, so here's his 12-point list, as-is except that I have corrected some typographic errors, added some punctuation, and thrown in some illustrations from Old Pueblo Archaeology Center and some uncopyrighted sources. AD

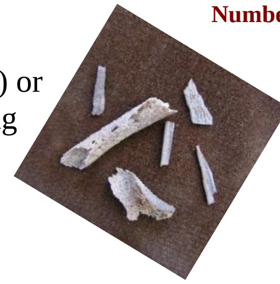
1. You'll need to complete college. You can start working with a Bachelors degree, or less, but if you want to stay in for a career you'll need a Bachelor's AND at least a Master's degree. You don't need to be an academic forever, but you'll need the credentials. Most students who stay in for a career have their BA or BS and MA or MS before they are 25-30 years of age. There is a some variability, but fieldwork can be very arduous, so it is a young person's calling. Many archaeologists work in fieldwork 8-10-15-20 years full time, but then look for academic or administrative or government jobs as an archaeologist where the field - office ratio is better. Those who are very academically and scientifically and office oriented become professors and lecturers, or museum staff, or government staff, then they spend much of the time indoors, but may still go out to do some fieldwork. Agencies like the Forest Service, BLM, National Park Service hire archaeologists. You can see the job announcements at https://www.usajobs.gov/, using key words like anthropologist, archaeologist, geologist. Most start at a GS 5-7 pay range.

2. You can volunteer to go on a dig overseas or somewhere in the USA, but many travel/dig programs want to charge a fee. These programs often are filled with adventurers, more than with professionals or than with students who want to become professionals. One can have a lot of fun with the adventurers, but you must choose wisely. You can earn a lot of fun and travel, which is good experience, but little academic credential or knowledge gain could also result. You'll have to separate fun fun from the fun training and know when to do both.

3. If you are a student who really wants to be a professional archaeologist, you'll need to go to field school. Often this is done through a University program for college credit which can be applied to your Bachelors degree or Masters degree. You usually have to pay tuition and a fee to attend field school (and give up your paid job for several weeks).



4. If you have your first two years of general course work out of the way, that is good. If you are low in science or math, I encourage you to learn more science and math. Take STEM classes, and introductory statistics classes for earth science majors (not math majors). Also take archaeology, geology, biology courses that have lab and or fieldwork involved. GIS and LiDAR mapping technologies and computers are the way of the world, so they may count toward the degree as well as offer later opportunity. Anything that has to do with methods of science – the doing of science – that's what you need to learn. Study DNA and genetics if you want to go into paleo anthropology. You will be working with geneticists. Study human bodies if you want to be a forensic anthropologist.



5. Sometimes you can take a course in faunal (animal bone ID and taxonomy) or osteology (human bone ID and taxonomy) or pollen analysis and turn that training into a consulting opportunity to pay your way through grad school. I have hired specialists at $1-2K a pop to analyze a collection and write a report (which becomes part of a larger report). Specialist skills are in demand.

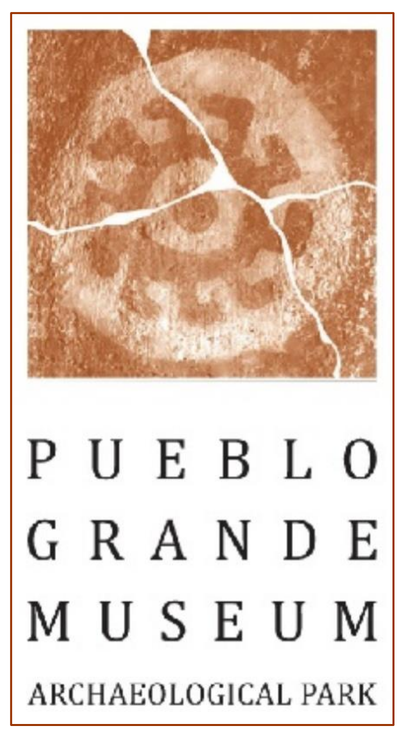
6. If you are an artist, teach yourself technical and scientific drawing; you can always earn some extra money and experience that way. People who learn how to edit and layout, stylize and compose books are needed in earth and anthropological sciences. The archaeologist can do the work, but she still relies on lab and museum specialists and editors and publishers to help.

7. Cultural anthropologists and ethnographers deal with culture and language, and often are interested in living peoples and complicated issues like freedom, democracy, migration, environment and preservation of diversity. Check that out, and, make alliances with them if you are an archaeologist.

8. You must take your degree and make your way, because almost no one has a ready-made job for you. You'll have to teach yourself how to create opportunities for paid work and research. Most anthropologists are way outside the box when it comes to jobs. HR recruiters don't hire them – they want to put recruits in a box, then hire into that box (accountant, police officer; sales manager, etc.) – most anthropologists and archaeologists eat the box.

9. Whatever you do, do it with passion to the point other people think you are crazy. Know it and own it better than your colleagues. There is real reward in not being a bragger, but in knowing and doing it better than anyone else, and sharing it all with others. If you know it, share it.

10. You will make enemies for the most stupid of reasons during a career. Sometimes, there's no going back to correct it. Nonetheless, treat everyone with respect and genuine interest and friendship – even your enemies – you will meet them again over the course of your career. You may even work with them repeatedly. It is a competitive world out there.



11. If you want to volunteer, go volunteer at the Heard Museum or Pueblo Grande Museum (or your local city museum or a house museum). Define what volunteer work you'd want to do. The National Park Service http://www.nps.gov/getinvolved/volunteer.htm will put you in proximity of professionals who can give you additional advice. There are other places to volunteer : http://www.usaconservation.org/, etc. Remember, you volunteer for love of an issue or to gain specific experience you might not otherwise get. You must know what experience you want to gain, and once you volunteer, make it for a set period of time (6 mos. for example). Always keep your volunteer commitment. If you complete your commitment and it's not what you want to do, move on.

12. Be sure to put your volunteer work on your résumé. You may be a student now, but you can develop a résumé (one page) as well as a CV (*curriculum vitae*). Your résumé tells a story in one page. Usually it is an opportunity for a deeper conversation (formal or informal). The conversation is where you get to tell your story and give an "elevator speech" and a sales pitch and a thirty second ad – for yourself – for a job, for a contract, for a growth opportunity, for the need to establish a short or long term business relationship, etc.

Eve Ball ca. 1920 (left); and interviewee Asa Daklugie, son of Chief Juh and nephew of Geronimo, 1955; photos courtesy of Lynda Sánchez

Thursday December 16, 2021, 7 to 8:30 p.m. Arizona/Mountain Standard Time*

Apache Warriors Tell Their Side free Zoom presentation by author-historian Lynda A. Sánchez **for** Old Pueblo's Third Thursday Food for Thought series: https://zoom.us/webinar/register/WN_JYWiXGriRjOBGKe5OW0rfA.

Tuesday December 21, 2021, 8 a.m. to noon Arizona/Mountain Standard Time*

Winter Solstice Tour to Los Morteros and Picture Rocks Petroglyphs Archaeological Sites with archaeologist Allen Dart, Marana and Tucson areas, Arizona; $30 donation ($24 for Old Pueblo Archaeology Center and Friends of Pueblo Grande Museum members):
https://www.oldpueblo.org/wp-content/uploads/2021/08/20211221v1LosMorterosPictureRocksWinterSolsticeTour.pdf

Photo of a complex petroglyph array at the Picture Rocks site courtesy of the Picture Rocks Redemptorist Renewal Center

San Francisco Red and Mogollon Red-on-brown pottery vessels, photos courtesy of Pottery Typology Project, Office of Archaeological Studies, New Mexico Museum of Indian Arts and Culture, Santa Fe

Mondays January 10-March 28, 2022, 6:30 to 8:30 p.m. Arizona/Mountain Standard Time*

The Mogollon Culture of the US Southwest 12-session adult education class online via Zoom, taught by archaeologist Allen Dart; $99 donation ($80 for Old Pueblo Archaeology Center, Friends of Pueblo Grande Museum, and Arizona Archaeological Society members):

https://www.oldpueblo.org/wp-content/uploads/2021/08/20220110-0328v1TheMogollonCultureOfTheUSSouthwestFlyer.pdf

Saturday February 26, 2022, 8 a.m. to 1 p.m. Arizona/Mountain Standard Time*

Tucson and Marana Yoeme (Yaqui Indian) Communities car-caravan cultural sites tour with Yoeme traditional culture specialist Felipe S. Molina, Tucson and Marana areas, Arizona; $35 donation ($28 for Old Pueblo Archaeology Center and Friends of Pueblo Grande Museum members):
https://www.oldpueblo.org/wp-content/uploads/2021/11/20220226v2TucsonMaranaYoemeYaquiIndianCommunitiesFlyer.pdf

Typical home in Yoem Village, Marana, Arizona, in 1936: Homes were built with railroad ties, saguaro cactus ribs, metal roofing and mud; R. B. Spicer photo courtesy of Felipe Molina

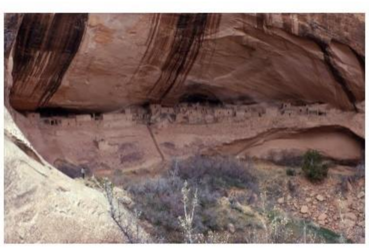


Photo by Jeffrey S. Dean of Kiet Siel Pueblo, one of the sites discussed in the Archaeology of the Southwest class

Wednesdays June 8-August 24, 2022, 6:30 to 8:30 p.m. Arizona/Mountain Standard Time*

Archaeology of the Southwest 12-session adult education class online via Zoom, taught by archaeologist Allen Dart; $99 donation ($80 for Old Pueblo Archaeology Center, Friends of Pueblo Grande Museum, and Arizona Archaeological Society members):

https://www.oldpueblo.org/wp-content/uploads/2021/11/20220608-0824v1ArchaeologyOfTheSouthwestOnlineClassFlyer.pdf

Wednesdays September 21-December 14, 2022, 6:30 to 8:30 p.m. Arizona/Mountain Standard Time*

The Hohokam Culture of Southern Arizona 12-session adult education class online via Zoom, taught by archaeologist Allen Dart; $99 donation ($80 for Old Pueblo Archaeology Center, Friends of Pueblo Grande Museum, and Arizona Archaeological Society members):

"Norton Family" Hohokam cut-shell figurines, Norton Allen Collection, Arizona State Museum, University of Arizona, photo by Arthur W. Vokes

https://www.oldpueblo.org/wp-content/uploads/2021/11/20220921-1214v1TheHohokamCultureOfSouthernArizonaClassFlyer.pdf

* Southern Arizona does not switch to Daylight Saving Time each year, so when the rest of the US does, Mountain Standard Time is the same as Pacific Daylight Time.

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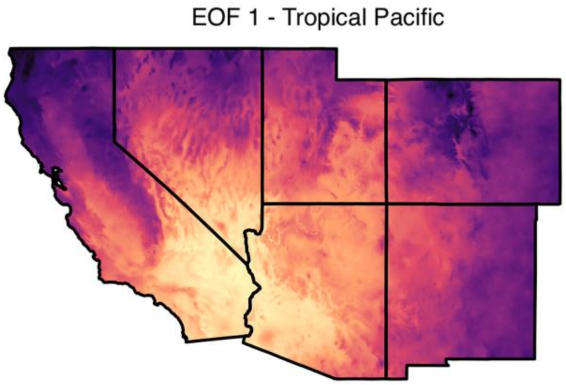

EOF 1, one of the six leading "empirical orthogonal function" spatial patterns of observed droughts and floods over the past 100 years in the US Southwest (see page 1 article)

Old Pueblo Archaeology

Bulletin of Old Pueblo Archaeology Center

Located at 2201 W. 44th Street in the Tucson Unified School District's Ajo Service Center
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Old Pueblo Archaeology Center's *Archaeology Opportunities* Membership and Discounts Program

Archaeology Opportunities is a membership program for persons who wish to support Old Pueblo Archaeology Center's education efforts and perhaps even to experience for themselves the thrill of discovery by participating in research. Membership is also a means of getting discounts on the fees Old Pueblo normally charges for publications, education programs, and tours. Members of *Archaeology Opportunities* at the Individual membership level and above are allowed to participate in certain of Old Pueblo's archaeological excavation, survey, and other field research projects, and can assist with studies and reconstruction of pottery and other artifacts in the archaeology laboratory. Membership benefits include a 1-year subscription to the Old Pueblo Archaeology electronic quarterly bulletin, opportunities to participate in Old Pueblo's member-assisted field research programs, discounts on publications and archaeology-related items, and invitations and discounts for field trips and other events.

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