Title
The Oxford Handbook of Southwest Archaeology

ISBN
9780199978427

Authors
Habicht Mauche, JA
Duff, AI
Shackley, S

Publication Date
2017-09-06

DOI
10.1093/oxfordhb/9780199978427.001.0001

Peer reviewed

CHAPTER 40

MINERALS

ANDREW I. DUFF, JUDITH A. HABICHT-MAUCHE, AND M. STEVEN SHACKLEY

The ancient peoples of the Southwest made use of a wide range of lithic and mineral resources, some of which were available locally to most communities, and others that could only be obtained through long-distance acquisition from limited and specific locations. The materials discussed here—clay, temper, and mineral pigments (including lead) used to make pottery, as well as tool stone, salt, and turquoise—range from those used for routine tasks on a daily basis to those more closely associated with ritual action. Their acquisition often required ritual preparation, prayers, and special trips to named places, many of which are part of the fabric of oral traditions and have shaped enduring cultural landscapes. For each of these materials, we briefly discuss their distribution, archaeological traces, analytical characterization, and means of sourcing. Tracing the movement of these resources across ancient landscapes has formed the basis of regional models of social, political, and economic interaction in Southwest archaeology.

Pottery Clay, Temper, and Pigments

Clay, defined here as a fine-grained earthy material that is malleable when wet and rigid when fired, is ubiquitous in the Southwest. For over two millennia, Native groups have used clay to manufacture fired figurines and ceramic containers, which became increasingly common after 200 CE (Heidke and Habicht-Mauche 1998). Southwest archaeologists have identified a series of distinct pottery styles that demarcate archaeological cultures and define regional temporal sequences. Beginning with Anna Shepard's groundbreaking research at Pecos Pueblo (Kidder and Shepard 1936), it has become clear that Southwestern potters were fairly conservative in their choice of clays, tempers (non-plastic additives), slips, and pigments, creating well-defined technological traditions that can be characterized using a diverse suit of mineralogical and chemical techniques. Over the last eighty years, Southwest archaeologists have used these techniques to reconstruct strategies of ancient pottery production and exchange and, in turn, to model local, regional, and interregional processes of economic and social interaction, migration, and community and identity formation.

Clay is exposed in primary contexts in many parts of the northern and central Southwest. For much of the Colorado Plateau, geological formations with deposits formed in marine and near-shore contexts are routinely exposed throughout the mesa and canyon country, providing ample access to beds of relatively high-quality, workable clays. In other regions, such as the Basin and Range provinces of the southern Southwest and along most portions of the Rio Grande Rift, weathered and/or transported deposits that derive from a wide variety of parent materials were utilized. Since materials suitable for the manufacture of pottery containers occur throughout the Southwest, potters generally did not have to travel beyond the seven-kilometer threshold typical of most non-industrial potters worldwide (Arnold 1985), and many communities had suitable clay within one to two kilometers. Non-plastic fabric additives (tempers), used to stiffen clays for hand building and to prevent cracking during drying and firing, were also widely available. The most common tempers used by Southwest potters include sand, crushed rock, and crushed sherd (grog), although naturally silty secondary or coarse residual clays were often utilized without the addition of temper (e.g., Fowles et al. 2007). These are often inappropriately referred to as "self-tempered" clays. Pueblo and Apache potters in the northern Rio Grande, for example, favored highly micaceous primary clays for the production of cooking vessels (Eiselt and Ford 2007).

In many parts of the Southwest, a thin wash or slip (clay in watery suspension) was added to the surface of pots to alter their color and to provide a smooth, uniform painting surface. High-quality slip clays, particularly the white-firing slips favored by Ancestral Pueblo potters of the northern Southwest, may have been much more limited in their distribution than potting clays and may have been acquired from more select and distant locations. Most decorated pottery in the Southwest was painted with various iron- or manganese-based mineral pigments, organic (carbon) pigments made from plant materials, or lead or lead-copper based glaze-paints.

Most characterization studies of Southwest pottery have focused on the composition and sourcing of ceramic pastes (clay, plus non-plastics and temper). Common low-tech methods include visual identification of pastes using low-power stereomicroscopes and oxidation (refiring) studies. Visual inspection of ceramic fabrics are often used to sort pottery collections into general paste categories, especially in regions where crushed rock or sand was used as temper, such as the Rio Grande Valley (Habicht-Mauche 1993; Shepard 1942), or where naturally occurring non-plastics are geologically distinct, such as parts of the Hohokam area (Abbott et al. 2007:465). In oxidation analyses, a small chip of pottery is fired to a temperature thought to exceed the original firing temperature, usually around 900°–1000° C, in order to develop the fully oxidized color of the source clay (Shepard 1980:103–113). Refired sherd colors are often tabulated using a Munsell Color Chart and are aggregated into groups of like colors for comparison (e.g., Mills 1987; Windes 1977), with the spectrum usually running from beige or buff to dark reds, largely an indication of the relative amount of iron content in the clay. Refired sherd colors are often compared with the fully oxidized colors of test tiles of field clays collected around presumed manufacturing sites, which facilitate development of preliminary inferences about the potential of local pottery production. The results of visual paste sorts and refiring studies usually result in sourcing hypotheses that are tested using more high-tech mineralogical and chemical techniques.

Anna Shepard (1936, 1942) pioneered the use of optical mineralogy (ceramic petrography) to source archaeological pottery production in the Southwest. Petrographic analysis focuses on the identification of natural or added non-plastic lithic and mineralogical inclusions in ceramic pastes, which can be linked to the geological distribution of these materials in the landscape to determine potential pottery production areas. In the Rio Grande Valley, where potters traditionally favored the use of geologically distinct crushed rock tempers, ceramic analysts have successfully employed qualitative petrographic techniques to identify production source areas, often down to the level of specific villages (Habicht-Mauche 2002). In the Gila-Salt Hohokam Core and Tonto and Tucson basins areas of the southern Southwest, where secondary alluvial clays and sand tempers were commonly utilized for pottery production, more quantitative "petrofacies" techniques employing petrography (e.g., Heidke et al. 2002) or an electron microprobe (e.g., Abbott 2000; Abbott et al. 2007) have allowed for the characterization of local clay resource zones.

Bulk analysis techniques—methods that characterize all components of the ceramic paste and temper together—have been used throughout the Southwest, and these are especially appropriate in contexts where grog tempering was the norm. Several different bulk techniques have been used, but instrumental neutron activation analyses (INAA) has been used most widely and over the longest period. Case studies employing INAA in the greater Southwest are too numerous to detail, but the chapters in Glowacki and Neff (2002) provide key examples. What is particularly important is that Southwest researchers have developed one of the most extensive regional databases in the world using INAA, with large numbers of samples used to define numerous regionally specific chemical reference groups. The cumulative database continues to expand, as researchers conduct new analyses and utilize existing sample data (see Figure 40.1 for sites and other locations mentioned in this chapter).

Chemical element analyses have also been conducted on paints and slips, complementing analyses of pastes and/or tempers. For example, Gosser and colleagues (1998) used particle-induced X-ray emission (PIXE) analysis of white slip and paints on Salado polychromes from the Tonto Basin to identify patterns in slip raw material selection both within periods and over time. Speakman and Neff (2002) used laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) to characterize white slip paints on Mesa Verde pottery, and also explored the ability of the technique to distinguish mineral and organic paint. Time of flight–laser ablation–inductively coupled plasma–mass spectrometry (TOF-LA-ICP-MS) has been used to characterize glaze paint and slip pigments on White Mountain Red Ware vessels from Bailey Ruin in east-central Arizona (Duwe and Neff 2007). Ceramic paints, especially glaze paints, have

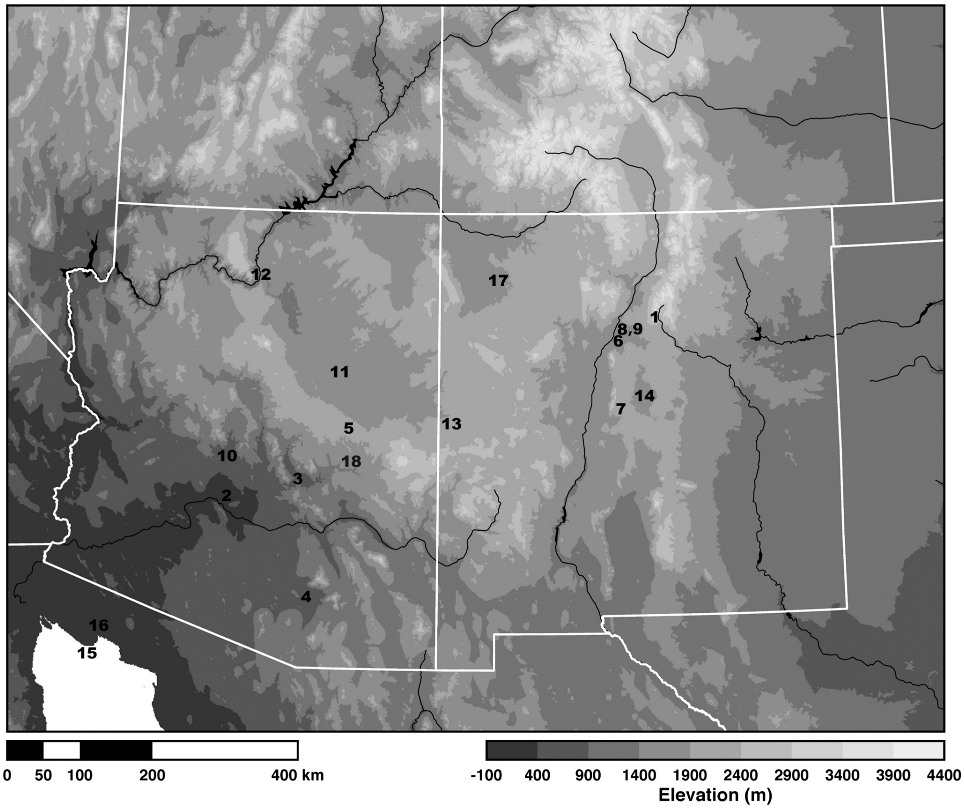

FIGURE 40.1. Locations of places mentioned within this chapter. (1) Pecos Pueblo, (2) Gila-Salt River Hohokam Core/Phoenix Basin, (3) Tonto Basin, (4) Tucson Basin, (5) Bailey Ruin, (6) Tunque, (7) Quarai, (8) Cerrillos Hills, (9) San Marcos Pueblo, (10) New River, (11) Homolovi III, (12) Hopi Salt Mine, (13) Zuni Salt Lake, (14) Estancia Basin, (15) Salina Grande, (16) Salina del Pinacate, (17) Pueblo Bonito/Chaco Canyon, (18) Canyon Creek Mine/Grasshopper Pueblo.

also been characterized using an electron microprobe (e.g., Huntley 2008; Huntley et al. 2007). Microprobe analyses of glaze paints have focused on defining locally specific modes of production or "glaze recipes," which, in turn, have allowed researchers to trace the movement of technological knowledge, and probably potters themselves, across the dynamic landscape of the late pre-Hispanic Southwest.

Lead

Lead is a key constituent in glaze paints and, as such, merits further discussion. At various times and places, Ancestral Pueblo potters used vitreous glaze paints to decorate their pottery. The earliest Southwestern glaze paints are found on Pueblo

I pottery (700–900 CE) from the Four Corners area. Vitrified paints are also occasionally encountered on various types of Casas Grandes polychromes from northern Mexico dating to the late thirteenth through early fifteenth centuries. However, the most enduring, widespread and best studied of the glaze-paint traditions is associated with the Pueblo IV period in Arizona and New Mexico. The earliest Pueblo IV glaze-paints appear along the Mogollon Rim between 1250 and 1275 CE, quickly spreading to the Upper Little Colorado and Zuni regions and finally to the Rio Grande by around 1300 CE. Glaze-painted pottery ceased to be made in the Mogollon and Zuni areas around the middle of the fifteenth century, with the exception of a brief revival at Zuni during the Mission period. Many Eastern Pueblo communities along the Rio Grande continued to make glaze wares up through the end of the Pueblo Revolt period around 1700 CE (Huntley et al. 2012).

The production of glaze paints requires the use of a flux, which reduces the melting point of silica, allowing glass to form on the surface of ceramic vessels at low firing temperatures. While Ancestral Pueblo potters appear to have experimented with other materials, such as copper (Fenn et al. 2006; Huntley 2008), the overwhelming majority of Southwest glaze-paints utilized lead as the primary fluxing agent. Microscopic and chemical analyses of raw pigments and fired glaze paints suggest that galena (lead sulfide ore) was probably ground and then roasted to produce powdered lead oxide. This lead oxide pigment would likely have been mixed with an organic binder and possibly other ground minerals (copper, iron, or manganese) or slip clay to produce a paint that vitrified upon firing. However, attempts to experimentally replicate this technique have been only moderately successful (Blinman et al. 2012).

Chunks of raw galena have been recovered archaeologically from known glaze ware–producing communities, such as Tunque (Bice et al. 2003) and Quarai (Huntley et al. 2007). A utility ware jar filled with galena crystals was found near a small jacal site north of Socorro, New Mexico, and reed tubes packed with powdered galena have been reported from Rabid Ruin in Arizona (Huntley et al. 2012). This evidence suggests that raw galena was usually transported from mining areas to villages to be processed locally into ceramic paints. Regional variation in glaze paint recipes, even among communities utilizing lead ore from the same source, further suggests that paint was locally processed and mixed. Powdered lead oxide may also have been used as a pigment in other contexts, perhaps to paint human bodies, katsina masks, or other ritual paraphernalia.

During the 1970s, archaeological excavations were conducted at two pre-Hispanic mines in the Cerrillos Hills district of New Mexico: Mina del Tiro and Bethsheba. The lead workings at Bethsheba consisted of a trench that extended some 70 meters up a small hill, averaged one meter wide, and was over 8 meters deep at its top. Tools and methods used to mine lead were very similar to those used in the nearby turquoise workings (see later discussion in this chapter). Associated ceramics indicate that lead mining in the Cerrillos Hills was concentrated in the Pueblo IV period, about 1300–1700 CE (Bice et al. 2003).

Lead has a somewhat limited but widespread distribution across the Southwest. It is found in a variety of geologic contexts, extending from the southern Rocky Mountains, along the mountain flanks of the Rio Grande trench, along the mountainous edge of the Mogollon Rim, and throughout the southern basin and range regions of New Mexico and Arizona. Because lead ores in the Southwest mineralized in such diverse geologic contexts, ratios of the four stable isotopes of lead have been used successfully to "fingerprint" different source areas and to trace shifting lead procurement patterns during the Pueblo IV period (Habicht-Mauche et al. 2000; Huntley et al. 2012). While there is some overlap between the lead isotope signatures of different source areas, overall trends in the data usually allow researchers to draw fairly robust conclusions about historic patterns of acquisition within specific glaze paint–producing areas. Better instrumentation, such as multicollector inductively coupled mass spectrometers or use of secondary isotopic tracers such as strontium, should allow even clearer discrimination between sources in the future (Aggarwal et al. 2008; Thibodeau et al. 2013).

Lead isotope analyses of glaze paints from the Mogollon Rim, Zuni, and the Rio Grande suggest that potters in each region favored the use of lead from only a few select sources, even though other sources were readily available and sometimes closer. This pattern is most clearly documented for the northern and central Rio Grande area, where glaze-ware potters utilized the Cerrillos lead source almost exclusively (Habicht-Mauche et al. 2000). Once a community of potters began using a specific source, they tended to stick with that source until forced to develop a new one because of demographic or sociopolitical obstacles. The best example of this scenario comes from Zuni, where fourteenth-century glaze ware potters shifted from using Cerrillos lead to sources in southern New Mexico at about the same time that large Pueblo IV villages in the nearby Galisteo Basin began making glaze-painted pottery (Huntley 2008). Certain communities, such as San Marcos Pueblo, located adjacent to the Cerrillos district, may have asserted some control over access to specific lead-mining areas. Choices regarding the utilization of specific lead sources may also have been embedded within broader resource-collecting strategies, especially those associated with the acquisition of other rare or ritually significant minerals such as turquoise (Huntley et al. 2012) (see later discussion).

Obsidian, Other Volcanic Rocks, and Secondary Siliceous Sediments

A variety of stone raw materials were used to produce chipped and ground stone artifacts in the Southwest. Flaked stone tools (projectile points, as well as various cutting and scraping tools) were produced from obsidian, most other volcanic rocks, and secondary siliceous sediments such as chert, chalcedony, and derivatives such as jasper and agates. Ground stone tools such as ornaments and milling stones (metates and mortars) were often produced from other volcanic rocks, such as basalt and andesite.

Obsidian

Obsidian, the quenched, disordered, vitreous form of the volcanic rhyolite, has been a favored raw material among both ancient tool producers and modern archaeologists who are drawn by the ease with which it can be chemically characterized (Shackley 2005). It produces an extremely fine edge and makes excellent cutting tools and sharp projectile points. In many regions, obsidian was imported through exchange or direct procurement, either because adequate raw materials were not available nearby or because it presented a superior option, making its acquisition worth the effort (Shackley 2005).

Unlike other heterogeneous rocks or minerals, obsidian, by definition, is chemically homogeneous (with some exceptions), with no crystalline structure. This allows for its rapid and accurate elemental characterization using a variety of instrumental methods, dominated by X-ray fluorescence spectrometry (XRF; Shackley 2011a). Obsidian occurs in a number of source locations, each defined by discrete chemical signatures (Figure 40.2; Shackley 2005), though many of these raw materials were obtained from secondary deposits in stream basins some distance from the primary sources (Church 2000).

Because the elemental characterization and source assignments are so accurate, archaeologists have successfully used obsidian data to infer a variety of social and territorial processes. Questions that have been addressed using obsidian sourcing include Paleoindian territoriality and procurement (Hamilton et al. 2013; Shackley 2005; Vierra et al. 2012), Chacoan era procurement and distribution (Duff et al. 2012), shifts in Sedentary Hohokam exchange and social identity (Fertelmes et al. 2012; Shackley 2005), social interaction in the Mimbres region (Taliaferro et al. 2010), interaction and migration from the Mesa Verde region (Arakawa 2006; Arakawa et al. 2011), and late pre-Hispanic period migration and social networking (Mills et al. 2013). It is important to note that in most archaeological contexts, obsidian artifacts comprise a minority of the raw materials used. However, the ease and accuracy of characterization, and its movement across great distances, have elevated obsidian provenance studies to the forefront of interpreting the past in the Southwest.

Other Volcanic Rocks

Other volcanic rocks—basalt, andesite, dacite, and rhyolite—were used to produce chipped and ground stone implements, especially milling stones (metates and mortars). However, due to the heterogeneous, large mineral character of these raw materials, they have not been subjected to as much intensive instrumental study as obsidian (Shackley 2011a). The presence of a crystalline structure creates greater source variability than homogeneous obsidian using XRF as an analytic method (Shackley 2011b).

Dacite is a relatively high-silica volcanic rock that is very fine-grained in most cases and consequently flakes nearly as easily as obsidian. A study of northern New Mexico

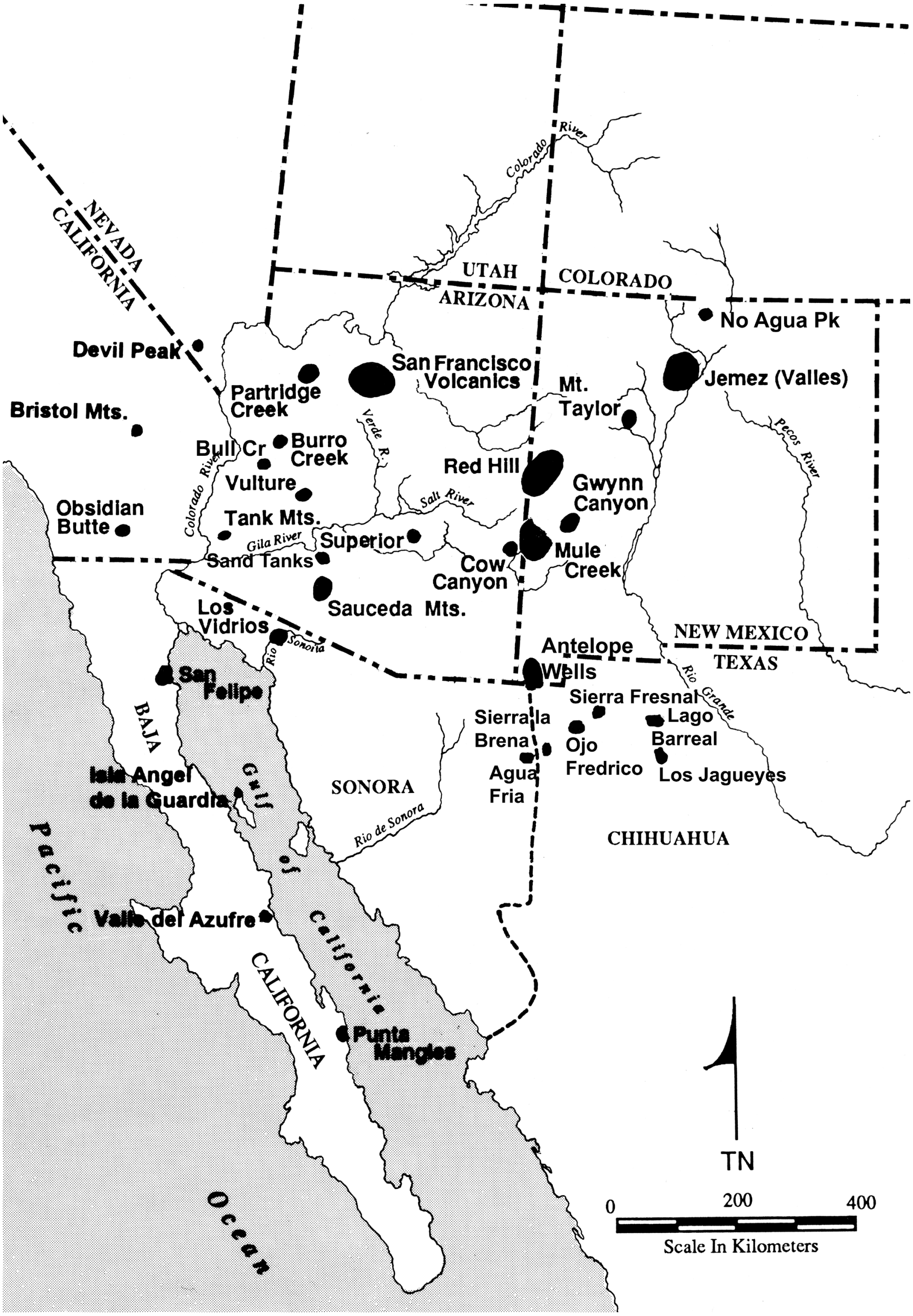

FIGURE 40.2. Distribution of sources of archaeological obsidian in the North American Southwest and surrounding regions.

Adapted from Shackley (2009).

dacite suggests that it was transported as far as obsidian in all time periods throughout the region (Shackley 2011b). Basalt and andesite were frequently obtained to produce ground stone artifacts, particularly metates and mortars. Large ground stone quarry sites are located throughout the Southwest, and a few have been characterized via petrography or other chemical analysis techniques. The New River area north of Phoenix, for instance, contains "quartz-basalt" quarries used to produce ground stone, and analysis of thin sections demonstrates its circulation to the Hohokam core (Doyel 1991, and references therein). Bostwick and Burton (1993) documented additional ground stone quarry locations on the peripheries of the Phoenix Basin, where several basalts with differing inclusions were identified using back-scattered-electron/energy dispersive X-ray microscopy. Chemical analyses confirmed the different primary inclusions, but they suggest that these materials are distinct enough that they can be distinguished visually. Though sandstone is not a volcanic, Fratt and Biancaniello (1993) used petrography to source ground stone implements made of sandstone to two different formations in the vicinity of Homolovi III.

Secondary Siliceous Sediments (Chert and Chalcedony)

Secondary siliceous sediments are rocks that precipitated from a parent material and that contain a high proportion of silica (SiO_2), often over 95% by weight. If the precipitation is through volcanic rocks such as andesite or rhyolite, the crystalline structure is fibrous and often requires some thermal heat treatment to make it "flakeable." If the sediment is precipitated through limestone (or in some cases, sandstone), the structure is often granular and may not need thermal heat treating to make a good media for chipped stone tool production. Other sediments can be silica stone, produced through hydrothermal processes such as occurs around hot springs or fumaroles, and this material can sometimes be an excellent media for tool production. Chert and chalcedony are frequently used for chipped stone tool production in the Southwest, providing tools that are resistant to breakage and wear. Additionally, adequate cherts and chalcedonies are common in many areas, requiring limited procurement effort compared to obsidian. Some well-known sources of chert or chalcedony in the Southwest include "Zuni spotted chert" from the Zuni Mountains in western New Mexico, "Chuska chert" from the northeastern portion of the Navajo Tribal Land in Arizona, petrified (silicified) wood from northern Arizona in and around Petrified Forest National Park, and Cerro Pedernal, a chalcedony source used in pre-Hispanic times for chipped stone tool production and by the Spanish for making gun flints in northern New Mexico. High-quality chert and other raw material were imported or directly procured, sometimes from great distances (e.g., Cameron 2001), especially during the Paleoindian period (Hamilton et al. 2013). Alibates jasper from the Texas Panhandle, found at Eastern Pueblo sites such as Pecos, reflects increased interaction between Southwest farmers and Plains bison hunters during the late pre-Hispanic and early colonial periods. Raw materials of varying quality come from many more sources in the Southwest. Most of these materials have been characterized visually (e.g., Arakawa 2006; Cameron 2001; Green 1985).

Salt

Locations where salt has been gathered are well documented in the anthropological literature for the Southwest, as are the traditions associated with its acquisition and use. However, high-quality and accessible salt is a relatively rare occurrence; sources were therefore valued and have become storied places. There are several mines and saline lakes or basins where salt was regularly gathered, primarily in the northern portions of the Southwest. Though present geologically, there are few accessible or exposed sources of salt in the Basin and Range province of the southern Southwest (Rauzi 2002).

Most documented locations where salt has been procured continue to be visited for salt collection. There is a series of deposits located near the confluence of the Little Colorado and Colorado rivers at the Grand Canyon, with the primary source known as the Hopi Salt Mine. Hopi make trips linked to initiation rites or for other ritual purposes, utilizing a defined route or corridor that includes numerous shrines (e.g., Ferguson et al. 2009; Titiev 1937). Titiev (1937; see also Simmons 1942:232–246) described a trip to the Hopi Salt Mine in 1912, detailing many ceremonially significant points along the route, as well as other secondary salt sources.

Located south of Zuni Pueblo in west-central New Mexico, the Zuni Salt Lake is an excellent salt source that was utilized by several different Southwestern native groups (Duff et al. 2008; Hart and Othole 1993; Hill 1940; see also Ferguson and Kuwanwisiwma, Chapter 8 in this volume). There are several trails that converge on this source, some of which may date to the Chaco era (ca. 900–1150 CE; Ferguson et al. 2009; Marshall 1997). Stevenson (1904:354–361) details the Zuni's annual trip to the lake to collect salt, including ritual preparations, offerings, travel, actions at the lake, etiquette, and the return to Zuni. Hopi trails used to visit the Zuni Salt Lake are detailed in Ferguson et al. (2009), and several sources document Hopi travel to the Zuni Salt Lake (see Ferguson et al. 2009 and Hill 1940, and sources therein). Trips by Hopi were made for initiation rituals, as well as personal pilgrimages (e.g., Simmons 1942:252–255). Acoma and Laguna also regularly made trips to the Zuni Salt Lake (Duff et al. 2008), as did the Navajo (Hill 1940).

Several saline deposits are located in the Estancia Basin, east of the Manzano Mountains and Mountainair, New Mexico, associated with the villages of the Salinas district. Harrington (1916:535–537) describes these as the primary sources used by Rio Grande Pueblos. Kraemer (1976) discusses the history of exploitation of this source, noting its widespread distribution and industrial uses after Euroamerican contact.

Additional salt locations are mentioned by Hill (1940:5–7), and Harrington's (1916) documentation of Tewa ethnogeography includes reference to several locations where salt was gathered, including near the confluence of the Chama and Rio Grande rivers and from a spring north of San Idelfonso. Morris (1928) documented a salt mine near Camp Verde, associated with artifacts and evidence of extensive mining, but colonial or contemporary use of this location is not known. Roughly a century ago, Lumholtz (1912:261–273, Maps) documented two salt sources (Salina Grande and Salina del

Pinacate) adjacent to the Gulf of California to which gathering expeditions were made by Akimel and Tohono O'odham groups.

Hill (1940) suggested that a similar "salt gathering complex" characterized the acquisition of salt among many of the Southwest's native groups, noting the various preparatory rituals associated with an expedition to gather salt, its recovery, and the return home with salt. This is generally associated with the story of Salt Woman, Salt Mother, or Salt Old-Woman, occasionally accompanied by the War Twins or War Gods. In brief, Salt Mother used to live closer to various groups, but after being subjected to various transgressions and insults, she chose to relocate (Hill 1940:17). Thus, people must now make a pilgrimage to visit Salt Mother, though the precise location of her home differs by salt location (Harrington 1916; Hill 1940). Preparation for the sojourn to gather salt variously required ritual washing or prohibitions, with behavioral proscriptions associated with the act and timing of collection (Hill 1940:18–19; Stevenson 1904). There was a "state of truce" (Kraemer 1976:24; also Harrington 1916:536) for different groups that gathered salt from the Salinas sources. Similarly, a "zone of neutrality" surrounding the Zuni Salt Lake was also recognized (Duff et al. 2008; Hart and Othole 1993), with proscriptions defining what actions were appropriate when nearby. Thus, the collection of salt, though a necessary physiological resource, was enmeshed in ritual, pilgrimage, and oral tradition, making this a potent resource, especially when human energy was the sole source of transport to acquire salt from distant locations.

Turquoise

Among modern Pueblo groups, turquoise has important symbolic and cosmological significance and is commonly used as part of traditional dress, to decorate ritual paraphernalia and architectural spaces, and is deposited as offerings in shrines. Archaeologically, turquoise and similar looking blue-green minerals ("cultural turquoise") have been recovered from pre-Hispanic sites widely distributed across the Southwest and dating as early as 500 CE (Mathien 2001; Sigleo 1975), indicating that these cultural practices have deep historical roots.

In pre-Hispanic contexts, processed turquoise usually occurs either as ornaments or as powdered pigments. Ornaments include beads, pendants, and tessarae. Tessarae were often used to produce wood or shell-backed mosaic pieces in combination with other stones or shell. Blue-green pigments were used to paint a wide variety of sacred paraphernalia, most often of wood, but also of basket, bone, ceramic, and stone. Turquoise fragments or ornaments are often recovered from discrete deposits that indicate that they played a role in the ritual dedication, decoration, or decommissioning of both domestic and communal architecture (Hedquist and Thibodeau 2013). Turquoise ornaments also appear as grave goods or in contexts that suggest their use in mortuary events. Of particular note are the over 200,000 turquoise artifacts recovered from architectural and mortuary contexts in Chaco Canyon. Most spectacularly, several thousand turquoise pieces were recovered from a single mortuary context in the Chaco great house of Pueblo Bonito (Mathien 2001). This concentration of turquoise artifacts is unparalleled in the ancient Pueblo world, leading to much speculation regarding the economic role and social value of turquoise within the Chaco system.

Nevertheless, turquoise beads and pendants are found on sites throughout the Southwest from early agricultural times through the colonial period. The technology needed to produce these ornaments was relatively simple and widespread. Turquoise workshops and processing areas are identified archaeologically by the presence of stone drills and lapidary abraders in association with turquoise debris and ornament blanks. During the Pueblo II period (ca. A900–1150 CE), turquoise ornaments appear to have been diffusely produced at both small sites and great houses in a variety of contexts within Chaco Canyon and throughout the San Juan Basin. While the total amount of turquoise ornaments produced and consumed during the Chaco era increased significantly after 900 CE, there is no evidence to suggest that the intensity of production ever expanded beyond a fairly low-level household industry. Consumption, however, seems to have been concentrated within specific mortuary and dedicatory contexts (Mathien 2001).

Geologically, the distribution of high-quality turquoise in western North America is concentrated in a broad U-shaped arc running from northern Nevada south through southern California and northern Baja California, eastward across southern Arizona, Sonora, Chihuahua, and New Mexico, and then north again up to central Colorado. Evidence of pre-Hispanic mining activities and processing workshops has been identified at dozens of source areas throughout the region (Hull et al. 2008; Weigand 1994). Among the best studied of these source areas is the Cerrillos Hills in north-central New Mexico.

Archaeological surveys of the Cerrillos district (Warren and Mathien 1985; Mathien 2001) have identified at least ten locations with clear evidence of pre-Hispanic turquoise mining and processing, including the famous Mount Chalchihuitl mining area, which alone covers more than 8 hectares. Sites associated with Pueblo turquoise mining range from pits, quarries, and underground mines to workshop areas, hearths, campsites, and isolated sherd scatters. Artifacts recovered from these sites include stone mining and lapidary tools, as well as generalized chipped stone and pottery. Associated pottery suggests two major episodes of pre-Hispanic mining: the Pueblo II period and the Pueblo IV period from after 1350 CE to at least 1680. The pottery type that ties mining activities to the Chaco era, Red Mesa Black-on-white, was produced across large areas of the Southwest to the south and west of Cerrillos, and to date no studies have been undertaken to pinpoint the homeland of the Pueblo II miners with greater accuracy (Mathien 2001). Based on ceramic frequencies, the heaviest use of this source area seems to have occurred significantly after the demise of the Chaco system. Temper analysis of the later glaze-painted wares suggests that late pre-Hispanic to early colonial period mining activities were dominated by local residents from the San Marcos Pueblo, a large village 3 kilometers east of the Cerrillos mining district (Warren and Mathien 1985).

Another source area that has received some archaeological attention is the Canyon Creek mine, located below the Mogollon Rim on the Grasshopper Plateau in east-central Arizona (Welch and Triadan 1991). This ancient turquoise mine occurs as a series of discrete excavations into the cliff ledges above Canyon Creek in the rugged uplands north of the Salt River. Associated with these excavation pits were extensive tailings and waste piles, and the remains of heavy diorite mauls. Fragments of brown corrugated pottery and other artifacts indicate a predominately pre-Hispanic focus for mining activities. While it was not possible to more precisely date this associated cultural material, archaeological surveys indicate that occupation of the Grasshopper Plateau exploded around the turn of the fourteenth century, suggesting that the most intensive use of the Canyon Creek mine was probably by local inhabitants of the region during the Pueblo IV period (Welch and Triadan 1991). Recently, a new generation of characterization studies (see later discussion) have convincingly linked turquoise manufacturing debris from Room 113 in the nearby Pueblo IV town of Grasshopper Pueblo to the Canyon Creek mine, located 25 kilometers away (Hedquist and Thibodeau 2013; Welch and Triadan 1991).

Another strategy for examining changing regional and interregional patterns of turquoise acquisition and exchange is to determine compositional fingerprints for the various geological sources and to match these fingerprints to raw turquoise and finished artifacts recovered from various sites. Initial attempts during the 1960s through 1980s, most notably at Brookhaven National Laboratory using neutron activation analysis (but also see Sigleo 1975), focused on developing turquoise source fingerprints based on differences in trace and rare earth element concentrations. While several publications report that the Brookhaven Lab had some success in chemically distinguishing between turquoise sources in the Southwest and Mesoamerica and in linking artifacts from archaeological sites to specific source areas (Harbottle and Weigand 1992; Weigand et al. 1977), the data from these studies were never published, making it impossible to assess their claims or replicate their results.

There are a number of reasons that characterization studies of turquoise are particularly complex and problematic. First, researchers must be careful to distinguish actual "chemical turquoise" (copper-aluminum hydrous phosphate) from any number of other blue or blue-green minerals that look like turquoise and were used in similar cultural contexts, so-called "cultural turquoise" (Hull et al. 2008; Kim et al. 2003). In addition, attempts to chemically characterize turquoise have been hindered by the chemical variability of individual deposits, abundant impurities, and the susceptibility of turquoise to weathering and alteration (Hull et al. 2008; Thibodeau et al. 2007). Recently, preliminary but promising results have been reported by various labs using diverse techniques and instrumentation, including combined mineralogical and chemical techniques using X-ray diffraction and PIXE (Kim et al. 2003), high-precision lead and strontium stable isotope analyses using multicollector inductively coupled plasma mass spectrometry (MC-ICP-MS) and thermal ionization mass spectrometry (TIMS) (Hedquist and Thibodeau 2013; Thibodeau et al. 2007; Thibodeau et al. 2015), and combined hydrogen and copper stable isotope analyses using a secondary ion mass spectrometer (Hull et al. 2008). While these results are still somewhat limited, collectively they suggest that various communities in the Southwest maintained differential access to usually multiple sources of turquoise, some of which were hundreds of kilometers distant. These new approaches suggest that in the near future, turquoise sourcing may complement other material sourcing techniques, such as those used for characterizing obsidian, lead, and pottery, to help us better delineate the temporal and spatial dynamics of regional and interregional social networks in the Southwest, and potentially between the Southwest and Mesoamerica. However, the current state of these studies is insufficient to support or contest any specific economic models or sociopolitical interpretations.

Conclusions

Scholars have made tremendous strides in identifying the minerals used by the peoples of the Southwest. This information has been used to reconstruct networks of interaction, the development and transmission of technical knowledge, and the production and circulation of resources, artifacts, and people throughout the Southwest. When combined with its rich ethnographic record and the enduring traditions of the Southwest's Native Peoples, archaeological analyses of minerals will remain a fruitful source of new insights.

References Cited

Abbott, David R.
2000 *Ceramics and Community Organization among the Hohokam*. University of Arizona Press, Tucson.

Abbott, David R., Alexa M. Smith, and Emiliano Gallaga
2007 Ballcourts and Ceramics: The Case for Hohokam Marketplaces in the Arizona Desert. *American Antiquity* 72(3):461–484.

Aggarwal, Jugdeep, Judith Habicht-Mauche, and Chelsey Juarez
2008 Application of Heavy Staple Isotopes in Forensic Geochemistry: A Review. *Applied Geochemistry* 23:2658–2666.

Arakawa, Fumiyasu
2006 Lithic Raw Material Procurement and the Social Landscape in the Central Mesa Verde Region. Unpublished Ph.D. dissertation, Department of Anthropology, Washington State University, Pullman.

Arakawa, Fumiyasu, Scott G. Ortman, M. Steven Shackley, and Andrew I. Duff
2011 Obsidian Evidence of Interaction and Migration from the Mesa Verde region, Southwest Colorado. *American Antiquity* 76:773–795.

Arnold, Dean E.
1985 *Ceramic Theory and Cultural Process.* Cambridge University Press, Cambridge.

Bice, Richard A., Phyllis S. Davis, and William M. Sundt
2003 *Indian Mining of Lead for Use in Rio Grande Glaze Paint*. The Albuquerque Archaeological Society, Albuquerque, New Mexico.

Blinman, Eric, Kari L. Schleher, Tom Dickerson, Cynthia L. Herhahn, and Ibrahim Gundiler
2012 Making a Glaze: Multiple Approaches to Understanding Rio Grande Glaze Paint Technology. In *Potters and Communities of Practice*, edited by Linda S. Cordell and Judith A. Habicht-Mauche, pp. 107–116. Anthropological Papers of the University of Arizona No. 75. University of Arizona Press, Tucson.
Bostwick, Todd W., and James H. Burton
1993 A Study in Sourcing Hohokam Basalt Ground Stone Implements. *Kiva* 58(3):357–372.
Cameron, Catherine M.
2001 Pink Chert, Projectile Points, and the Chacoan Regional System. *American Antiquity* 66(1):79–102.
Church, Tim
2000 Distribution and Sources of Obsidian in the Rio Grande Gravels of New Mexico. *Geoarchaeology* 15:649–678.
Duff, Andrew I., T. J. Ferguson, Susan Bruning, and Peter Whiteley
2008 Collaborative Research in a Living Landscape: Pueblo Land, Culture, and History in West-Central New Mexico. *Archaeology Southwest* 22(1):1–24
Duff, Andrew I., Jeremy M. Moss, Thomas C. Windes, John Kantner, and M. Steven Shackley
2012 Patterning in Procurement of Obsidian in Chaco Canyon and in Chaco-era Communities in New Mexico as Revealed by X-Ray Fluorescence. *Journal of Archaeological Science* 39:2995–3007.
Duwe, Samuel, and Hector Neff
2007 Glaze and Slip Pigment Analyses of Pueblo IV Period Ceramics from East-Central Arizona using Time of Flight-Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (TOF-LA-ICP-MS). *Journal of Archaeological Science* 34:403–414.
Doyel, David E.
1991 Hohokam Exchange and Interaction. In *Chaco and Hohokam: Prehistoric Regional Systems in the Southwest*, edited by Patricia L. Crown and W. James Judge, pp. 225–252. School of American Research Press, Santa Fe, New Mexico.
Eiselt, B. Sunday, and Richard I. Ford
2007 Sangre de Cristo Micaceous Clays: Geochemical Indices for Source and Raw Material Distribution, Past and Present. *Kiva* 73(2): 219–238.
Fenn, Thomas R., Barbara J. Mills, and Maren Hopkins
2006 The Social Contexts of Glaze Paint Production and Consumption in the Silver Creek Area. In *The Social Life of Pots*, edited by Judith A. Habicht-Mauche, Suzanne L. Eckert, and Deborah L. Huntley, pp. 60–85. University of Arizona Press, Tucson.
Ferguson, T. J., G. Lennis Berlin, and Leigh J. Kuwanwisiwma
2009 Kukhepya: Searching for Hopi Trails. In *Landscapes of Movement: The Anthropology of Paths, Trails, and Roads*, edited by James E. Snead, Clark L. Erickson, and J. Andrew Darling, pp. 20–41. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia.
Fertelmes, Craig M., David R. Abbott, and M. Steven Shackley
2012 Obsidian Source Characterization at Las Colinas: Shifting Exchange Patterns during the Hohokam Sedentary-Classic Transition. *Kiva* 77:281–311.
Fowles, Severin M., Leah Minc, Samuel Duwe, and David V. Hill
2007 Clay, Conflict, and Village Aggregation: Compositional Analyses of Pre-Classic Pottery from the Taos District, New Mexico. *American Antiquity* 72(1):125–152.

Fratt, Lee, and Maggie Biancaniells
1993 Homol'ovi III Ground Stone in the Raw: A Study of the Local Sandstone Used to Make Ground Stone Artifacts. *Kiva* 58(3):373–391.
Glowacki, Donna M., and Hector Neff (editors)
2002 *Ceramic Production and Circulation in the Greater Southwest: Source Determination by INAA and Complementary Mineralogical Investigations*. The Cotsen Institute of Archaeology, University of California, Los Angeles.
Gosser, Dennis C., Michael A. Ohnersorgen, Arleyn W. Simon, and James W. Mayer
1998 PIXE Analysis of Salado Polychrome Ceramics of the American Southwest. *Nuclear Instruments and Methods in Physics Research B* 136–138:880–887.
Green, Margerie
1985 *Chipped Stone Raw Materials and the Study of Interaction on Black Mesa, Arizona*. Center for Archaeolocial Investigations, Occasional Paper No. 11. Carbondale, Illinois.
Habicht-Mauche, Judith A.
1993 *The Pottery from Arroyo Hondo Pueblo: Tribalization and Trade in the Northern Rio Grande*. Arroyo Hondo Archaeological Series, vol. 8. School of American Research, Santa Fe.
2002 Torturing Sherds: Ceramic Petrography and the Development of Rio Grande Archaeology. In *Traditions, Transitions, and Technologies: Themes in Southwestern Archaeology*, edited by S. Schlanger, pp. 49–58. University of Colorado Press, Boulder.
Habicht-Mauche, Judith A., Stephen T. Glenn, Homer Milford, and A. Russell Flegal
2000 Isotopic Tracing of Prehistoric Rio Grande Glaze-Paint Production and Trade. *Journal of Archaeological Science* 27:709–713.
Hamilton, Marcus J., Briggs Buchanan, Bruce B. Huckell, Vance T. Holliday, M. Steven Shackley, and Matthew E. Hill
2013 Clovis Paleoecology and Lithic Technology in the Central Rio Grande Rift Region, New Mexico. *American Antiquity* 78(2):248–265.
Harbottle, Garman, and Phil C. Weigand
1992 Turquoise in Pre-Columbian America. *Scientific American* 266(2): 78–85.
Harrington, John Peabody
1916 *The Ethnogeography of the Tewa Indians*. Twenty-ninth Annual Report of the Bureau of American Ethnology, 1907–08, pp. 29–636. Government Printing Office, Washington, D.C.
Hart, E. Richard, and Andrew Othole
1993 The Zuni Salt Lake Area: Potential Impacts to Zuni Traditional Cultural Properties by the Proposed Fence Lake Mine. In *Traditional Cultural Properties of Four Tribes: The Fence Lake Mine Project*, edited by E. Richard Hart and T. J. Ferguson, Vol. 1, Section 2. Institute for the North American West, Seattle, Washington.
Hedquist, Saul L., and Alyson M. Thibodeau
2013 Sacred Turquoise: Blue-Green Stone in the Late Prehispanic Pueblo World. Paper presented at the 78th Meeting of the Society for American Archaeology, Honolulu, Hawaii.
Heidke, James M., and Judith A. Habicht-Mauche
1998 The First Occurrence and Early Distribution of Pottery in the North American Southwest. *Revista de Arqueología Americana* 14:65–99.
Heidke, James M., Elizabeth J. Miksa, and Henry D. Wallace
2002 A Petrographic Approach to Sand Tempered Pottery Provenance Studies: Examples from Two Hohokam Local Systems. In *Ceramic Production and Circulation in the Greater Southwest: Source Determination by INAA and Complementary Mineralogical*

Investigations, edited by Donna M. Glowacki and Hector Neff, pp.152–178. The Cotsen Institute of Archaeology, University of California, Los Angeles.

Hill, W. W.

1940 Navajo Salt Gathering. *The University of New Mexico Bulletin* 3(4):3–25.

Hull, Sharon, Fayek Mostafa, Frances Joan Mathien, Phillip Shelley, and Kathy Roler Durand

2008 A New Approach to Determining the Geological Provenance of Turquoise Artifacts Using Hydrogen and Copper Stable Isotopes. *Journal of Archaeological Science* 35:1355–1369.

Huntley, Deborah L.

2008 *Ancestral Zuni Glaze-Decorated Pottery: Viewing Pueblo IV Regional Organization through Ceramic Production and Exchange*. Anthropological Papers of the University of Arizona No. 72. University of Arizona Press, Tucson.

Huntley, Deborah L., Thomas Fenn, Judith A. Habicht-Mauche, and Barbara J. Mills

2012 Embedded Networks? Pigments and Long-Distance Procurement Strategies in the Late Prehispanic Southwest. In *Potters and Communities of Practice*, edited by Linda S. Cordell and Judith A. Habicht-Mauche, pp. 8–18. Anthropological Papers of the University of Arizona No. 75. University of Arizona Press, Tucson.

Huntley, Deborah L., Katherine A. Spielmann, Judith A. Habicht-Mauche, Cynthia L. Herhahn, and A. Russell Flegal

2007 Local Recipes or Distant Commodities? Lead and Chemical Compositional Analysis of Glaze Paints from the Salinas, New Mexico. *Journal of Archaeological Science* 34:1135–1147.

Kidder, Alfred V., and Anna O. Shepard

1936 *The Pottery of Pecos*, Vol. 2. Phillips Academy Papers of the Southwest Expedition No. 7. Yale University Press, New Haven, Connecticut.

Kim, Jangsuk, Arleyn W. Simon, Vincent Ripoche, James W. Mayer, and Barry Wilkens

2003 Proton-Induced X-Ray Emission Analysis of Turquoise Artifects from Salado Platform Mound Sites in the Tonto Basin of Central Arizona. *Measurement Science and Technology* 14: 1579–1589.

Kraemer, Paul M.

1976 New Mexico's Ancient Salt Trade. *El Palacio* 82(1):22–30.

Lumholtz, Carl

1912 *New Trails in Mexico*. Charles Scribner's Sons, New York.

Marshall, Michael P.

1997 The Chacoan Roads: A Cosmological Interpretation. In *Anasazi Architecture and American Design*, edited by B. Morrow and V. B. Price, pp. 62–74. University of New Mexico Press, Albuquerque.

Mathien, Frances Joan

2001 The Organization of Turquoise Production and Consumption by Prehistoric Chacoans. *American Antiquity* 66(1): 103–118.

Mills, Barbara J.

1987 Ceramic Analysis. In *Archaeological Investigation at Eight Small Sites in West-Central New Mexico*, by Patrick Hogan with contributions by Glenna Dean, Janette M. Elyea, Elizabeth M. Garrett, Linda Mick-O'Hara, and Barbara J. Mills, pp. 83–130. Office of Contract Archaeology, University of New Mexico, Albuquerque.

Mills, Barbara J., Jeffery J. Clark, Matthew A. Peeples, W. R. Haas, Jr., John M. Roberts, Jr., J. Brett Hill, Deborah L. Huntley, Lewis Borck, Ronald L. Breiger, Aaron Clauset, and M. Steven Shackley

2013 Transformation of Social Networks in the Late Pre-Hispanic US Southwest. *PNAS* 110:5785–5790.

Morris, Earl H.

1928 An Aboriginal Salt Mine at Camp Verde, Arizona. *Anthropological Papers of the American Museum of Natural History* 30(3):75–97.

Rauzi, Steven L.

2002 *Arizona Has Salt!* Circular 30. Arizona Geological Survey, Tucson.

Shackley, M. Steven

2005 *Obsidian: Geology and Archaeology in the North American Southwest*. University of Arizona Press, Tucson.

2009 The Topaz Basin Archaeological Obsidian Source in the Transition Zone of Central Arizona. *Geoarchaeology* 24(3):336–347.

2011b Sources of Archaeological Dacite in Northern New Mexico. *Journal of Archaeological Science* 38:1001–1007.

Shackley, M. Steven (editor)

2011a *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*. Springer, New York.

Shepard, Anna O.

1942 Rio Grande Glaze Paint Ware: A Study Illustrating the Place of Ceramic Technological Analysis in Archaeological Research. *Contributions to American Anthropology and History*, 7(39): 129–262. Carnegie Institution of Washington, Washington, D.C.

1980 [1956] *Ceramics for the Archaeologist*. Publication 609. Carnegie Institution of Washington, Washington, D.C.

Sigleo, Anne Colberg

1975 Turquoise Mine and Artifact Correlation for Snaketown Site, Arizona. *Science* 189(4201):459–460.

Simmons, Leo W.

1942 *Sun Chief: The Autobiography of a Hopi Indian*. Yale University Press, New Haven, Connecticut.

Speakman, Robert J., and Hector Neff

2002 Evaluation of Painted Pottery from the Mesa Verde Region Using Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS). *American Antiquity* 67(1):137–144.

Stevenson, Matilda Coxe

1904 *The Zuni Indians: Their Mythology, Esoteric Fraternities, and Ceremonies*. Twenty-third Annual Report of the Bureau of American Ethnology, 1901–02, pp. 1–608. Government Printing Office, Washington, D.C.

Taliaferro, Matthew S., Bernard A. Schriever, and M. Steven Shackley

2010 Obsidian Procurement, Least Cost Path Analysis, and Social Interaction in the Mimbres Area of Southwestern New Mexico. *Journal of Archaeological Science* 37:536–548.

Thibodeau, Alyson M., Judith A. Habicht-Mauche, Deborah L. Huntley, John T. Chesley and Joaquin Ruiz

2013 High Precision Isotopic Analyses of Lead Ores from New Mexico by MC-ICP-MS: Implications for Tracing the Production and Exchange of Pueblo IV Glaze-Decorated Pottery. *Journal of Archaeological Science* 40:3067–3075.

Thibodeau, Alyson M., Joaquin Ruiz, and John T. Chesley

2007 Lead and Strontium Isotopes as Geochemical Tracers of Turquoise. *Society of Archaeological Sciences Bulletin* 30:10–14.

Thibodeau, Alyson M., David J. Killick, Saul L Hedquist, John T. Chesley, and Joaquin Ruiz
2015 Isotopic Evidence for the Provenance of Turquoise Artifacts in the Southwestern United States. *Geological Society for America Bulletin* 27(11–12): 1617–1631.
Titiev, Mischa
1937 A Hopi Salt Expedition. *American Anthropologist* 39:244–258.
Vierra, Bradley J., Margaret A. Jodry, M. Steven Shackley, and Michael J. Dilley
2012 Late Paleoindian and Early Archaic Foragers in the Northern Southwest. In *From the Pleistocene to the Holocene: Human Organization and Cultural Transformations in Prehistoric North America*, edited by C. Britt Bousman and Bradley J. Vierra, pp. 171–196. Texas A&M University Press, College Station.
Warren, A. Helene, and Frances Joan Mathien
1985 Prehistoric and Historic Turquoise Mining in the Cerrillos District: Time and Place. In *Southwestern Culture History: Collected Papers in Honor of Albert H. Schroeder*, edited by Charles H. Lange, pp. 93–127. Papers of the Archaeological Society of New Mexico No. 10. Ancient City Press, Santa Fe.
Weigand, Phil C.
1994 Observations on Ancient Mining within the Northwestern Regions of the Mesoamerican Civilization, with Emphasis on Turquoise. In *In Quest of Mineral Wealth: Aboriginal and Colonial Mining and Metallurgy in Spanish America*, edited by Alan K. Craig and Robert C. West. *Geoscience and Man* 33:21–35.
Weigand, Phil C., Garman Harbottle, and E. V. Sayre
1977 Turquoise Sources and Source Analysis: Mesoamerica and the Southwestern U.S.A. In *Exchange Systems in Prehistory*, edited by Timothy K. Earle and Jonathan E. Ericson, pp. 15–34. Academic Press, New York.
Welch, John R., and Daniela Triadan
1991 The Canyon Creek Turquoise Mine, Arizona. *Kiva* 56(2):145–164.
Windes, Thomas C.
1977 Typology and Technology of Anasazi Ceramics. In *Settlement and Subsistence along the Lower Chaco River: The CGP Survey*, edited by Charles A. Reher, pp. 279–370. University of New Mexico Press, Albuquerque.