PETROGRAPHY AND NAA: CASE STUDIES FROM THE AMERICAN SOUTHWEST

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Within ceramic studies, two techniques have been employed to look at production and exchange in many ancient societies. Initially petrography was the method of choice thanks to the pioneering work of Anna O. Shepard in America and Henry W.M. Hodges in Britain who showed how this technique was ideal for understanding patterns of production and distribution (Shepard 1942; Hodges 1962). With the development of bulk chemical compositional techniques such as neutron activation analysis (NAA) and X-ray fluorescence (XRF), these methods came to be used increasingly to examine provenance and exchange instead of petrography (Peacock 1977: 25; Wilson 1978: 227, 231). However, several researchers recognized that the chemical data alone were often not successful in identifying the provenance of the ceramics analyzed (Bishop *et al.* 1982; Stoltman 2001). This lead to a number of studies that combined the two methods with great success (Badre *et al.* 2005; Ben-Shlomo *et al.* 2008; Day *et al.* 1999; Goldberg *et al.* 1986; Tsolakidou and Kilikoglou 2002).

Although Anna O. Shepard's work highlighted the utility of petrography in the American Southwest, its use waned in this region. Chemical data became the chosen method for examining ceramic production and exchange. This was probably due in part to the ease of acquiring such data and the belief that specialized knowledge was not needed for its interpretation. Samples could be sent to the laboratory and results returned. The archaeologist could then either use the statistical work carried out by the laboratory or explore the data with their own statistical tests. This increased the popularity of chemical methods, as petrography required someone with advanced knowledge of geology and there was a lack of such individuals. Notable exceptions to this trend were projects in northwestern New Mexico where petrography continued to be the preferred method and work carried out by Elizabeth Miksa in southern Arizona that utilized statistical models of sand composition (Eckert 2008; Miksa and Heidke 2001; Schleher 2010). More recently, American petrographers are combining NAA and petrographic

Figure 1. Location of sites in southeastern Arizona and southwestern New Mexico.

data with great success (Habicht-Mauche 1993 and Stoner *et al.* 2008 are a few). In the American Southwest, the use of both types of data has not been common but two recent studies have shown the utility of this approach. In this geological diverse area, petrography can be used to assign a provenance to the chemical groups identified statistically in the NAA data.

The first study examined decorated ceramics produced in southern Arizona and New Mexico during the 13th-15th centuries, a time when migrant groups were moving south into areas already (but sparsely) inhabited and introducing new styles of decorated ceramics. In order to determine those sites that were producing the decorated ceramics, called Maverick Mountain Series and Salado polychrome wares, and the extent of exchange, NAA data were acquired on 462 samples from 15 sites (Figure 1). Ten of the sites were located in southwestern New Mexico along the Upper Gila and Mimbres rivers. Five sites were in southeastern Arizona, one located in the Globe Highlands area, one in Sulphur Springs Valley, and three in the Safford Basin. Statistical analysis of the NAA data included repeat runs of four tests, principal components analysis, hierarchical cluster analysis, K-means cluster analysis, and discriminant analysis. This revealed that the samples could be placed into 18 chemical groups.

Through the analysis of 32 thin sections of brown, red, and decorated wares, information was provided on the likely origin of the chemical groups and the connection between some of them (Table 1, omits unassigned samples and outliers). Further, the results showed the importance of petrography, especially for groups comprised entirely of decorated samples from many sites in the various areas. It became clear that a number of sites along the Upper Gila River and its tributaries, mostly likely 3-Up, Dinwiddie, and Ormand Village, were producing the decorated ceramics (see Figure 1). They featured sand temper dominated by a variety of volcanic rock fragments including rhyolitic tuff and some basalt and andesite. Several chemical groups appeared to represent this production and indicate additional sites not sampled were also likely producing decorated wares. Surprisingly, some sites in this area were shown not to be making decorated wares, at least with the samples analyzed. The red and brown wares from these sites featured sand temper characteristic of the local geology. For example, sherds from TJ Ruin

NAA Group	# of Samples	Petrography Sample	Petrography Results	Interpretion
1	47	1 brown ware	Volcanic sand (basaltic andesite rich)	Local production of brown, red, and decorated wares at 3-Up (Upper Gila)
2	7	1 brown ware	Volcanic sand (rhyolite rich)	Local production of brown ware at TJ Ruin (Upper Gila)
3	67	1 brown ware, 4 decorated wares	Volcanic sand (basaltic andesite rich)	Production of brown, red, and decorated wares in the Upper Gila (possibly at Ormand Village)
4	12	1 red ware	Granitic sand	Local production of brown and red wares at Dutch Ruin (Upper Gila)
5	3	1 brown ware	Granitic sand	Local prodcution of brown ware at LA39035 (Upper Gila)
6	13	1 brown ware, 1 decorated ware	Volcanic sand with minor granite	Probable local production of brown, red, and decorated wares at Dinwiddie (Upper Gila)
10	24	1 decorated ware	Volcanic sand (basaltic andesite rich)	Production of decorated wares in the Upper Gila (possibly at Buena Vista)
11	59	2 brown wares, 1 decorated ware	Granitic sand, minor metamorphic	Local production of brown, red, and decorated wares at Kriver Kiva/Spear Ranch (Safford Basin)
13	17	3 brown wares	Volcanic sand (rhyolite and andesite rich)	Local production of brown and red wares in the Mimbres (Janss and Stailey sites)
15	11	1 brown ware	Volcanic sand (rhyolite and andesite rich)	Local production of brown and red wares in the Mimbres (Disert site)
19	22	1 decorated ware	Volcanic sand (basaltic andesite rich)	Production of decorated wares in the Upper Gila (possibly at Ormand Village)
20	6	1 brown ware	Granitic and volcanic sand	Local prodcution of red ware at Kuykendall (Sulfur Springs Valley)
21	73	3 decorated wares	Volcanic sand (basaltic andesite rich)	Production of decorated wares in the Upper Gila
22	53	1 brown ware, 4 decorated wares	Volcanic sand (basaltic andesite rich)	Probable production of decorated wares in the Upper Gila
23	17	1 decorated ware	Volcanic sand (basaltic andesite rich)	Probable production of decorated wares in the Upper Gila
25	6	not sampled	none	Likely production of decorated wares in the Globe Highlands as all samples from this area
26	20	1 decorated ware	Granitic, volcanic, and metamorphic sand	Production of decorated wares in the Globe Highlands
27	5	not sampled	none	Likely production of decorated wares in the Globe Highlands as all samples from this area
Total	462	32		

Table 1. Chemical groups identified in the statistical analysis of the NAA data, number of samples in each chemical group, samples selected for petrography, petrographic results and interpretation.

contained dominantly rhyolitic tuff rock fragments, while samples from Dutch Ruin and LA39035 contained inclusions indicative of a sand derived from granite. These sites did receive decorated wares from other producers, most probably those along the Upper Gila River.

Exchange of the decorated wares made in the Upper Gila River to the Mimbres Valley seems likely along with a lack of evidence for production of these wares in this area. The examined decorated wares contained a sand temper similar to those from the Upper Gila samples. The local brown and red wares also had a dominantly volcanic-derived sand temper, but for these samples the basalt and andesite were more common than the rhyolitic tuff. This is what would be expected of sand produced by the mountains in the Mimbres Valley that are mainly composed of mafic rock outcrops. This appears to confirm that during the period under study, the Mimbres Valley appeared to be acquiring decorated ceramics from several regions but not making any locally (Hegmon *et al.* 1998: 151-153).

Finally, production of decorated wares was attested in the Safford Basin and Globe Highlands, but not at the single site in Sulphur Springs Valley. The decorated sample from Spear Ranch in the Safford Basin featured a sand temper with granite, gneiss, and schist similar to the temper in the brown ware from the site. The nearest mountain is characterized by granite and various metamorphic rocks indicating production probably occurred at Krider Kiva and/or Spear Ranch. Analysis of a sample of decorated pottery from Gila Pueblo revealed that although the sample was not likely produced at this site due to the presence of various volcanic rock fragments and schist, it was probably derived from a nearby area, possibly to the north. The site of Kuykendall in Sulphur Springs Valley appears to have received vessels from producers in the Upper Gila River. The polychrome sherd analyzed contained a variety of volcanic rock fragments similar to those from that area. On the other hand, the red vessel analyzed contained a sand temper with granite and rhyolite inclusions that could be found locally based on the geology of the nearby outcrops.

The overall picture is one of multiple producers and exchange of vessels throughout the region with a major late 13th century population increase. Sites producing the decorated ceramics could also acquire them from other producers, indicating a need to stay in contact with the other diasporic groups

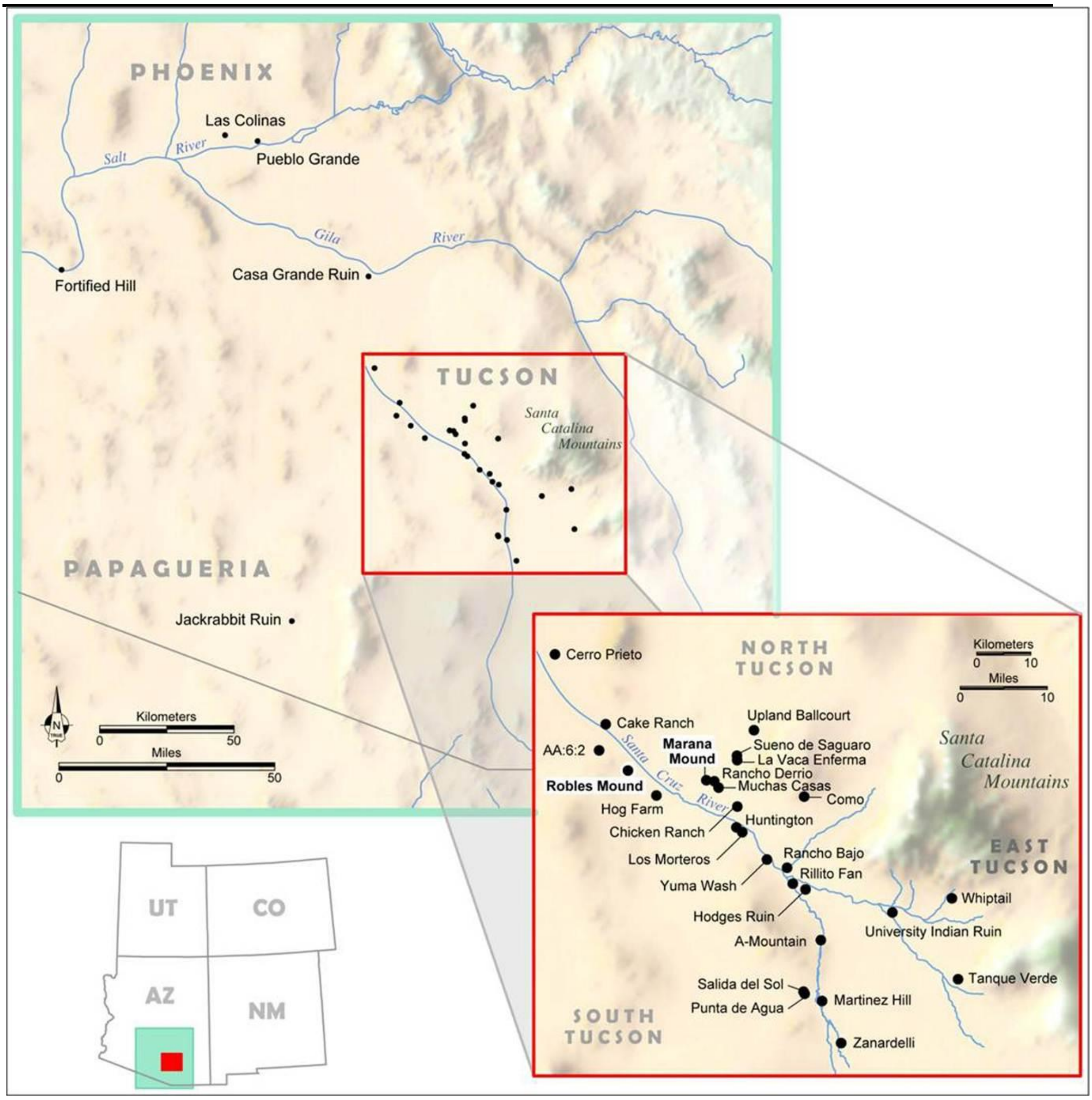

Figure 2. Location of sites in southern Arizona.

(communities united by common ancestry but separated by space) through pottery exchange. Clearly the decorated wares were integral to the social and economic system of this newly established network. The petrographic analysis provided important meaning to the chemical groups and was able to confirm those areas consuming and producing decorated wares.

A second study was conducted on Tanque Verde Red-on-brown pottery found at sites in southern Arizona from 1150-1300 AD. This period saw a change in settlement patterns and architecture, with sites no longer having ball courts for social interaction and now featuring mounds that may have served a similar function. Undoubtedly these changes were also reflected in the economic and social sphere, and the movement of Tanque Verde Red-on-brown was one way to assess this. A NAA database of over 600 samples was compiled by Dr. Suzanne Fish, Dr. Paul Fish, and Dr. Karen Harry, mostly from samples excavated at sites in the northern Tucson Basin (Figure 2; Harry 2003). The statistical analysis suggested production and movement of this ware

NAA Group	# of Samples	Petrography Sample	Petrography Reults	Interpretion
A	164	7	Mixed volcanic sand with some granite and granodiorite	Production at the northern end of the Tucson Mountains (possibly the Huntington and/or Los Morteros site)
BC	223	20	Mixed volcanic sand with some granite	Production along the northeastern side of the Tucson Mountains (Yuma Wash and possibly a nearby site)
E	31	0	-	Production possibly at Hog Farm and Cake Ranch (northeastern Tucson Basin)
F	21	0	-	Production possibly at Muchas Casas (northeastern Tucson Basin)
G	28	0	-	Production possibly at La Vaca Enferma and Sueno de Saguaro (northeastern Tucson Basin)
J	61	9	Mixed volcanic sand	Production along the southeastern side of the Tucson Mountains (possibly at the Cleawater site or nearby sites
S. Tucson	29	0	-	Production at sites probably in the southern Tucson Basin)
Phoenix 1	11	0	-	Production at site(s) in the Phoenix Basin
Phoenix 2	4	0	-	Production at site(s) in the Phoenix Basin
Papagueria	30	0	-	Production at site(s) in the Papagueria
Total	602	36		

Table 2. Chemical groups identified in the statistical analysis of the NAA data, number of samples in each chemical group, samples selected for petrography, petrographic results and interpretation.

throughout the area and beyond, but little information was acquired on specific production sites.

A recently completed petrographic analysis of Tanque Verde Red-on-brown sherds from two sites in the Tucson Basin, Yuma Wash and Clearwater, had indicated several locations of production along the Tucson Mountains (Ownby *et al.* 2011). Research in this area has utilized a comprehensive collection of sands that captures the high geological variability in this area. In fact, point counting these sands and the sand temper in the sherds has meant assignments to sand composition areas (called petrofacies) can be made through a discriminant model (Heidke and Miksa 2000). This allows fairly precise identification of provenance, based on the well-tested assumption that sand source identifies where pottery was made (Heidke 2011: Table 4.10). In the case of Yuma Wash, the sand had a unique composition that is likely local to the site. The sand contained common rhyolite with a few more mafic rock fragments and inclusion derived from granite. The presence of the granite and its constituent minerals indicated flood deposits that would have been readily available at Yuma Wash. In order to shed light on the distribution of Tanque Verde Red-on-brown, NAA data were acquired for these petrographically analyzed samples and added to the existing database. Multiple statistical analyses using the same four tests mentioned previously resulted in the reduction of unassigned samples in the original NAA database and a connection between the chemical groups and the petrographic samples.

The results revealed that while the original chemical groups were retained, a new group was identified, Group J, and a division of the Phoenix group into two was possible (Table 2, omits unassigned and outliers). Group A now contained samples that had been assigned petrographically to a region in the northern Tucson Mountains. The sand temper contained a variety of volcanic rocks and inclusions of granodiorite. Two large sites in this area, Los Morteros and Huntington, are likely production locations, although the latter site is more probable for geological reasons.

Petrographic samples assigned a provenance along the northeastern side of the Tucson Mountains, including the Yuma Wash site, were consistently placed into Group BC, providing a likely provenance for this group. Similarly, samples with sand from an area in the southeastern section of the Tucson Mountains were placed in Group J, suggesting another Tanque Verde Red-on-brown production location. The potters in this area utilized volcanic sand with common rhyolite fragments, some of which had been altered into hypabyssal rock fragments.

The remaining groups, however, did not contain any of the samples analyzed petrographically and could only be given a possible provenance based on where the pottery was most prevalent. There is some support for this assertion in the Yuma Wash data, where more of the Tanque Verde Red-on-brown was locally produced than imported. Therefore, Group E sherds may have been produced at two sites in the northern Tucson Basin, Hog Farm and Cake Ranch. Group F sherds were mostly found at the site of Muchas Casas, suggesting a possible location for their manufacture. The sites of La Vaca Enferma and Sueno de Saquaro contained most of the Group G samples and these sites may be their production location. Finally, several samples came from areas outside the Tucson Basin, but the small numbers of sherds and lack of petrographic analysis make it difficult to assign a provenance to these chemical groups.

These results indicate that in the Tucson Basin, Tanque Verde Red-on-brown was produced at a number of sites and distributed predominantly to sites within a 20 km radius. Producers of this ware also acquired pottery from other producers, indicating a need for social and economic interaction between groups. In comparison with the earlier decorated ceramic traditions in the Tucson Basin, this period shows an increase in the number of producers, possibly reflecting a changing need for more contact and/or the importance of mound sites for bringing people together to exchange vessels (Heidke *et al.* 2002; Heidke 2009). This study, like the previous one, illustrates the importance of even a small amount of petrography for identifying where the samples in a chemical group are likely to have been made. More petrography for both projects would provide further illumination on the production and distribution of these important decorated wares.

The approaches taken in these studies have both utilized an existing set of NAA data, but added petrography to illuminate the meaning and origin of the chemical groups. Without the petrographic data, it would have been clear that pottery was being exchanged but the location of the producers, and thus the distance exchange took place, would not have been known. The complicated interaction between producers and consumers was more fully realized once provenance assignments were made. For ceramic studies in the American Southwest, it is hoped this approach will continue to be applied. However, for this region and more broadly, it may continue to be the petrographers that make a loud and convincing call for petrography to be used in conjunction with NAA. This starts with the publication of studies showing that petrography provides the necessary data for understanding chemical groups and interpreting them in way that answers archaeological questions. Second, I believe it will be important for petrographers to continue to attend meetings, put edited volumes together, and generally let the archaeologists know we are here and ready to collaborate. For my part, I sense we are heading in that direction already, thanks to the Ceramic Petrology Group, and more archaeologists will see the necessity of having petrographic data in combination with the chemical data on their pottery.

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References

Badre, L., Boileau, M.C., Jung, R., and Mommsen, H. 2005. The Provenance of Aegean- and Syrian-Type Pottery Found at Tell Kazel (Syria). *Ägypten und Levante* XV, 15-47.

Ben-Shlomo, D., Maeir, A.M. and Mommsen, H. 2008. Neutron activation and petrographic analysis of selected Late Bronze and Iron Age pottery from Tell es-Safi/Gath, Israel. *Journal of Archaeological Science* 35, 956-964.

Bishop, R.L., Rands, R.L., and Holley, G.R. 1982. Ceramic compositional analysis in archaeological perspective. In Schiffer, M.B. (ed.), *Advances in Archaeological Method and Theory 5*. New York, Academic Press, 275-330.

Day, P.M., Kiriatzi, E., Tsolakidou, A., and Kilikoglou, V. 1999. Group Therapy in Crete: A Comparison Between Analyses by NAA and Thin Section Petrography of Early Minoan Pottery. *Journal of Archaeological Science* 26, 1025-1036.

Eckert, S.L. 2008. *Pottery and Practice: The Expression of Identity at Pottery Mound and Hummingbird Pueblo*. University of New Mexico Press, Albuquerque.

Goldberg, P., Gould, B., Killebrew, A. and Yellin, J. 1986. Comparison of neutron activation and thin-section analyses on Late Bronze Age ceramics from Deir el-Balah. In Olin, J.S. and Blackman, M.J. (eds.) *Proceedings of the 24th International Archaeometry Symposium*. Washington, D.C., Smithsonian Institution Press, 341-351.

Habicht-Mauche, J.A. 1993. *The Pottery from Arroyo Hondo Pueblo, New Mexico Tribalization and Trade in the Northern Rio Grande*. Arroyo Hondo Archaeological Series, vol. 8. School of American Research, Santa Fe.

Harry, K. 2003. *Economic Organization and Settlement Hierarchies. Ceramic Production and Exchange Among the Hohokam*. Praeger Publishers, Westport.

Hegmon, M., Nelson, M., and Ruth, S. 1998. Abandonment and Reorganization in the Mimbres Region of the American Southwest. *American Anthropologist* 100, 148-162.

Heidke, J.M. 2009. Multi-village Specialized Craft Production & the Distribution of Hohokam Sedentary Period Pottery, Tuscon, Arizona. In Quinn, P.S. (ed.), *Interpreting Silent Artefacts: Petrographic Approaches to Archaeological Ceramics*. Archaeopress, Oxford, 227-244.

Heidke, J.M. 2011. Prehistoric Pottery Containers from the Julian Wash Site, AZ BB:13:17 (ASM). In Wallace, H. D. (ed.), *Craft Specialization in the Southern Tucson Basin: Archaeological Excavations at the Julian Wash Site, AZ BB:13:17 (ASM): Part 1. Introduction, Excavation Results, and Artifact Investigations*. Anthropological Papers No. 40. Center for Desert Archaeology, Tucson, 263-294.

Heidke, J. M. and Miksa, E.J. 2000. Correspondence and Discriminant Analyses of Sand and Sand Temper Compositions, Tonto Basin, Arizona. *Archaeometry* 42, 273-299.

Heidke, J. M., Miksa, E.J. and Wallace, H.D. 2002. A Petrographic Approach to Sand-Tempered Pottery Provenance Studies: Examples from Two Hohokam Local Systems. In Glowacki, D. M. and Neff, H. (eds), *Ceramic Production and Circulation in the Greater Southwest: Source Determination by INAA and Complementary Mineralogical Investigations*. Monograph No. 44. Cotsen Institute of Archaeology, University of California, Los Angeles, 152-178.

Hodges, H.W.M. 1962. Thin sections of prehistoric pottery: an empirical study. *Bulletin of the Institute of Archaeology* 3, 58-68.

Miksa, E.J., and Heidke, J.M. 2001. It All Comes Out in the Wash: Actualistic Petrofacies Modeling of Temper Provenance, Tonto Basin, Arizona, USA. *Geoarchaeology* 16, 177-222.

Ownby, M. F., Lavayen, C.P., and Miksa, E.J. 2011. Binocular and Petrographic Analysis of Pottery from the Yuma Wash Site. In Swartz, D.L. (ed.), *Excavations at the Yuma Wash Site and Outlying Settlements* (Draft). Anthropological Papers No. 49. Center for Desert Archaeology, Tucson.

Peacock, D.P.S. (ed.) 1977. *Pottery and early commerce. Characterization and trade in Roman and later times*, London, Academic Press.

Schleher, K. L. 2010. *The Role of Standardization in Specialization of Ceramic Production at San Marcos Pueblo, New Mexico*. Unpublished PhD. Dissertation, University of New Mexico, Albuquerque.

Shepard, A. O. 1942. *Rio Grande Glaze Paint Ware: A Study Illustrating the Place of Ceramic Technological Analyses in Archaeological Research*. Contributions to American Anthropology and History No. 39. Carnegie Institution, Washington, D.C.

Stoltman, J.B. 2001. The Role of Petrography in the Study of Archaeological Ceramics. In Goldberg, P., Holliday, V. T., and Ferring, C.R. (eds.), *Earth Sciences and Archaeology*, 297-326. Kluwer Academic/Plenum Publishers, New York/Boston.

Stoner, W., Pool, C.A., Neff, H. and Glascock, M.D. 2008. Exchange of Coarse Orange pottery in the Middle Classic Tuxtla Mountains, Southern Veracruz, Mexico. *Journal of Archaeological Science* 35, 1412-1426.

Tsolakidou, A. and Kilikoglou, V. 2002. Comparative analysis of ancient ceramics by neutron activation analysis, inductively coupled plasma-optical-emission spectrometry, inductively coupled plasma-mass spectrometry, and X-ray fluorescence. *Analytical and Bioanalytical Chemistry* 374, 566-572.

Wilson, A.L. 1978. Elemental Analysis of Pottery in the Study of its Provenance: A Review. *Journal of Archaeological Science* 5, 219-236.