# Neutron Activation Analysis of Ceramics from Five Archaeological Sites in Antigua, West Indies


Christophe Descantes,[1] Robert J. Speakman[2] and Michael D. Glascock[3]

[1]Archaeological Research Facility, 2251 College Building,
University of California, Berkeley CA 94720-1076 USA
—*email:* cdescantes@berkeley.edu

[2]Museum Conservation Institute, Smithsonian Institution,
Museum Support Center, 4210 Silver Hill Road, Suitland MD 20746 USA

[3]Archaeometry Laboratory, Research Reactor Center,
University of Missouri–Columbia, 1513 Research Drive, Columbia MO 65211 USA



## Abstract

Ceramics of multiple styles from five archaeological sites on Antigua were analyzed at the University of Missouri Research Reactor Center to obtain a better understanding of ceramic compositional variability within Antigua. Bulk chemical characterizations of pottery were determined by neutron activation analysis. Findings suggest that all of the ceramics in our sample were made from locally available, naturally tempered clays, and that there is compositional continuity through time despite the different stylistic and locational attributes of the sherds.



## Keywords

Caribbean, provenance studies, Antigua, ceramics, NAA.


## Introduction

The Caribbean is an underrepresented region for studies into the compositional nature of ancient material culture (but see Carini 1991; Crane 1993; Hofman and Bright 2004; Knippenberg 2006; Padilla et al. 2006). Compositional analyses of artifacts can provide insights into issues of production, use, exchange, consumption and diagenesis. With large representative data sets from archaeological sites and resources, issues of ancient population movements into the region, the development of exchange networks within and among various island archipelagoes, and local adaptations and prehistoric developments can be addressed.

This compositional study investigates the chemical compositions of ceramic assemblages from five archaeological sites on the Caribbean island of Antigua, Lesser Antilles, for an understanding of compositional changes through time and insights into ceramic production. The 102 ceramic specimens were collected from the following five sites (Table 1): Indian Creek (PA-04), Royall's (JO-11), Mill Reef (PH-01), Winthorpe's East (GE-01) and Muddy Bay (PH-14). Previously, we investigated ceramic sherds samples from the Indian Creek site (Descantes et al. 2007).

In 1973, the late Professor Irving Rouse of Yale University and the Antigua Archaeological Society excavated several middens at the Indian Creek site (Rouse and Morse 1999). Yale's Peabody Museum of Natural History permitted us to analyze a sample of their extensive collection. The ceramic specimens from the remaining four sites were all excavated in the 1990s and generously supplied by Dr. Reginald Murphy, Curator and Archaeologist of the Antigua and Barbuda national parks.

Antigua has an island area of 284 km$^2$ and is situated in the Guadeloupe Passage of the Lesser Antilles in the Caribbean Sea (Figure 1). The Indian Creek site, with a ceramic assemblage from


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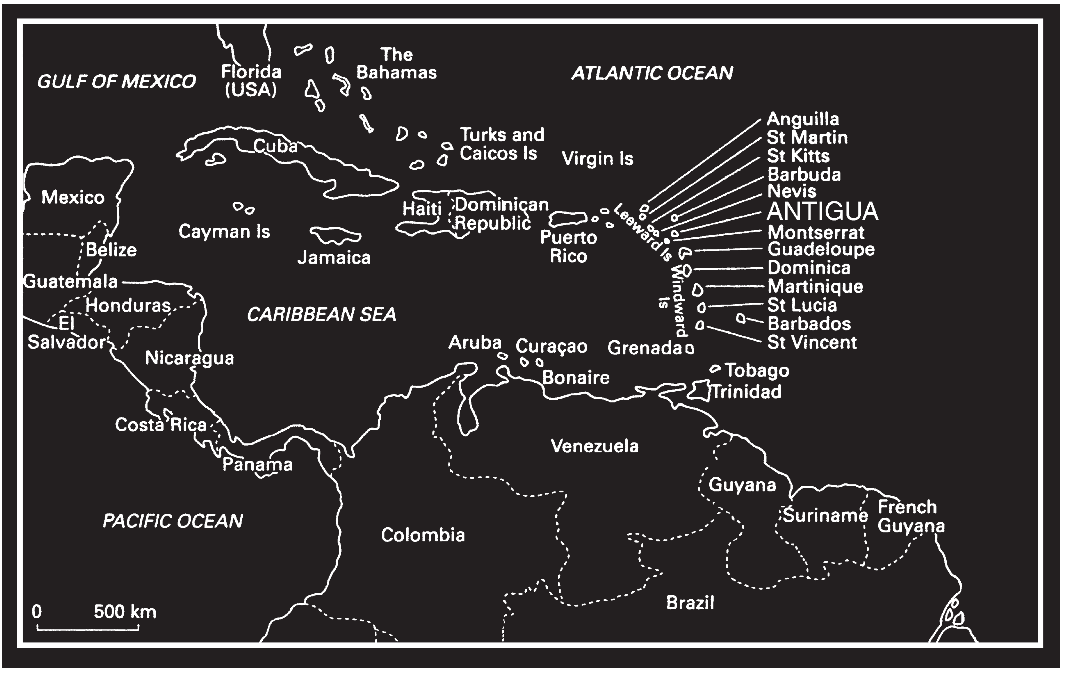


FIGURE 1. Antigua among the islands of the Caribbean.

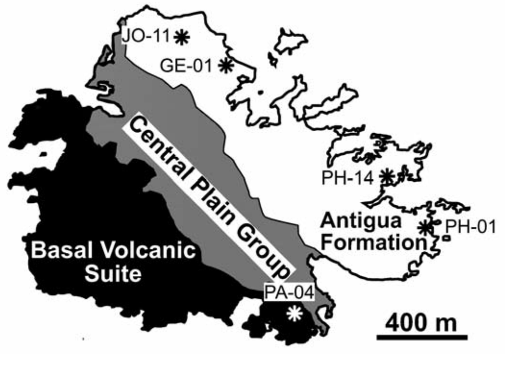


FIGURE 2. Five site locations and the three geological provinces of Antigua. *Legend:* GE-01, Winthrop's East; JO-11, Royall's; PA-04, Indian Creek; PH-01, Mill Reef; PH-14, Muddy Bay.

all three Ceramic Age series, lies between two inlets, English Harbour to its west and Marmora Bay to its east. One kilometer inland from the northern coast, ceramic sherds from the site of Royall's are diagnostic of the early Saladoid (Murphy 1999:144). The Mill Reef site, which has been the focus of much research, is located on the east coast of Antigua. The 10 sherd specimens from the Mill Reef site are recognized as part of the Terminal Saladoid on Antigua (Murphy 1999:205). The ceramic assemblage of the Winthorpe's East site, situated in the waterfront of Winthorpe's Bay, is diagnostically Post-Saladoid (Murphy 1999:69). Situated on the east coast of Antigua, the Muddy Bay site ceramics are also identified as Post-Saladoid (Murphy 1999:250).

The island is characterized by three distinctive geological regions (Figure 2): the Basal Volcanic Suite, the Central Plain Group and the Antigua Formation (Multer et al. 1986:2–7). The Basal Volcanic Suite region, located in the southwestern reaches of the island, is composed of Late Oligocene agglomerates, lavas, tuffs and intrusions. The Indian Creek site is situated on sediments of volcanic origin; the region may also contain occasional lenses of shell- and coral-fragment limestone, deposited on the sea floor during volcanic eruption intervals (Tomblin 2005:13). The Central Plain Group includes mixed terrestrial and marine sediments, whereas the Antigua Formation comprises limestone uplands. All sites, except the Indian Creek site, are on the Antigua Formation, which is made up of limestone layers laid down between 30 and 23 million years ago (Tomblin 2005:15). The limestone uplands contain occasional layers of compacted volcanic dust from renewed small-scale eruptions, as well as

TABLE 1. Cultural and site provenience of ceramic specimens from five archaeological sites on Antigua.

| | Antiguan sites | | | | |
|---|---|---|---|---|---|
| **Ceramic Age culture series** | **Indian Creek PA-04** | **Royall's JO-11** | **Mill Reef PH-01** | **Winthorpe's East GE-01** | **Muddy Bay PH-14** |
| Saladoid | 24 | 10 | 0 | 0 | 0 |
| Terminal Saladoid | 19 | 0 | 10 | 0 | 0 |
| Post-Saladoid | 19 | 0 | 0 | 10 | 10 |

minor layers of clays, sands and gravels from the eroding flanks of volcanic peaks (Tomblin 2005: 15).

The five assemblages (Figure 3) under study span the Ceramic Age of Antigua, that is, the Saladoid (AD 71 to 600), Terminal Saladoid (AD 600 to 900), and Post-Saladoid (AD 900 to 1500). Compared with the rest of the Caribbean, peoples with ceramic technology arrived late on Antigua. Only ceramics from the poorly understood Freeman's Bay Phase (AD 1200 to 1500), which have only been identified at the site of Freeman's Bay (PA-01) in southeast Antigua, are not represented in this study. The first pottery-making style found on Antigua, the Saladoid tradition, originated from the Orinoco region of present-day Venezuela (Rouse and Morse 1999). The maritime Amerindians lived in large sedentary villages and cultivated root crops, practicing what Petersen (1997:119) has called a tropical forest subsistence economy. Plain pottery and two decorated wares characterize the Indian Creek complex (Saladoid) at the Indian Creek site. Rouse and Morse (1999) described the first decorated ware as a relatively thin white-on-red ware (WOR), which has fine particles of grit temper, many vessel shapes and a combination of modeling, incision or punctation. The second ware is a zoned-incised-crosshatched ware (ZIC), lighter in color, thin-walled, finely tempered with grit or sand, and only found in bowl vessel shapes. Most are unpainted; many are red-slipped like their WOR counterparts (Rouse and Morse 1999:29). Thick-walled disc-shaped griddles and cylinders comprise the other ceramic artifacts of the complex. The diagnostic ceramic traits of Saladoid wares at Royall's also include WOR, polychrome and overall white painting, ZIC, D-shaped strap handles, rounded handles with short cylindrical nobs, tabular lugs, and flanged rims that are at times incised or decorated with raised or button-like nubbins (Murphy 1999:148).

The Mill Reef site typifies the divergence from the traditional Saladoid to the Terminal Saladoid. The second chronological series of ceramic and cultural development on Antigua is the Terminal Saladoid (Murphy 1999). The Mill Reef complex is characterized by ceramic style changes and an increase in settlements on Antigua. Mill Reef pottery is characterized as thicker, cruder and lighter in surface color than the early Saladoid pottery (Murphy 1999:206). WOR painted vessels are present, but there is a noticeable deterioration in quality, sophistication, artistry and technological ability. No ZIC sherds, decorated rims, adornos, modelling, D-shaped strap handles, round button-like nubbins or polychrome painted vessels were recovered. Finely incised labial flanges and tabular lugs are also absent (Murphy 1999:206). Similarly, Rouse and Morse discovered that only WOR was found in the Mill Reef Complex at the Indian Creek site, and the diversity of vessel shapes and the quality of construction decreases. Smooth surface finishes, elongated vertical ridges modeled into zoomorphic heads, and simple rectilinear designs of mostly isolated groups of parallel white lines are introduced in this complex (Rouse and Morse 1999:36–37). Red slip washes still dominate in the ceramic assemblage of the complex, as do the presence of ceramic cylinders and griddles.

The ceramics of the Post-Saladoid have been described as relatively hard, thick-walled and poor in quality, according to Rouse and Morse (1999: 39) when characterizing the ceramics from the Mamora Bay complex at the Indian Creek site. Other ceramic characteristics of this complex at Indian Creek include the persistence of bird's head lugs, plain strap or rod handles, and semicircular or rectangular tabs, in addition to large particles of

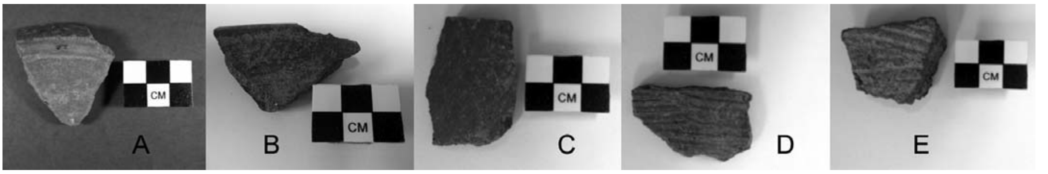


FIGURE 3. Ceramic sherd samples. **A.** Indian Creek site (CANT052), Saladoid style. **B.** Royall's site (CANT064), Saladoid style. **C.** Mill Reef site (CANT100), Terminal Saladoid style. **D.** Winthorpe's East site (CANT074), Post-Saladoid style. **E.** Muddy Bay site (CANT088), Post-Saladoid style.

grit. Of the decoration, scratching, scoring and red slipping remain common, while incised lines become broader and deeper. Murphy (1999) finds diagnostic attributes of this Post-Saladoid to be broad-line, curvilinear incisions, overall red slip, thickened and folded wedge-shaped rims, scratched surfaces and, although not common, crudely applied white paint. The ceramic changes are accompanied by increases in settlement numbers and a change in subsistence strategy to greater use of marine resources (Murphy 1999).

## Analytical Methods

The compositional data are used to address issues of compositional variability, production and use, as well as changes through time. Neutron activation analysis (NAA) was applied to sherd specimens from five Antiguan sites to investigate the compositional variation of the ceramic pastes. Representative ceramic specimens were chosen from the five Antiguan assemblages for the compositional analyses. NAA is a precise and accurate analytical technique for determining elemental abundances of materials. In brief, NAA involves activating the nuclei of elements in the sample by bombarding them with neutrons generated from a nuclear reactor. Once activated, radioactive nuclei emit gamma rays with characteristic energies. Detectors count the gamma radiation and measure their energies to determine the concentrations of specific elements. Statistical algorithms are then applied to the chemical data to identify compositional groups and to calculate the probabilities that an artifact originates from a particular source. The automated gamma-ray counting system at the University of Missouri Research Reactor Center (MURR) accumulates and stores spectra, performs a peak search and a pulse pile-up correction, and calculates elemental abundances correcting for decay time, spectral interferences and sample weight. Abundances are then calculated in relation to National Institute for Standards and Technology standards (e.g., SRM1633a), which are irradiated at the same time as the unknown samples. Neff's (2000) GAUSS® routines are used to reduce the data, which includes substituting missing data, generating bivariate plots and biplots, calculating principal components, and calculating probabilities of group membership based on Mahalanobis distances. The compositional data and accompanying contextual data can be accessed online from the MURR Archaeometry Laboratory (MURR 2008).

## Results

Before identifying groups in the chemical data, we applied a correction to the sherds with calcium concentrations greater than 1% (see Steponaitis et al. 1996; Cogswell et al. 1998). The calcium correction, which did not have an appreciable effect on the group structure, was not used in a previous NAA of the Indian Creek site ceramic specimens (see Descantes et al. 2007). The high calcium abundances are most likely a result of either the original clay sources or a calcium-rich temper. As in previous treatments of ceramics with enriched calcium concentrations, we eliminated the elemental concentrations of calcium and strontium. Nickel and uranium concentrations of the data were also eliminated because of their low detection limits. Twenty-nine elemental abundances were used to determine group membership.

A four-group structure was identified in the Antiguan ceramic specimens: Group 1 (n=6), Group 2 (n=4), Group 3 (n=74) and Group 4 (n=4). The compositional groups can be graphically represented in principal component space (Figure 4) and in elemental space (Figure 5). Statistical tests based on Mahalanobis distances sup-

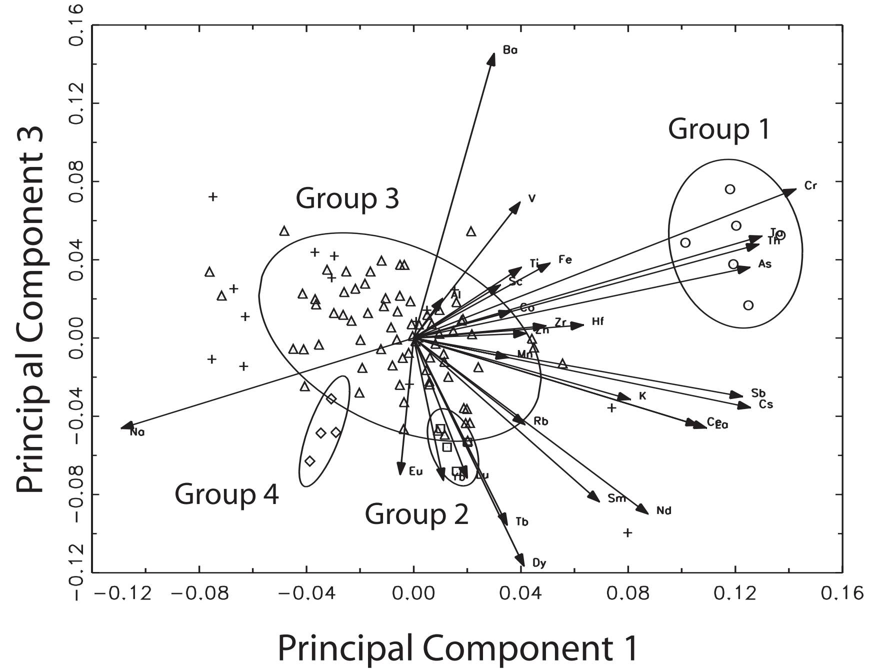


Figure 4. Variance–covariance matrix PCA biplot of principal components 1 and 3 showing the four compositional groups identified in the Antiguan ceramic sample. Ellipses represent 90% confidence level for membership in the groups. Unassigned specimens (+) are not labeled.

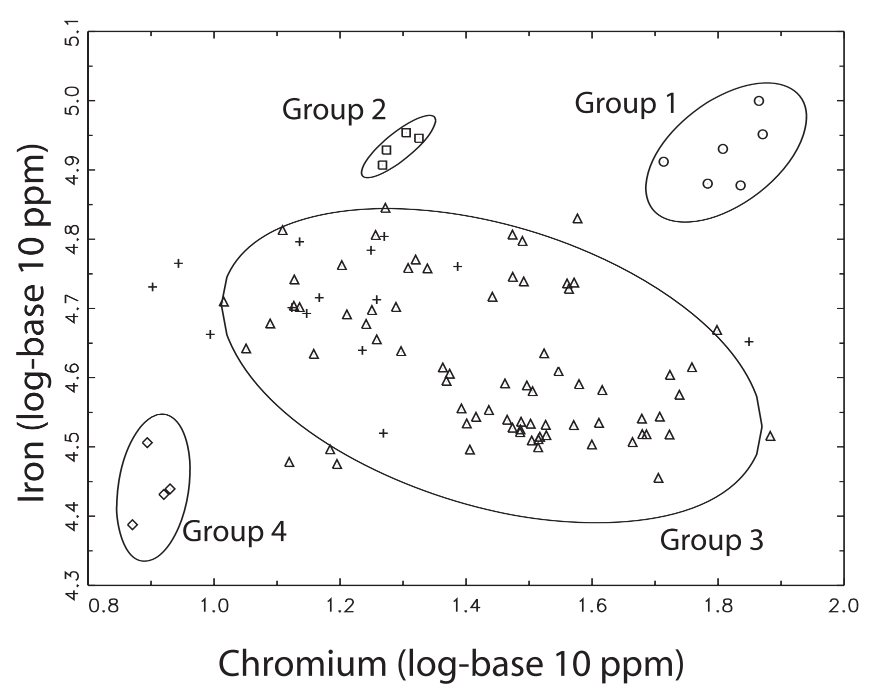


Figure 5. Bivariate plot of base-10 logged chromium and iron concentrations showing the four compositional groups identified in the Antiguan ceramic sample. Ellipses represent 90% confidence level for membership in the groups. Unassigned samples (+) are not labeled.

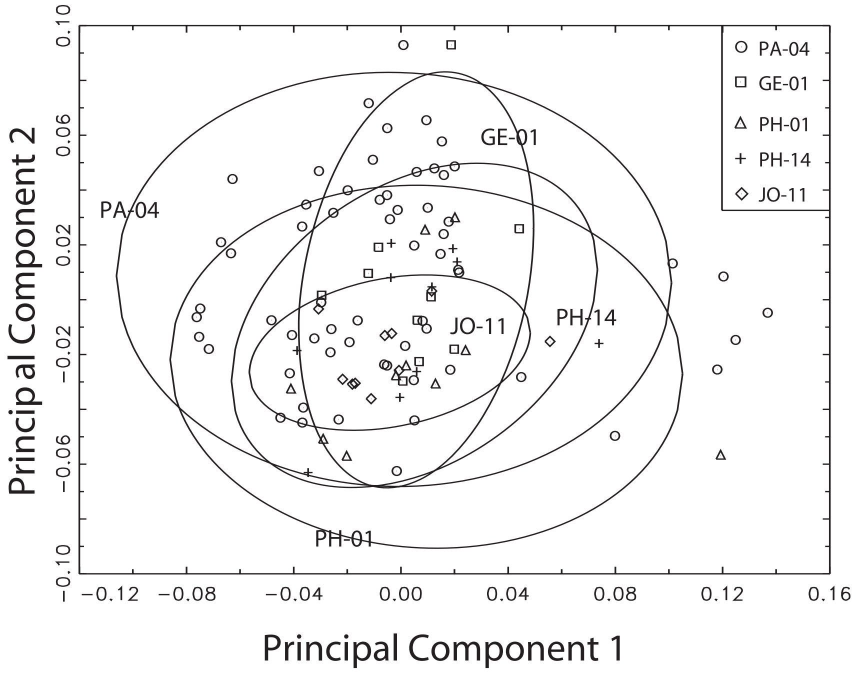


FIGURE 6. Variance–covariance matrix PCA plot of principal components 1 and 2 displaying the five Antiguan site groups. Ellipses represent 90% confidence level for membership in the groups.

port the graphical representation of the group structure. Nine principal components (89% of the variance) and a cut-off probability of 1% were used to refine further the membership of Group 3. The small membership sizes of the other identified compositional groups precluded robust statistical tests, leaving us to test statistically the probability of the other members having membership in Group 3. Fourteen specimens (13.7%) could not be assigned to any of the identified compositional groups, but five of the unclassified specimens (4.9%) resemble statistically the large and chemically diverse Group 3 (see Figures 4 and 5). The plotted elemental vectors and the principal component data show which elements contributed to the differentiation of the four groups (see Figure 4). Group 1 is distinguished from the other three compositional groups by having richer concentrations of chromium, sodium, cerium and hafnium. Compositional Group 4 tends to have a higher concentration of vanadium than the other groups. Groups 2 and 3, 76% of the specimens, are intermediate in elemental concentrations relative to the other compositional groups.

At this preliminary stage there is little compositional differentiation between the ceramics found at the five sites (Figure 6, Table 2). Compositional Group 3 ceramics are found in all five sites and Group 4 ceramics are only found on the sites on the limestone-layered Antiguan Formation. The Royall's site only has Group 3 ceramics. Group 2 compositional ceramics are only found at the Indian Creek site. When examining the compositional variation of the ceramics among the three chronological culture series, all the chemical compositional groups are found in the three Ceramic Age series, except for Group 2, which is only identified in the early Saladoid at the Indian Creek site (Table 3, Figure 7). Future compositional studies on a larger representative sample may provide more compositional diversity and definitive patterns of the Antiguan ceramic compositional space.

## Discussion

A four-group structure based on chemical composition is identified in the Antiguan ceramic sample. There does not seem to be strong patterns of correlation between the chemical composition

Table 2. Site provenience and compositional group affiliation of ceramic specimens from five archaeological sites on Antigua.

| | Antiguan sites | | | | |
|---|---|---|---|---|---|
| **Chemical groups** | **Indian Creek PA-04** | **Royall's JO-11** | **Mill Reef PH-01** | **Winthorpe's East GE-01** | **Muddy Bay PH-14** |
| Group 1 | 5 | 0 | 1 | 0 | 0 |
| Group 2 | 4 | 0 | 0 | 0 | 0 |
| Group 3 | 41 | 9 | 8 | 9 | 7 |
| Group 4 | 0 | 0 | 1 | 1 | 2 |
| Unassigned | 12 | 1 | 0 | 0 | 1 |

of the sherd specimens and their particular site provenience and chronological style (see Tables 2 and 3, Figures 6 and 7). Despite small sample sizes at four of the sites, Group 3, the largest and most diverse compositional group in the sample, predominates in all five sites and all three chronological culture series. However, Group 2 ceramics are only found during the Saladoid and at the Indian Creek site, and Group 4 ceramics are not found in the Saladoid or at the Indian Creek site. Throughout the temporal culture series at the five Antiguan sites, the bulk of the ceramics from our sample were made from similar clay source or ceramic recipes, or both. Despite the ceramic and sociocultural changes during this 1,500 year period (see Keegan 2000), ceramic recipes seem to have remained unchanged.

At present the data do not imply that the chemical composition of ceramic recipes differed greatly between sites or varied drastically over time. However, the earlier compositional analysis of ceramics from only the Indian Creek site, which included potsherds from all three chronological culture series, was interpreted as having more compositional heterogeneity in the early Saladoid pottery (Descantes et al. 2004, 2007). This may have been linked to a standardization of ceramic production or a gradual decline in the ceramic technologies through time, as has been suggested by Murphy (1999:313), Rouse and Morse (1999) and others. The ceramic sample in this study did not allow for a diachronic investigation of ceramic compositional change at the other four sites.

We hypothesize that all four identified groups were locally produced, given the geologic characteristics of Antigua. The petrographic analysis conducted by David Hill (2005, 2006) links the geology of Antigua with the analyzed ceramic specimens. Hill suggests that the inclusions in the ceramic pastes are natural, as opposed to added temper. The ceramic potsherds that contain exclusively volcanic rock fragments are more likely to derive from the Basal Volcanic Suite in the southwestern region of Antigua, whereas pots containing both limestone and volcanic rock fragments are made with clays from the Central Plain. Compositional Group 1 ceramics seem to have been made with clays deriving from the Southwest Volcanic District, whereas clays used for compositional Group 2 ceramics derive from the Central Plain District. The ceramic specimens in Group 3 are composed of diverse varied mineralogical suites of volcanic rock and limestone fragments. None of the Group 4 specimens received a mineralogical examination. A raw material study of Antiguan clays would permit us to conclude with certainty whether the inclusions are indeed natural and to tie the compositional groups to clay source areas on the ground. The analysis of more ceramics will allow us to identify subgroups

Table 3. Compositional group affiliation and culture series of Antiguan ceramic specimens.

| | Ceramic Age culture series | | |
|---|---|---|---|
| **Chemical groups** | **Terminal Saladoid** | **Post-Saladoid** | **Saladoid** |
| Group 1 | 3 | 2 | 1 |
| Group 2 | 4 | 0 | 0 |
| Group 3 | 24 | 21 | 29 |
| Group 4 | 0 | 1 | 3 |
| Unassigned | 3 | 5 | 6 |

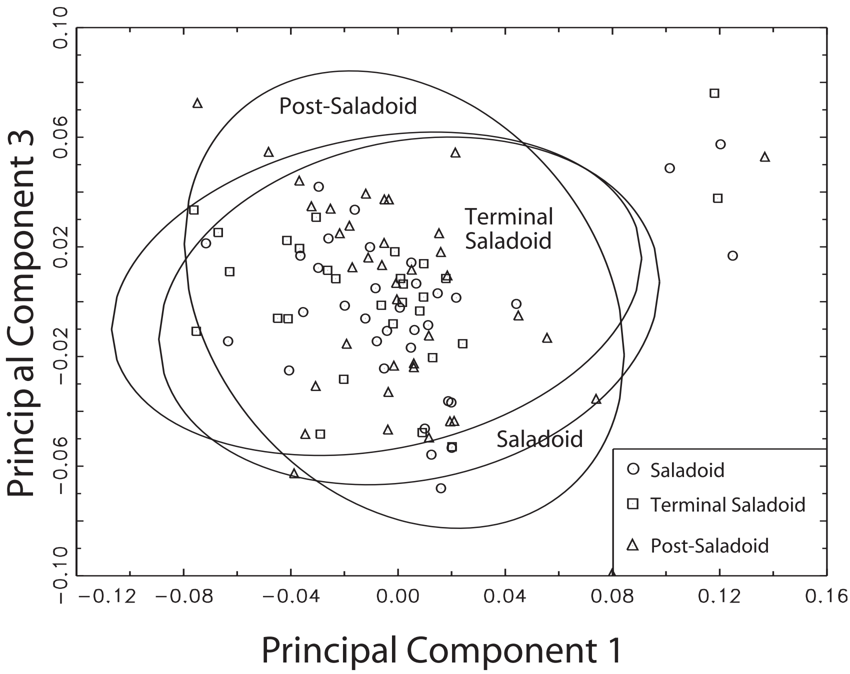


FIGURE 7. Variance–covariance matrix PCA plot of principal components 1 and 3 showing the three Antiguan chronological culture series. Ellipses represent 90% confidence level for membership in the groups.

within this large and diverse group.

Throughout the three temporal culture series at the five Antiguan sites, the bulk of the ceramics from our sample were made from similar clay sources and ceramic recipes. This core group is referred to as Compositional Group 3. The large and diverse compositional Group 3 includes WOR, ZIC, plain and incised wares obtained from all the Ceramic Age culture series.

## Conclusions

This preliminary study into the bulk chemical compositional variability of prehistoric Antiguan ceramics using NAA has shown that at least a four-group structure can be identified. The core compositional Group 3 was found to predominate in all of the Ceramic Age culture series and the five archaeological sites. Throughout the Antigua's Ceramic Age, most ceramics from our sample were made from similar Antiguan clay sources and ceramic recipes. New insights about past ceramic production behaviors on Antigua will be gained when future research includes a detailed study of raw clays from Antigua to tie the compositional groups to clay source areas. Finally, a larger sample of sherds from geographically diverse archaeological sites spanning the entire Ceramic Age will allow for a more diachronic perspective into the ceramic behaviors of Antiguan potters.

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