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Examining changes in the organisation of earthenware production in a prehispanic Philippine polity using laser ablation-inductively coupled plasma-mass spectrometry

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Abstract

Although significant historical research has been done on traditional Southeast Asian kingdoms and chiefdoms, little archaeological work has been undertaken on changes in the economic systems of pre-colonial maritime societies in Asia, especially on the role of specialised craft production in the development of pre-modern complex societies. This project examines changes in the organisation of earthenware production in the prehispanic coastal polity of Tanjay in the Philippines (A.D. 500-1600). More than 250 earthenware pieces from six archaeological sites from the Tanjay region were analysed using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at Chicago's Field Museum. Ceramic samples were drawn from two residential zones in central Tanjay, an elite neighborhood and a non-elite area; two secondary settlements located several kilometers upriver; an upland, swidden farming site; and a contemporaneous, and likely competing, coastal polity 40 km down the coast from Tanjay. Initially, it was expected that changes in the pattern of earthenware production in the Tanjay region would favour one scenario or the other – either continued production at dispersed, local sites or increased specialised and centralised production. So far, however, the preliminary ceramic compositional evidence indicates that both scenarios seem to have been taking place during the centuries prior to Spanish contact. Ceramic production appears to have continued on a local level, with potters from each site making pottery to be used by nearby inhabitants, but there also is evidence that sites, such as the elite Tanjay neighborhood, began to make ceramics expressly for local consumption by elites and for foreign trade.

Introduction

Significant historical research has been done on traditional Southeast Asian kingdoms and chiefdoms (Hall, 2011; Higham, 1989; Reid, 1999; Scott, 1994; Wolters, 1999), but only a few archaeological projects have focused on changes in the economic systems of pre-colonial maritime societies in Southeast Asia. The research presented here fits into a larger body of work examining the political economy of ancient trading polities in Southeast Asia (Andaya, 1995; Bacus and Lucero, 1999; Bronson, 1977; Junker, 1999; Manguin, 1991) and, in particular, the role of specialised craft production in the development of pre-modern complex societies (Brumfiel and Earle, 1987; Costin, 1991, 2001, 2004; Costin and Wright, 1998; Hruby and Flad, 2007; Spielmann, 2002). Specifically, I use laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) to investigate changing patterns of pottery production at Tanjay (A.D. 500-1600), a coastal chiefdom in the central Philippines that underwent significant growth in the centuries before Spanish contact.

Many anthropologists consider craft specialisation a key element of the political economies of complex societies (Brumfiel and Earle, 1987; Costin, 2001, 2004), and archaeologists have attempted to define forms of specialisation and their material correlates (Brumfiel and Earle, 1987; Costin, 1991; Sinopoli, 1988). Access to specialised goods or services generally serves as a basis for economic, political, and ritual power for leaders competing to control aspects of production and distribution, such as raw materials, products, transport, knowledge, and specialists themselves. Examples of specialised goods functioning as political currency for elites include the production of feathered-cloaks in Hawaiian chiefdoms (Earle, 1997, 2002), the mining of chert and the manufacture and distribution of stone tools at the Maya site of Colha (Shafer and Hester, 2000), and the production of bronze vessels in the late Shang state in northern China (Underhill, 2002). The agency of craft specialists likely plays an important, but often neglected, role in the organisation of production systems, and questions about the social and economic gain of producers and their consumers need to be considered (Brumfiel, 1998; Costin, 1998; Sinopoli, 1998). As Spielmann (2002) points out, craft specialisation may not only stem from political, economic, or environmental pressure; increasing demands for socially valued goods, such as fancy earthenware for ritual feasts (Junker and Niziolek, 2010), also may spur an increase in specialised craft production (Spielmann, 2002).

Previous archaeological research suggests that the political economies of Tanjay and other expanding maritime polities of Southeast Asia underwent changes in the early second millennium A.D., including increased foreign trade with China, expansion of wealth circulation through ritual feasting, and intensification of inter-polity competition through slave-raiding and agricultural intensification (Junker, 1993, 1999a, 1999b, 2003; Bacus, 1996, 1998; Gunn, 1997). These changes were likely accompanied by greater centralisation of craft production and increased specialisation of pottery and metal goods. This assumption, however, is based on limited empirical evidence.

Geochemical analysis, specifically LA-ICP-MS, provides more rigorous testing of a key part of this hypothesis: that the production of earthenware became increasingly specialised and centralised in prehispanic Tanjay. These changes are possibly a function of leaders attempting to control local access to craft goods used as political currency in cementing local alliance networks necessary for foreign luxury goods trade. However, they also might be the result of craftspeople locating themselves at the polity center to exploit economic and social opportunities created by burgeoning trade at ports such as Tanjay, which provided domestic, ritual, and foreign goods to interior populations in exchange for exotic forest materials important in foreign trade.

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Sample description

A total of 289 earthenware samples (Table 1) from excavations and surveys at six sites in or near the Tanjay region (Figure 1) were analysed using LA-ICP-MS. Purposive sampling was used to select ceramics from sites representing a variety of ecological environments, sizes, and social groups. These sites include the lowland sites of Tanjay (including the Santiago Church and Osmeña Park locales), Aguilar, and Mendieta; the mountain site of Turco; and Bacong, in another river drainage system. This paper focuses on the results from the later two cultural phases, the Santiago (A.D. 1100-1400) and Osmeña (A.D. 1400-1600) periods, which include 257 earthenware sherds. Tanjay is a multi-component site, approximately 50-70 hectares in size, and was occupied from A.D. 500 to the present. Tanjay is a primary polity with elite and non-elite residential zones yielding burials, ceramic and metal production areas, foreign and local prestige goods, ritual objects, and fortifications (Junker, 1999b). In Tanjay, Santiago Church is a hypothesised elite area, particularly in the Santiago and Osmeña periods, whereas Osmeña Park is a non-elite area. Two secondary centers upriver from Tanjay are the Aguilar and Mendieta sites (about 4-7 hectares in size). Aguilar is a multi-component site from the Aguilar and Osmeña periods (A.D. 500-1000 and 1400-1600). Mendieta is another multi-component site with occupation evidence in all three protohistoric phases from A.D. 500-1600. Both sites are much smaller than Tanjay and contain foreign and local prestige goods, habitation debris, postholes, and hearths (Junker, 1999b). Turco is a 15th-16th century upland farming hamlet 20 km into the interior and measures 0.25-1.25 hectares. Surface collections there produced few prestige goods, some habitation debris, postholes and hearths, but no evidence of metal or pottery production (Junker, 1999b). Earthenware samples also include pottery from a trading polity contemporaneous to Tanjay, 40 km to the south called Bacong (A.D. 1000-1500) (Bacus, 2000). Artifacts found there include Asian porcelains, glass beads, decorated local earthenware, iron (slag and metal pieces), and nonlocal plain and decorated pottery (Bacus, 2000).

Materials and Methods

Analysis at the Field Museum's elemental analysis facility (EAF) was conducted using a Varian ICP-MS with a New Wave UP213 laser for the introduction of solid samples. Instrumentation details and analysis parameters, along with information on sensitivity, accuracy, and reproducibility are described in Dussubieux *et al.* (2007); however, some parameters are reviewed here. The laser operates at 70% (0.2 mJ) with a pulse frequency of 15 Hz. Sample size is limited by the dimensions of the laser ablation chamber (six cm wide and five cm high). All ceramics used were small sherds, each less than two cm wide. Per EAF procedures (Dussubieux *et al.*, 2007), for each sample, 10 ablation spots with a diameter of 100 μm and an acquisition time of 60 s consisting of nine replicates each were made. The clay matrix itself was targeted in various areas of each sherd with visible temper avoided as much as possible. Before analysis, each sherd was checked for surface contamination and each spot was pre-ablated for several seconds before readings started. ^{29}Si was the internal standard, and NIST glass SRM n610 and NIST clay SRM n679 were used, along with blank measurements recorded throughout the day, to calculate concentrations with procedures developed by Dussubieux *et al.* (2007) based on the Gratuze method (Gratuze, 1999). New Ohio Red Clay also was used to calculate elemental concentrations and served to monitor instrument precision (Golitko, 2010).

For each sample, 55 elemental isotopes were read: ^{7}Li, ^{9}Be, ^{11}B, ^{23}Na, ^{24}Mg, ^{27}Al, ^{29}Si, ^{31}P, ^{35}Cl, ^{39}K, ^{44}Ca, ^{45}Sc, ^{49}Ti, ^{51}V, ^{53}Cr, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{65}Cu, ^{66}Zn, ^{75}As, ^{85}Rb, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{93}Nb, ^{107}Ag, ^{111}Cd, ^{115}In, ^{118}Sn, ^{121}Sb, ^{133}Cs, ^{137}Ba, ^{139}La, ^{140}Ce, ^{141}Pr, ^{146}Nd, ^{147}Sm, ^{153}Eu, ^{157}Gd, ^{159}Tb, ^{163}Dy, ^{165}Ho, ^{166}Er, ^{169}Tm, ^{172}Yb, ^{175}Lu, ^{178}Hf, ^{181}Ta, ^{197}Au, $^{206,\,207,\,208}$Pb, ^{209}Bi, ^{232}Th, and ^{238}U. Of these 55 elements, 45 were used for statistical analysis. ^{7}Li, ^{31}P, ^{35}Cl, ^{75}As, ^{88}Sr, ^{107}Ag, ^{111}Cd, ^{137}Ba, ^{178}Hf, and ^{197}Au were omitted because of concerns regarding precision and potential post-depositional alteration. Table 2 shows the averages and standard deviations of the elemental compositions of ceramics from each site.

Statistical procedures were conducted using GAUSS Runtime 5.0 routines developed by Hector Neff at the Missouri University Research Reactor (Glascock, 1992), SPSS v.12, and Microsoft Excel. First, parts-per-million elemental values were converted to log-base-10 values. Next, principal components (PC) analysis was performed on the

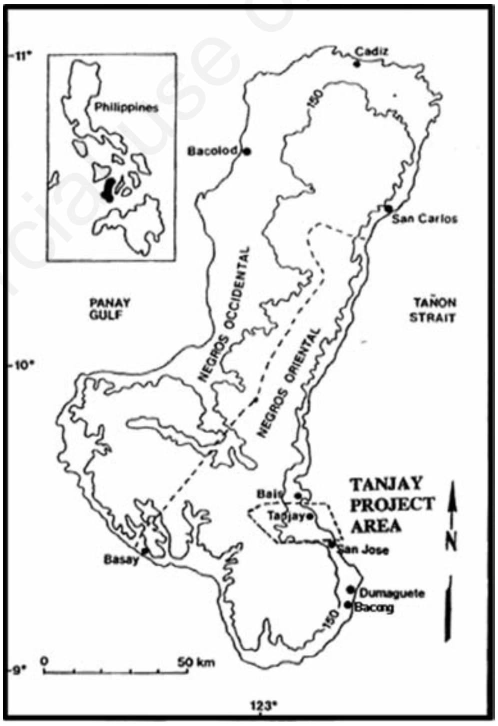

Figure 1. Map of the research area.

Table 1. Number of ceramic sherds analysed using laser ablation-inductively coupled plasma-mass spectrometry by site and period.

Site	Aguilar period	Santiago period	Osmeña period	Total
Aguilar	22	3	2	27
Bacong	0	9	0	9
Mendieta	0	28	29	57
Osmena park (Tanjay)	2	31	48	81
Santiago Church (Tanjay)	8	49	34	91
Turco	0	0	24	24
Total	32	120	137	289

dataset to compress the 45 elemental variables into a smaller number that would ease statistical analysis. One way of determining how many PCs to retain for analysis is to plot the eigenvalues on a scree plot. Where a *kink* appears suggests which value should be the cut-off point (Baxter, 1994). For this analysis, the plot indicated that the first six PCs would be sufficient for analysis, accounting for more than 76% of the variability in the data. Then, because change in production patterns over time was the focus, hierarchical cluster analysis was run on the ceramic groups by period. These hypothetical groups then were refined using biplots of PC values, Mahalanobis distance measurements for group membership probabilities, and canonical discriminant analysis.

Results and Discussion

When possible, all six PCs were used for statistical procedures. PC 1 is associated primarily with Y and some of the rare earth elements (REE) (Pr, Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, and Yb); PC 2 with Na; PC 3 with Cr, Ni, Cu, Nb, Ta, and Mn; PC 4 with Rb, Mg, K, and Mn; PC 5 with Co, Cs, Na, Ca, and Mn; and PC 6 with Na, Ca, and Zn. For the Santiago period, three main chemical groups emerged and four for the Osmeña period.

Santiago period

For the Santiago period (A.D. 1100-1400), initially three main groups were apparent (Groups 1, 2, and 3), best illustrated in a biplot of PCs 1 and 2 (Figure 2). Groups 1 and 3 are distinguished from Group 2 by higher concentrations of Na associated with PC 2 and Groups 2 and 3 have higher concentrations of REEs, associated with PC 1, compared to Group 1. Table 3 lists the average elemental concentrations for each of the main Santiago period ceramic groups and subgroups. Group 1 (n=19) has mostly sherds from Bacong (n=7), south of Tanjay, but also includes five pieces from Osmeña Park, three each from Mendieta and Santiago Church, and one from Aguilar. This group suggests that ceramics (or the products therein) were exchanged between Bacong and the Tanjay region, possibly through alliance building activities such as feasting and bridewealth exchange. Because Group 1 contains a majority of samples from Bacong, it is very possible that these sherds are from vessels made in Bacong brought to Tanjay through trade.

Group 2 (n=25) is primarily comprised of sherds from Osmeña Park (n=14) but also includes nine sherds from Santiago Church and two from Aguilar. This might indicate that potters from Osmeña Park used a clay source geologically distinct from sources used for some ceramics used at Santiago Church (Subgroups 3c and 3d), but that some pottery produced at Osmeña Park was distributed to Santiago Church and Aguilar, suggesting possible centralised production (or that Osmeña Park and Santiago Church potters sometimes used the same clay source or recipe).

Upon examination, it became clear that Group 3 has four subgroups (3a, 3b, 3c, and 3d) (Figure 3). Subgroup 3a (n=4) contains two sherds from Osmeña Park and one sherd each from Santiago Church and Bacong. Subgroup 3a, with its small sample size, is difficult to interpret. Subgroup 3b (n=19), enriched in REEs, Nb, and Ta, is made up solely of sherds from Mendieta suggesting that Mendieta potters used a clay source distinct from those used by Tanjay potters. Subgroup 3c (n=21), which has higher values on PC 3 (Mn, Cu, and Ni), is composed mainly of pottery from Santiago Church (n=15) but also includes five sherds from Osmeña Park and one from Mendieta. Subgroup 3d (n=21) consists mostly of sherds from Santiago Church (n=17), in addition to two sherds from Osmeña Park and two from Mendieta and is associated with lower values on PC 3. Together, Subgroups 3b, 3c, and 3d form a picture of fairly localised production, with limited exchange of some ceramics between sites. Along with this pattern, we see evidence of some centralised production (Group 2) and intra-island exchange (Group 1).

Osmeña period

For the Osmeña period (A.D. 1400-1600), four main compositional groups emerged (Figure 4). Table 4 lists the average elemental concentrations and their standard deviations for the main groups and subgroups. Group 1 (n=16), with lower con-

Table 2. Site averages (ppm) and standard deviations for Santiago and Osmeña period ceramics.

	Aguilar		Bacong		Mendieta		Osmeña Park		Santiago Church		Turco	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Be	2.31	0.74	2.47	0.69	2.00	0.56	1.46	0.60	1.35	0.38	2.25	0.81
B	39.53	13.85	32.08	14.84	20.92	13.15	23.73	15.07	19.83	7.62	31.49	16.59
Na	7191.92	4736.11	11646.80	9260.49	14428.52	7802.24	10377.31	6925.33	13224.42	7391.53	13093.19	11656.87
Mg	5019.80	1263.36	8165.63	12822.64	12532.10	4968.57	8623.53	3667.26	9730.60	3851.54	5053.43	2447.24
Al	272676.59	51134.23	239512.73	34028.78	223774.14	24146.33	198467.03	43585.93	193254.38	34025.88	250715.82	61133.74
Si	488904.43	73389.28	607716.23	49940.16	591183.06	43456.12	630008.32	58413.91	613733.36	54403.27	597101.05	77076.75
K	8129.64	3663.24	3679.92	549.55	14182.47	10991.40	12108.41	7954.24	14262.50	6149.74	5157.09	3435.50
Ca	37322.10	7307.88	25584.64	18883.80	21760.35	6334.75	21460.53	9558.49	26303.79	10798.10	19077.66	10957.11
Sc	23.34	9.35	14.35	5.90	20.47	5.26	17.72	4.98	19.70	5.56	16.42	6.24
Ti	6777.76	2719.08	6176.78	2204.77	6215.10	1752.36	5982.38	2222.46	5819.57	2145.35	6585.67	2101.51
V	167.15	43.35	137.10	51.12	165.23	61.73	153.73	50.87	165.57	67.32	120.94	83.62
Cr	49.41	19.02	14.72	6.27	23.29	7.34	31.20	14.19	32.55	17.86	32.90	26.03
Mn	803.26	433.50	1983.12	1388.40	942.48	665.53	579.74	374.74	818.14	720.63	2097.93	3597.65
Fe	128681.32	35757.01	80988.63	23862.29	91631.11	28343.01	95249.61	27996.75	99344.75	32876.77	97607.07	38861.77
Co	14.20	4.65	15.44	8.25	17.80	9.50	11.21	5.52	14.27	7.28	18.99	21.71
Ni	53.99	25.54	6.15	3.57	23.37	12.32	18.97	9.32	16.73	8.36	13.63	8.10
Cu	142.59	32.99	126.50	100.02	152.40	80.71	128.99	69.66	113.80	39.80	45.25	30.51
Zn	126.17	22.53	75.06	34.10	137.83	68.62	205.13	254.06	139.39	98.44	83.96	33.85
Rb	22.93	11.80	13.77	4.91	61.93	23.76	41.24	18.22	39.26	17.61	33.58	35.21
Y	25.81	13.46	15.39	8.08	26.53	11.18	15.47	5.26	17.38	6.46	22.28	9.94
Zr	163.23	24.48	92.30	9.17	155.06	51.06	132.84	49.59	120.48	47.18	241.36	125.95
Nb	8.01	2.02	5.99	0.87	9.15	3.64	7.22	3.08	6.79	3.54	14.72	7.71
In	0.11	0.07	0.05	0.02	0.07	0.02	0.06	0.02	0.06	0.03	0.08	0.03
Sn	1.55	0.47	2.26	1.94	1.45	0.31	1.71	2.34	1.28	0.50	2.33	1.22
Sb	0.41	0.12	0.31	0.12	0.41	0.14	0.51	0.30	0.41	0.19	0.86	0.44
Cs	0.72	0.58	1.62	0.47	3.56	1.90	1.56	1.29	1.24	0.59	4.14	2.87
La	16.42	4.91	11.73	4.25	17.89	6.29	12.88	5.71	15.36	7.10	19.37	7.50
Ce	32.47	11.00	30.98	14.76	28.45	10.81	23.03	10.27	27.79	12.20	46.82	43.89
Pr	5.26	1.93	2.80	1.26	5.00	2.28	3.61	1.38	4.43	1.81	5.74	2.16
Nd	17.79	5.82	14.98	6.12	21.43	10.14	14.48	5.36	17.22	6.86	22.60	8.98
Sm	5.23	2.39	3.36	1.76	4.83	2.25	3.15	1.11	3.71	1.24	4.78	1.95
Eu	1.53	0.72	0.92	0.36	1.45	0.48	0.92	0.29	1.24	0.38	1.91	0.56
Gd	5.57	4.65	2.78	1.56	4.76	2.15	2.68	0.94	3.41	1.36	4.56	2.78
Tb	0.67	0.30	0.37	0.20	0.73	0.30	0.42	0.14	0.51	0.17	0.58	0.24
Dy	4.44	1.90	2.78	1.45	4.99	1.95	3.06	1.09	3.53	1.51	4.36	1.68
Ho	0.87	0.40	0.60	0.32	1.00	0.41	0.64	0.23	0.72	0.25	0.83	0.34
Er	2.77	1.31	1.81	0.96	3.04	1.15	1.96	0.65	2.28	0.73	2.53	1.01
Tm	0.41	0.19	0.29	0.14	0.46	0.16	0.31	0.10	0.37	0.16	0.41	0.17
Yb	2.46	1.20	1.71	0.78	2.66	0.90	2.05	1.10	2.08	0.60	2.50	1.02
Lu	0.39	0.16	0.26	0.12	0.41	0.14	0.30	0.09	0.34	0.10	0.38	0.15
Ta	0.51	0.07	0.39	0.05	0.60	0.23	0.48	0.20	0.47	0.20	1.02	0.54
Pb	31.44	9.26	18.12	6.45	18.48	3.99	21.88	12.95	21.64	7.56	28.05	9.45
Bi	0.44	0.21	0.20	0.12	0.27	0.14	0.27	0.16	0.26	0.15	0.23	0.18
Th	5.59	0.85	4.61	0.67	4.72	1.53	4.53	2.02	4.24	1.82	7.80	3.92
U	2.49	0.70	1.17	0.35	1.99	0.48	2.00	1.06	2.21	0.89	4.25	1.83

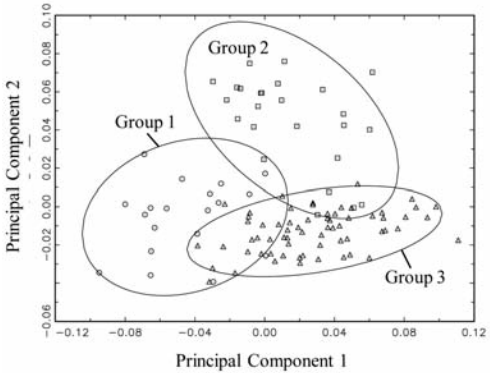

Figure 2. Principal components biplot of the main chemical groupings for the Santiago period. Ellipses delimit 90% confidence boundaries.

centrations of Rb and K and higher concentrations of Mn, is dominated by sherds from the Turco site (n=15), an upland farming hamlet, and includes one sherd from Aguilar. Because there is no additional evidence indicating that pottery production took place at Turco (*e.g.* ceramic workshops or production locales), it has usually been assumed that the farmers there received pottery through trade with lowland populations. Interestingly, Group 1, because it contains only one sherd from the main Tanjay sites, suggests that people at Turco either made their own pottery from a clay source different from Tanjay sources or received pottery from outside the Tanjay region. Group 2 (n=12), enriched in Na, contains primarily sherds from Turco, but also includes three sherds from Mendieta and one sherd each from Osmeña Park and Santiago Church. Evidence from Group 2, like that of Group 1, supports the idea that pottery, possibly containing interior forest products crucial in long distance trade, from Turco was distributed to lowland sites. Alternatively, it is possible that these earthenware vessels were produced at Mendieta, a known production locale, and distributed to mountain populations. Analysing additional sherds from Turco would clarify these relationships.Initially, Subgroups 3a, 3b, and 3c comprised a single, larger group (Group 3, with higher concentrations of Mg overall), as did 4a, 4b, and 4c (Figure 5). Subgroup 3a (n=10) mainly contains sherds from Mendieta, with one sherd from Osmeña Park, possibly indicating that Mendieta potters continued to draw materials from local clay sources. Subgroup 3b (n=15) is made up of sherds from Mendieta (n=7) and also includes five sherds from Santiago Church and three from Osmeña Park. Subgroup 3b suggests that some potters from the three locales were using the same clay source, that there was some exchange taking place between the three areas, or that some ceramics were produced at a central location and distributed to multiple sites. Subgroup 3c (n=16) has eight sherds from Osmeña Park and six sherds from neighbouring Santiago Church. One sherd is also from Aguilar and one from Mendieta. Subgroup 3c leads to similar, multiple interpretations as Subgroup 3b – the utilisation of the same clay source or recipe, exchange between sites, or a central production area. Subgroup 4a (n=19), which is depleted in REEs, consists of nine sherds from Osmeña Park, five from Santiago Church, four from Mendieta, and one from Turco. Subgroup 4b (n=29), which is higher in Na than Subgroup 4c and higher in REEs than 4a, is comprised of 16 sherds from Osmeña Park and 10 from Santiago Church, along with three from Mendieta. Subgroups 4a and 4b, along with the Group 3 subgroups, suggest that multiple clay sources or recipes were used throughout the region but, because these subgroups consist of several samples from multiple sites, that production might be centralised at a few locations. Because Subgroups 4a and 4b are geochemically distinct from one another, potters may have used different clay sources at different times or to produce different ware types; or, several workshops produced goods from their own local clay sources and distributed their wares to households throughout the Tanjay region. Subgroup 4c (n=17), with lower concentrations of Na, is made up of 10 sherds from Osmeña Park and seven from Santiago Church. Subgroup 4c, because it is made up of samples solely from Tanjay (including Santiago Church and Osmeña Park), could indicate potters in Tanjay produced goods for use by inhabitants of Tanjay and not for trade to other settlements.

In the Osmeña period, both local and specialised pottery production are evident. Although we still see a couple geochemical groups that are fairly homogeneous in terms of site membership, we also see groups emerging with more samples from a variety of sites, possibly indicating the specialised production of some earthenwares that were distributed beyond their production sites.

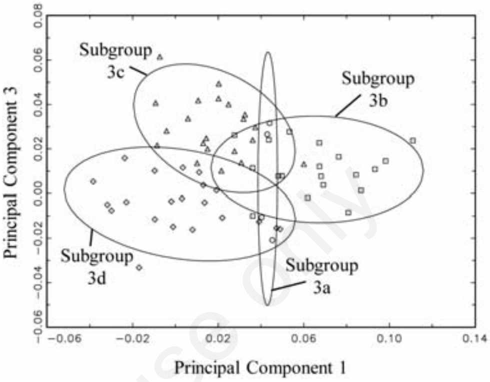

Figure 3. Principal components biplot of the chemical subgroups for Santiago period main group 3. Ellipses delimit 90% confidence boundaries.

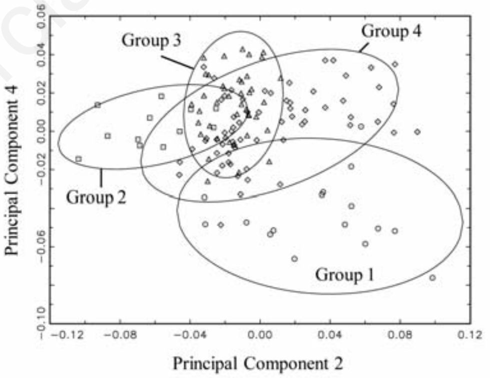

Figure 4. Principal components biplot of the main chemical groupings for the Osmeña period. Ellipses delimit 90% confidence boundaries.

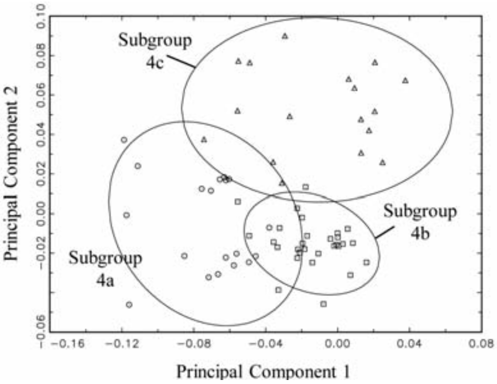

Figure 5. Principal components biplot of the chemical subgroups for Osmeña period main group 4. Ellipses delimit 90% confidence boundaries.

Table 3. Chemical group averages (ppm) and standard deviations for Santiago period ceramics.

	Group 1		Group 2		Subgroup 3a		Subgroup 3b		Subgroup 3c		Subgroup 3d	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Be	1.77	0.78	2.06	0.73	1.33	0.40	1.93	0.32	1.57	0.38	1.33	0.32
B	25.43	14.36	28.33	15.78	29.55	14.52	15.37	3.66	20.95	9.15	24.56	8.46
Na	13935.42	8724.11	2953.57	1478.93	12145.05	5324.20	7714.38	1521.38	13913.95	3657.39	16039.84	3771.65
Mg	6585.65	3822.00	7902.88	2567.67	19133.33	13874.80	14529.67	3016.59	12598.03	4307.50	8895.72	3081.74
Al	210972.81	50674.09	237940.81	37202.66	179825.11	22036.29	216428.27	12645.00	177311.35	24318.89	187164.34	30608.30
Si	642776.02	58609.92	571165.93	41208.14	571232.82	22802.20	570339.13	34378.25	633713.32	52791.99	625488.24	42782.86
K	8221.13	4505.16	9030.58	3849.53	15293.81	11927.51	9913.92	1395.70	15863.17	4774.93	15416.50	4084.30
Ca	23612.95	13630.41	24918.57	7841.30	22388.75	13014.52	22426.20	4418.84	17475.86	8719.59	28685.21	9357.20
Sc	13.15	3.69	20.80	4.67	23.05	3.44	23.04	3.75	21.30	4.43	17.02	4.00
Ti	5136.28	1789.40	7832.68	2353.22	7116.64	2290.83	7426.35	1089.81	5815.46	1267.43	4895.28	1325.90
V	115.53	34.34	167.92	49.67	184.22	44.96	211.65	44.69	182.96	39.37	144.00	39.99
Cr	19.64	9.52	46.27	13.78	21.55	9.70	26.56	4.93	34.51	13.62	25.84	7.66
Mn	1009.10	971.27	470.15	372.49	2267.28	1585.83	1245.42	586.99	1207.91	735.95	454.67	229.47
Fe	77254.79	19341.53	117123.92	14697.31	140359.35	25564.96	112418.65	18703.53	99737.27	26312.44	89065.32	29213.86
Co	10.76	5.08	9.74	3.86	20.84	13.24	23.75	8.36	20.02	8.36	9.78	2.99
Ni	14.24	11.99	28.99	16.55	13.85	10.23	28.89	9.01	21.79	6.71	11.71	3.13
Cu	118.79	65.61	165.71	60.44	75.97	35.64	161.48	58.54	153.00	56.61	117.96	50.71
Zn	89.44	42.63	170.19	66.57	497.75	506.61	177.06	39.61	132.61	58.79	95.32	32.92
Rb	29.92	21.70	37.14	17.25	45.56	35.54	62.80	13.91	49.99	14.48	40.83	12.03
Y	12.62	3.46	17.32	7.26	21.81	8.41	33.88	8.97	21.13	4.68	17.32	4.53
Zr	102.25	33.37	183.48	34.82	122.07	38.45	164.25	23.88	106.96	28.85	116.86	30.78
Nb	6.15	3.47	10.35	2.39	8.28	1.44	10.65	1.37	4.97	1.44	6.63	1.88
In	0.05	0.02	0.08	0.02	0.10	0.05	0.08	0.01	0.06	0.02	0.05	0.02
Sn	1.60	1.38	1.72	0.24	2.19	0.64	1.41	0.18	1.26	0.35	1.13	0.23
Sb	0.31	0.10	0.59	0.15	0.91	0.83	0.44	0.09	0.35	0.12	0.35	0.11
Cs	1.90	1.86	1.10	0.79	1.39	0.43	4.25	1.81	1.88	0.69	1.34	0.29
La	10.17	3.82	15.81	5.75	23.12	8.38	20.85	5.93	14.24	4.30	18.33	8.54
Ce	20.10	11.65	25.89	11.81	47.22	4.08	32.28	8.97	28.84	10.56	32.86	14.16
Pr	2.49	0.93	4.20	1.33	6.54	2.51	6.41	1.85	4.37	1.06	5.14	2.02
Nd	10.87	3.40	16.03	5.28	28.89	8.60	28.42	8.28	18.33	4.17	19.28	6.62
Sm	2.45	0.62	3.65	1.26	4.82	1.88	6.33	1.92	4.19	0.82	4.17	1.09
Eu	0.78	0.16	1.00	0.35	1.76	0.67	1.74	0.42	1.34	0.24	1.27	0.26
Gd	2.11	0.46	3.02	0.98	4.30	1.56	6.00	1.58	3.75	0.84	3.60	1.38
Tb	0.32	0.07	0.49	0.16	0.60	0.16	0.91	0.24	0.60	0.10	0.53	0.14
Dy	2.36	0.56	3.47	1.22	6.43	3.58	6.19	1.54	4.15	0.94	3.52	0.81
Ho	0.47	0.10	0.78	0.22	0.89	0.30	1.27	0.32	0.86	0.15	0.75	0.18
Er	1.49	0.35	2.33	0.69	2.67	0.86	3.72	0.98	2.65	0.43	2.28	0.57
Tm	0.24	0.05	0.35	0.10	0.68	0.45	0.53	0.15	0.42	0.07	0.36	0.08
Yb	1.39	0.31	2.80	1.59	2.41	0.67	3.24	0.68	2.38	0.31	2.13	0.46
Lu	0.22	0.05	0.35	0.10	0.39	0.07	0.50	0.11	0.39	0.06	0.34	0.09
Ta	0.42	0.19	0.72	0.15	0.43	0.06	0.69	0.12	0.34	0.09	0.48	0.12
Pb	18.61	7.89	24.94	6.28	28.32	17.86	19.94	3.26	22.26	5.74	18.16	3.75
Bi	0.20	0.09	0.46	0.11	0.19	0.08	0.26	0.10	0.23	0.10	0.25	0.17
Th	3.91	1.42	7.13	1.22	4.32	1.29	5.61	0.88	3.09	0.96	4.17	0.95
U	1.51	0.58	2.33	0.76	3.41	3.09	1.98	0.33	1.78	0.69	2.82	1.04

M, medium value; SD, standard deviation.

Table 4. Chemical group averages (ppm) and standard deviations for Osmeña period ceramics.

	Group 1		Group 2		Subgroup 3a		Subgroup 3b		Subgroup 3c		Subgroup 4a		Subgroup 4b		Subgroup 4c	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Be	2.46	0.94	2.11	0.73	2.49	0.74	1.69	0.48	1.21	0.25	1.19	0.30	1.28	0.30	1.31	0.32
B	37.66	16.17	35.22	21.01	28.67	7.69	17.25	6.05	28.07	17.78	14.92	8.25	16.78	7.21	17.04	7.53
Na	9696.29	8923.97	24208.74	12174.75	16747.02	4364.60	12353.15	5506.69	16565.75	4225.28	14921.52	8590.63	14955.97	6663.06	4145.46	4076.76
Mg	4165.38	2052.49	7094.49	2337.71	15905.01	3976.10	13835.01	4735.10	8416.25	2462.24	4871.94	1911.93	9507.95	3209.70	7908.83	2546.17
Al	250714.26	73914.01	242611.97	36688.04	226795.40	28903.28	211758.12	30713.41	201673.51	21713.46	205207.15	44319.61	177952.66	38986.27	231583.96	30220.89
Si	585099.37	104798.19	608450.73	36599.08	592827.94	24086.01	568610.06	42581.53	606705.19	42443.99	648969.47	55299.38	659395.79	49281.66	577032.52	46284.91
K	3610.27	1923.65	22396.94	21836.90	17224.80	4868.19	13485.95	6549.76	19692.10	8606.56	10969.58	8661.30	11477.18	3911.82	7493.47	4525.18
Ca	16859.26	10692.04	22030.56	10745.51	18843.23	4676.04	28543.45	13220.83	31359.63	7920.89	27744.66	11226.59	20703.36	9974.76	19645.14	6888.93
Sc	18.62	8.42	14.44	3.90	21.66	4.15	22.68	3.54	18.06	2.42	12.50	3.12	17.74	4.91	23.69	5.53
Ti	6979.85	2481.09	5821.00	1731.36	5829.13	1020.62	6465.29	1701.33	5000.66	1099.97	4303.09	1144.32	4882.79	1088.95	8487.95	2719.99
V	159.81	84.72	50.67	17.20	173.16	47.27	177.03	33.52	134.04	22.53	106.12	26.55	156.72	46.47	223.22	100.82
Cr	47.25	22.54	6.43	4.67	26.40	5.17	30.11	13.68	25.14	4.70	18.63	5.08	25.93	9.14	48.78	24.75
Mn	2743.73	4178.01	462.89	369.22	733.21	318.51	1444.64	1039.08	540.26	249.89	490.16	285.97	779.01	288.50	485.75	408.45
Fe	113606.43	46094.41	60585.72	18225.05	96078.64	13641.80	103935.54	15320.33	88952.12	28108.00	68361.30	17230.07	83095.87	23585.16	125510.98	38029.68
Co	23.71	24.75	7.32	3.36	18.09	4.50	20.64	8.78	10.27	2.71	8.59	3.66	15.11	5.52	12.02	4.94
Ni	19.53	10.04	4.90	2.05	33.33	14.33	19.05	6.22	12.46	7.34	11.01	3.63	16.99	5.33	24.54	12.20
Cu	62.80	37.05	23.93	12.79	232.51	95.42	155.76	52.87	97.67	49.73	74.19	29.81	97.46	34.98	133.53	51.53
Zn	88.21	36.65	77.39	41.66	149.34	74.63	409.14	337.71	155.85	81.31	82.32	23.44	111.71	82.70	209.84	283.30
Rb	13.63	10.38	89.97	27.66	72.87	18.39	54.26	18.31	48.04	12.99	32.08	17.24	36.35	13.24	23.63	11.39
Y	25.08	10.59	20.10	6.63	24.61	5.51	29.66	10.37	15.76	3.33	9.00	2.31	17.58	4.67	12.66	4.00
Zr	223.72	133.50	285.50	71.09	135.23	29.79	159.85	49.46	131.74	35.95	89.92	19.89	94.08	21.16	155.51	46.87
Nb	12.16	6.36	19.73	5.87	7.68	1.75	8.23	2.99	7.21	1.54	4.91	0.96	4.39	0.97	9.71	3.13
In	0.09	0.05	0.06	0.02	0.10	0.02	0.07	0.02	0.05	0.01	0.04	0.01	0.05	0.01	0.09	0.02
Sn	2.48	1.39	2.01	0.61	1.64	0.26	1.48	0.46	2.92	4.95	1.00	0.29	0.97	0.18	1.75	0.46
Sb	1.02	0.43	0.38	0.16	0.48	0.19	0.49	0.16	0.56	0.41	0.37	0.12	0.31	0.11	0.65	0.16
Cs	2.72	2.24	5.24	2.82	4.08	1.78	2.27	1.16	1.98	2.55	1.37	0.78	1.48	0.51	0.82	0.32
La	19.15	6.83	19.46	6.84	13.34	3.83	22.48	8.59	15.97	4.50	9.31	2.98	11.55	2.65	12.04	4.20
Ce	54.67	50.23	32.23	12.93	20.26	4.08	39.40	9.76	28.21	6.44	16.74	6.60	22.15	5.15	18.74	6.04
Pr	6.39	2.12	4.72	1.81	3.46	0.68	6.46	2.31	4.19	1.13	2.37	0.72	3.65	0.84	3.34	1.15
Nd	24.68	9.19	18.33	7.10	14.86	2.70	26.36	9.60	16.13	4.07	8.96	2.66	15.10	3.14	13.30	4.35
Sm	5.64	2.09	3.76	1.38	3.55	0.53	5.76	1.98	3.34	0.63	1.84	0.50	3.42	0.79	2.83	1.00
Eu	2.04	0.55	1.65	0.52	1.19	0.25	1.66	0.44	1.16	0.20	0.76	0.21	1.09	0.27	0.78	0.27
Gd	5.78	3.65	3.80	1.65	4.18	2.01	5.18	1.59	2.91	0.65	1.61	0.41	3.28	1.29	2.63	1.41
Tb	0.66	0.27	0.54	0.20	0.65	0.16	0.83	0.25	0.43	0.09	0.24	0.06	0.47	0.11	0.39	0.15
Dy	5.03	1.62	3.62	1.29	4.65	0.85	5.68	1.85	3.08	0.55	1.73	0.41	3.34	0.84	2.60	0.89
Ho	0.96	0.34	0.72	0.27	0.92	0.18	1.16	0.35	0.62	0.11	0.35	0.08	0.69	0.18	0.54	0.18
Er	2.91	1.07	2.24	0.73	2.98	0.49	3.49	1.06	1.96	0.38	1.12	0.23	2.21	0.48	1.75	0.52
Tm	0.48	0.17	0.35	0.12	0.48	0.07	0.54	0.16	0.31	0.06	0.18	0.04	0.35	0.07	0.29	0.09
Yb	2.91	1.04	2.06	0.62	2.61	0.49	3.00	0.79	1.76	0.35	1.09	0.23	2.06	0.33	1.71	0.40
Lu	0.44	0.14	0.31	0.10	0.40	0.08	0.48	0.13	0.28	0.06	0.18	0.04	0.33	0.06	0.29	0.08
Ta	0.88	0.51	1.23	0.37	0.50	0.12	0.53	0.18	0.49	0.12	0.34	0.07	0.30	0.07	0.60	0.20
Pb	31.08	10.43	21.70	5.92	19.95	3.79	28.21	13.09	23.55	9.33	14.71	3.37	16.38	4.56	26.54	20.11
Bi	0.32	0.23	0.10	0.05	0.39	0.15	0.24	0.11	0.26	0.16	0.23	0.17	0.16	0.08	0.35	0.10
Th	6.67	3.43	8.78	3.67	3.74	1.09	4.91	1.35	4.78	1.13	3.33	0.90	2.70	1.08	5.78	1.53
U	4.51	1.96	3.23	1.20	1.95	0.55	2.13	0.65	2.57	0.84	1.68	0.66	1.39	0.34	2.31	0.65

M, medium value; SD standard deviation.

Conclusions

Overall, these results suggest that the specialised production of earthenware may have increased in the Osmeña period in the Tanjay region. However, local production continued to some extent, as indicated by discrete geochemical groupings of ceramics from Mendieta. In addition, this study further demonstrates the utility of applying geochemical analysis to regional and microregional archaeological studies of pottery production and distribution. Next steps include determining whether chemical groups vary by ceramic type and function and incorporating samples from the earlier Aguilar period (A.D. 500-1000). Several clay samples will be analysed, as well. This research also provides data that can be incorporated into larger projects concerning interregional and long-distance exchange in the Philippines, such as ones including the Guthe Collection of Philippine ceramics at the University of Michigan's Anthropology Museum.

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