Neutron Activation Analysis of Inka Pottery from Fifteen Archaeological Sites in the Lurín Valley, Central Coast of Peru: Insights into Production and Exchange

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Abstract
NAA is applied to a sample of 360 archaeological ceramics mostly dating to the Late Horizon (1470 – 1532 CE) from the major Inka center of Pachacamac and fourteen additional sites in the Lurín valley of Peru's central coast. Results indicate Inka pottery was produced by multiple communities of practice working in distinct locations and the importation of small amounts of pottery from the Inka capital Cuzco, and networks of distribution for this pottery and sociopolitical boundaries in the region are discussed based on results.

Keywords
Neutron Activation Analysis; thin section petrography; archaeology; pottery; Inka

Introduction and Archaeological Background

Tawantinsuyu, the empire of the Inkas, expanded out of the capital region of Cuzco during the Late Horizon (c. 1470 – 1532 CE) to encompass more than 2 million km^2 of Andean South America, controlling an estimated 10 million subjects [1]. Strategies for organizing and exerting control over subjects varied region-to-region, depending on multiple factors, including local resources that existed which the empire wanted to exploit, the distance from the imperial core, levels of local cooperation and resistance, population density, and existing degrees of political integration [2–4]. A commonality of Inka control was the production of state-sponsored rituals, ceremonies, feasts, and other events which promoted the empire's power through the provision of food and drink served in pottery decorated in imperial Inka styles [5]. Inka pottery was recognizable throughout the empire, as it was made in a standard suite of forms and decorated in a limited set of repeated geometric designs [6, 7]. Subjects paid tribute to the empire through labor, called *mit'a* [8], which included military service, working state-owned agricultural lands, or for skilled craft producers, the creation of crafts in distinctive imperial styles [8, 9]. This led to Inka pottery, a ware that was standardized in form and appearance, being produced all throughout the empire by a diversity of producers with different backgrounds, materials, and techniques for pottery production. Previous limited studies into the production of Inka pottery [1, 2, 9–13] have shown diverse models for the level of control over production exerted by the Inkas and the range of distribution that products from one workshop or community of producers may extend. The standardized appearance of Inka pottery additionally may belie both connections and boundaries that existed in the past.

Because of this outward standardization and internal heterogeneity, bulk compositional analysis such as neutron activation analysis (NAA) is an important tool for the study of Inka pottery production. While the outward appearance, in decoration and form, of a ceramic vessel is adaptable and can be copied without knowledge transmission between potters [14], attributes of pottery with lower visibility tend to be more technologically conservative [15]. Furthermore, the techniques that result in these low-visibility attributes are learned during process-oriented transmission by participating in a community of practice, which is a group of individuals that participate in an activity system and transmit knowledge about that activity [16, 17]. Two potters working in different regions may produce a final product, for example an Inka *urpu*, which is outwardly identical in appearance, but they have made different decisions at different steps in the production process to complete the finished product, and those decisions were informed by their social setting and by participation in a community of practice [18, 19]. Following the chaîne-opératoire approach, a finished pottery vessel can be viewed as the culmination of these decisions [19]. Investigating the bulk composition of that vessel through NAA can then, as a proxy, allow these chaînes-opératoires to be compared to each other, and boundaries which may not have been previously visible uncovered [20, 21].

This research applies this approach to the study of Inka pottery from Pachacamac and fourteen additional sites in the Lurin valley of Peru's central coast (Fig. 1). How was the production of Inka pottery at an important imperial center and smaller settlements in its surrounding valley organized? Was it produced centrally at one location and distributed long distances across the valley, or was its production decentralized and distribution and exchange more restricted? Did different communities of practice supply different contexts, sites, or regions?

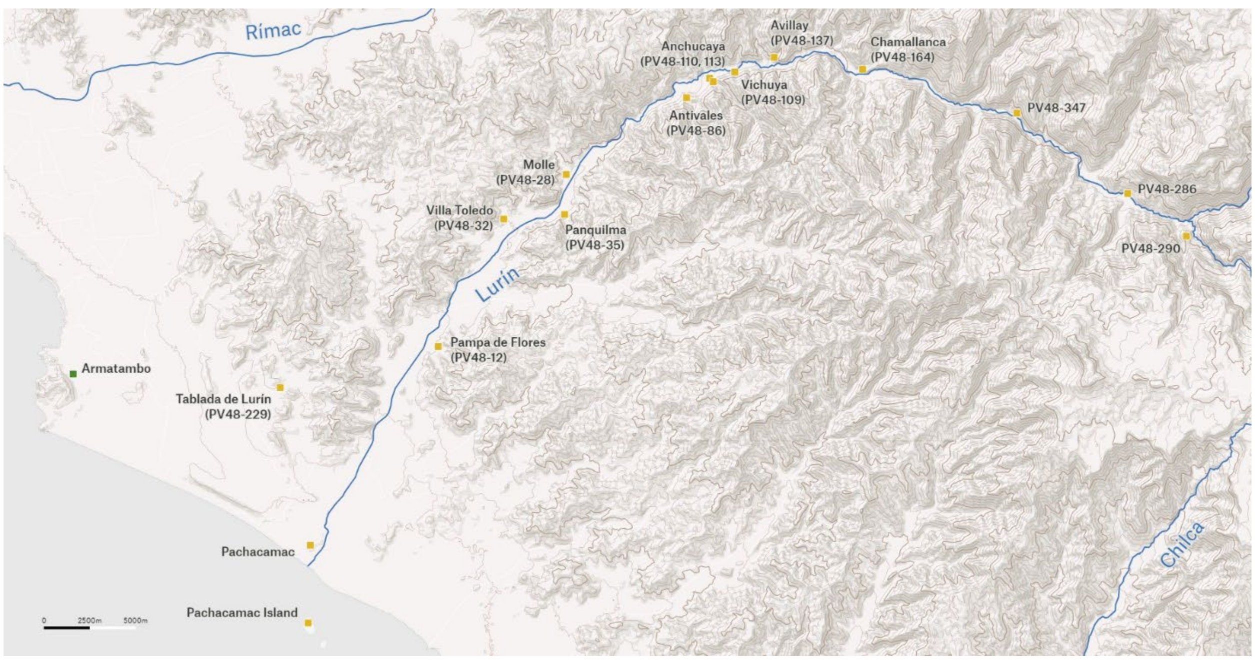

Fig. 1 Map of the Lurín valley, showing sites where samples were excavated and collected, or otherwise mentioned in the text.

Pachacamac is a 465-hectare archaeological site located on the Pacific coast just to the north of the mouth of the Lurín River (Fig. 2). Presently it sites just south of metropolitan Lima. Human occupation at Pachacamac dates back at least as far as the Early Intermediate Period (200 – 600

CE) [22]. During the Late Horizon (1000 – 1470 CE), prior to Inka conquest, Pachacamac was the political center of the Ychsma polity, a hierarchical society centered on the Lurín and Rímac valleys of Peru's central coast [23]. It was also the home to an oracular *wak'a* (that, at the time of Spanish conquest, had pan-Andean importance [24].

Pachacamac was brought under the control of the Inka empire around 1460 to 1470 CE [25, 26], and the Inkas transformed the site into a major Inka political and ceremonial center. This included the abandonment of some pre-Inka spaces, relocation of parts of the population, and large-scale architectural modifications, including the renovation of existing structures and the construction of new ones, such as the Pilgrims' Plaza, the Mamacona "Convent," the Tauri Chumpi palace, and the Temple of the Sun [23, 27–30]. While the practice of remodeling and building over existing structures at subjugated political centers was not uncommon, the renovation at Pachacamac is likely the most monumental example of the Inka adapting its architecture and planning to an existing layout [31]. Ethnohistoric sources describe the Inka incorporation of Pachacamac as motivated by the cultivation of coca and the appropriation of the important religious center of Pachacamac [23, 32, 33], and the ceremonies that occurred in Inka spaces there utilized pottery in the distinctive Inka styles for their production.

Pachacamac's large size and apparent imperial importance are unique in the central coast and in the Lurín valley, and this research is focused on elucidating the relationship that it had as a center with surrounding settlements. Research into Inka pottery production and distribution has identified multiple models, from the production at a central location and distribution across an entire region [34] to a small embedded workshop creating material for use at one specific structure [35]. Previous research into Inka pottery production at Pachacamac [36] has identified multiple compositional groups present, which may correspond to multiple communities of practice. To what extend were the products of these communities distributed beyond the imperial center of Pachacamac?

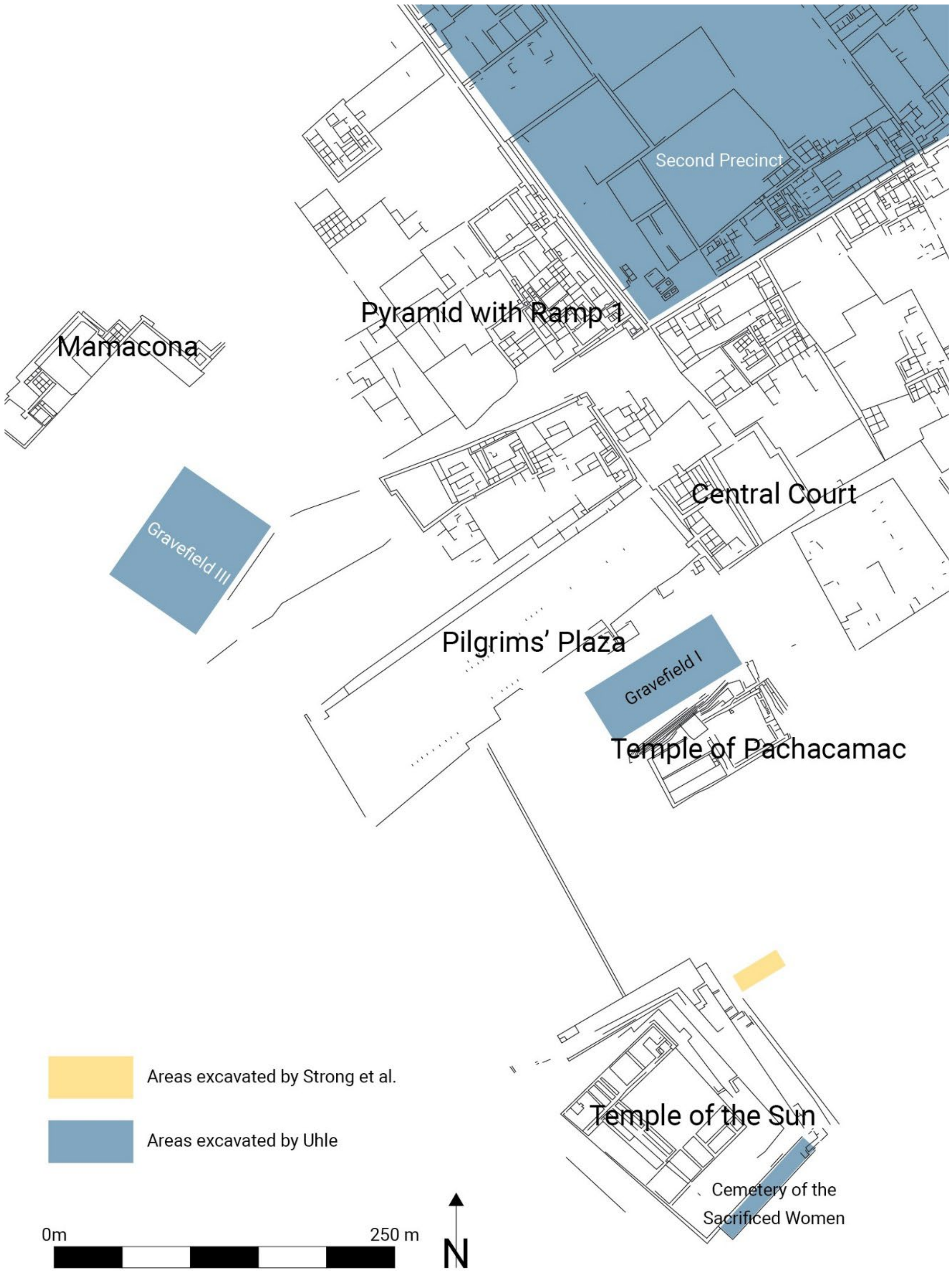

Fig. 2 Map of Pachacamac, showing locations of excavations by Max Uhle and William Duncan Strong, with additional notable structures highlighted.

Methods

The Archaeometry Laboratory at MURR has been processing samples and collecting data with the same parameters for its entire 35-year existence to ensure data interoperability and to create a comprehensive database of archaeological materials, including pottery. Laboratory methods for the analysis of archaeological ceramics at MURR have been described in detail elsewhere [37–39]. To briefly summarize, a fragment of roughly 1 cm^2 was removed from each sherd that was analyzed. Because NAA is a bulk analytical technique, all surfaces were removed with a silicon-carbide grinding tool to account for any compositionally distinct decorations added to the surface of the pottery, either through a slip clay or pigments used for decoration. This also accounts for any post-depositional contamination from taphonomic processes. The burred pieces were rinsed in deionized water and allowed to dry. Samples were then homogenized into a fine powder using an agate mortar and pestle and placed in a drying oven for a minimum of 24 hours at 105° C. Once completely dry, samples were weighed into two vials: 100 mg of powder was weighed into a high-density polyethylene vial, and 200 mg of powder weighed into a high-purity quartz vial and sealed under vacuum. Weights are recorded to the nearest 0.01 mg, and values were within ± 2 mg of the target weight.

The portions of the samples in the polyethylene vials were loaded into rabbits in pairs and transported to the reactor via a pneumatic tube system for an irradiation of five seconds by a neutron flux of 8×10^{13} n cm^{-2} s^{-1}. At the beginning, middle, and end of this process, standards from NIST of SRM1633c Coal Fly Ash, SRM688 Basalt Rock, and an in-house quality control of New Ohio Red Clay were also irradiated under the same parameters. After a decay of 25 minutes, samples were counted for a period of 12 minutes by high-purity germanium detectors, yielding values in parts per million for 9 elements: Al, Ba, Ca, Dy, K, Mn, Na, Ti, and V.

The portions of the samples in quartz vials were bundled in groups of 50 samples along with standards from NIST of SRM1633c Coal Fly Ash, SRM679 Brick Clay, and New Ohio Red Clay as a quality control. These bundles were irradiated for a period of 24 hours in a neutron flux of 6 $\times 10^{13}$ n cm^{-2} s^{-1}. After an initial decay of seven days, these samples were washed and placed on automatic sample changers which moved samples in front of a high-purity germanium detector for a period of 30 minutes each, yielding counts for As, La, Lu, Nd, Sm, U, and Yb. Samples were then allowed to decay for an additional two weeks before being returned to the sample changers for a second detection period of 2.5 hours, yielding counts for Ce, Co, Cr, Cs, Eu, Fe, Hf, Ni, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr.

Sample

Previous analysis [36] examined the composition of 149 ceramic vessels from a midden on the northeast face of the Temple of the Sun at Pachacamac, excavated by William Duncan Strong and colleagues in 1941 [40]. This pottery was stylistically Inka polychrome, dating to the Late Horizon, as well as styles local to the central coast, including contemporary Ychsma styles dating to the Late Horizon and Late Intermediate Periods (CE 1000 – 1470), and Lima styles of pottery, dating to the Early Intermediate Period (CE 200 – 600). Analysis of these data identified three distinct compositional groups. Inka Polychrome samples were present in all three compositional groups, while samples decorated in contemporary and earlier local styles were present only in one of the groups. Additionally, of the two groups comprised of Inka pottery, one of these groups was primarily just one form: the Inka *urpu*, a long-necked, pointed-bottomed vessel used for the serving and storage of *chicha*, a maize beer central to Andean ceremonial life and the most ubiquitous Inka form found outside the imperial capital. *Urpus* were also members of the other two compositional groups.

Building on the results of this earlier analysis, the sample was expanded by an additional 211 ceramic vessels, bringing the total sample size to 360. Fifty eight of these new samples were from Pachacamac: 38 from Strong and colleagues' excavations at the Temple of the Sun, and 20 from the 1897 excavations of Max Uhle [41], who excavated and made collections at several loci around the site, including a cemetery on a southeast terrace of the Temple of the Sun, several cemeteries around the site including one at the base of the Temple of Pachacamac, and the second precinct, an elite residential sector immediately to the north of Pachacamac's ceremonial core. Three samples were excavated from Pachacamac Island, a small, rocky island immediately off the coast of Pachacamac in 1935 by Harris Kennedy, a medical doctor visiting the island under the auspices of the Harvard Club of Boston, a local alumni association. Samples from Pachacamac Island were Inka polychrome in style, except for one "waster," a piece of pottery that became deformed or otherwise unusable during the firing process. The remaining 150 samples were collected from an additional thirteen sites in the Lurín valley by Thomas C. Patterson during a survey in 1964 (Fig. 1, Table 1) [42–44]. These sites vary in size and level of

Inka presence. Some have significant Inka constructions and presence, while others are secondary or tertiary centers with only minimal evidence of Inka activity. All samples are currently curated in museums or collections facilities in the United States, including the American Museum of Natural History in New York (AMNH), the University of Pennsylvania Museum of Archaeology and Anthropology in Philadelphia (Penn Museum), and the Harvard Peabody Museum of Archaeology and Ethnography in Cambridge (Peabody), and appropriate permissions were obtained from these museums prior to analysis.

The samples that were chosen were restricted to one of a few categories: pottery that was stylistically Inka Polychrome; pottery that was decorated in styles that were closely associated with Inka presence in the valley, like polished blackware, a style not present in pre-Inka periods of Ychsma pottery [45] that is more commonly associated with the Chimú of Peru's north coast [9] or the Chincha of Peru's south coast [46] but that saw a wider distribution along Inka networks during the Late Horizon; a select few forms of contemporary local Ychsma styles of pottery, including the cara-gollete, a form that shared morphometric similarities to the Inka *urpu* and that was made primarily during the Late Horizon [45, 47], and wasters. Inka polychrome pottery was focused on three primary forms that were commonly found in the Lurín valley (and are among the most frequent to be found in Inka contexts in the provinces [48]): *urpus*, flat bowls with vertical walls, and shallow plates. These forms were all primarily used for serving or storing comestibles that were consumed at state-sponsored ceremonies, and as a result played an important role in the creation and maintenance of imperial power among subjects of the Inkas [5, 48]. Inka Polychrome pottery comprised 54% of the sample (n = 195), and is the focus of this research.

Table 1 Distribution of decorative styles and Inka polychrome forms by site

	Inka Polychrome Pottery				
Site	***Urpu***	**Bowl**	**Plate**	**Blackware**	**Local Styles**
Pachacamac	34	9	43	19	102
Pachacamac Island	1	—	1	—	1
Tablada de Lurín (PV48-229)	2	1	—	1	2
Pampa de Flores (PV48-12)	2	4	—	6	10
Villa Toledo (PV48-32)	8	3	—	4	3
Panquilma (PV48-35)	3	4	—	5	—
Molle (PV48-28)	1	1	—	2	—
Antivales (PV48-86)	—	1	—	4	—
Anchucaya (PV48-110, 113)	—	3	—	4	—
Vichuya (PV48-109)	—	1	—	—	—

Avillay (PV48-137)	29	2	1	—	1
Chamallanca (PV48-164)	3	—	—	1	—
PV48-347	26	3	1	—	—
PV48-286	4	2	—	—	—
PV48-290	3	3	—	—	—

Results

Prior to any analysis of the data, the element nickel was first removed, as values registered below laboratory detection limits for 84% (302 out of 360) samples. The remaining 32 elements were used in a suite of multivariate statistical analyses that are commonly used to interpret archaeological compositional data [49–53]. The goal of these analyses is to identify distinct homogenous groups. In the interpretation of compositional data of archaeological artifacts, these groups are often assumed to represent geographically restricted sources, based on the provenance postulate [54], with the most largest or most frequently occurring groups assumed to represent local material, based on the criterion of abundance [55]. While these are valuable interpretations and insights that can be gleaned from compositional data, these data also hold the potential to examine a more nuanced picture of the archaeological past, especially when applied in combination with complementary methods. Ceramics are an anthropogenic phenomenon, and while the elemental composition of a piece of pottery is in part the product of the geologic materials used in its creation, it is also affected by choices made by potters during the production process [19, 56]. As these production processes, or chaînes opératoires, are informed by the social environment in which techniques for pottery production are learned, so to can differences between them elucidate social and political boundaries. The bulk compositional analysis of pottery is a useful proxy for the investigation of differences between multiple chaînes opératoires—while the specific differences in choices made by potters will often require additional analyses to thoroughly describe, these choices can and often do result in compositional variation. For this reason, the majority of elemental values detected were used in the statistical analysis of the dataset.

Samples were assigned to compositional groups using a combination of hierarchical cluster analysis (HCA), the calculation of a total variation matrix (TVM), and principal component analysis (PCA) [38]. After group assignments were made, group membership was evaluated and refined through the calculation of Mahalanobis distances (MD).

Building on the results of the previous study [36], the 360 total samples were assigned into 5 compositional groups, along with 22 outliers (Fig. 3). The full dataset can be found in Appendix A. Results from the PCA (Fig. 4) indicate that the elements that are positively loaded for PC1 are Cs, Sb, As, Rb, Zn, and Th; for PC2, Cr, Ca, Ta, Ce, La, Nd, and Dy; and for PC3, Ca, As, V, Mn, and Co. Instead of assigning groups a number, groups were named based on either a defining characteristic of their members, or a probable location of their manufacture. After assignment into compositional groups and evaluation of group composition, samples were compared by decorative style, and Inka polychrome samples were compared by form (Table 1). Inka Polychrome pottery is present in each group. The distribution of samples from each compositional group was also compared by site (Table 2).

Table 2 Distribution of compositional groups by site

Site	Lower Lurín	Armatambo	Urpu	Upper Lurín 1	Upper Lurín 2	Outlier
Pachacamac	104	77	18	2	—	6
Pachacamac Island	1	—	1	—	—	1
Tablada de Lurín (PV48-229)	1	4	—	—	—	1
Pampa de Flores (PV48-12)	17	5	—	—	—	—
Villa Toledo (PV48-32)	8	10	—	—	—	—
Panquilma (PV48-35)	10	2	—	—	—	—
Molle (PV48-28)	3	1	—	—	—	—
Antivales (PV48-86)	2	—	—	—	—	3
Anchucaya (PV48-110, 113)	2	4	—	—	1	—
Vichuya (PV48-109)	1	—	—	—	—	—
Avillay (PV48-137)	9	5	1	14	—	4
Chamallanca (PV48-164)	—	1	—	—	3	—
PV48-347	1	8	—	11	1	5
PV48-286	2	—	—	3	—	1
PV48-290	—	—	—	5	—	1

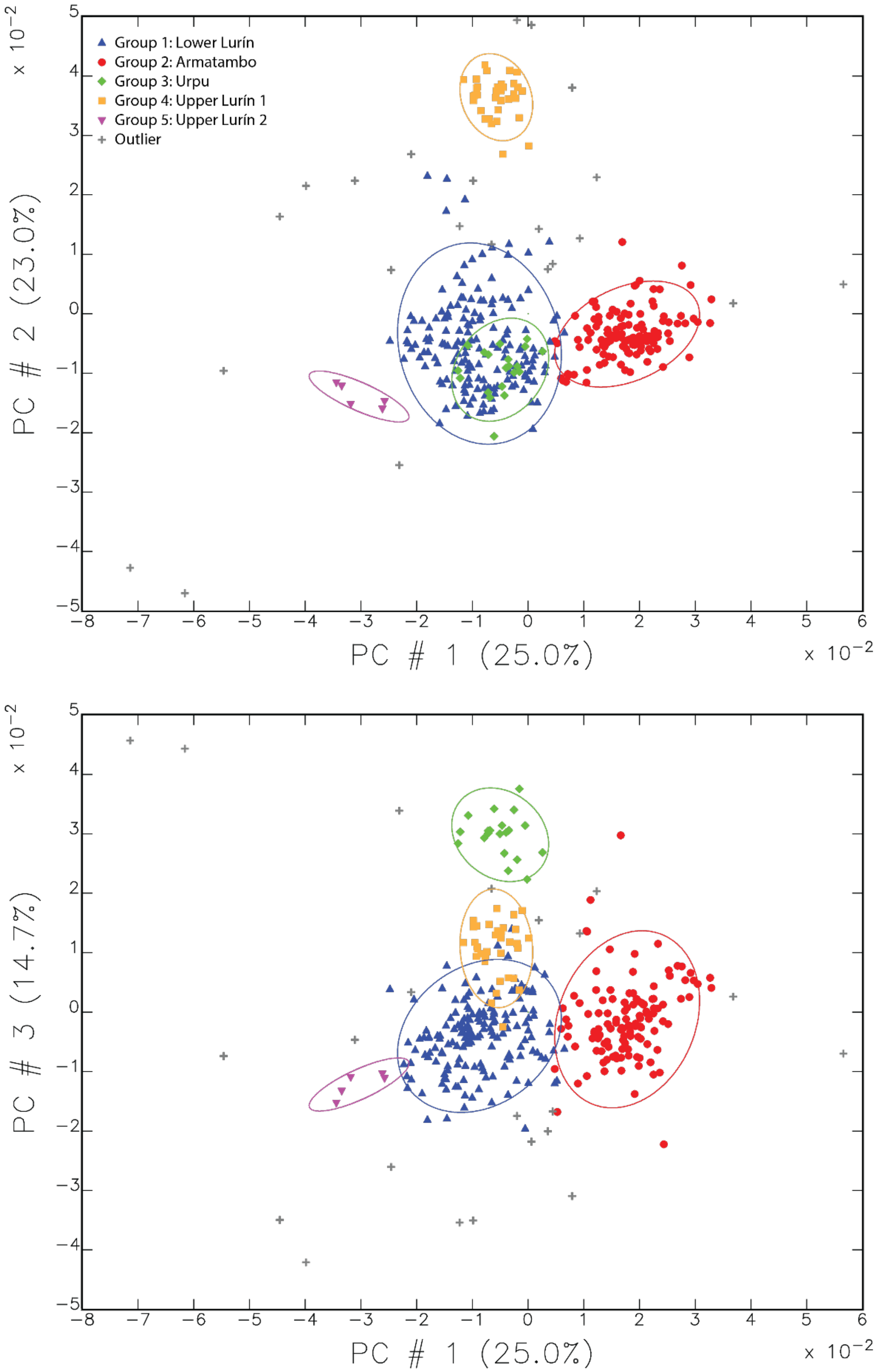

Fig. 3 Scatterplots of PC1 vs PC2 and PC3 showing compositional groups identified in this analysis. Ellipses are drawn at 90% confidence intervals.

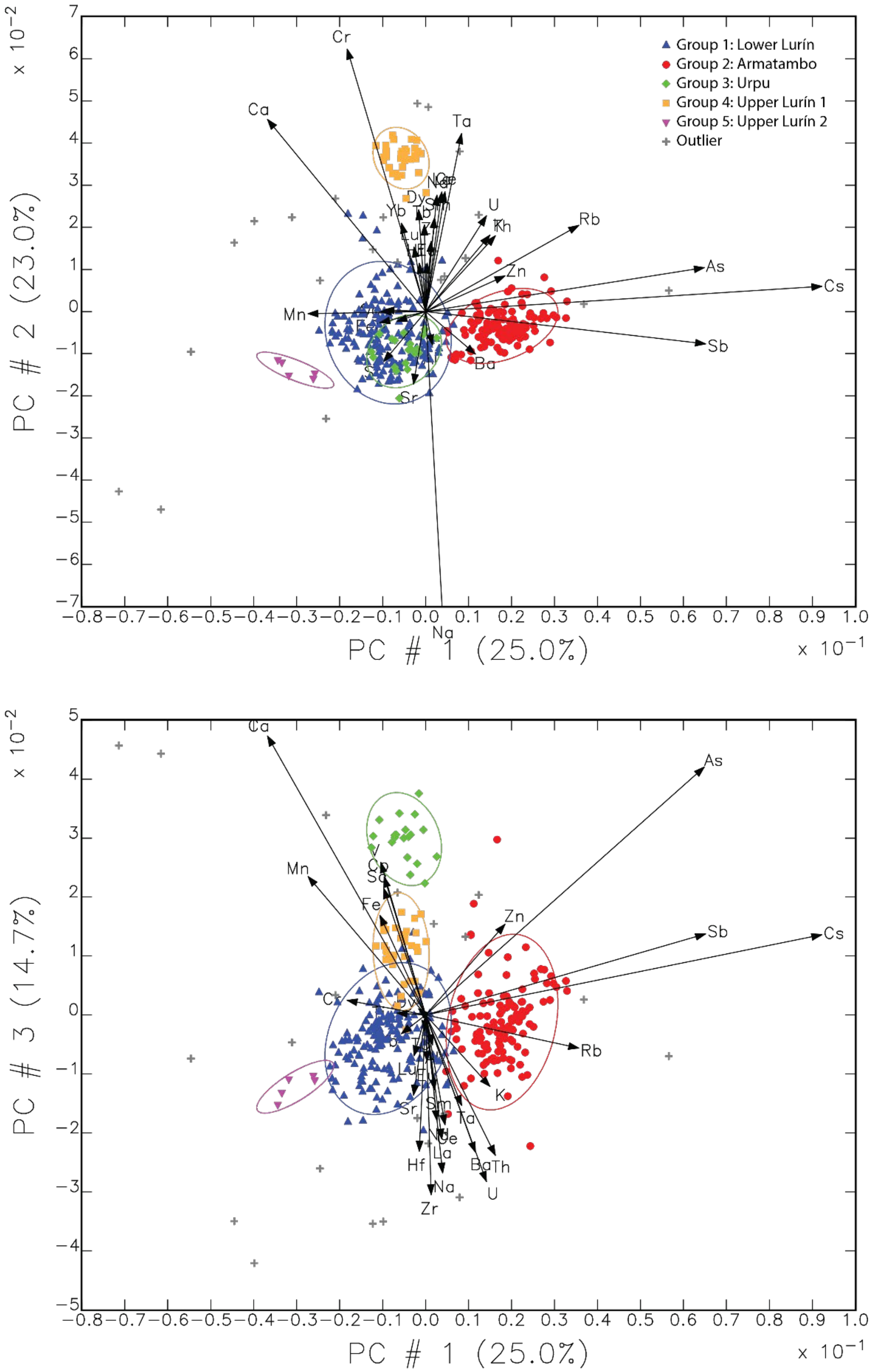

Fig. 4 Biplot of PC1 vs PC2 and vs PC3 showing compositional groups identified in this analysis and elemental vectors, scaled to 50%. Ellipses are drawn at 90% confidence intervals.

Group 1: "Lower Lurín"

The first group, which I refer to as "Lower Lurín," corresponds with the previously identified Group 1 [36]. This group is comprised of 161 members. From the earlier study, nearly all of the local styles, both earlier Lima and later Ychsma, were assigned to this group. Additionally, 56 samples in this group are Inka Polychrome in style, including 19 *urpus*, 21 bowls, and 14 plates. Of the samples, 104 were from Pachacamac, and 53 were from other sites in the valley. This group is called "Lower Lurín" because the location of its production is hypothesized to be somewhere in the lower Lurín valley. While no workshops or other evidence of ceramic production dating to the Inka period have been found at Pachacamac itself, it is hypothesized that this pottery was produced at least in the region, and potentially at the site of Pampa de Flores, due to the presence of wasters from there that are assigned to this group.

Group 2: "Armatambo"

The second group, which I refer to as "Armatambo," corresponds with the previously identified Group 2 [36]. This group is comprised of 117 members. A total of 68 samples assigned to this group are Inka Polychrome, including 26 *urpus*, 10 bowls, and 27 plates. A total of 52 samples were from Pachacamac, and 40 were from other sites in the valley. This group is called "Armatambo" because it is hypothesized that these samples originated at the site of Armatambo, which was another Inka state installation located on the Pacific coast approximately halfway between the Lurín and Rímac valleys. While samples from Armatambo have not yet been analyzed using NAA, there are visual similarities in the petrographic analysis of samples assigned to this group and recently published samples from Armatambo [57], including the mineralogy, size, angularity, and frequency of aplastic inclusions (Fig. 5). Additionally, previous research by Krzysztof Makowski and colleagues [58] utilizing Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry comparing pottery from the Lurín valley to clay sources in the region identified three possible loci of clay extraction, one of which is near Armatambo and compositionally distinct from other extant sources in the valley. Further compositional analysis of material from Armatambo would lend additional support to this hypothesis, and is a future direction for research.

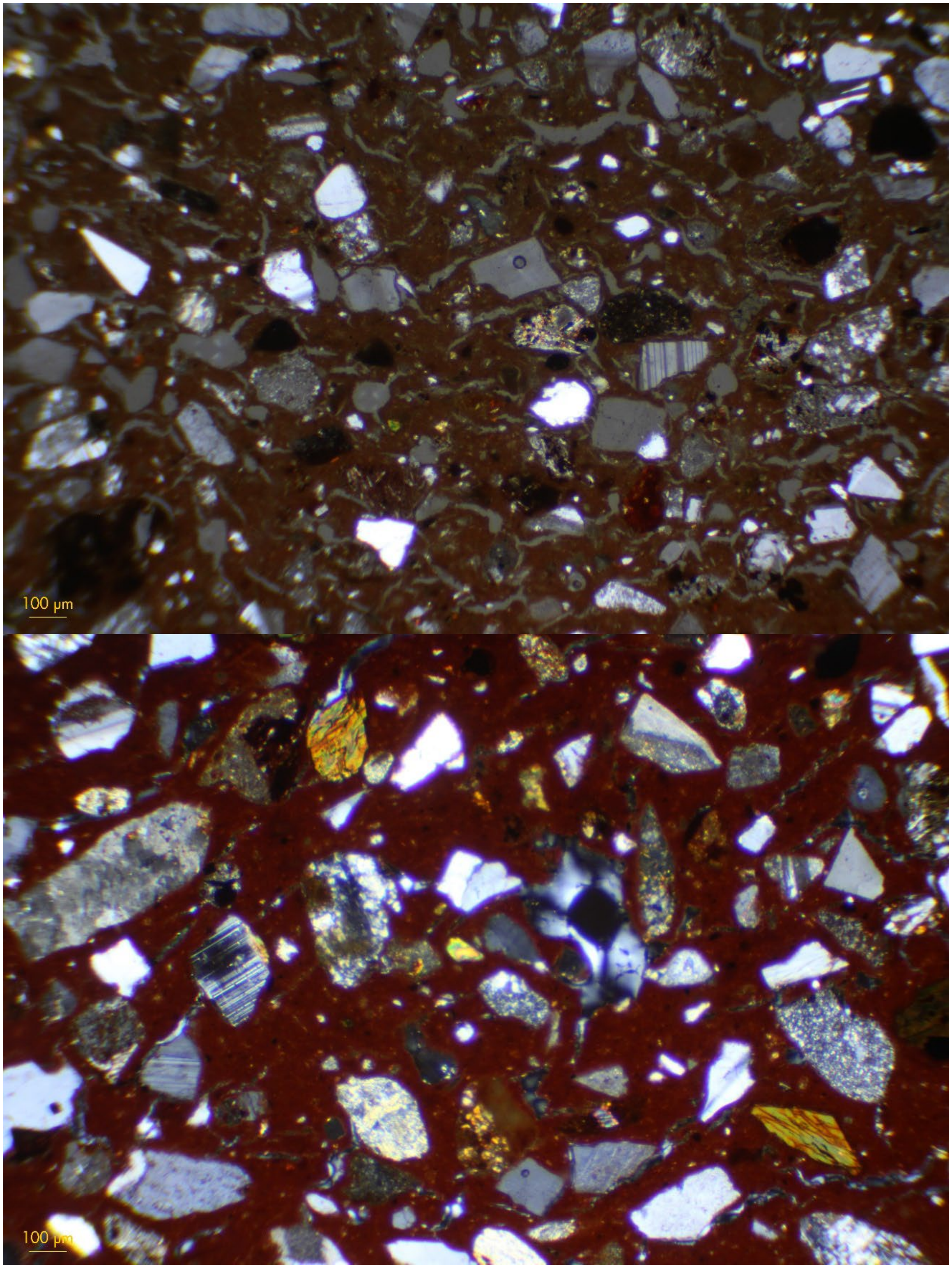

Fig. 5 Photographs of petrographic thin sections at 4x magnification in cross-polarized light (XPL) showing artifacts that have similarities to those illustrated in Pareja et al. Above: Penn Museum object no. 34277D; Below: AMNH Object No. 41.1/8966 V34.

Group 3: "Urpu"

The third group, which I refer to as "Urpu," correspond with the previously identified Group 3 [36]. This group is comprised of 20 members, all of which are Inka Polychrome and 19 of which are *urpus*, with one plate. Additionally, 19 of these samples were from Pachacamac, while the remaining sample is an *urpu* from the site of Avillay. Petrographic analysis of this group supports a relationship between this group and some members the Armatambo group. Petrography of members of this group is defined by angular, coarse to very coarse inclusions of intrusive igneous rocks, including granites and diorites. There are some samples assigned to the Armatambo group that are distinct from the petrography previously described which are characterized by inclusions that share the same size, angularity, frequency, and level of sorting as those in the Urpu group. The only distinction is that the samples in the Armatambo group have inclusions of extrusive igneous rocks, like rhyolite and basalt (Fig. 6). Both intrusive and extrusive igneous rocks outcrop in the lower Lurín valley and around the area of Armatambo, and this group may represent a single community of practice utilizing a distinct raw material to create a specific form of pottery (the *urpu*), or pottery that was meant to be used in a specific location, as nearly all samples assigned to this group were from the Temple of the Sun at Pachacamac.

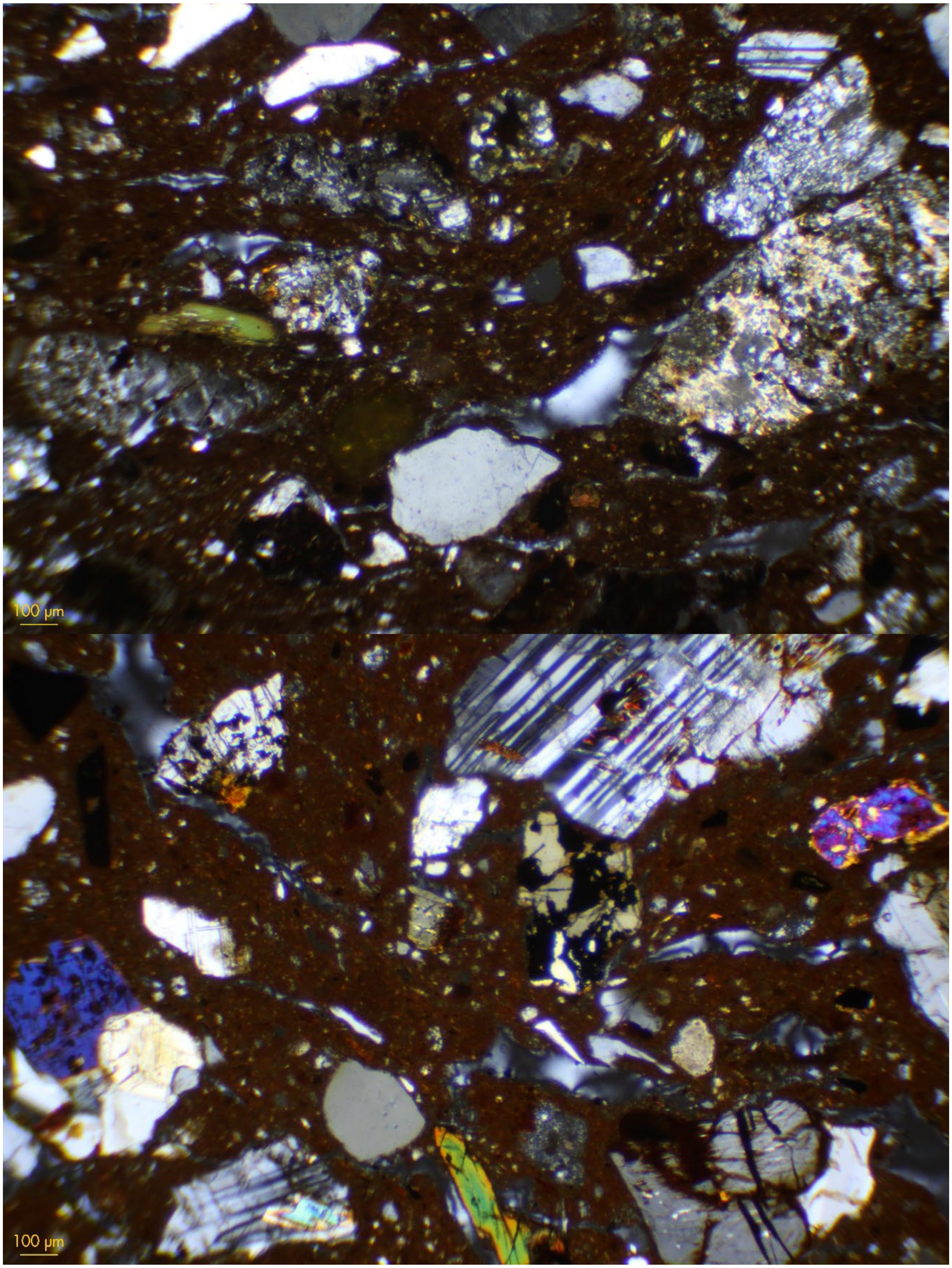

Fig. 6 Photographs of petrographic thin sections at 4x magnification in cross-polarized light (XPL) showing the difference in minerology between members of the Armatambo group (above)

and members of the Urpu group (below). Above: AMNH object no. 41.1/8966 V01; Below: AMNH object no. 41.1/8966 U11.

Group 4: "Upper Lurín 1"

The fourth group, referred to as "Upper Lurín 1" was newly identified in the expansion of this study. This group is comprised of 35 members, all of which are Inka Polychrome pottery, including 33 *urpus* and 2 bowls. Just two samples are from Pachacamac, and the remaining 33 ssamples are from sites up-valley. Aside from the Pachacamac samples, all members of this group are from sites in the far upper valley, including Avillay, PV48-347, PV48-290, and PV48-286. Based on an analysis of macroscopic characteristics, Feltham [43] hypothesized two Inka pottery manufacturing centers for the Lurín valley: one at Pachacamac and one at Sisicaya, near Chamallanca. Citing thorough ethnohistoric research, she proposed that these manufacturing centers corresponded to a political division within Inka administration of the valley that corresponded to a pre-Inka boundary between the inhabitants of the lower Lurín valley and the Yauyos, who incurred into the upper valley from the highlands. While the location of the manufacturing centers cannot be confirmed by the compositional data alone, it is likely that this compositional group corresponds to the products of the upper manufacturing location, and the macroscopic appearance of its members, with a paste that is browner compared to the more orange-colored paste of the lower valley samples, corresponds to the distinctions described by Feltham.

Group 5: "Upper Lurín 2"

The final compositional group, referred to as "Upper Lurín 2," was also newly identified in this expansion of the study. It is the smallest compositional group, being comprised of just five members. All members of this group are Inka polychrome pottery, including 4 *urpus* and 1 bowl, and all were found at upper-valley sites. It is difficult to make any resolute statements about such a small group, but it is possible that this group represents either a distinct community of practice working in the same location as the one which produced pottery assigned to Upper Lurín 1, or a distinct choice in practice made by the same community, similar to the relationship between the Urpu and Armatambo groups. Alternatively, it could represent a unique locus of manufacture for Inka pottery separate from the others already discussed.

Outliers

In addition to the groups discussed above, there were 22 outliers that were not assigned to any groups. These groups were compared to the database of archaeological ceramics at MURR. This database contains over 8,900 samples from South America, most of which are from the Andes, spanning nearly the entire time depth of ceramic production on the continent.

A comparison was made against Inka pottery from the capital region of Cuzco which were analyzed at MURR as part of a research project of Richard Burger [59]. A total of five samples had compositional similarity with compositional groups from Cuzco: two samples, one from Pachacamac Island and one from PV48-347, fit with Burger's Group 2, and three samples, one from Pachacamac, one from Avillay, and one from PV48-290 fit with Burger's Group 4A (Fig. 7). Analysis from petrography shows that several of these samples have a red paste with a well-sorted andesite temper, which is a hallmark of pottery from Cuzco (Fig. 8) [60]. Previous studies have used NAA to identify imports from Cuzco to other provincial Inka centers [1], and this phenomenon is observed in the Lurín valley as well.

Additional outliers could not be reliably assigned to any compositional groups from other loci of Inka manufacture that have been previously identified in the MURR database. These ceramics may represent communities of practice outside the Lurín valley, innovation by individuals or communities of practice utilizing different materials and methods, or statistical variation within the raw materials used.

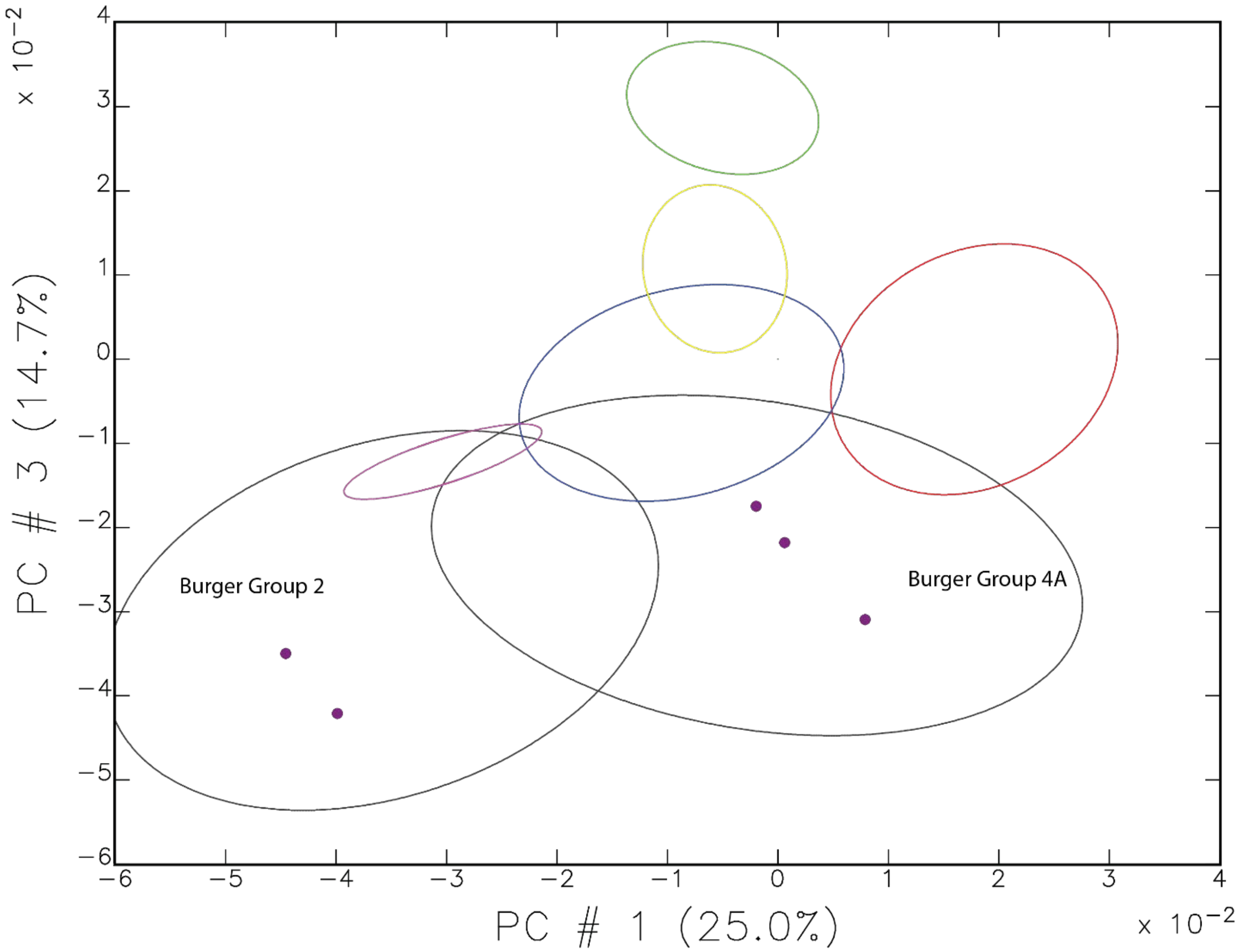

Fig. 7 Scatterplot of PC1 vs PC3 showing compositional groups identified in this analysis along with the two Cuzco compositional groups identified by Burger et al., and outlier samples assigned to those groups. Ellipses are drawn at 90% confidence intervals.

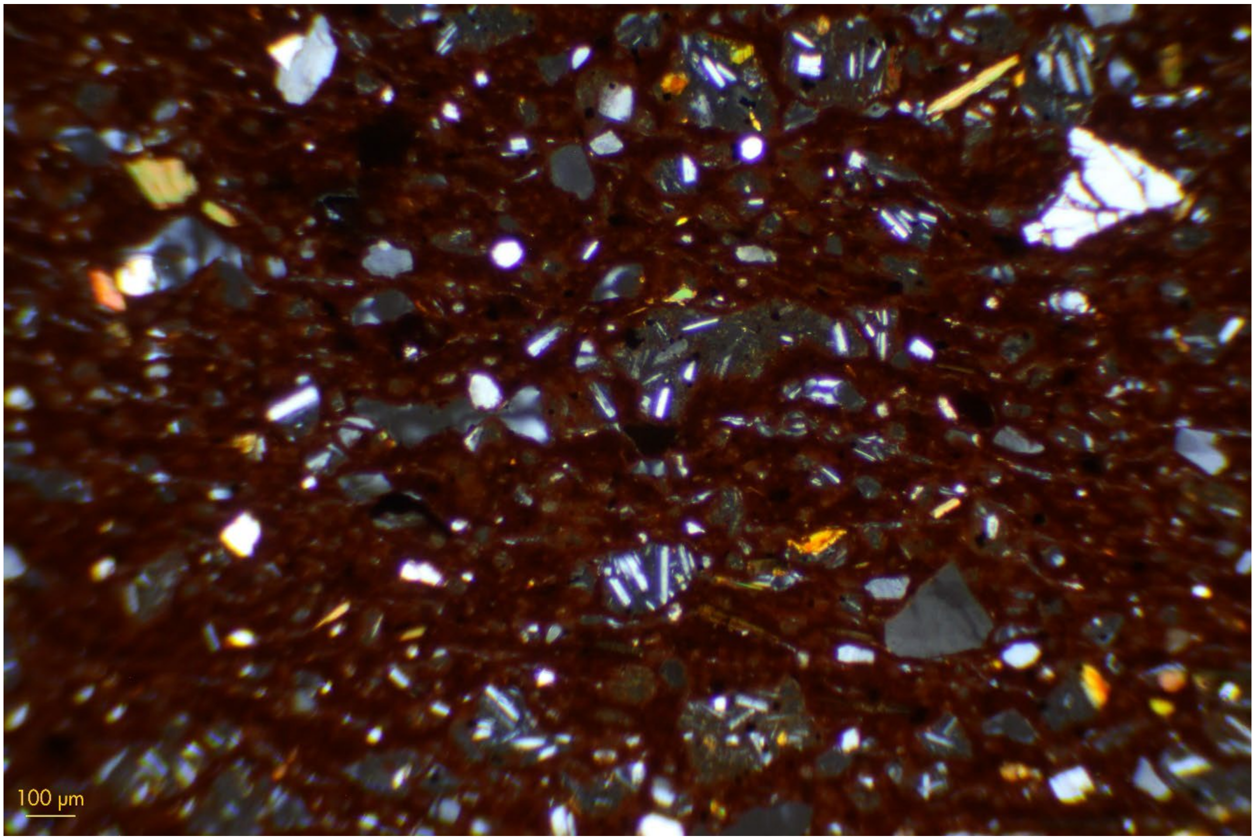

Fig. 8 Photographs of petrographic thin section at 4x magnification in cross-polarized light (XPL) showing andesite temper that is typical of the Cuzco region. AMNH object no. 41.1/8970 B.

Discussion

The distribution of forms among the groups is complicated somewhat by the prevalence of plates at Pachacamac, which are almost entirely absent from other sites in the valley. In a chi-squared goodness of fit test excluding Pachacamac, the distribution of forms across the compositional groups was found to be not significant ($p = .1813$). Outside of Pachacamac, *urpus* dominate the assemblage of Inka Polychrome pottery (n = 58 of 71, 81.7%). While the assemblages analyzed here represent surface collections, and more thorough excavation may change the picture, based on these data, whatever state-sponsored events occurred in the Lurín valley outside of Pachacamac did not utilize plates or bowls as frequently as those that occurred at Pachacamac. Analysis of quantitative (e.g., rim diameter, wall thickness, wall angle) and qualitative (e.g., paint color scheme, the presence and direction of burnishing, decorative motifs present) attributes of similar forms of Inka pottery across the compositional groups revealed no significant differences between the compositional groups. Building on conclusions from previous research [36], the decoration of Inka pottery was standardized across different communities of practice, and perhaps this was an element of Inka pottery production that was overseen or controlled directly or indirectly by state agents, or at the very least that innovation within established canons of decoration was discouraged.

The distribution of compositional groups was also compared across sites. Pottery from the two Upper Lurín groups was generally restricted to sites in the upper valley, with only two samples from Upper Lurín 1 being found at Pachacamac. In contrast, the Lower Lurín and Armatambo groups are generally restricted to sites in the lower valley, with only a few samples collected at sites up-valley of Avillay. The Urpu group was restricted to Pachacamac except for one sample from Avillay. Within lower valley sites, some sites did appear to have more pottery from either the Lower Lurín group or the Armatambo group. Comparing the distribution of samples of different compositional groups across specific excavation contexts at Pachacamac, there are no contexts that have pottery from just one group. If these compositional groups represent different communities of practice, their products (which are standardized across compositional boundaries in measures of form and decoration) are not distributed across different networks, but appear to be present together in multiple contexts, potentially supporting movement of these objects to a greater degree of freedom within the region (though less so across other social or political boundaries, like the one between the lower and upper portions of the valley).

The site of Avillay stands out from this distribution pattern, as it had pottery in roughly equal proportions from both up-valley (n=14) and lower-valley (n=15) compositional groups. Without samples from better controlled excavation contexts, it is difficult to hypothesize this anomalous distribution pattern. Inka structures did exist at Avillay [61] and it may have played an important role in the administration or control of the middle valley, or otherwise had a stronger Inka presence than other sites in the region.

Conclusions

There are several conclusions that can be drawn from the interpretation of these data. First, there were multiple communities of practice supplying Inka Polychrome pottery to Pachacamac, and these communities of practice were also supplying Inka Polychrome pottery to other sites in the

Lurín valley. There were at least two distinct communities of practice involved in this production, hypothesized to have been located at Armatambo and Pampa de Flores, or somewhere else in the lower Lurín valley. It is possible that there were greater than two communities involved, and the presence of distinct groups identified by thin section petrography (Figs. 6 and 7) comprising a single compositional group supports this interpretation. Additionally, at least one of these communities of practice utilized a different material when making a different form, as evidenced by the Urpu group's petrographic similarity and compositional and mineralogical dissimilarity to some members of the Armatambo group.

Second, the existence of a political boundary that is described in ethnohistoric documents in the upper Lurín valley is supported by compositional data. With regards to the movement of pottery, while this boundary is identifiable, it also was not firm and small amounts still moved across it in both directions, especially to larger sites. Small amounts of pottery from other Inka centers outside the valley and region (like the capital of Cuzco) were also brought to major centers in the Lurín valley.

Finally, this research demonstrates that beyond applications of provenience, bulk compositional analysis like NAA is a useful tool for identifying distinct communities of practice, especially when used as part of a multi-method approach, in concert with complementary techniques like thin section petrography.

Acknowledgments

The Archaeometry Laboratory at MURR is supported by Grant number 2208558 from the National Science Foundation. This research was supported, in part, by a Dissertation Fieldwork Grant number 9810 from the Wenner-Gren Foundation. I am especially grateful to Thomas C. Patterson for permission to sample the Lurín valley survey collection, and to John Bierhorst and DJ Conley for assistance with sampling. I thank Sumru Aricanli, Charles Spencer, David Hurst Thomas, and Kristen Mable at the American Museum of Natural History; Clark Erickson, Lucy Fowler Williams, Bill Wierzbowski, and Marie-Claude Boileau at the Penn Museum; Viva Fisher and Laura Costello at the Harvard Peabody Museum; and Frank Martinez at Burgess Storage in Riverside, California. As the author of this paper, I am responsible for its contents, errors, and any unintentional misinterpretations.

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