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STUDYING TECHNOLOGICAL PRACTICES AT A LOCAL LEVEL: NEUTRON ACTIVATION AND PETROGRAPHIC ANALYSES OF EARLY CERAMIC PERIOD POTTERY IN CENTRAL CHILE*

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We discuss neutron activation and petrographic analyses of domestic ceramics and some raw materials from five archaeological sites in the Valdivia de Paine locality, in Central Chile. During the time period studied, the area was occupied by small-scale horticultural groups with disperse and sedentary or semi-sedentary settlement patterns. The analyses indicate that diverse local raw material sources were used in pottery production, and shared by members of different co-residential units and between different cultural groups. The data indicate as many similarities as differences among the technological practices of pottery-producing groups who lived in spatial proximity. The results have implications for the understanding of pottery-producing communities at a local level, as well as small-scale groups in general.

KEYWORDS: NAA, PETROGRAPHY, POTTERY, LOCALITY, SMALL-SCALE GROUPS, CENTRAL CHILE

INTRODUCTION

Early Ceramic Period archaeology in Central Chile has a long history of focusing on regional-scale cultural description and social organization (Falabella and Sanhueza 2005–6; Sanhueza *et al*. 2007). In recent years, research has been carried out using a local-scale approach. This level of analysis is especially relevant in understanding how small-scale groups operate; for these groups, the locality is one of the clearest and most meaningful levels of social and economic life, and is where a community organizes itself and technological traditions are reproduced (Kolb and Snead 1997).

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One approach to studying the relationships within a community and its technological practices is to explore cultural decisions in producing and using domestic items, such as pottery. Within this latter category, one of the most promising attributes for studying local-scale phenomena is ceramic paste. Ethnoarchaeology provides evidence that distinct aspects of the ceramic production chain can be shared by social units of different sizes and scales, and that the choice of raw materials and paste preparation will vary at the level of minor social units, such as families or co-residential groups (Arnold 1993; Druc 1996; Stark 1999; Gosselain 2000). This coincides with our experience with pottery from small-scale groups of the Early Ceramic Period; morphological and decorative attributes are widely dispersed on a regional scale, while the pastes show greater local variation (Sanhueza 2004; Sanhueza and Falabella 2007). This pattern occurs in many other archaeological cases worldwide (e.g., Sassaman and Rudolphi 2001; Parkinson 2006; Lee 2007).

The primary objective of this study is to present the results from neutron activation and petrographic analyses of pottery from a locality in Central Chile, to examine whether the technological traditions and raw material sources were shared by potters within this locality, or if access to these was based on co-residential groups. Neutron activation and petrography are especially useful for investigating these matters. The study of paste inclusions with petrographic techniques provides information about the pottery-makers' practices as related to sites for collecting sands derived from distinct geomorphological deposits, and about provenience—be they added by the potters or included naturally in the clay. Neutron activation creates compositional groups based on the combined clay component and inclusions within the sample, and distinguishes the various sources on the basis of their geochemical profiles.

At this stage, we have reached three important conclusions. The first is that despite the local-scale study, we have managed to detect differences in the chemical patterns and in the mineralogy of the ceramic raw materials. The second is that the samples from each archaeological site originate from diverse sources available in the surrounding area. The third is that distinct cultural units used raw material sources from the same sub-region and geological parent rocks, but that they differentiate themselves with regard to their preferences in preparing the paste. These results have implications for the understanding of social organization in Central Chile during the Early Ceramic Period and for ceramic production among small-scale groups.

First, we will introduce the archaeological context and local geology. Then, we will describe the sherds' provenience, the criteria used to select samples and the methodology employed. Lastly, we will use the results of petrographic and neutron activation analyses (NAA), along with our own arguments, to support our conclusions.

BACKGROUND

The archaeological context

During the Early Ceramic Period, Central Chile was inhabited by sedentary and semi-sedentary small-scale groups, with disperse settlement patterns and lacking institutionalized hierarchies, who practised horticulture and manufactured and used pottery (Falabella and Stehberg 1989). The available data indicate that these groups organized pottery production on a local level (Sanhueza 2004). Until now, analysis of materials on a regional level has identified different cultural units, which are partially or completely contemporaneous, within the same territory. Of these, the Llolleo and La Palma units have been identified in the study area. Although these two units share some characteristics, differences between them are recognized in pottery styles, ritual items, ornaments, burial practices and subsistence strategies (Sanhueza *et al*. 2003; Rivas and

González 2008). La Palma is characterized by domestic pots with wide lips and inverted rims, funerary practices with no ceramic pots in burial offerings, mainly *Chenopodium quinua* as the domesticated plant resource, 'fish-tail' ceramic pipes, malachite beads and labrets as bodily ornaments, and mainly fine-grained and obsidian lithic artefacts. Llolleo is characterized by wide-mouthed domestic pots with everted rims, maize as an important dietary cultivated plant, smoking pipes with double perforated tubes, burial practices that include funerary urns and ceramic vessel offerings, lithic beads for personal adornment, and expedient lithic artefact production. One of the unresolved questions is whether knowledge of the availability of raw material sources and of paste preparation methods was shared between potters from these different cultural units. Another question is whether this knowledge circulated among potters from different co-residential groups belonging to the same cultural unit.

This study is based on archaeological data obtained in a 10 × 5 km area, which we identify as the Valdivia de Paine locality, which is situated in the southern part of the Santiago Basin in Central Chile. The archaeological record comes from full-coverage pedestrian surface surveys, along transects 100 m apart, with systematic collections of ceramics in separate 100 m collection units. We identified six areas with a high density of ceramic materials, and which we refer to as archaeological sites (Falabella *et al*. in press). We studied five of these sites (VP1, VP2, VP3, VP4 and VP5) (Fig. 1). Only one site, VP6, was not included in the analyses due to logistical problems. The surface areas of these sites fluctuate between 35 000 and 630 000 m^2, and the distances separating them between 1700 and 7200 linear metres. The sites were interpreted as habitation settlements due to the high density of ceramic sherds, a characteristic of domestic areas, which generally show the highest rates of vessel usage, breakage and discard. We obtained samples from the sites for analysis through archaeological fieldwork, using intensive surface collections and test pits. The majority of the archaeological sites result from two or more intra-site artefact clusters that overlap spatially. The intra-site clusters (depositional areas *sensu* Carr 1984) are the end product of primary and secondary middens associated with the ancient dwellings. The main post-depositional processes are agricultural disturbances (ploughing) that have blurred the boundaries of the original occupation and ruled out any possible stratigraphic resolution. We suggest, therefore, that these intra-site clusters correspond to co-residential areas occupied over time.

Each of the intra-site clusters was assigned to one of the previously known cultural units in the region, on the basis of the material remains and on the morphological and decorative characteristics of the ceramics recovered. VP1 comprises four clusters (VP1/A, VP1/B, VP1/C and VP1/D), whose principal component is Llolleo. VP2 contains three clusters (VP2/A, VP2/B and VP2/C), all Llolleo. VP3 has four clusters: VP3/A and VP3/B are Llolleo, VP3/C has an ambiguous cultural classification, andVP3/D is La Palma. VP4 comprises just one Llolleo cluster. VP5 has two clusters (VP5/A and VP5/B), both with La Palma as their principal component (Fig. 2).

The different clusters were dated using thermoluminescence (TL). A grouping of more early dates (45 BC to AD 700) dominates in VP3/C and VP3/D, is abundant in VP5 and is weakly represented in VP1, VP3/A and VP3/B. The later dates (AD 800–1400) are dominant in VP1, VP2, VP3/A, VP3/B and VP4; do not exist in VP3/D; and are weakly represented in VP5 and VP3/C. Figure 3 clearly shows that each site has a wide chronological range.

The geological setting

Mineralogical affinities are governed by the distribution of geological formations. The study area is located in the far southern portion of a basin of continental Quaternary sedimentary fill. The

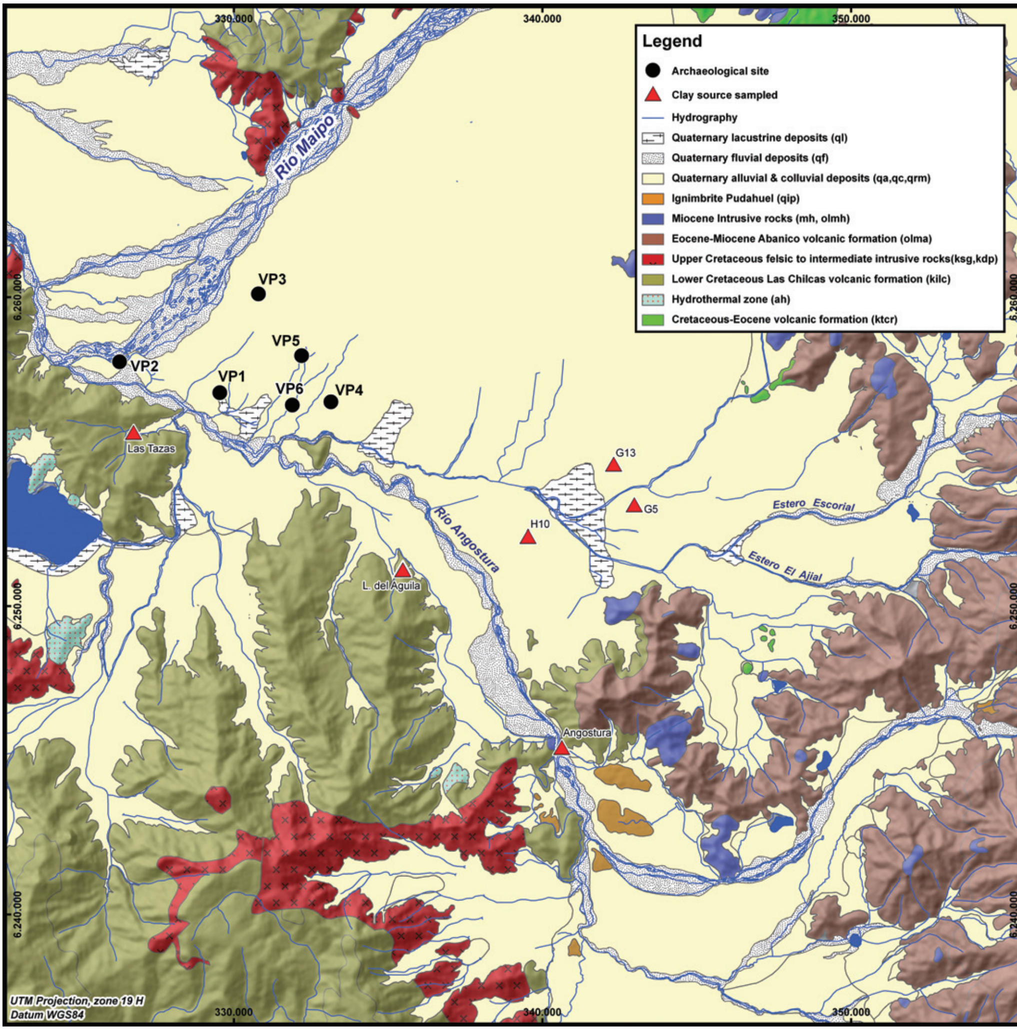


Figure 1 *A map showing the Valdivia de Paine locality, the geological formations (after Selles and Gana 2001), the archaeological sites and the locations of the clay sources sampled.*

principal geological formations are as follows: in the south and the south-west, there is the Las Chilcas formation (kilc), an intermediate-felsic volcanic formation from the Lower Cretaceous, and pyro- and epiclastic rocks with a similar composition, as well as felsic to intermediate intrusive stocks with amphiboles, biotite and pyroxenes from the Upper Cretaceous (ksg). To the south-east and the east, there is a large volcanic formation known as Abanico (olma). The latter is made up primarily of andesitic–basaltic and rhyolitic rocks from the Upper Eocene (?) to Lower Miocene, intercepted by intrusive intermediate-mafic stocks of the same age (olmh) (Sellés and Gana 2001) (Fig. 1).

Underlying the study area is a large deposit of continuous clay sediments. These clays—which are generally montmorillonite and, to a lesser degree, vermiculite—could have been collected at naturally exposed sections or by digging up the subsoil. The clays start to appear just a few

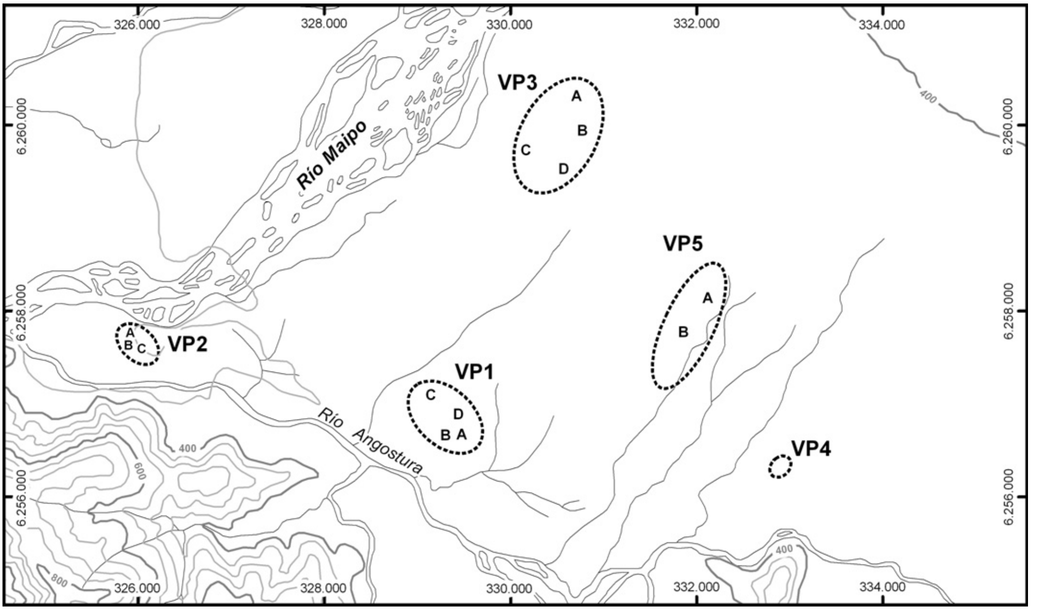


Figure 2 *The spatial distribution of the archaeological sites and intra-site clusters in the Valdivia de Paine locality.*

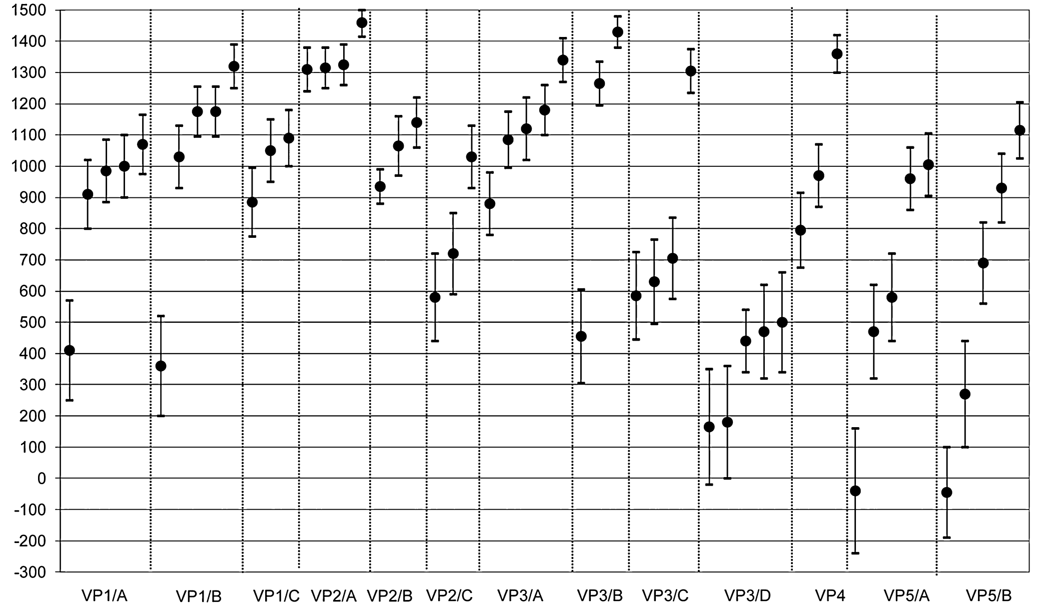


Figure 3 *Thermoluminescence dating of ceramics from the Valdivia de Paine locality: negative ages are calendar years* BC*; positive ages are calendar years* AD*. The TL dates were processed at the Pontificia Universidad Católica de Chile Luminescence Laboratory, using the quartz inclusion technique (Fleming 1970). Error estimations were made using the method proposed by M. J. Aitken (Aitken and Alldred 1972). The annual dose for the site and the ceramics was calculated by using dosimetry with calcium sulphate crystals doped with dysprosium ($CaSO_4$:Dy) (Deza and Román 1986).*

centimetres below the surface. Other sources of clay have been noted in the Las Chilcas altered deposits of felsic volcanic rocks—that is, rhyolites—and kaolinites are found specifically in intrusive rocks in the Angostura area. Sands useful for tempers can be collected in rivers and tributaries. The Maipo River carries mafic–intermediate volcanic sand (andesites, basalts) swept down from high up in the Andes Mountains, as well as intrusive rock detritus. The smaller Angostura River contains mafic–intermediate volcanic sand, felsic volcanic rocks (dacites) and minor quantities of intrusive rocks. Intrusive rocks are better represented in sand from minor tributaries such as El Ajial and El Escorial, which originate in the mountain foothills and flow into the Angostura River.

The above-mentioned geological formations are characterized by four groups of mineralogical associations—intermediate volcanic, felsic volcanic, intermediate intrusive and felsic intrusive. The greatest challenge for the local-scale approach used in this study is that the same raw material deposits are within reach of all the settlements. The biggest natural difficulties posed by the locality itself are that the mineralogical differentiation is not very marked, and that the rivers and tributaries tend to mix sediment from different geological formations.

SAMPLING AND ANALYTICAL METHODS

Sample selection

The pottery recovered consists entirely of sherds. The majority of these are from vessels that, given their shape, surface treatment and use wear, can be categorized as cooking ware used for food processing, consumption and storage (Falabella *et al*. 1993).

We characterized pastes from 20% of all the sherds collected, examining them visually using a fresh break under 10–40× magnification with a binocular microscope. The pastes were assigned to groups on the basis of size, shape, colour, frequency and the visible mineralogy of inclusions. We identified six major paste groups, all sand tempered, according to their dominant mineral inclusions. Once these groups were formed, we selected 46 samples for petrography and 139 samples for neutron activation from within those major paste groups (Table 1). We selected only undecorated, thick-walled sherds that could be assigned to cooking pots, or '*ollas*', which are the most frequent vessel category at these domestic sites, and only body sherds, to prevent damage to more diagnostic material. These criteria select for a common vessel category, frequently used and discarded in residential areas, and select for the most popular fabrics. They privilege a type of vessel of probable local manufacture, and exclude from our analysis unique and poorly represented vessels that could be circulating within the region.

For the petrographic samples, we chose one or more sherds from the major paste groups at each site, and included more samples from the most abundant groups to measure internal variability.

For the NAA, we selected sherds from each site/intra-site cluster, and the number of samples selected from each paste group in these clusters is proportional to their frequency.

Clays were non-systematically collected from clay beds underlying archaeological sites and from sources known by local informants. We prepared three briquettes using clays from different loci of Quaternary sediment deposits (G13, G5 and H10), three others with clay from two loci in the Las Chilcas formation (Las Tazas and Lomas del Aguila) and one from the Angostura intrusive body (Fig. 1 and Table 1). Preparation of the briquettes showed that the quality of these clays is appropriate for ceramic production. Only the briquette from Las Tazas had poor workability. Prior to the analysis, the briquettes were fired in an electric kiln until they reached a temperature of 700°C.

Table 1 *The numbers of samples for petrography and NAA: site/intra-site cluster and associated chronological range*

Site/intra-site cluster	*Associated TL date range*	*Number of samples*	
		Petrography	*NAA*
Ceramic samples			
VP1/A	AD 410–1070	6	16
VP1/B	AD 360–1320	3	4
VP2/A	AD 550–695	2	8
VP2/B	AD 870–1075	5	12
VP3/A	AD 880–1340	4	19
VP3/B	AD 455–1430	4	11
VP3/C	AD 585–1305	4	14
VP3/D	AD 165–500	3	15
VP4	AD 795–1360	7	20
VP5/A	40 BC – AD 1005	8	20
Total		46	139
Clay samples			
G13		1	1
G5		1	1
Las Tazas		1	1
Lomas del Aguila 1		1	1
Lomas del Aguila 2		1	
H10		1	1
Angostura		1	
Total		7	5
Total number of samples analysed		53	144

Analytical procedures

The petrographic sections were prepared and analysed in the laboratories of the Chilean National Service of Geology and Mining. The main objective was to determine possible sources of raw materials when distinctive rock fragments or mineral associations were present in the sample. The technique employed combines qualitative mineral identification and quantitative grain counting. A 4 μm reticle was used. Each thin section was examined under 50× and 100× magnification, using a polarizing microscope with integration Platte III. All individual mineral or rock grains were counted along transects as grains passed in succession through the field of view, using a mechanical stage device that allowed perpendicular movement of the slide along the length and width of the section. The inclusions were noted until 100 observations (mineral/rock inclusion, clay matrix) were reached. Rock/mineral inclusions were identified by their visual proprieties and quantified to determine the presence and the relative proportion of the different grains in the sample, their abundances and their associations. The combination of inclusions was, when possible, assigned to a geological formation and, in the event that this formation was close to the study area, was proposed to be of local provenience or, on the contrary, to be of foreign provenience. Thus, a petrographic classification was developed. The prepared thin sections were filed and are curated in the Laboratory of Archaeology, at the Department of Anthropology, University of Chile, and are available for further analyses.

The pottery samples for NAA were prepared and were analysed at the University of Missouri Research Reactor (MURR), using standard procedures for the analysis of pottery and ceramic raw materials (Glascock 1992). In brief, two irradiations, three gamma-ray counts and a standard-comparator approach to calibration were used to obtain concentration data for 33 elements. The standard reference materials SRM-1633b Fly ash and SRM-688 Basalt were used as primary standards. SRM-278 Obsidian Rock and Ohio Red Clay were used for quality control.

Quantitative analysis of the data generated by NAA follows pattern-recognition methods described by Neff (2000). Cluster analysis and principal components analysis were run on the variance–covariance matrix of the logged elemental data, and a number of principal component plots and bivariate plots of the elements were then examined to identify groups of compositionally homogeneous samples. Although the small group size precluded statistical testing of most groups by Mahalanobis distances, probabilities of group membership in the larger groups were evaluated.

RESULTS

Petrographic results

Petrographic analysis of 31 ceramic sherds and five clay briquettes revealed mineralogical associations corresponding to four geological units: intermediate volcanic, felsic volcanic, intermediate intrusive and felsic intrusive (Fig. 4). Three ceramic and two clay samples consisted of mixtures of distinct igneous rocks or their derivates, and in two thin sections there was insufficient data to make a geological association (see the Appendix). No evidence found indicated that any of the samples necessarily contained inclusions of foreign origin. Petrography of the samples analysed confirmed that, in the majority of cases, the initial visual descriptions with the binocular microscope had organized the ceramic universe into paste groups with geological correlations. The V and VB groups showed inclusions from the intermediate volcanic formation. The Gr group primarily consisted of felsic intrusive rocks, the same associated with paste group HB. BGr contained felsic volcanic or felsic intrusive rocks. VGr had a mix of volcanic and intrusive rocks. Furthermore, it became clear that the paste analysis with the binocular microscope did not manage to differentiate felsic volcanic from felsic intrusive bodies (BGr); however, it did separate two similar mineralogical groupings (V and VB). These problems did not significantly alter the percentage structure for the geological formations represented among the pottery assemblage according to site/intra-site cluster obtained with the binocular microscope analysis (Table 2). All of the sites showed intermediate and felsic volcanic, felsic intrusive and mixed igneous rocks paste groups.

One significant result in terms of assigning a local provenience to the samples is the identification of granites with a marked graphic texture in 50% of the ceramic thin sections and in two of the clay samples (Lomas del Aguila and Angostura) (Fig. 4 (b)). These granites are associated with small intrusive bodies formed by rapid cooling or with apophysis of intrusive rocks, which have been specifically described in western Angostura, in the study area (Sellés and Gana 2001), and are not present in other parts of the region.

Neutron activation results

The ceramic samples were assigned to seven compositional groups; however, four of the groups consist of too few samples to allow robust statistical analysis. Table 3 shows the number of samples assigned to each group. Figure 5 is a plot showing the compositional group structure.

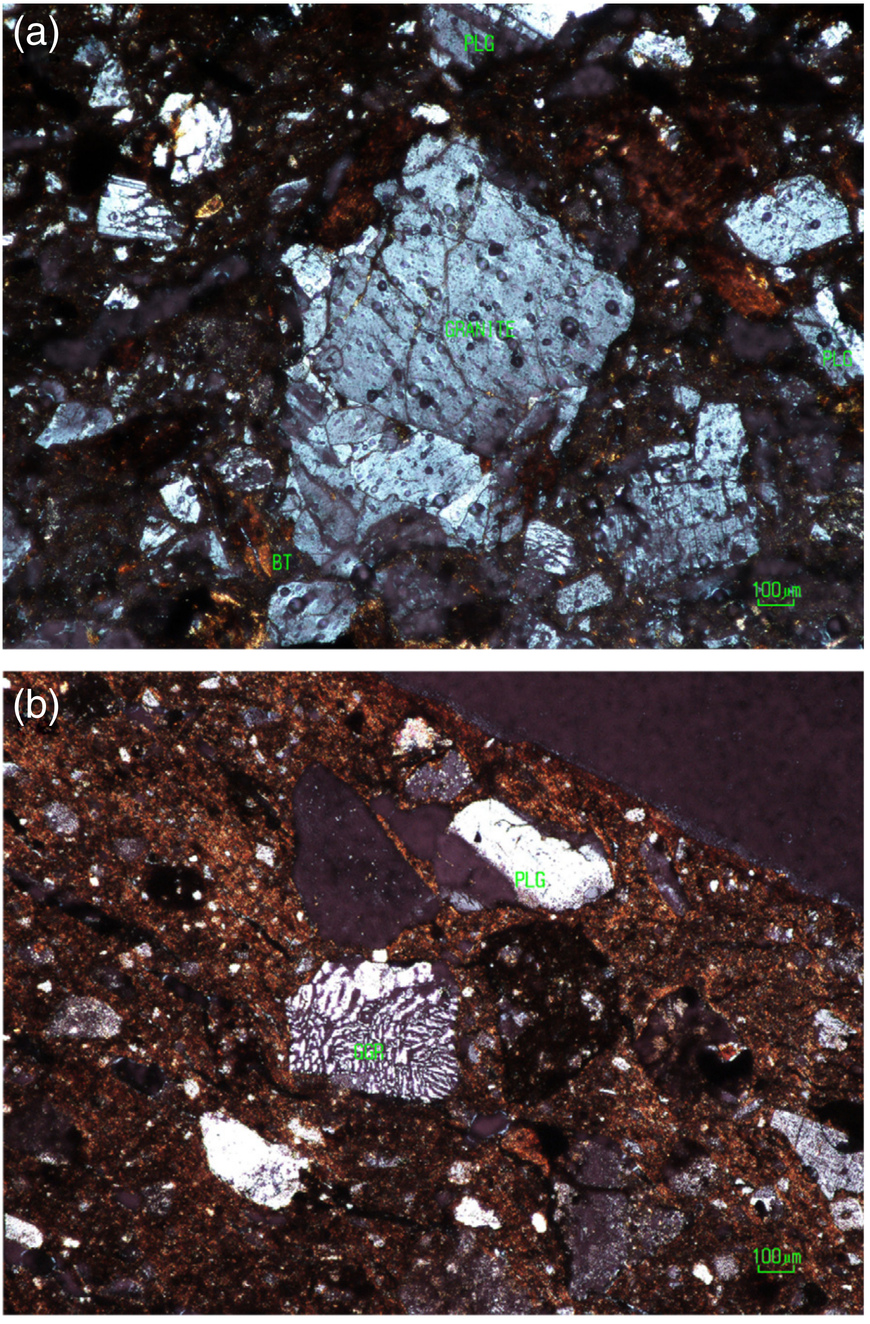
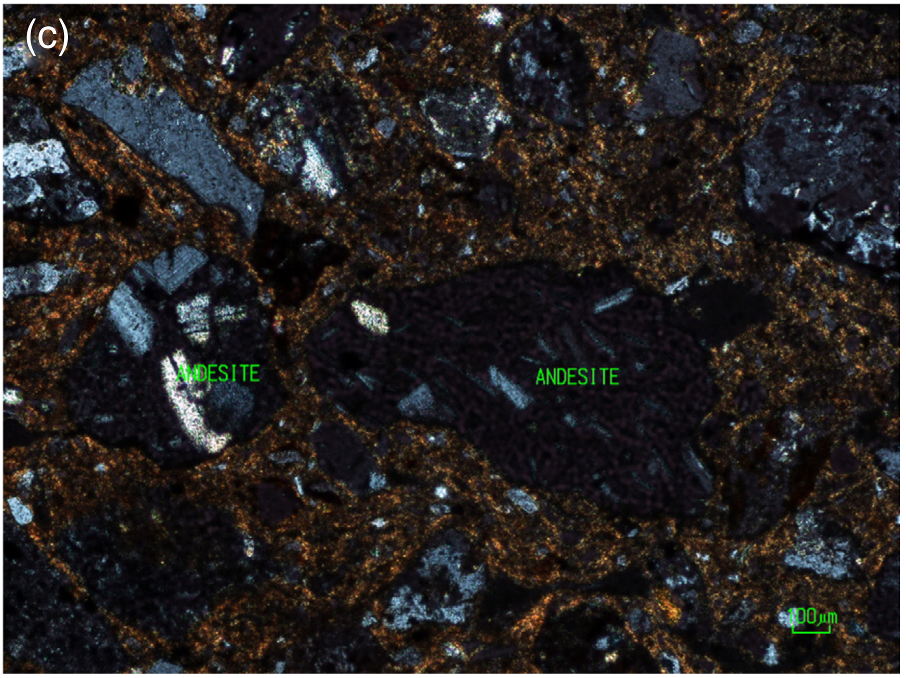


Figure 4 *Thin-section photomicrographs (crossed nicols) of ceramic samples from the Valdivia de Paine archaeological sites, representing different geological compositions. (a) A granite inclusion formed by quartz, plagioclase, small k-feldspar fragments, plagioclase mineral grains (PLG) and biotite (BT): intermediate intrusive composition. (b) A granite grain with graphic texture (GGR): felsic intrusive composition. (c) Andesite grains with porphyritic texture, and plagioclase mineral grains: intermediate volcanic composition. (d) Dacite with porphyritic texture and plagioclase phenocrysts, plagioclase (PLG) and quartz (QZ): felsic volcanic composition.*



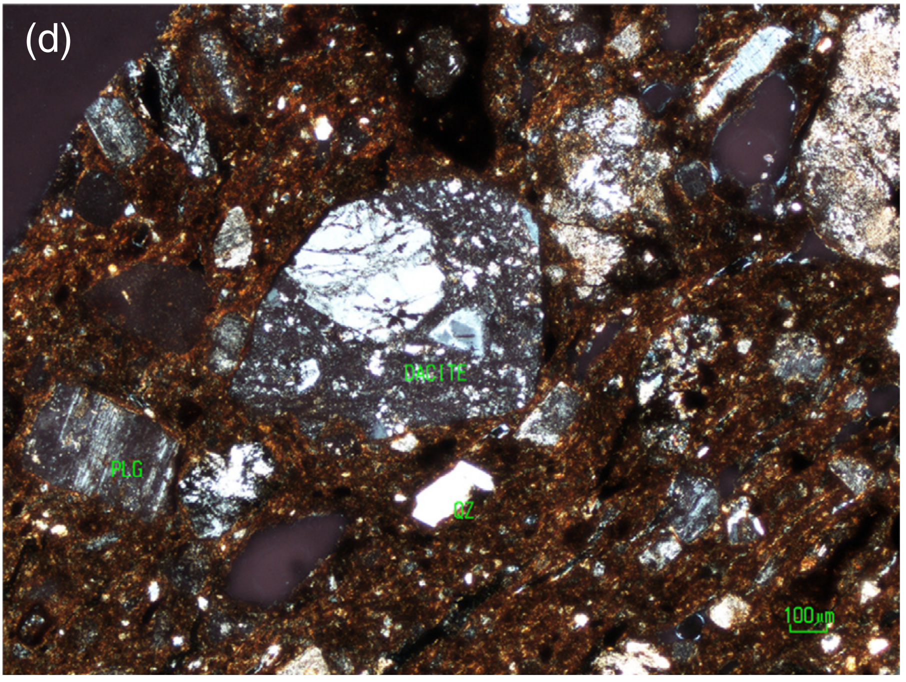


Figure 4 (*Continued*)

Table 2 *The paste group frequency (%) per site/intra-site cluster: results from binocular microscope analyses*

Site/intra-site cluster	*HB*	*BGR*	*GR*	*VGR*	*VB*	*V*	*Other*	*Number of sherds*
VP1/A	0.5	**26.3**	6.3	0.1	**59.6**	2.0	5.2	1059
VP1/B	**27.8**	13.3	10.1	2.4	**41.1**	1.7	3.7	903
VP2/A	0.0	0.0	15.4	10.4	**70.3**	0.0	3.8	182
VP2/B	0.0	0.0	20.4	2.6	**69.2**	3.7	4.1	461
VP3/A	0.3	4.7	**38.9**	16.0	**37.0**	2.8	0.3	576
VP3/B	1.2	12.0	**33.1**	1.6	**45.4**	5.6	1.2	251
VP3/C	0.5	1.0	**47.0**	19.8	**31.2**	0.5	0.0	202
VP3/D	0.0	0.0	**54.0**	**37.6**	0.0	4.1	4.4	780
VP4	0.0	0.0	22.7	0.0	**65.9**	7.1	4.4	735
VP5/A	0.0	7.7	**37.6**	**42.4**	8.1	3.0	1.2	596
VP5/B	0.0	3.8	**51.5**	**30.5**	12.4	1.7	0.0	1110
Total								6855

Table 3 *The results of the NAA by paste group*

Paste group	*Group 1*	*Group 2*	*Group 3*	*Group 4*	*Group 5*	*Group 6*	*Group 7*	*Unass*	*Total*
BGr			1				7	3	11
GR				12	7	2	7	13	41
HB		4							4
V	2					1		3	6
VB	21	2	1	3			22	11	60
VGr			1	2			8	6	17
Total	23	6	3	17	7	3	44	36	139

Group 1 includes 23 pottery samples that are very distinct from the other compositional groups. These samples contain a higher concentration of chromium compared to other groups within the data set. This group almost exclusively contains samples that have a volcanic rock–based paste (Fig. 6 and Table 3).

Group 2 includes six samples that are also very distinct from the other compositional groups. These samples have the second highest concentrations for chromium and the group can only be separated from Group 1 on the basis of slightly lower chromium concentrations. This group contains mainly the HB paste from VP-1 and some samples from the VP-4 archaeological site.

Groups 3 and 6 have only three samples each. We are hesitant to call three samples a compositional group; however, these samples seem to plot in principal component and elemental space consistently near members of their respective groups rather than near any of the other established compositional groups.

Group 4 includes 17 samples that can only be separated in elemental space by their low concentrations for chromium and thorium when compared to the other chemical groups. This group almost exclusively contains samples that have granitic rock inclusions in the paste.

Group 5 contains seven samples and is the last non-core compositional group. These samples differentiate themselves clearly from the core group by higher concentrations for zinc (Fig. 7). Samples in this group contain granitic rocks in the paste.

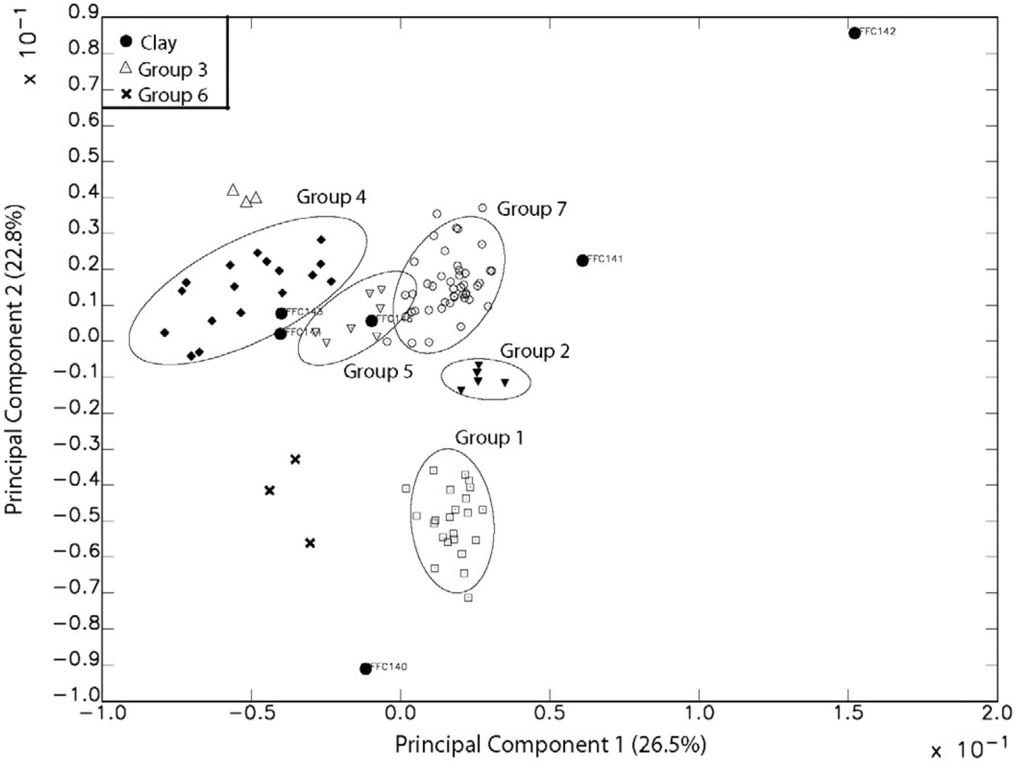


Figure 5 *A principal component plot showing the compositional groups and the placement of the clays. The ellipses represent 90% confidence intervals for membership in each of the groups.*

Group 7 contains 44 samples and is the last of the discernable compositional groups. The greater number of samples and the diverse descriptive data suggest that these samples belong to a regional core group. This group contains samples from all the paste groups.

The clays were initially projected against the compositional groups using a principal component plot (Fig. 5). Membership probabilities were then calculated for samples appearing near to or within a compositional group's confidence ellipse (Table 4). Samples from clay sources G5 and G13 have a surprisingly high probability of being included in Group 4. We caution on assuming that these are the clay sources for Group 4, because the group's small size does not allow for robust Mahalanobis distance calculations.

DISCUSSION

The petrographic and NAA results are complementary to the understanding of the ceramic technological practices in Valdivia de Paine. Each technique recognized patterns, but identified different forms of ceramic variation. The compositional and petrographic groups do not necessarily coincide. Some chemical groups have a mineralogical explanation, while others do not. Combining these two lines of evidence clearly provides a better interpretation than considering each result on its own.

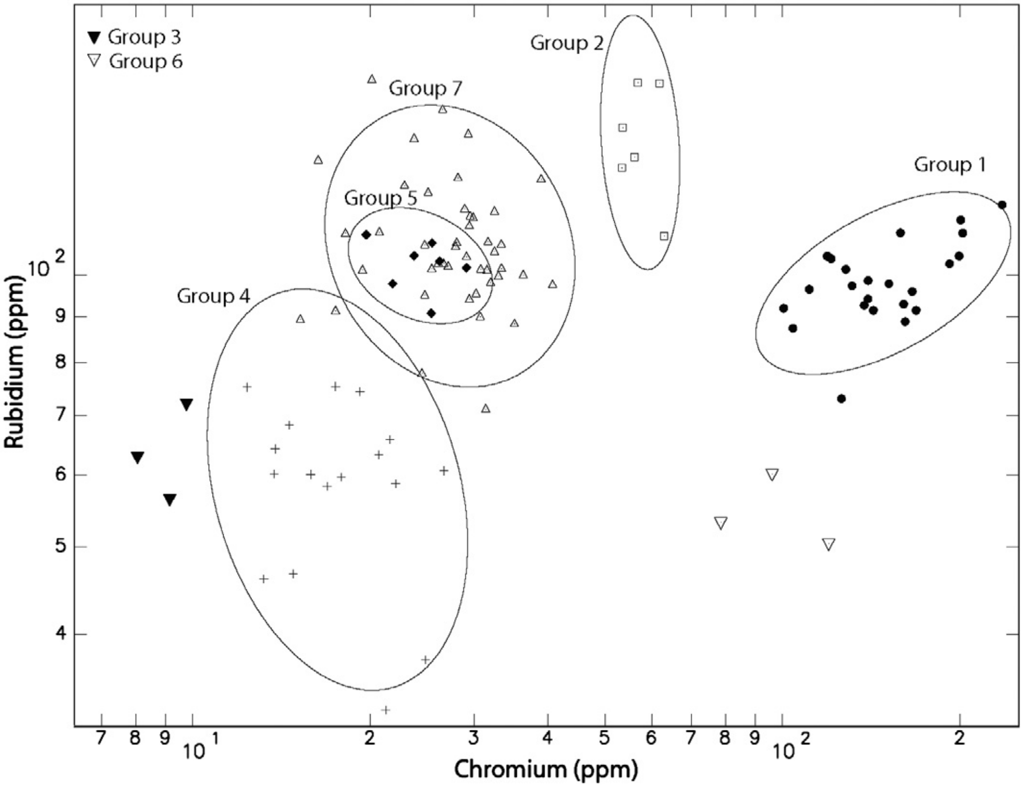


Figure 6 *A bivariate plot of chromium and rubidium (log base 10 ppm): the ellipses represent a 90% confidence interval for group membership.*

The first issue that we put forward is the quantity and variety of raw material sources found at the archaeological sites and their respective intra-site clusters. The petrographic data show that at practically all of the sites studied, there are ceramics from the four principal geological units in the Valdivia de Paine locality. The seven compositional groups resulting from the NAA suggest that the pottery was produced using at least the same number of raw material sources. The NAA results demonstrate that the samples do not form chemical groups on the basis of a specific archaeological site, nor on a specific intra-site cluster (Fig. 8 and Table 5). The chemical data were also grouped by whether a volcanic rock or granite was used in the paste. The results of these groupings also suggest that paste (based on a simple volcanic and intrusive separation) does not necessarily form chemical groups either (Table 3). The combined petrographic and NAA data show, without a doubt, that the potters knew and collected clays and sands from various sources to produce ceramic vessels, and that these sources are of diverse geological origin. This variety could be based on the wide availably and ubiquity of clays in the locality studied, as these materials do not seem to have been a scarce resource there.

A second issue is whether that diversity is related to chronology, with a possible shift in clay extraction sites due to depletion or other causes. We do not have a precise chronological control for each pottery sample, and the archaeological contexts from where they were taken have broad date ranges. Nevertheless, when comparing VP3/D or VP5—the earliest dates—with VP1, VP2, VP3/A, VP3/B and VP4—the later dates—the data show that the analysed samples are not

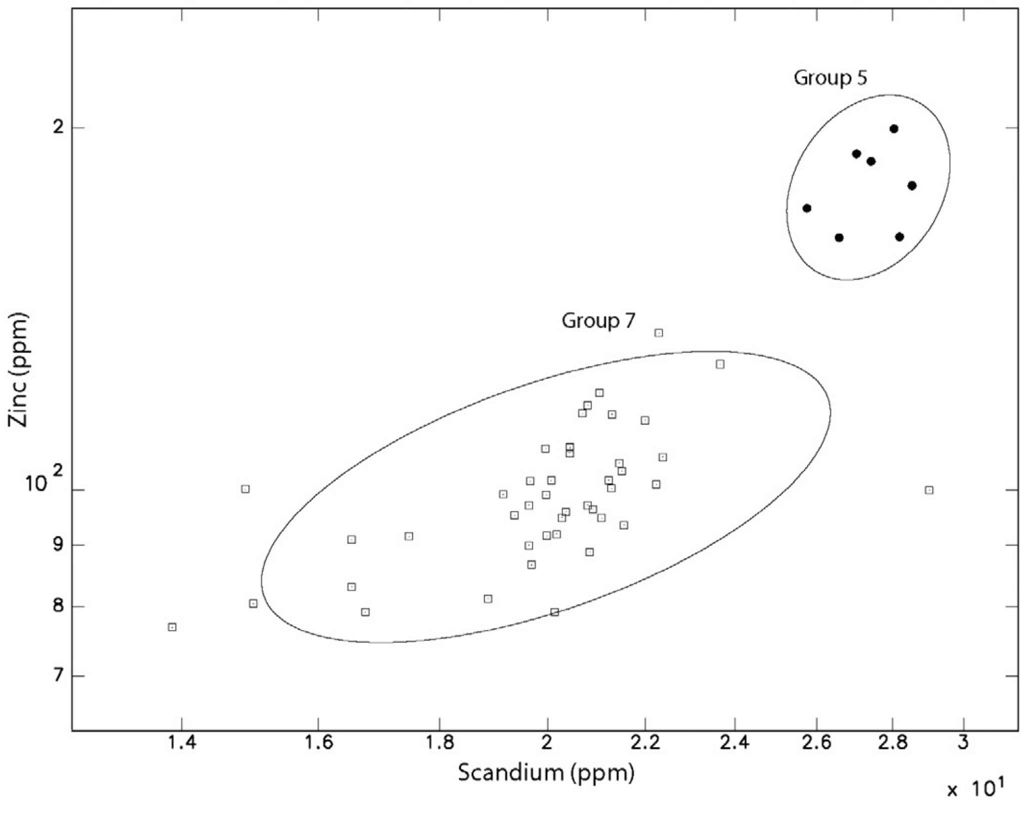


Figure 7 *A bivariate plot of scandium and zinc (log base 10 ppm): the ellipses represent a 90% confidence interval for group membership.*

Table 4 *The membership probabilities (%) of the clay samples based on four principal components*

Sample ID	*Clay source*	*Group 1*	*Group 2*	*Group 4*	*Group 5*	*Group 6*
FFC143	G5	0.00	2.34	63.07	3.52	0.00
FFC144	G13	0.00	1.87	37.62	6.33	0.00
FFC145	H10	0.00	7.03	0.87	2.44	0.01

ordered according to geological provenience or chemical group. We did not find any chronological differences among the distribution of paste groups in the samples dated using TL either. This suggests that similar clays from the same geological parent rocks were used over the years by several generations of pottery-makers, and it supports the idea that the technological traditions related to raw materials and paste preparation were maintained for at least 1000 years in this locality.

The third issue regards cultural specificity in use of raw material sources. The chemical data results suggest that cultural assignations do not lead to any chemical groupings. Nevertheless, the results from the paste analysis using a binocular microscope show that the frequency of the paste

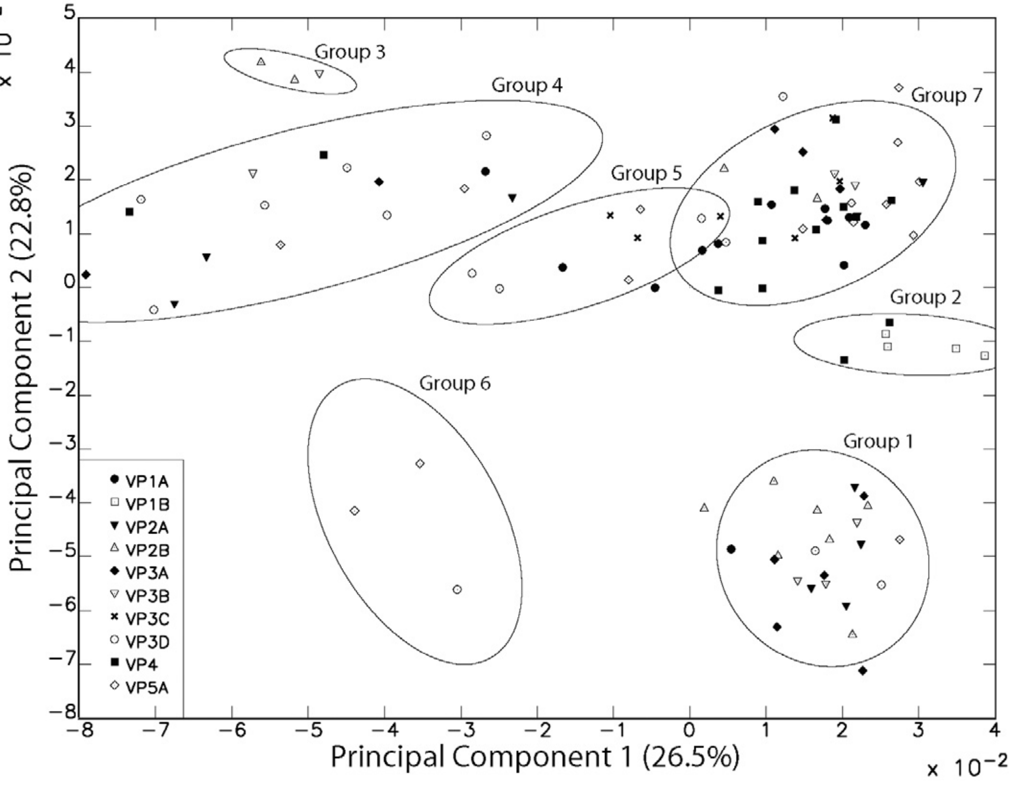


Figure 8 *A principal component plot showing the compositional groups coded by site/intra-site cluster: the ellipses represent 90% confidence intervals for membership in each of the groups.*

Table 5 *The results of the NAA by site/intra-site cluster*

Site/intra-site cluster	*Group 1*	*Group 2*	*Group 3*	*Group 4*	*Group 5*	*Group 6*	*Group 7*	*Unass*	*Total*
VP1/A	1			1	1		9	4	16
VP1/B		4							4
VP2/A	4			3			1		8
VP2/B	7		2				2	1	12
VP3/A	5			2			4	7	18
VP3/B	3		1	1			3	4	12
VP3/C					2		4	8	14
VP3/D	2			6	2	1	3	1	15
VP4		2		2			10	6	20
VP5/A	1			2	2	2	8	5	20
Total	23	6	3	17	7	3	44	36	139

groups varies according to cultural components (Table 2). The sites and intra-site clusters with Llolleo culture components (VP1/A, VP1/B, VP2/A, VP2/B, VP3/A, VP3/B and VP4) share a preference for sources derived from volcanic rocks (VB paste group) and for unimodal sand tempers. The La Palma contexts (VP3/D, VP5/A and VP5/B) have a preference for felsic intrusive sources (Gr), mixed volcanic and intrusive inclusions (VGr), and heterogeneous grain size. This suggests the existence of a substantial difference in choosing the preferred locus for obtaining raw materials. We believe these characteristics are a consequence of the reproduction of technological practices (selection of raw materials, paste preparation methods) transmitted and shared within each cultural unit over time. In the case of Llolleo, all indications are that the 'recipe' for preparing the paste included adding sand temper collected in rivers. As for La Palma, the paste preparation method is still not well defined.

The fourth issue is whether the raw material sources were 'local'. It is not a simple task to determine the provenience. It is widely recognized that ceramic materials are often heterogeneous, since pottery manufacture involves many stages that generally alter the original raw materials (Shepard 1976; Rye 1981; Rice 1987). Due to this process, there is little chance of finding a perfect match between a specific clay's chemical and mineralogical profiles and ceramic samples from vessels manufactured using that same clay (Arnold *et al*. 1991, 2000). Despite this, we have sufficiently robust data to back the claim in this study that at least some raw materials were procured in the vicinity of the Valdivia de Paine locality. First, the correspondence between chemical profiles of the sedimentary clays (G5, G16 and H10) with chemical Group 4 suggests that clays from the Quaternary sediment deposit underlying a large number of the archaeological sites in the area were used in the sample studied. These clays have a very fine grain size and, if they were used as a base for ceramic production, must have needed a temper to be added. This mixing alters the original traces of each component in the clay, but does not make them disappear completely. Second, as we indicated in the 'Petrographic results' section, half of the samples show a very specific type of graphic-textured granite, which has only been described in intrusive rocks that are near to the study area and that were specifically present in two of the clay briquettes. This is a quite unmistakable sign that, even though this granite type was not present in all samples, it is highly common, and it leads us to conclude that such samples' original vessels were manufactured using materials obtained from sources near to the sites. A third fact, although less definitive, is the high degree of correlation between all of the mineralogical associations of the thin sections and the geological formations that surround the Valdivia de Paine locality, from which it can be inferred with a high probability that the ceramic samples are local.

If to all the above-mentioned we add that no evidence has been found for specific production areas, as is common for low-scale production, and that other ceramic attributes (surface treatment, rim and lip form) are also heterogeneous, the results of our analysis support the interpretation of ceramic production on a household/community level, as has been concluded in previous studies (Sanhueza 2004). With the available data, we are unable to say whether there were pottery-makers in each of the co-residential groups, or just a few potters who produced for the entire Valdivia de Paine population. However, it is quite evident that in accordance with the parameters used for archaeological ceramic research (Costin 1991), we are not dealing with a form of specialized production. This also supports the conclusion that mainly local resources were being used (Arnold 1985).

The results of this study illuminate some significant aspects of technological practices in the Valdivia de Paine locality. Beyond favouring specific collection sites and replicating their own technological traditions, artisans from distinct co-residential units and of different cultural units seem to have also shared knowledge and use of raw material sources. This fact is relevant for understanding how pottery-producing communities organized themselves, as well as for social relations at the local level.

Within the Llolleo cultural unit, all indications are that traditional knowledge about places to find raw materials and paste-preparation methods were shared among potters from distinct co-residential units. This situation is to be expected and may have various, non-exclusive explanations. On the one hand, we are dealing with co-residential groups in close spatial proximity; that is, they inhabited the same locality, which in addition is not very diverse in terms of geology. Co-residential groups belonging to the same cultural unit did not live isolated from one another. Rather, they tended to have links for co-operation and to form alliances, thus constituting an actual community in the sense of permitting members to interact frequently, and allowing a true 'community of practices' to form (Lave and Wenger 1991). We also cannot rule out the possibility that vessels were circulated among the distinct co-residential groups or, further, that not all of them manufactured pottery, as we have indicated previously. However, with reference to the latter case, the most common tendency is for the different groups to be self-sufficient in terms of manufacturing basic domestic implements.

The relationship between the Llolleo and La Palma cultural units is somewhat more difficult to discern due to the partial chronological gap. In this case, the clustering of sherds found at domestics sites of both units in the same chemical groups (Table 5) suggests that access to raw material sources was not exclusive to just one unit in the Valdivia de Paine locality. This must lead us to explore the implications of sharing knowledge and access to certain resources. It is likely that some practices (and presumably social ties) were shared across cultural boundaries. Nonetheless, despite that, the chemical signal and mineralogy of the ceramic samples suggests the use of similar sources, Table 2 reveals a clear behavioural difference via the grains included in the matrix. Thus, although clay sources were perhaps being shared, clearly the specific paste recipe is exclusive to each cultural unit. In this sense, the ceramic practices also constitute a differentiating factor within the locality.

CONCLUSIONS

The main goal of this study was to investigate whether local communities shared technological practices and raw material sources for pottery production, or if access to these was based on minor social units, such as co-residential units. The use of a local-scale perspective has allowed us to address some aspects of these questions. The results show that the mineralogical characteristics and chemical profiles of the ceramics are useful, even at a local level and in geological environments with little differentiation, for distinguishing raw material sources. We found evidence showing the use of various sources of clay and sands for temper, which must be local. This variety is not necessarily ordered according to co-residential unit or chronology. On the contrary, these sources were exploited over the course of the lengthy Early Ceramic Period. We have demonstrated that cultural units—in this case, Llolleo and La Palma—shared access to raw material sources but had different temper profiles, which suggests that the pottery-makers differentially shared and applied their knowledge of ceramic production. Incorporation of the petrographic information and the compositional analyses has been fundamental in achieving these conclusions. The compositional data provided more precise information on the natural variation of the raw materials; the petrography provided a better way of detecting culturally differentiated recipes for manufacturing pottery.

The results make it possible to understand some aspects of ceramic technological practices, and they offer a new look into the relationships among the Llolleo groups, and between these and the La Palma groups, living in different co-residential units in the Valdivia de Paine locality. Looking beyond its historical specificity, this case study also provides important comparative data for understanding variations in how ceramic production is organized in small-scale groups worldwide. Specifically, the study supports the idea that pastes are an attribute that is generally reflective of communities of practice.

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APPENDIX

Results from petrographic analyses

Composition/ rock	*Paste group*	*Amp*	*Bt*	*Qz*	*Cal*	*Chl*	*Ep*	*Fsp*	*Pl*	*Px*	*Ser*	*Tur*	*Op*	*Da*	*Ig*	*An*	*Grd*	*Gr*	*Qzt*	*Ar*	*Di*	*CM*	*ID*
Ceramic samples																							
Felsic intrusive	BGR	1	4		3		2	3	14		3		2	3		1		12				52	17
Felsic intrusive	BGR		4	8			2	4	12		2		2	1		2		12				50	18
Felsic intrusive	BGR	1	3	5			2	6	10				2	2				12	1			55	46
Felsic intrusive	GR	1	3	7		1	1	6	12		1		3			2	2	8				53	15
Felsic intrusive	GR	1	2	6			2	4	13		2		3	3		2	2	10				50	16
Felsic intrusive	GR			9			3	3	12		1		2	3		1		12		1		53	24
Felsic intrusive	GR	1	1	4			3	3	14	2			3	4		2		10	2	1		50	36
Felsic intrusive	GR	2		6			4	3	20		1		4	1		2	1	10			1	45	8
Felsic intrusive	GR	1	2	8			2	3	9	3			2	4				10	1			55	45
Felsic intrusive	HB	1	3	6				6	9		2		1	3		1		20				48	21
Felsic intrusive	HB		3	7				3	10		2		2	4		1		17		1		50	22
Felsic intrusive	HB			4			3	2	6		1		2	4		1		16		1		60	23
Felsic intrusive	VGR			10			2	3	15	3		1	1	2				10				53	1
Felsic intrusive	VGR		2	7			1	4	9				2	2				20				55	2
Felsic intrusive	VGR	1	2	5			3	8	10				2	4		3		11				50	37
Felsic intrusive	VGr	1		5			3	3	16	2				5		3	2	5				55	12
Felsic volcanic	BGR	1		4			7	3	20				2	10		5		1				47	9
Felsic volcanic	GR	2	1	8			3	2	10	2			2	10		3		3				54	35
Intermediate intrusive	GR		10	5				2	20	1			3			2	10				3	44	4
Intermediate volcanic	BGR		5	3			3	2	10		1		2	8		7		3				55	25
Intermediate volcanic	V		2	3			3	1	18				1	4		15				1		52	26
Intermediate volcanic	V			3			3		14	2			2	2		21		1		1	1	50	27
Intermediate volcanic	V	1		4			2	1	22				4	7		7		1		1		50	10
Intermediate volcanic	VB			7			1	3	15	4			2	3		10		3			1	50	3
Intermediate volcanic	VB	3	1			1	1	1	15	1				3		12		1	1			60	6
Intermediate volcanic	VB		1	5			1	1	12				1	2		23		2		1		50	30
Intermediate volcanic	VB			1			2	1	21					2		20						53	11
Intermediate volcanic	VB	1	1	2		1		3	17	1	1		1	5		8		2		1		55	42
Intermediate volcanic	VGR	1	1	3			3	1	15	1			2	3		9		1	1	4		55	38

Intermediate volcanic	VGR	1	1	3	2	1	2	2	13			2	2		11		2	1	1		55	40
Intermediate volcanic	VGR	1	1	3		1	2	2	12			1	3		15		2	1	1		55	41
Mixed rocks	GR	3		3			8	1	10	3	2	3	1		7	3	5	1			50	7
Mixed rocks	V	3	3	2				1	23	1		3	2		5	1	8	2		1	45	5
Mixed rocks	V	1	1	5			2	2	9	1		1	5		11		9		1		52	34
Mixed rocks	V	2	2	5		1	2	2	16	2	1	2	3		14		1				47	14
Mixed rocks	VB	1	3	5			3	2	14		2	2	3	2	8		3		2		50	19
Mixed rocks	VB	1	3	5			3	2	16	2	1	2	2		6		7				50	20
Mixed rocks	VB	2	2	5			2	3	10	2	1	1	5		7		5	3			53	31
Mixed rocks	VB	1	1	6			1	2	14	1	1		4		10		9		2		48	32
Mixed rocks	VB		1	7			3	4	10	2	1	1	4		8		7	2			50	33
Mixed rocks	VB	1	3	5			2	4	15		2	2	6		3	2	5				50	13
Mixed rocks	VGR			5			2	1	14	1	2	3	2		12		8				50	29
Mixed rocks	VGR		1	4			3	1	16	1		2	1		15		6				50	28
Mixed rocks	VGR	2	2	4		1	3	3	12	1		2	3		6		6				55	39
Unidentified	GR	1	1	19			2		18		2	2	1		2		1		1		50	43
Unidentified	GR	3	2	10			2	2	17	6	1	2								2	53	44
Clay samples																						
Mixed rocks			1	3			2	2	18			1	3		4		5			1	60	47
Intermediate volcanic				4				1	4				3		8						80	48
Mixed rocks			3	4				5	7			1	1		3		4	2			70	49
Felsic volcanic				2				2	5			1	22		1		1				65	50
Felsic volcanic			1					2	15				14		1		1	1			65	51
Felsic volcanic			2	5				3	10			1	7		1		4	2			65	52
Felsic intrusive				8				4	12			1	6		1		12	1			55	53

Amp, amphibole; Bt, biotite; Qz, quartz; Cal, calcite; Chl, chlorite; Ep, epidote; Fsp, feldspar; Pl, plagioclase; Px, pyroxene; Ser, sericite; Tur, tourmaline; op, Opaques (hematite, magnetite); Da, dacite; Ig, ignimbrite; An, andesite; Grd, granodiorite; Gr, granite; Qzt, quartzite; Ar, arenite; Di, diorite; CM, clay matrix; ID, sample ID number.