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CHEMICAL AND PETROGRAPHIC ANALYSIS OF PRE-HISPANIC POTTERY FROM THE SOUTHERN ABAUCÁN VALLEY, CATAMARCA, ARGENTINA*

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Neutron activation (NAA) and petrographic analyses were carried out on Late and Inca Period pottery from 15 archaeological sites and several clay samples in the southern Abaucán Valley, Catamarca, Argentina. The results from the NAA and petrographic analyses provide new data concerning local versus non-local pottery production and vessel exchange for these two pre-Hispanic cultural periods. The chemical data demonstrate the use of different clay sources over time until the Inca appearance in the region, when a more structured and controlled production is observed. Petrographic analyses show a similar change in the ceramic paste recipes used by ancient potters.

KEYWORDS: NAA, PETROGRAPHY, INCA AND LATE PERIODS, NORTHWESTERN ARGENTINA

INTRODUCTION

Pottery production during the Late Period (*c*. AD 900–1450) in northwestern Argentina has been characterized as primarily a household industry, becoming increasingly intensified and concentrated following the appearance of the Incas in the region (D'Altroy *et al*. 1994, 2000; Williams 1999, 2000; Plá and Ratto 2007; Cremonte and Williams 2010; De La Fuente 2011a; Puente 2012). Most pottery production in these chiefdom sociopolitical contexts was for local consumption and distribution, following different technological organization schemes expressing several degrees of standardization, specialization, firing technology and use of ceramic raw materials along the region (Plá and Ratto 2007; Wynveldt 2008; Páez and Arnosio 2009; Páez 2010; Zagorodny *et al*. 2010; De La Fuente 2011a; Puente 2012; Rasmussen *et al*. 2012).

This paper presents the results obtained through the compositional characterization by NAA (*N* = 314) and petrographic studies (*N* = 60) of a large archaeological ceramic sample belonging to Late and Inca Periods in the southern sector of the Abaucán Valley, Department of Tinogasta, Province of Catamarca, northwestern Argentina. Additionally, we characterized a non-extensive clay sample (*N* = 14) from different hydric basins in the study region and a few comparative sherds from the Middle and Early Periods.

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THE GEOGRAPHICAL AND PRE-HISPANIC CULTURAL CONTEXTS: THE SOUTHERN SECTOR OF THE ABAUCÁN VALLEY

The southern sector of the Abaucán Valley includes an inter-mountain area of around 30 km^2, located along the border sector between the Catamarca and La Rioja provinces (Fig. 1) (Sosic 1972). The area was heavily occupied from the Early Period (*c*. 600 BC – AD 500) through to the Late (c. AD 900–1450) and Inca (c. AD 1480–1530) Periods. To date, more than 25 archaeological sites have been surveyed and studied (De La Fuente 2011b). Late Period sites are characterized by abundant surface ceramic materials associated with earthen architecture, whereas the Inca sites have stone masonry surface architecture (De La Fuente 2011a, 227–8). One of these Inca sites, Costa de Reyes No. 5, classified as a *tambo*, is particularly interesting because evidence of pottery production (about six pottery kilns) was detected nearby. To date, we have

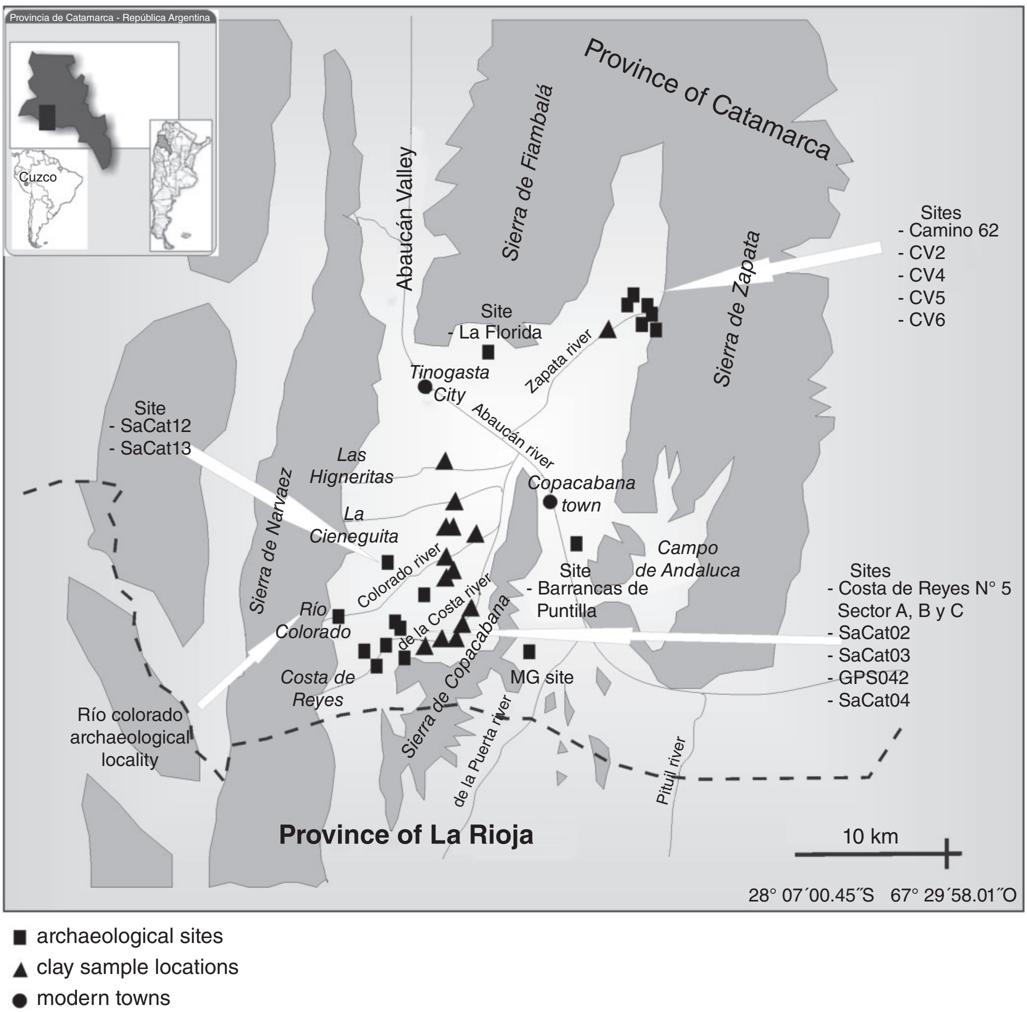

Figure 1 *The southern sector of the Abaucán Valley, showing the archaeological sites mentioned in the text (Province of Catamarca, Argentina).*

thermoluminescence dates on 68 ceramic fragments from nine archaeological sites, mainly Inca and Late Period sherds (Sanagasta culture), which allows us to establish a relative chronology for the area (De La Fuente *et al*. 2010).

POTTERY PRODUCTION DURING THE LATE AND INCA PERIODS IN NORTHWESTERN ARGENTINA

Late Period pottery production in northwestern Argentina has traditionally been characterized as a household industry, representing small-scale production units making different types of vessels mainly for local consumption and distribution (e.g., Wynveldt 2008; Páez 2010; Zagorodny *et al*. 2010; De La Fuente 2011a; Puente 2012). Regional ceramic styles were characteristic of the different valleys (Puente 2012).

After occupation of northwestern Argentina, the Incas obtained ceramics by intensifying production by local potters and by creating labour enclaves of colonists called *mitmaqkuna* (cf., Murra 1980, 1982; D'Altroy 1992; D'Altroy and Williams 1998; Hayashida 1999; Williams 2000). Inca pottery was extremely standardized in form and decoration throughout all the controlled territory (Meyers 1975; D'Altroy and Bishop 1990; D'Altroy 1992; Bray 2003), although sometimes the vessels appear blended with local styles at a local level (cf., D'Altroy 1992; Hayashida 1999; Kriscautzky 1999; Williams 1999, 2000). In northwestern Argentina, there are differences between the Inca/Cuzco, Inca Provincial and local styles of ceramics (Calderari and Williams 1991; Williams 1999, 2000). Local Late Period ceramic styles (Sanagasta and Belén) and Inca Provincial are generally assumed to be locally produced in northwestern Argentina, whereas Inca/Cuzco and Inca/Diaguita Chileno ceramic types are expected to come from the Cuzco area and Chile, respectively. Inca 'administrative centres' were places where pottery production was concentrated, and ceramic goods were exported from these centres and distributed throughout each region for local and state consumption (D'Altroy and Bishop 1990; D'Altroy *et al*. 1994; Williams 1999, 2000). However, there is some contradictory evidence from other Inca settlements, classified as *tambos*, where several pottery production stages have been recorded (cf., Bárcena and Roman 1986–7; Hayashida 1999, 340–1).

As pointed out by Williams (1999, 2000) and Cremonte and Williams (2010), the distribution of Cuzco ceramics was restricted to specific geographical regions such that most of the Inca ceramics produced in northwestern Argentina were for regional consumption (Cremonte and Williams 2010, fig. 2). However, the compositional evidence indicates that some types of vessels of low height and weight, such as shallow plates, were transported far away, to regions very distant from the Inca capital, Cuzco (D'Altroy and Bishop 1990; D'Altroy *et al*. 1994; D'Altroy and Williams 1998; Cremonte and Williams 2010).

MATERIALS AND METHODS

For the present study, we analysed 324 samples by NAA, including 310 archaeological pottery and 14 clay samples. In addition, technological analyses through ceramic petrography were carried out on 60 of the same sherds. The ceramic samples came from 15 archaeological sites located in the study region (Fig. 1 and Table 1). Clay samples were collected in different hydrological basins in the region (Río Colorado, Río de la Costa and Río Zapata) (Fig. 1). Late Period Sanagasta typical vessel forms are urns, bowls and *ollas* (De La Fuente 2011a). Urns were mainly used for infant burials and bowls to process and serve food (De La Fuente 2011a, figs. 5, 6 and 8). *Ollas* were utilized for cooking and storage of different kind of foods and liquids (De

Table 1 *Pottery analysed by INAA (n = 310)/petrography (n = 60), southern sector of Abaucán Valley*

Site	*Early Period*	*Middle Period*	*Late Period*				*Inca Provincial*	*Belén/Inca*	*Diaguita Inca*	*Total NAA/petrography*
	Saujil	*Aguada*	*Sanagasta*	*Belen*	*Abaucán*	*Indet.*				
Costa de Reyes No. 5										
Sector A (CRSA)				3			4	1	1	9/0
Sector B (CRSB)			13/7				29/4	7	7	56/11
Sector C (CRSC)							6	1	1	8/0
SaCat02			6	3			1/1			10/1
SaCat03			11/5	3			1	1		16/5
SaCat04	9	10	2							21/0
GPS 042 Barreal			4/2	4/2			12/5			20/9
Camino 62 (C62)			5	1			3			9/0
CV6—Inca			2/2				1			3/2
Río Colorado (RC)	5		4/2							9/2
CV5			12/4	1/1				1		14/5
CV2			18/5	11/2			3	1		33/7
CV4				5			1			6
Barrancas f/La Puntilla (BP)		3	12/4	6/1						21/5
La Montura del Gigante (MG)		10	1	8		2				21
SaCat12			7/1	9	1		1			18/1
SaCat13			6/3	14/1			12/7	1/1	3	36/12
Totals	14/0	23/0	103/35	68/7	1/0	2/0	74/17	13/1	12/0	310/60
Percentages	4.52/0	7.42/0	33.23/58.33	21.94/11.66	0.32/0	0.64/0	23.87/28.33	4.19/1.66	3.87/0	100/100

La Fuente 2011a, fig. 4). *Aríbalos* and shallow plates are typical Inca standardized ceramic forms. *Aríbalos* were used mainly for transport and storage of liquids (e.g., *chicha*), whereas plates were used to serve solid or semi-solid foods in different domestic and ritual contexts (Hayashida 1999; Williams 2000; Bray 2003, figs. 1 and 2, table 2).

Chemical analyses by NAA were conducted at the Archaeometry Laboratory at the University of Missouri Research Reactor (MURR), according to the analytical procedures established by Glascock (1992). Along with the pottery samples, reference standards of SRM-1633a (coal fly ash) and SRM-688 (basalt rock) were similarly prepared, as well as quality control samples of SRM-278 (obsidian rock) and Ohio Red Clay. Clay samples were fired in a furnace to 700°C for 1 h. A portion of each clay was then ground to powder in an agate mortar to homogenize the samples.

NAA of pottery at MURR consists of two irradiations and three gamma counts, resulting in the detection of 32 elements (Glascock 1992). Petrographic analyses were conducted at the Laboratory for Ceramic Petrology and Conservation, University of Catamarca. Mineral inclusions and rock fragments were identified by qualitative analyses and then submitted to quantitative analysis as described in De La Fuente (2011a, 240–1).

DATA TREATMENT

A statistical package developed at MURR was used for the interpretation of the data. Statistical analysis was carried out on base-10 logarithms of the concentrations of all 32 chemical elements. The methods used to interpret compositional data obtained from the analysis of archaeological materials are discussed in detail elsewhere (e.g., Bishop and Neff 1989; Glascock 1992; Neff 2000, 2002) and will not be described in detail here. Cluster and principal component analyses were performed on the NAA data set. Groups were initially defined on the basis of visual separation of the data on elemental bivariate plots and further refined using group membership probabilities based on Mahalanobis distance projections (Bishop and Neff 1989).

RESULTS

We began by examining only the pottery samples (n = 310). Figure 2 shows a principal components analysis (PCA) diagram differentiating the Inca/Diaguita Chileno from the northwestern (NWA) ceramic sherds (51.0% of total variance). As we show in Figure 2, at least 10 sherds form this compositional group (Group 1, 3.5%, n = 10). The larger NWA group presents itself as a single large compositional group. An additional small group (Group 2, 0.06%, n = 4) of four Late Period sherds is readily separated from the NWA group.

The large NWA group (n = 198) was subsequently subjected to PCA and bivariate element exploration in order to tease out internal variability (40.7% of total variance) for the two first PCs. This large group presents some patterned compositional variation at the intra-group level. This compositional variation was explored through bivariate plots of PCA and chemical elements. The results obtained thus far show seven additional ceramic groups: Groups 3 (G-3) to 9 (G-9) (Tables 2 and 3 and Fig. 3). The largest group, G-5 (39.7%, n = 123), is dominated by assemblages of Inca Provincial sherds (n = 51) and Late Period sherds, Sanagasta (n = 33) and Belén (n = 22), followed by a few Early (Saujil, n = 8) and Middle (Aguada, n = 7) Period ceramic sherds. The sherds in this group are from 13 archaeological sites (SaCat12, SaCat02, RC, Costa de Reyes, SaCat13, GPS042, CV5, BP, CV2, SaCat04, SaCat03, MG and C62)

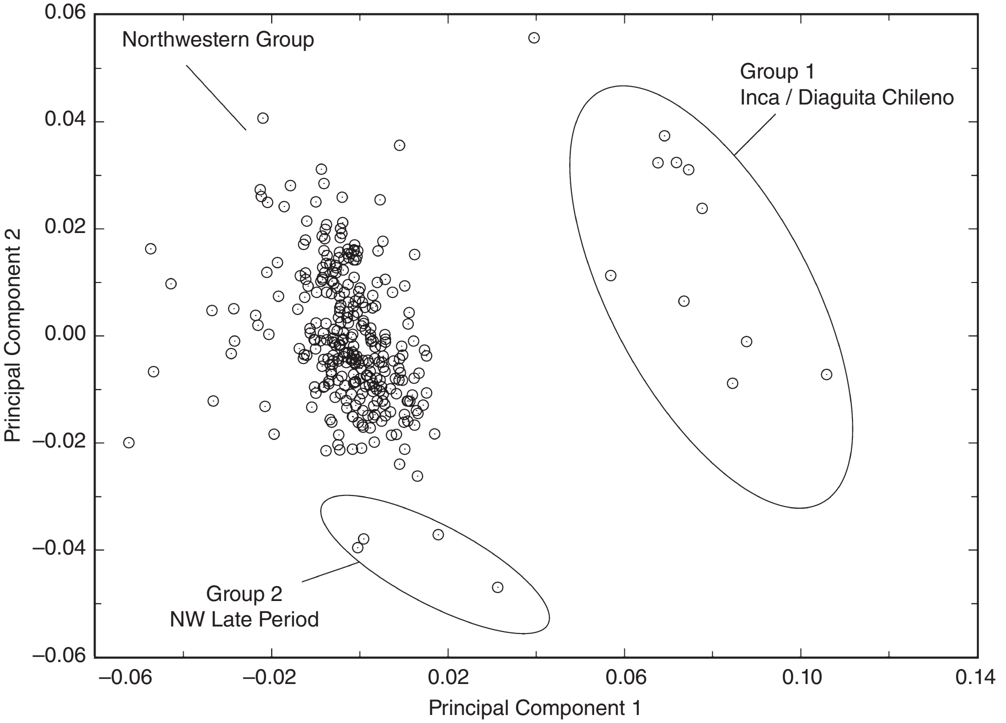

Figure 2 *A PCA diagram showing Groups 1 and 2 (ellipses represent 95% confidence).*

(Table 3). The second-largest group is G-3 (8.4%, n = 26) dominated by sherds from the Middle and Late Period (Sanagasta and Belén), and 57% (n = 15) of the sherds from this group are from the Montura del Gigante (MG) site. The remaining sherds are from the other sites (CV5, CV2 and BP) geographically close to the MG site. The third-largest group is G-4 (6.8%, n = 21), which is almost exclusively dominated by Late Period (Sanagasta) sherds from six different archaeological sites (BP, CV2, CRSB, SaCat12, RC and CV6). The fourth-largest group (G-9) (4.83%, n = 15) consists of mostly Late Period (Sanagasta and Belén) and a few Inca sherds; the sherds in this group are from nine archaeological sites (SaCat12, RC, SaCat13, GPS042, CRSB, CV5, BP, CV2 and SaCat03) (Fig. 3). The fifth-largest group is G-7 (2.6%, n = 8), almost exclusively grouping Late Period (Sanagasta) sherds from only one archaeological site (CV2) (Fig. 3). The remaining statistically defined compositional groups, G-6 (1.9%, n = 6) and G-8 (1.3%, n = 4), are too small to warrant detailed discussion, although it is worth noting that G-8 represents only one archaeological site (SaCat13) with Inca and Late Period (Belén) sherds. The unassigned sherds account for 26.1% (n = 81), which is a typical percentage for such a large sample and with the application of conservative group assignment criteria. The latter mostly overlap with Groups 5 and 9.

Ceramic petrography carried out on Late Period (n = 42) and Inca (18) ceramics shows the presence of high amounts of felsic minerals (quartz, alkali and plagioclase feldspars), and igneous rock fragments (granite), complemented with muscovite and biotite minerals, a few volcanic rock fragments (mainly andesite) and accessory minerals including amphibole and

Table 2 *Element concentrations and standard deviations (mean + SD) for the pottery compositional groups*

Element	*Group 1 (n = 10)*	*Group 2 (n = 6)*	*Group 3 (n = 26)*	*Group 4 (n = 21)*	*Group 5 (n = 123)*	*Group 6 (n = 6)*	*Group 7 (n = 8)*	*Group 8 (n = 4)*	*Group 9 (n = 15)*
Na (%)	1.72 ± 0.47	1.72 ± 0.38	1.67 ± 0.16	1.66 ± 0.26	1.85 ± 0.21	1.49 ± 0.11	1.32 ± 0.23	1.01 ± 0.53	1.96 ± 0.20
Al (%)	9.47 ± 0.70	8.27 ± 0.90	9.16 ± 0.46	8.31 ± 0.36	7.94 ± 0.50	9.53 ± 0.63	8.78 ± 0.19	9.45 ± 0.16	7.53 ± 0.52
K (%)	1.25 ± 0.19	2.90 ± 0.62	3.36 ± 0.15	3.07 ± 0.25	2.91 ± 0.25	3.58 ± 0.17	3.18 ± 0.19	2.91 ± 0.16	2.80 ± 0.15
Ca (%)	2.58 ± 0.46	2.21 ± 0.64	2.46 ± 0.48	2.55 ± 0.51	3.03 ± 0.81	2.01 ± 0.67	2.41 ± 0.24	2.30 ± 0.14	2.78 ± 0.77
Sc	20.45 ± 3.53	9.69 ± 1.7	17.22 ± 0.7	13.91 ± 0.6	14.89 ± 0.9	16.98 ± 0.7	14.19 ± 1.5	15.59 ± 1.4	13.26 ± 0.52
Ti	4918 ± 1185	2898 ± 837	4646 ± 390	3947 ± 495	3815 ± 401	4666 ± 415	3713 ± 436	5928 ± 1564	3418 ± 424
V	183.88 ± 52.8	81.21 ± 13.8	109 ± 8.3	89.06 ± 9.02	93.70 ± 11.1	129 ± 6.8	86.24 ± 11.7	129 ± 35	82.34 ± 10.2
Cr	25.44 ± 5.44	27.9 ± 5.1	55.9 ± 2.6	42.40 ± 1.01	45.08 ± 2.5	66.40 ± 0.6	37.59 ± 1.3	78.54 ± 4.3	39.34 ± 0.5
Mn	1310 ± 231	724 ± 116	848 ± 112	857 ± 101	940 ± 140	707 ± 91	951 ± 99	742 ± 453	838 ± 123
Fe (%)	5.97 ± 0.65	2.6 ± 0.28	4.95 ± 0.12	4.04 ± 0.14	4.14 ± 0.27	5.24 ± 0.27	4.04 ± 0.31	4.44 ± 0.15	3.72 ± 0.10
Co	18.7 ± 3.1	9.16 ± 1.1	18.9 ± 1.3	14.84 ± 0.7	15.7 ± 1.1	17.9 ± 0.6	15.17 ± 0.6	20.20 ± 9.9	14.30 ± 0.8
Zn	115 ± 44.6	74.32 ± 12.5	106 ± 5.9	92.24 ± 9.3	90.88 ± 8.4	108 ± 10.9	114 ± 6.2	95.72 ± 26.9	84.33 ± 8.3
As	15.87 ± 3.8	3.87 ± 1.3	10.32 ± 1.4	11.74 ± 3.1	8.33 ± 2.3	8.01 ± 4.0	6.99 ± 1.4	9.60 ± 2.3	7.44 ± 1.4
Rb	49.2 ± 9.07	156 ± 87.7	168 ± 7.1	178 ± 16.8	142 ± 13.4	189 ± 9.4	180 ± 10.9	163 ± 10.8	130 ± 7.4
Sr	347.7 ± 62.9	297 ± 189	309 ± 34	295 ± 72	309 ± 65	301 ± 38	289 ± 33	349 ± 198	306 ± 36
Zr	126.7 ± 38.1	135 ± 44	148 ± 16	146 ± 17	154 ± 21	139 ± 17	130 ± 21	220 ± 84	148 ± 17
Sb	1.79 ± 0.85	0.26 ± 0.08	0.76 ± 0.06	0.69 ± 0.08	0.52 ± 0.06	0.86 ± 0.06	0.53 ± 0.04	0.85 ± 0.49	0.46 ± 0.04
Cs	4.28 ± 1.24	20.4 ± 18.8	13.1 ± 0.6	16.33 ± 2.3	9.58 ± 1.1	15.01 ± 2.4	17.98 ± 1.8	19.18 ± 3.7	8.01 ± 0.8
Ba	358.1 ± 85.1	488 ± 144	492 ± 59	533 ± 91	470 ± 84	562 ± 122	507 ± 44	416 ± 110	460 ± 64
La	20.27 ± 5.31	32.3 ± 5.1	43.3 ± 2.4	38.38 ± 2.0	38.86 ± 2.7	44.96 ± 2.3	37.77 ± 4.7	48.43 ± 6.7	35.65 ± 1.6
Ce	42.67 ± 10.8	69.14 ± 11.9	90.8 ± 3.2	84.4 ± 7.0	82.87 ± 5.2	94.16 ± 4.1	90.75 ± 6.7	97.77 ± 14.5	75.26 ± 3.4
Nd	24.3 ± 6.7	28.9 ± 6.3	39.1 ± 3.7	35.55 ± 2.8	36.2 ± 3.1	42.73 ± 4.0	38.11 ± 4.6	42.34 ± 3.8	33.24 ± 2.4
Sm	5.33 ± 1.05	6.11 ± 1.4	8.2 ± 0.6	7.47 ± 0.48	7.53 ± 0.53	8.38 ± 0.63	7.90 ± 0.74	8.73 ± 0.85	6.84 ± 0.43
Eu	1.35 ± 0.20	1.01 ± 0.15	1.61 ± 0.05	1.40 ± 0.06	1.38 ± 0.08	1.62 ± 0.06	1.42 ± 0.05	1.74 ± 0.27	1.26 ± 0.03
Tb	0.68 ± 0.11	0.77 ± 0.25	1.06 ± 0.09	0.98 ± 0.09	0.94 ± 0.11	1.05 ± 0.10	1.01 ± 0.10	0.99 ± 0.17	0.87 ± 0.10
Dy	4.00 ± 0.9	5.20 ± 1.3	5.96 ± 0.33	5.21 ± 0.47	5.27 ± 0.43	5.82 ± 0.29	5.71 ± 0.43	5.64 ± 0.48	4.82 ± 0.34
Yb	2.54 ± 0.41	2.58 ± 0.83	3.49 ± 0.27	2.99 ± 0.19	3.0 ± 0.31	3.44 ± 0.34	2.99 ± 0.31	2.97 ± 0.46	2.70 ± 0.20
Lu	0.39 ± 0.06	0.36 ± 0.10	0.46 ± 0.02	0.41 ± 0.02	0.43 ± 0.04	0.48 ± 0.05	0.43 ± 0.06	0.42 ± 0.08	0.40 ± 0.04
Hf	5.17 ± 0.9	4.58 ± 0.92	4.87 ± 0.16	4.85 ± 0.37	5.16 ± 0.37	5.21 ± 0.40	4.45 ± 0.64	6.41 ± 1.31	5.01 ± 0.53
Ta	0.40 ± 0.06	1.46 ± 0.50	1.42 ± 0.11	1.25 ± 0.13	1.29 ± 0.13	1.34 ± 0.12	1.71 ± 0.41	2.17 ± 0.92	1.18 ± 0.14
Th	6.56 ± 2.1	14.9 ± 4.7	16.1 ± 0.6	13.52 ± 1.6	14.12 ± 1.5	15.98 ± 1.52	15.38 ± 2.95	13.5 ± 1.40	13.09 ± 1.30
U	1.63 ± 0.45	6.06 ± 3.7	4.39 ± 0.56	4.91 ± 1.24	5.88 ± 2.09	5.22 ± 0.83	5.97 ± 0.48	10.43 ± 5.10	5.18 ± 1.83

Table 3 *NAA compositional pottery groups by site*

Archaeological site	*G-1 I/DC*	*G-2 LP*	*G-3 MP/LP*	*G-4 LP*	*G-5 I/LP*	*G-6 LP*	*G-7 LP*	*G-8 LP*	*G-9 LP/I*	*Total*
Costa de Reyes No. 5										
Sector A					7					7
Sector B	8	2	1	2	24	1			4	42
Sector C					5					5
SaCat02				1	5					6
SaCat03					9	1			2	12
SaCat04			3		12	3				18
GPS 042 Barreal					13				2	15
Camino 62 (C62)					5					5
CV6—Inca				2			1			3
Río Colorado				2	4				1	7
CV5			4		5				1	10
CV2		1	1	4	10		6		1	23
CV4				4						4
Barrancas f/La Puntilla		1	2	4	2				1	10
La Montura del Gigante			15		2					17
SaCat12		2		1	5	1		1	1	11
SaCat13	2			1	15		1	3	2	24
Total	10	6	26	21	123	6	8	4	15	219

Key: I/DC, Inca/Diaguita Chileno; MP, Middle Period; LP, Late Period; I, Inca.

clinopyroxene (Fig. 4). The main mineralogical differences between the ceramics from the two pre-Hispanic periods are the presence of calcite (primary and secondary calcite), volcanic glass, and the unique presence of grog in the Inca ceramics (see the Appendix). The integration of the elemental compositional, petrographic and archaeological data is presented below.

DISCUSSION

Overall, most of the groups show unambiguous separation, although some overlap is present for Groups 5 and 9 (Fig. 3). G-9 is dominated by Late Period sherds (mostly Sanagasta), and they generally present high compositional variation in the whole sample. Late Period sherds similar to those in G-9 have larger quantities of felsic minerals than Inca sherds. A further exploration of the compositional structure of the data through bivariate plots of the elements and group membership probabilities shows a better separation of the groups than through PCA (Fig. 3). Compositionally, G- 9 is close to G-5, probably due to slight differences in the Cr concentrations coming from the clay sources. As previously stated, G-5 groups Inca Provincial and Late Period sherds together, probably representing a single clay source used by Inca and Late Period people (Fig. 3). G-3 includes almost exclusively Middle Period ceramics from one site (MG). The unambiguous chemical separation of G-3 from the rest of the groups indicates different clay source utilization or paste recipes at this site (Fig. 3).

The pronounced chemical variation observed in this study indicates that pottery production during the Late Period (Sanagasta and Belén) is more complex than in earlier periods. The

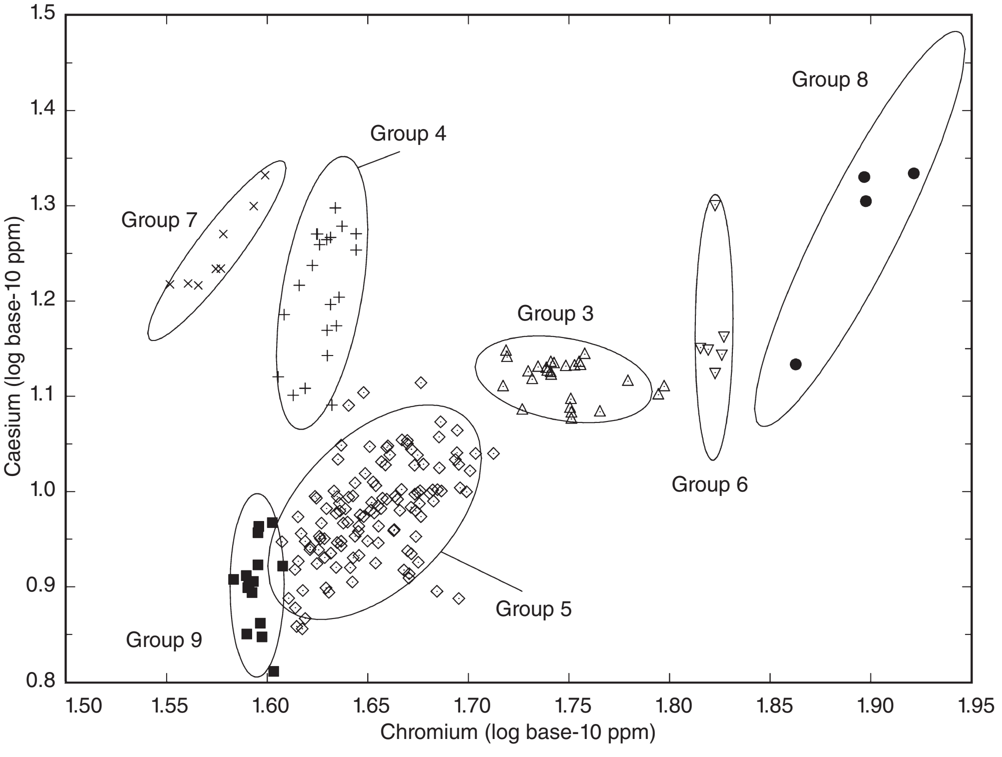

Figure 3 *A plot of the chromium and caesium base-10 logged concentrations of potsherds, showing compositional groups G-3 to G-9 as defined by Mahalanobis distance (ellipses represent 95% confidence).*

ceramic compositional groups (G-4, G-7 and G-9) are well separated on the bivariate plots (e.g., Cr/Ce, Cr/Ta and Cr/Eu), thus representing different geochemical fingerprints (Fig. 5). However, as stated earlier, additional research must be done to explore the influence of the high loadings of felsic minerals (quartz and feldspars) on the chemical patterns observed. The data indicate the possibility that more than two clay sources are represented by Late Period ceramics, which is probably the result of high mobility for these ceramic goods and the existence of exchange networks. The multiple compositional groups represented at the site of Costa de Reyes No. 5 (Table 3), which has six pottery kilns, may represent the work of different potters over time, before and during Inca occupation. One of these kilns has been dated by AMS to the end of the Late Period—AA95920 636 ± 36, 1289–1394 cal AD; OxCal v4.1.7 (McCormac *et al*. 2004; Bronk Ramsey 2009)—indicating that this kiln may have operated during the end of the Late Period. TL dates obtained on 68 ceramic sherds from different sites point towards a chronological separation during the Late Period of at least three stages: (1) AD 900–1300, (2) AD 1300–1480 and (3) AD 1480–1600 (De La Fuente *et al*. 2010). We observe that some of the compositional groups defined here have chronological sensitivity according to the TL dates obtained. Several TL dates obtained from ceramics in G-5, Inca and Late Period sherds, indicate that this group represents the time of Inca occupation and coexistence with the Late Period local population (De La Fuente *et al*. 2010, figs. 2 and 3). On the other hand, TL dates obtained for Late Period sherds in G-4 and

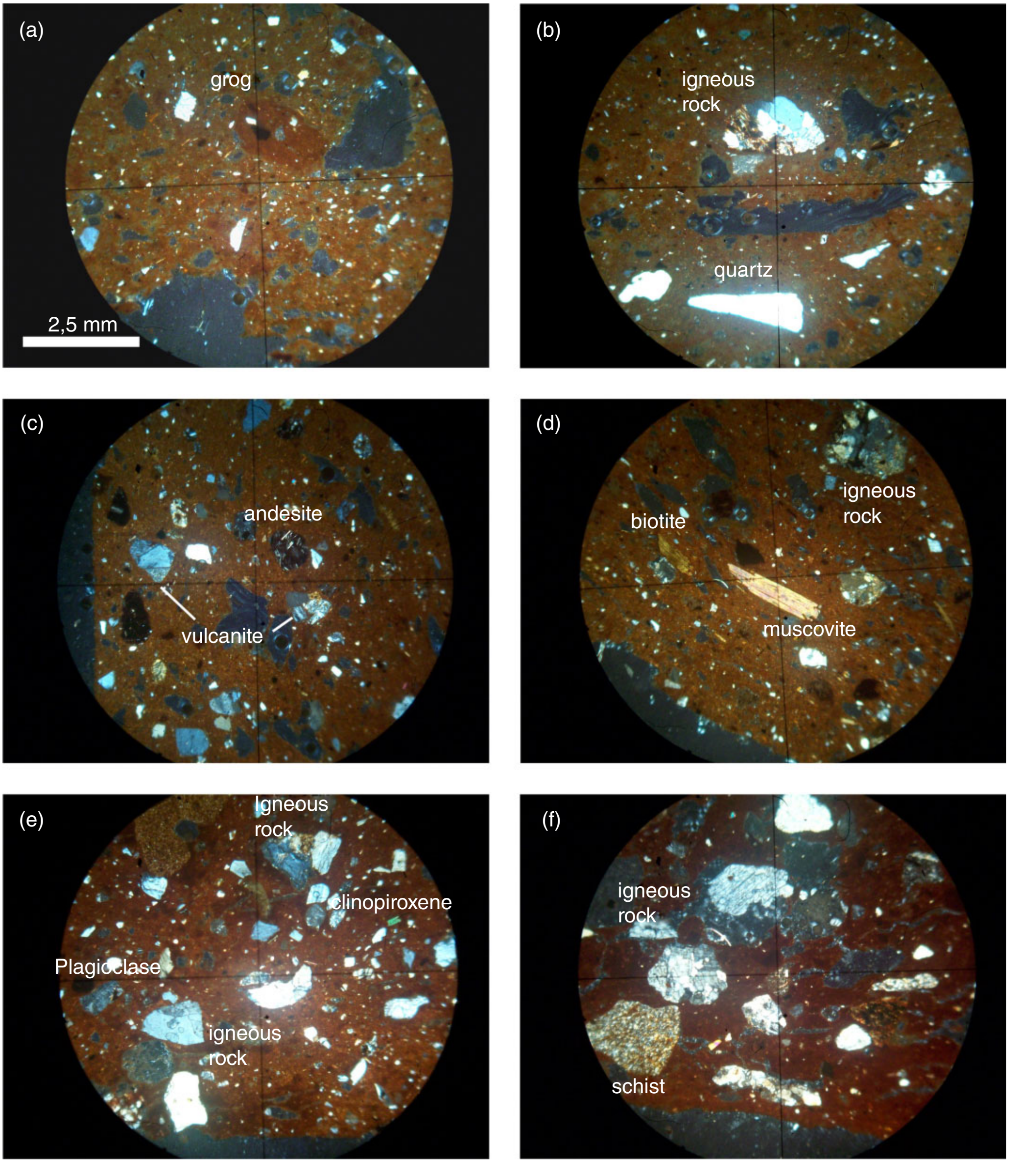

Figure 4 *Petrographic microphotographs of Inca and Late Period sherds: (a) DLF109, Inca, quartz grains and a grog inclusion; (b) DLF095, Inca, large inclusions of quartz and an igneous rock fragment; (c) DLF098, Inca, fine to medium quartz grains, volcanic rock fragments (vulcanites), and two andesite fragments; (d) DLF067, Late Period, fine quartz grains, muscovite and biotite inclusions, and igneous rock fragments; (e) DLF094, Late Period, medium quartz grains, plagioclase, igneous rock fragments, argillaceous inclusions and clynopiroxene; and (f) DLF194, Late Period, isotropic matrix, quartz inclusions, large igneous rock fragments and metamorphic rock fragment (schist). All microphotographs in 40× magnification.*

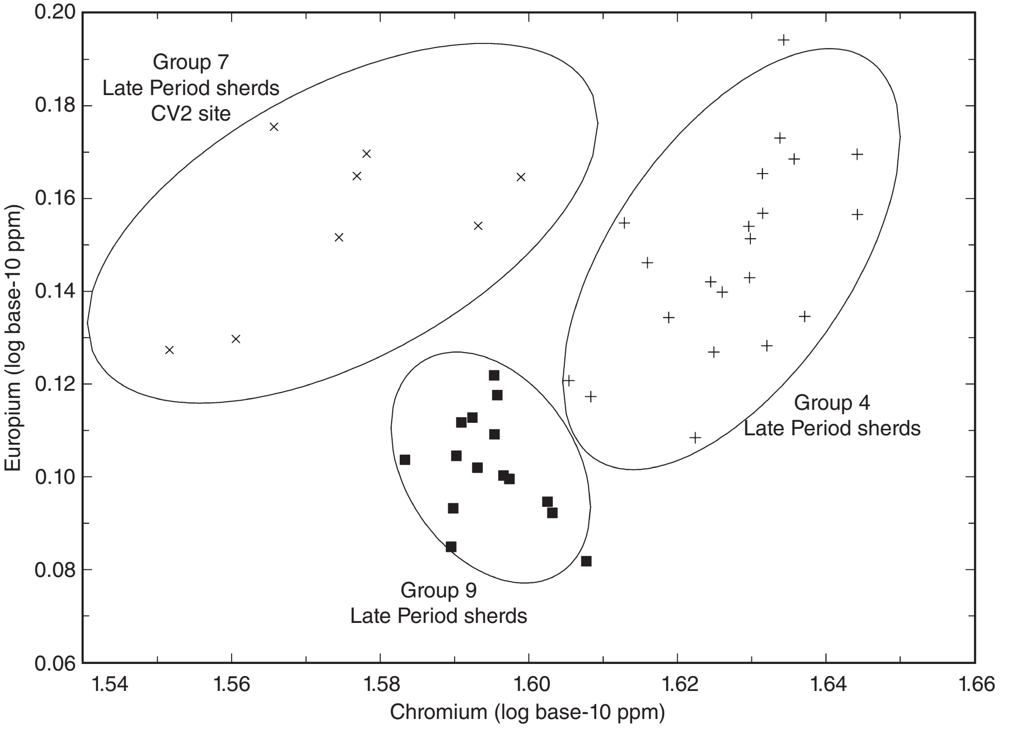

Figure 5 *A plot of the chromium and europium base-10 logged concentrations of potsherds (G-4, G-7 and G-9) (ellipses represent 95% confidence).*

G-9 compositional groups show that they are from the first and second stages of the Late Period, respectively (De La Fuente *et al*. 2010, fig. 3).

Concerning the ceramic forms involved in this study, G-5 includes a significant amount of large vessels (*aríbalos* and urns), whereas G-4, G-7 and G-9 show a predominance of bowls. This perhaps indicates high mobility of bowls in the region during the Late Period. Most ceramic forms analysed by petrography from the Late and Inca Periods show a homogeneous mineralogy, characterized by felsic minerals (quartz, alkali and plagioglase-series feldspars) especially for bowls and urns. The Inca form *aríbalo* shows the unique presence of grog, volcanic glass and to a lesser extent different forms of calcite (see the Appendix). Ceramic petrography points towards a change in the recipes for ceramic pastes from the Late Period to the Inca Period, and this change is reflected in the G-5 compositional group defined by NAA. As we stated earlier, Late Period ceramics contain higher amounts of felsic minerals than Inca sherds, which could have affected the formation of several Late Period compositional groups, with high concentrations for Cs and Rb, the alkali elements (see Table 2). This influence of mineralogy on chemical composition should be investigated further.

Results obtained by Ratto and collaborators in the middle sector of Abaucán Valley indicate the existence of a local conservative tradition of pottery production around the Batungasta site, using the same La Troya River clay sources over time (Ratto *et al*. 2002, 2004, 2006; Plá and Ratto 2007, fig. 2). In the southern sector of the Abaucán Valley, this does not seem to be the case. The results obtained, thus far, show a typically structured ceramic production for Inca and Late Period times (G-5), a pronounced compositional variation for Late Period ceramics (G-4, G-6, G-7, G-8 and G-9), together with an isolated Late Period group (G-2), and a use of different clays (G-3) during the Middle Period.

The clay samples analysed in this study (n = 14) were collected from six different rivers, as shown in Figure 1. Most clays are secondary clays in a Tertiary geological sedimentary environment characterized by tuffaceous sandstones, tuffs, fine-grained sandstones, mudstones and claystones (Sosic 1972). These are mixed with Quaternary fluvial and aeolian sediments deposited in the piedmonts of the hills (Sosic 1972). The clays separate into three groups and two isolated cases (Fig. 6): (a) C-1 constitutes clays from Río de la Costa; (b) C-2 includes three clay samples from the main Río Colorado; and (c) C-3 is formed by samples from the Higueritas River, Cienaguita Creek and samples from Río de la Costa (DLF313) and a secondary creek derived from the Río Colorado (DLF322) (Fig. 6). Sample DLF324 represents Río Zapata and is well separated on the elemental plots. Sample DLF323 also plots as an isolated case.

The clays were projected against the G-3, G4 and G-9 compositional groups using PCA. Clay samples DLF317, DLF313 and DLF322 have high probabilities of being included in G-3 (Middle Period), while sample DLF316 is very close to G-4 (Late Period) (Fig. 6). The remaining groups G-8, G-6 and G7 are too small to warrant further consideration. On the other hand, when the clays

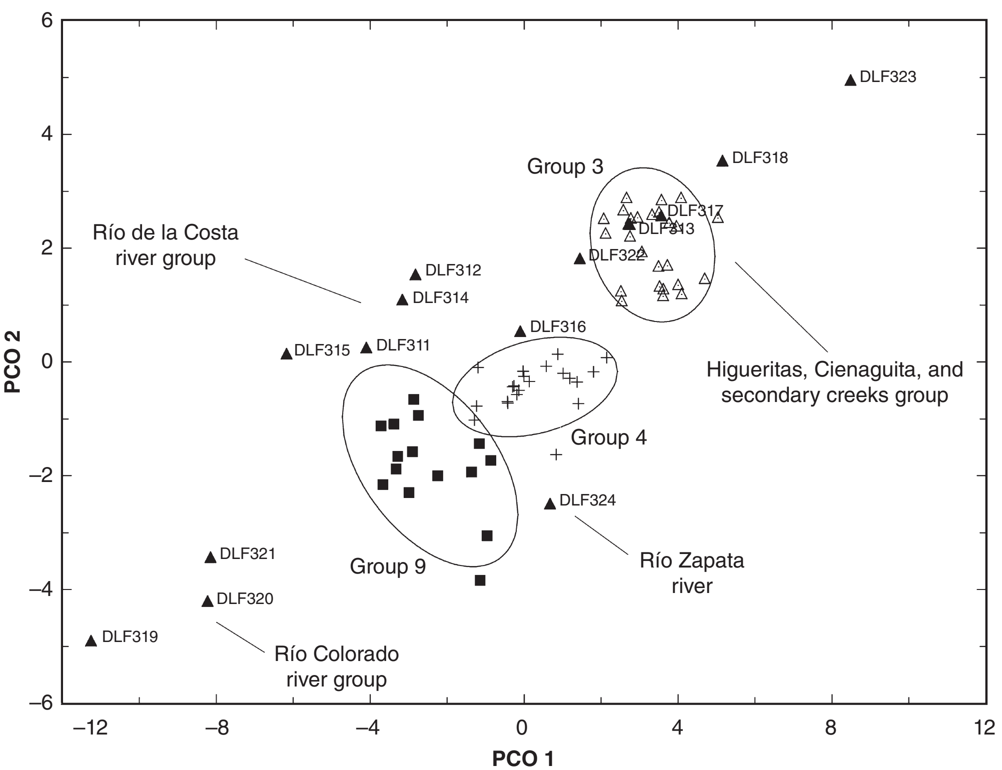

Figure 6 *A PCA plot showing the clay samples and compositional groups G-3, G-4 and G-9. Ellipses represent 95% confidence intervals for membership in each of the groups.*

were projected against G-5 using Mahalanobis distance calculations on the raw data, two clay samples, DLF312 (92.23%) and DLF324 (87.32%), were found to have high probabilities of being included in this group. At this point, we can say that clay groups as defined by NAA adequately represent the main hydrological basins along the region. This suggests that some of the river deposits were used as sources of clay over time during the Late to Inca Periods.

CONCLUSIONS

NAA and ceramic petrography of a large ceramic sample from northwestern Argentina have yielded results that are useful for explicating the organization of pottery production during the Late and Inca Periods in the southern sector of the Abaucán Valley. The results indicate the presence of nine compositional groups. Two of these groups (G-1 and G-2) are very unique and represent non-local pottery from Chile and Late Period ceramics with an unknown non-local provenance, respectively. The remaining seven groups (G-3 to G-9) are consistent with local pottery production in the geographical region under study. One of the groups, G-5, is formed by Inca and Late Period sherds, probably indicating the control of a specific clay source during Inca occupation in the region. G-3 represents almost exclusively one site and is formed by sherds from the Middle Period. The remaining groups (G-4, G-6, G-7, G-8 and G-9) are formed primarily by Late Period ceramics. These groups represent pronounced compositional variation for these ceramics, suggesting the high probability of exchange of these vessels across the region during the Late Period for G-6, G-7 and G-8; and the use of different clay sources over time for G-4 and G-9, as suggested by TL dating.

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APPENDIX: PETROGRAPHIC ANALYSIS (IN %; $N = 60$)

	NAA group	*Cultural period*	*Site*	*CQ*	*PQ*	*PF*	*KF*	*M*	*B*	*Ca*	*IgFr (p)*	*SedFr*	*MtFr*	*IgFr(v)*	*Gr*	*ArcInc*	*VG*	*An*	*Pir*
DLF188	G-2	LP	BP	62.26	1.88	11.32	1.88	15.09	5.66					1.88					
DLF195	G-3	LP	BP	57.14		9.52			14.28		4.76			4.76				9.52	
DLF194	G-4	LP	BP	50.98		3.92	3.92		5.88		13.72		9.80	5.88				5.88	
DLF184	G-4	LP	BP	45.45		18.18		9.09	4.54		9.09			4.54				4.54	4.54
DLF139	G-4	LP	CRSB	52.17		8.69		8.69	8.69		4.34					8.69		4.34	4.34
DLF030	G-4	LP	CV6	42.85	2.85	22.85		11.42	5.71		5.71							5.71	2.85
DLF031	G-4	LP	CV6	41.89	6.75	20.27		4.05	5.40	1.35	4.05		1.35	4.05		4.05		4.05	2.70
DLF037	G-4	LP	RC	48.93	8.51	14.89		4.25	2.12		4.25			4.25		2.12		8.51	2.12
DLF224	G-4	LP	CV2	41.46	12.19	24.39		2.43	2.43		4.87							7.31	4.87
DLF070	G-5	LP	SaCat13	54.54	6.06	12.12		3.03	9.09		3.03			6.06				3.03	3.03
DLF158	G-5	LP	CV5	58.82	5.88			11.76	5.88		5.88			5.88		5.88			
DLF160	G-5	LP	CV5	47.91		12.5		10.41	6.25		4.16		2.08	8.33		4.16		2.08	2.08
DLF227	G-5	LP	CV2	46.66	6.66	10.0		3.33	10.0		6.66					6.66		3.33	6.66
DLF084	G-5	LP	GPS042	53.06	8.16	16.32		6.12	8.16		2.04							6.12	
DLF203	G-5	LP	CV2	55.0		15.0					5.0			10.0				10.0	5.0
DLF140	G-5	LP	CRSB	45.0		10.0	5.0	15.0	5.0		10.0							5.0	5.0
DLF033	G-5	LP	RC	48.0	4.0	22.0		10.0	4.0		2.0		2.0			2.0		6.0	
DLF104	G-5	LP	CRSB	44.87	2.56	19.23		5.12	12.82	1.28	5.12	1.28		2.56				3.84	1.28
DLF155	G-5	LP	CV5	32.60	2.17	10.86		8.69	21.73		6.52					10.86		4.34	2.17
DLF200	G-5	LP	CV2	42.85		14.28		11.42	11.4		5.71			8.57				5.71	
DLF081	G-5	LP	SaCat13	43.39	5.66	18.86	1.88	9.43	5.66		3.77			5.66				3.77	1.88
DLF094	G-5	LP	GPS042	48.21	3.57	12.5		3.57	1.78		8.92		1.78	1.78		8.92		1.78	7.14
DLF143	G-5	LP	CRSB	43.75	6.25	20.83		8.33	6.25		2.08			4.16				6.25	2.08
DLF259	G-5	LP	SaCat03	52.77	2.77	11.11		11.11	5.55		5.55			5.55				2.77	2.77
DLF260	G-5	LP	SaCat03	48.35	6.59	8.79	2.19		5.49		7.69			5.49		9.89		4.39	1.09
DLF114	G-5	LP	CRSB	54.34		8.69			8.69	2.17	6.52		2.17	8.69				6.52	2.17
DLF118	G-5	LP	CRSB	50.79	7.93	11.11		7.93	6.34		7.93					4.76		1.58	1.58
DLF109	G-5	I	CRSB	37.20	4.65	11.62	2.32		13.95		4.65			4.65	13.95	4.65		4.65	
DLF095	G-5	I	GPS042	37.03		7.40		7.40	3.70		11.11			3.70	7.40	7.40		11.11	3.70
DLF087	G-5	I	GPS042	59.25		11.11		7.40						7.40	7.40			3.70	3.70

DLF098	G-5	I	GPS042	38.29		6.38		6.30	2.12	2.12	8.51			12.76	4.25		6.38	4.25	4.25
DLF105	G-5	I	CRSB	46.87		6.25	3.12	6.25	6.25	3.12					6.25	9.37	6.25		6.25
DLF049	G-5	I	SaCat13	45.16		9.67		12.90	6.45	6.45	3.22			6.45			3.22	6.45	
DLF052	G-5	I	SaCat13	36.84	1.75	8.77		10.52	3.50		7.01			7.01	8.77	3.50	5.26	5.26	1.75
DLF054	G-5	I	SaCat13	38.23		5.88	2.94	8.82	2.94		5.88			8.82	11.76			8.82	5.88
DLF056	G-5	I	SaCat13	46.66		10.0	3.33		10.0	3.33	8.33		1.66	3.33	6.66	3.33		3.33	
DLF057	G-5	I	SaCat13	34.28	2.85	8.57	2.85		8.57		8.57		2.85	5.72	8.57		5.71	8.57	2.85
DLF059	G-5	I	SaCat13	47.05		11.76	5.88		5.88		5.88			2.94		8.82		5.88	5.88
DLF062	G-5	I	SaCat13	46.15		7.69			7.69		5.76		1.92	5.76	7.69	3.84	7.69	3.84	1.92
DLF063	G-5	I	SaCat13	43.18		4.54	2.27	11.36	4.54	2.27	6.81		2.27	9.09		6.81		6.81	
DLF024	G-5	I	SaCat02	45.94		8.10		5.40	10.81	2.70	5.40				16.21			2.70	2.70
DLF099	G-5	I	GPS042	47.05	3.92	13.72		5.88		1.96	5.88			3.92	9.80		3.92	1.96	1.96
DLF101	G-5	I	GPS042	39.21	1.96	11.76	3.92	7.84	5.88		3.92			5.88	3.92	3.92	7.84	1.96	1.96
DLF006	G-6	LP	SaCat12	54.16		12.5		8.33	4.16		4.16			4.16				8.33	4.16
DLF258	G-6	LP	SaCat03	46.87	9.37	25.0		3.12	3.12		6.25							3.12	3.12
DLF073	G-7	LP	SaCat13	49.09		25.45		14.54						3.63				5.45	1.81
DLF208	G-7	LP	CV2	40.0		13.33	3.33	6.66	6.66	3.33	3.33		3.33	3.33		3.33		10.0	3.33
DLF229	G-7	LP	CV2	54.90	5.88	9.80		11.76			5.88			1.96		3.92		3.92	1.96
DLF067	G-8	LP	SaCat13	42.85		8.57		20.0	5.71		14.28							5.71	2.85
DLF156	G-9	LP	CV5	36.50	1.58	15.87	3.17	12.69	12.69		6.34			4.76				4.76	1.58
DLF091	G-9	LP	GPS042	39.62	7.54	16.98		5.66	9.43		3.77			5.66		3.77		5.66	1.88
DLF255	G-9	LP	SaCat03	47.36		15.78		5.26	10.52		5.26			5.27				5.26	5.26
DLF265	G-9	LP	SaCat03	55.88		8.82		5.88	8.82		5.88		2.94	5.88				2.94	2.94
DLF145	G-9	I	CRSB	35.48		12.90		6.45	9.67	3.22	9.67		3.22	3.22	9.67			6.45	
DLF152	G-9	I	CRSB	43.24	2.70	8.11		8.11		2.70	10.81			5.40	10.81			2.70	5.40
DLF178	Unassigned	LP	BP	52.17		8.69		8.69	4.34	4.34	13.04							8.69	
DLF089	Unassigned	LP	GPS042	51.85		14.81	3.70	11.11	3.70									7.40	7.40
DLF141	Unassigned	LP	CRSB	54.87	4.87	15.85		7.31	2.43		6.09			1.21		2.43		4.87	
DLF167	Unassigned	LP	CV5	61.53		11.53		7.69	11.53		3.84							3.84	
DLF204	Unassigned	LP	CV2	46.0	4.0	18.0	14.0	8.0	2.0					2.0		2.0		2.0	2.0

LP, Late Period; I, Inca Period. Temper references: CQ, crystalline quartz; PQ, polycrystalline quartz; PF, plagioclase feldspar; KF, potassium feldspar; M, muscovite; B, biotite; Ca, calcite; IgFr(p), igneous rock fragment (plutonic); SedFr, sedimentary rock fragment; MtFr, metamorphic rock fragment; IgFr(v), igneous rock fragment (volcanic); Gr, grog; ArcInc, argillaceous inclusions; VG, volcanic glass; An, amphibole; Pir, pyroxene.