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# Pottery production of Saujil vessels from the early period (Catamarca and La Rioja provinces), Northwestern Argentine region: An evaluation through neutron activation analysis

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ABSTRACT

Pottery production during the Early Period at Northwestern Argentine region has been characterized by the existence of a Grey-Horizon involving vessels fired under extreme reducing conditions, probably using some kiln-based firing structures. Neutron activation (NAA) and technological analysis were carried out on the Early Period pottery from 12 archaeological sites geographically located mostly at southwestern Catamarca and northern La Rioja provinces. Ceramic fabrics analysis suggests that several technological choices were implemented by potters as different regional potteŕs recipes to produce the vessels. Geochemical groups as defined by NAA indicate that at least three local production areas were working during the Early Period in these two geographical areas. Potters used local clays to produce most types of vessel forms.

## 1. Introduction

Pottery production during the Early Period (I-VI centuries) at Northwestern Argentine (NA) region is generally characterised by a local low-scale production to satisfy household requirements (Ratto et al., 2002, 2013; Korstanje et al., 2015; Pereyra Domingorena and Cremonte, 2017; Gasparotti and Pintar, 2019; Lazzari et al., 2019). Production of this Grey-Horizon pottery at southwestern Catamarca and northern La Rioja provinces has been recorded in several archaeological sites, and sometimes it regionally coexists with other several ceramic styles (Ratto et al., 2013; Callegari et al., 2015). One of most interesting aspects of pottery production in this period is the firing technology employed by ancient potters (Sempé, 1977). Most ceramic vessels, but not exclusively, were fired under reducing conditions using pottery kilns or kiln-based structures (González, 1977; Ratto et al., 2013, 2015; Vera and De La Fuente, 2018; Callegari et al., 2015). This firing technology feature has led classic NA archaeologists to propose the existence of a Grey Reduced Horizon pottery, mainly characterized by small and medium size vessels fired at reducing atmospheres displaying a specific greyish monochromatic repertoire of motifs (Sempé, 1977; González, 1977).

This paper presents new chemical (Neutron Activation Analysis – NAA–) and technological data obtained through an extensive ongoing research on pottery production during the Early Period at the NA region. It examines the main chemical and technological characteristics of Grey-Horizon Pottery from several archaeological sites geographically located at southwestern Catamarca and northern La Rioja provinces (Fig. 1). Provenance of pottery, recipes applied by potters, and geographical patterns of circulation of the vessels are furtherly discussed through the integration of chemical and technological data. Finally, the main aim of this paper is to define the degree and intensity of integration, inhabitants of prehispanic villages developed during the Early Period at southwestern Catamarca and northern La Rioja provinces.

## 2. Archaeological settings and background

The Early Period at the NA region presents a regional prehispanic settlement pattern usually characterized by different domestic

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architectural residential units, geographically distributed across rural or agricultural and pastoralist-based landscapes (Scattolin et al., 2009; Bonomo et al., 2010; Korstanje et al., 2015). Economy in this pre-hispanic time was based in the production of plants through agriculture and camelids herding (Korstanje et al., 2015). Crafting was primarily performed at household-based level and the appearance of regional distribution networks for some goods like pottery, obsidian and metals opens the discussion about the increasing social inequalities and complexities in the first millennium of the Christian era (Ratto et al., 2002; Lazzari et al., 2009, 2017, 2019; López Campeny, 2012; Pereyra Domingorena et al., 2020). Pottery production was carried out at household level, mainly for local consumption and distribution as in other areas of southern and Central Andes (Ratto et al., 2002; Feely, 2013; Falabella et al., 2013, 2019; Stovel et al., 2016; Druc et al., 2017; Echenique et al., 2018).

Geographically, the region under study is located on one hand in the

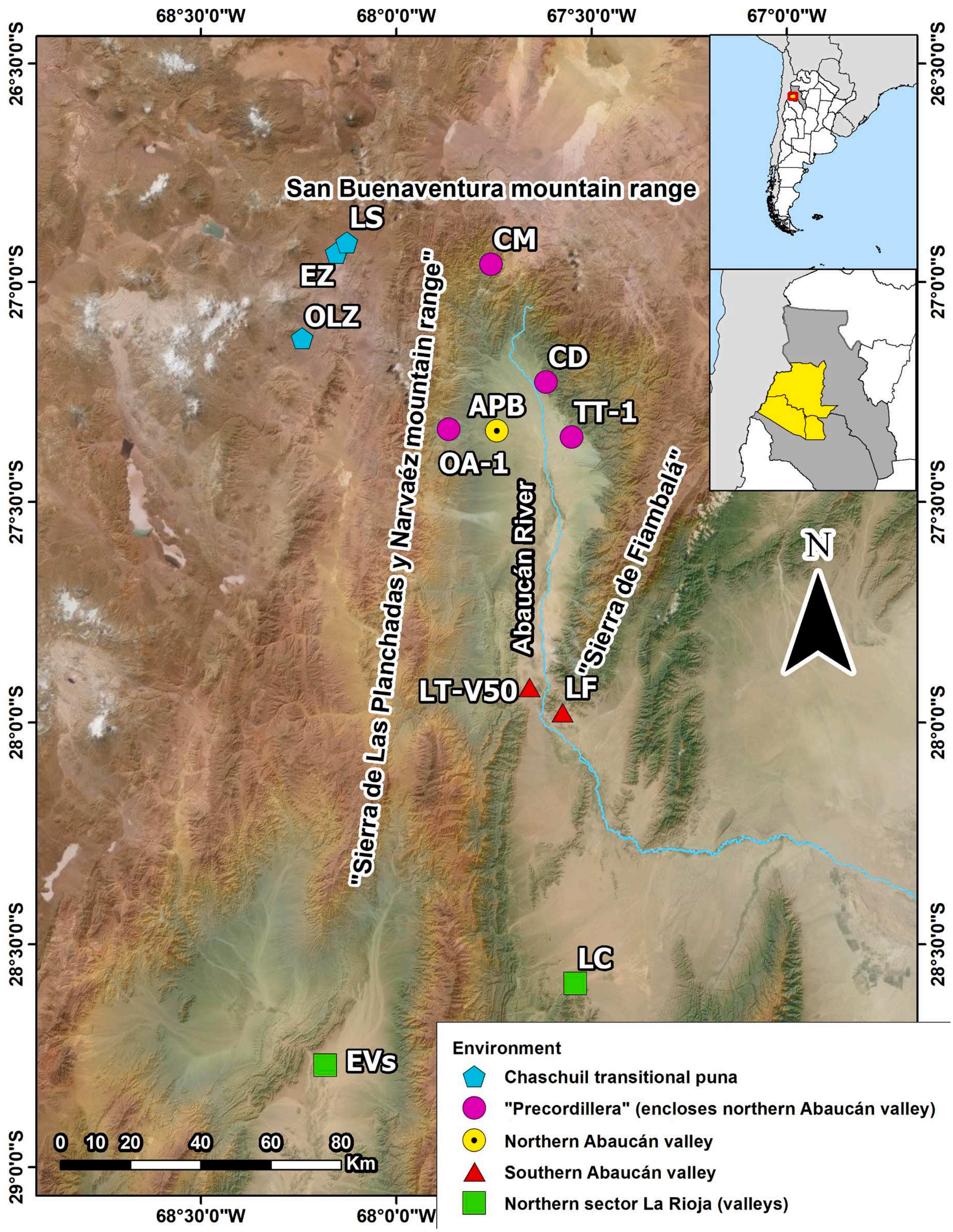


**Fig. 1.** Map with the geographical location of archaeological sites and the different environments mentioned in the text.

Department of Tinogasta, Province of Catamarca, and on the other hand in the Departments of Famatina and Vinchina, Province of La Rioja (Fig. 1). It presents three main environmental units in Catamarca: the Chaschuil transitional Puna sector (2500–5500 masl), the Precordillera sector (1500–2500 masl), and the Abaucán valley (northern and southern sectors) (1300–1500 masl), being the Abaucán Valley the main geographical unit (Fig. 1). The Abaucán Valley is a longitudinal geographical area extending north–south at Catamarca province. It is characterized by a topography of alternating valleys and mountains crossed by rivers that form the basin of Abaucán (Fig. 1). This river basin is complex and receives tributaries that pass through different geological provinces. In the northern sector the Abaucán receives inputs from rivers originating in the high peaks of Famatina System (Las Papas, Chuquisaca, Río Grande, Colorado, Río de Abajo) and the northwestern Sierras Pampeanas (Tatón, Agua del Médano). Also, it receives the waters from Chaschuil or Guanchín river at the town of Fiambalá. This river has a long course receiving inputs from tributaries originating in the geological province Cordillera Frontal, then crosess the Cordillera de Narváez (Famatina System) which also receives tributaries and finally drains into the Abaucán river. The rivers La Troya and El Puesto in the middle valley are also tributaries of Abaucán river (Ratto et al., 2015). To the south, Colorado and de La Costa rivers together with Las Higueritas and La Cienaguita creeks also drain to the Abaucán river (De La Fuente et al., 2015) (Fig. 1).

In the north of La Rioja Province, we consider two geographical areas: (1) the width Antinaco Valley (1450–1650 masl), located in the

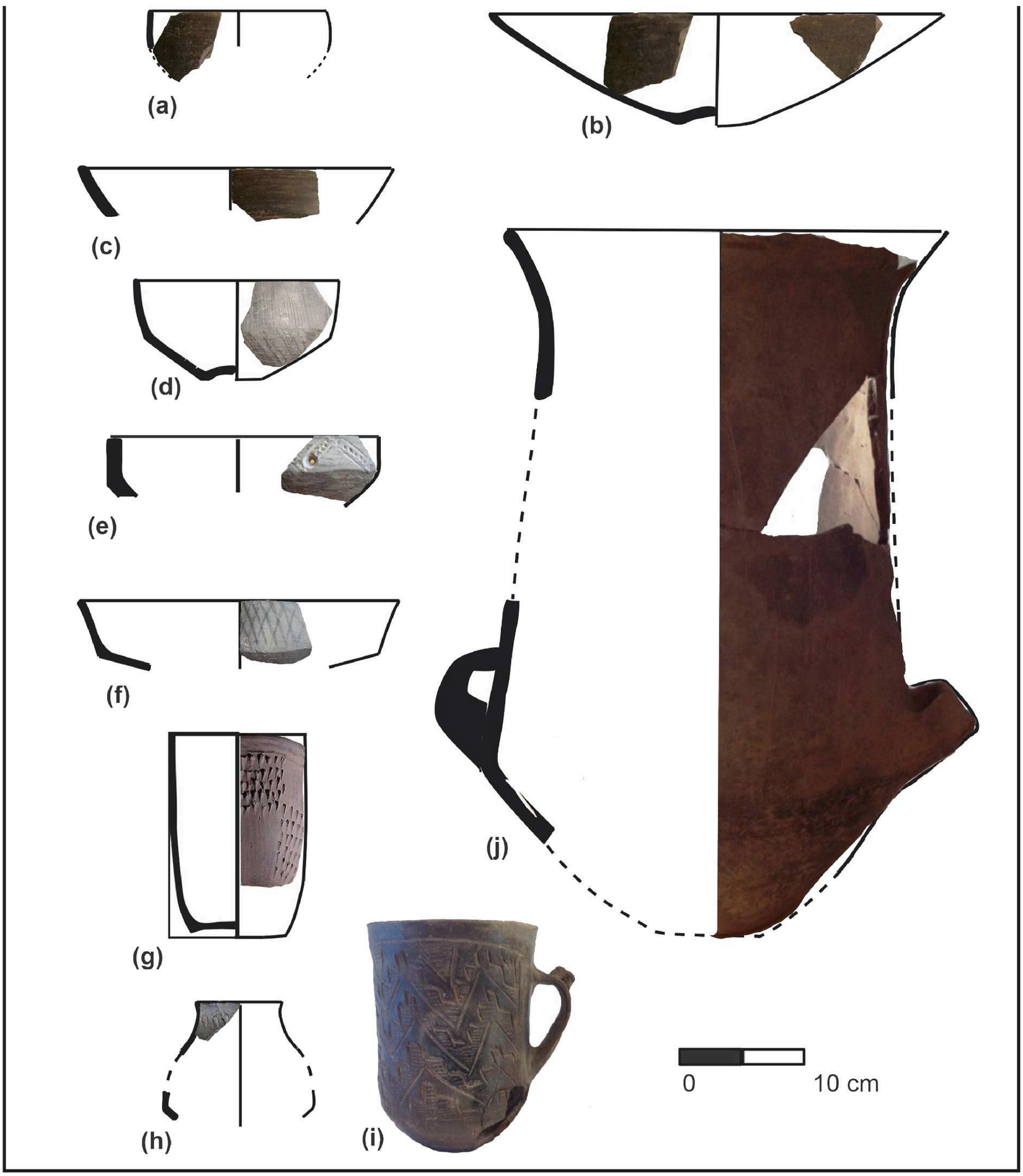


**Fig. 2.** Vessel forms for Saujil ceramic style. Bowls (a), (c)-(f); large bowl (b); vase (g); vessel (h); jar (i); urn (j).

northern sector of Department of Famatina, with the Chañarmuyo-Pituil river as the main water course. It limits to the east with Sierra de Velazco and with Paimán System to the west (Callegari et al., 2015) (Fig. 1); and (2) the northern sector of Department of Vinchina, known as the mud-banks Las Eras Viejas (1250–1350 masl). It consists of an extense plain weathered (denudated) by erosion extending along the east bank of Vinchina river in southwest-northeast direction, covering approximately 13 km$^2$ (Fig. 1).

Archaeological sites are in all these different environments and they last from Early to Inca Periods (I-XV centuries), although most pre-hispanic occupation is recorded for Early and Inca periods (Ratto et al., 2013; Callegari et al., 2015). Early period sites are characterized by present different forms, sizes and architectural features. Sites constituted by circular-shaped structures arrangements are the most classic settlement pattern for Early period (González, 1977), but sites with rectangular/quadrangular-shaped structures are also present at Abaucán valley. They were built using stones masonry as well as earthen walls (*tapia*) (Sempé, 1977; Bonomo et al., 2010; Callegari et al., 2015).

Grey-Horizon pottery in this geographical area comprises at least two ceramic types: Saujil and Ciénaga, and it involves bowls, urns, large bowls, cylindrical jars and vases as the main typical vessels forms (Sempé, 1977; Bonomo et al., 2010; Ratto et al., 2013; De La Fuente and Vera, 2015; Callegari et al., 2015). Vessels are mostly decorated using incised and engraving techniques. Fig. 2 shows the main vessel forms for the Grey-Horizon pottery.

Previous analytical research carried out in the area applying extensive NAA indicates that pottery production was mostly carried out locally in middle Abaucán Valley, and vessels were geographically distributed to the northern Abaucán valley and to the Chaschuil highlands of Precordillera area (Plá and Ratto, 2003, 2007; Ratto et al., 2013). It is assumed that La Troya river basin acted as a large raw material source of clays used by ancient potters through prehispanic times. Also, this research has emphasized on Batungasta archaeological site and its surroundings as a pottery production center for pre-Inca and Inca times.

Additional compositional research through NAA and ceramic petrography, done at southern Abaucán valley for Late and Inca periods, highlighted that pottery production was more strictly controlled for Inca times using only one local source of clays, whereas during the Late Period a more diverse production was observed (De La Fuente et al., 2015).

## 3. Ceramic sampling and analytical methods

### 3.1. Ceramic sample

Ceramic sample for this study is composed by 139 pottery sherds from 12 archaeological sites geographically distributed along the Chaschuil region and the Abaucán Valley in Catamarca and northern La Rioja Valleys of Vinchina and Antinaco (Fig. 1) (Ratto et al., 2013; Callegari et al., 2015). All the samples were analyzed by NAA and technologically investigated by using a low-magnification stereo microscope. Table 1 gives information on the pottery sample analyzed, archaeological sites, calibrated dates and their environmental location, and vessels forms per site. Most pottery belongs to Saujil ceramic type (116:139); a few sherds of Ciénaga ceramic type were also incorporated in the analysis for comparative purposes (23:139). Bowls are the most represented vessel form (87:139), followed by urns (22:139) (Table 1; Fig. 2a–f, j). Bowls were mainly used to process and serve food, whereas urns for infant burials (Fig. 2a–f) (Sempé, 1977).

### 3.2. Technological analysis

Sub-macroscopic technological analyses were performed with a stereo microscope at low magnifications (20X-40X) both at the Laboratory for Ceramic Petrology and Conservation, University of Catamarca, and at Instituto de Culturas, UBA-Conicet, University of Buenos Aires. All 139 sherds were observed in fresh transversal view and the main technological variables were recorded. Technological variables were type of temper, temper density, temper size, fabric texture and porosity, firing, surface treatment and decorative technique. Mineral inclusions and some rock fragments were identified by qualitative analyses and quantification were performed over fresh transversal cuts as described in Orton et al. (1993) and Druc (2015). Technological data were processed

**Table 1**
Archaeological sites, geographical location and sample composition. References: PRS: permanente residential site; SRS: seasonal residential site; TRS: temporary residential site. Details of radiocarbon dating: sites EZ, LS, OLZ, CM, OA, CAR, TT, APB, LTV (Ratto et al. 2013); site LF (De La Fuente et al. 2019, in press); sites LC and EVS (Callegari et al. 2015).

| Region (from west to east and south) | Environment and number of ceramic vessels | Altitude (masl) | Archaeological site | Type of occupation | Site Chronology (centuries of the era) | Vessel form | | | | | Number of vessels per site |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | large bowl | bowl | jar-vase | vessel | urn | |
| Chaschuil-Northern Abaucán Valley (Catamarca) | Chaschuil transitional puna (14:139) | 4050 | El Zorro (EZ) | SRS | IV-X | 2 | 3 | | 2 | | 7 |
| | | 4030 | Laguna Salada (LS) | SRS | VI-IX | | 4 | | | 1 | 5 |
| | | 4050 | Ojo de Las Lozas (OLZ) | TRS | first millennium | | 2 | | | | 2 |
| | Pre-cordilleran (close to northern Abaucán Valley) (25:139) | 3200 | Casa del Medio (CM) | PRS | X-XIII | 1 | | | | 1 | 2 |
| | | 2400 | Ojo del Agua-1 (OA) | TRS | X-XI | 3 | 5 | | 1 | | 9 |
| | | 1900 | Cardoso (CAR) | PRS | VIII-IX | | 1 | 1 | | | 2 |
| | | 1870 | Tatón 1 (TT) | PRS | late first millennium | | 7 | | 1 | 4 | 12 |
| | Northern Abaucán Valley (32:139) | 1900 | Aldea de Palo Blanco (APB) | PRS | I-X | | 24 | 1 | 5 | 2 | 32 |
| | Southern Abaucán Valley (42:139) | 1365 | LT-V50 (LTV) | PRS | VII-VIII | 5 | 3 | 2 | | | 10 |
| Tinogasta (Catamarca) | | 1250 | La Florida (LF) | PRS | III-VI | 1 | 19 | 1 | 2 | 9 | 32 |
| Northern sector (La Rioja) | Antinaco Valley (25:139) | 1550 | La Cuestecilla (LC) | PRS | I-XII | | 19 | | 2 | 4 | 25 |
| | Vinchina Valley (1:139) | 1250 | Eras Viejas-5 (EVS) | PRS | I-XV | | | | | 1 | 1 |
| Total | | | | | | 12 | 87 | 5 | 13 | 22 | 139 |
| Percentaje (%) | | | | | | 8,6 | 62,6 | 3,6 | 9,4 | 15,8 | 100 |

by multivariate statistics using the SPSS 18.0 software package. The chi-square statistical test ($x^2$) was performed to know the relationship between the shapes of the ceramic pieces and the technological groups generated, for which a significance level of 0.05 (p) and the degrees of freedom (df) were reported.

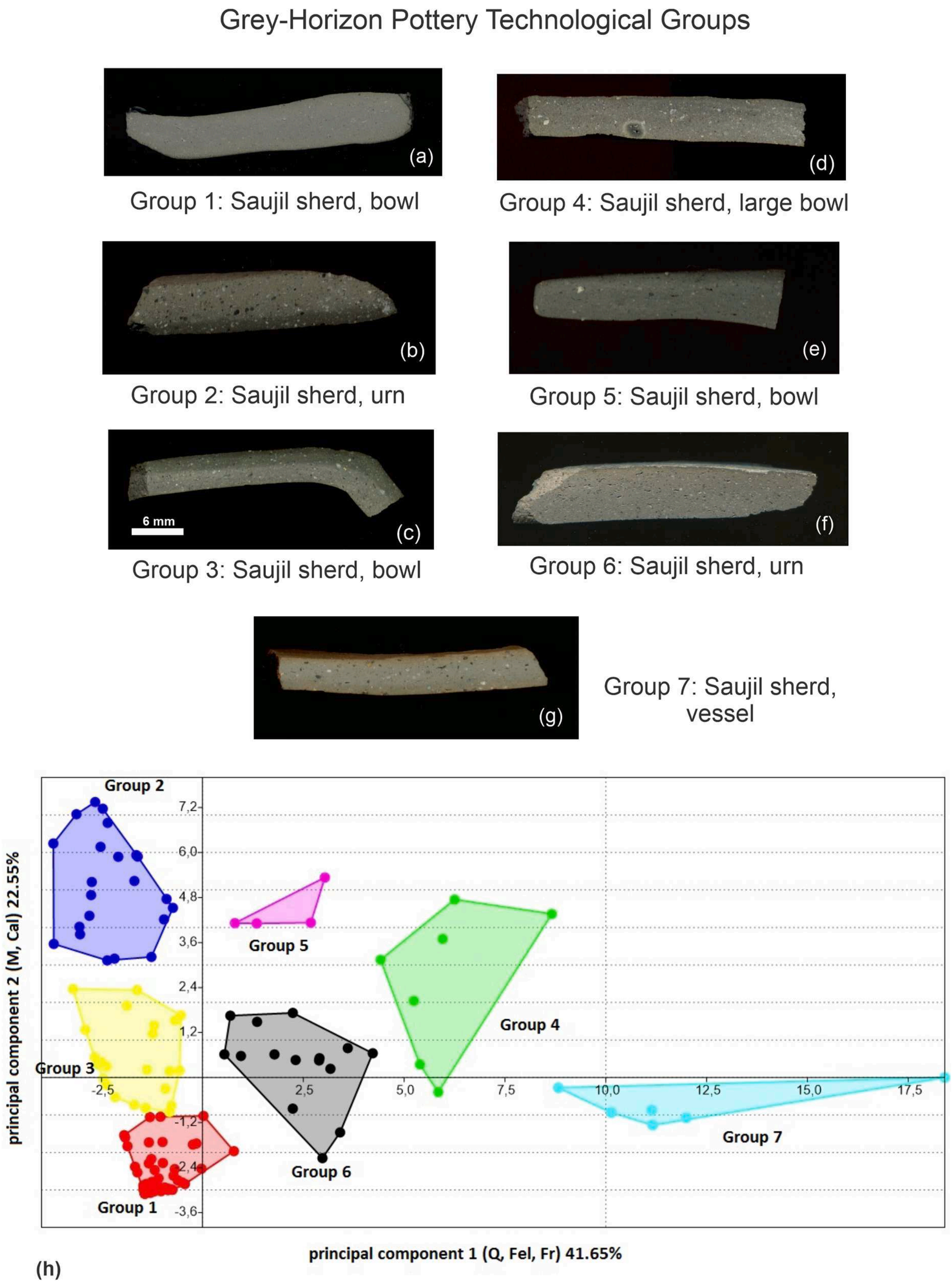


**Fig. 3.** Technological groups for Grey-Horizon pottery. (a)-(g) High magnification polished transversal image (4200 dpi) of different ceramic fabrics; (h) first two PĆs showing the different technological groups.

### 3.3. NAA analysis

Samples were prepared and analyzed by instrumental NAA at the laboratories of the Nuclear Analytical Techniques Group of the Ezeiza Atomic Center (Argentine Atomic Energy Commission) (Plá and Ratto, 2007). Sample masses of about 100 mg were sealed in high purity quartz ampoules and put into aluminum capsules, together with reference materials for their irradiation. Irradiations were done at the RA-3 reactor (current thermal flux $6.10^{13}$ $cm^{-2}$ $s^{-1}$, 8.5 Mw) for 3 h. Two measurements were performed after approximately seven and thirty-day decay respectively, for the determination of twenty-two elements: As, Ba, Ce, Co, Cr, Cs, Eu, Fe, Gd, Hf, La, Lu, Nd, Rb, Sb, Sc, Sm, Ta, Tb, Th, U and Yb. However, not all elements, such as As, Gd and Ba, were considered due to undetermined values (missing or under the detection limit values), in some samples. The measurements were done using Ortec HP Ge detectors (30% efficiency and resolution 1.8 keV for the 1332.5 keV Co-60 peak) coupled to an Ortec 919 buffer multichannel analyzer module (using Gamma Vision software for data acquisition). For concentration calculation, software developed at the laboratory was used, NIST standard reference material 1633b Coal Fly Ash was used as a calibration standard, and NIST SRM 2709 San Joaquin Soil, China National Research Centre CRM GBW07405 (GSS-5 soil) and interlaboratory standard andesite for quality assessment. The reproducibility of the method was tested analyzing standard reference materials NIST SRMs 2709 San Joaquin Soil and 699 Brick Clay (Munita et al. 2001) and USGS AGV. Since 2001, the NAT laboratory has been accredited under ISO/IEC 17,025 standard by the Argentine national accreditation body (OAA) and the current accredited scope for geological and related matrices includes Ce, Cs, Co, Eu, Fe, La, Sc, Sm, and Th.

### 3.4. Chemical data treatment

A statistical package developed at MURR (GAUSS Run Times ver. 8.0) was used for the interpretation of the data. Statistical analysis was carried out on base-10 logarithms of the concentrations of all 19 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 for the NAA data set. Groups were initially defined based on 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). The chi square was performed to know the relationship between the technological and chemical groups, as well as between the compositional groups and the vessels forms, for which a significance level of 0.05 (p) and the degrees of freedom (df) were reported. Additionally, an analysis of variance (ANOVA -F-) test was performed to explore the statistical relationship between the chemical groups and the vessel thicknesses.

## 4. Results

### 4.1. Technological groups

The visual examination of Grey-Horizon pottery under the stereo microscope revealed that mostly ceramic pastes present well packed very fine-grained quartz (Q) tempered fabrics, fired under reducing conditions (Fig. 3a–g). The mineral load was registered in frequency and then transformed into a percentage, for which its presence was weighed in relation to the fraction of temper in each vessel sample. Table 2 presents the range of variation in percentage of the mineral load of the vessels recovered in different environments. Generally, it is observed that the whole sample has low loadings of very fine/fine grained temper compared to the matrix, whose values are mostly around 90% or more, regardless of the recovery environment. Thus, within the analyzed sample, the percentage of temper varies between 0 and 20%, but the median is located around 6%.

Technological analyses of all sherds readily allowed observe that the sample is characterised by the presence of felsic minerals. Quartz (Q), feldspars (Fel), and rock fragments (Fr) are the main constituents of ceramic fabrics (Fig. 3a–g, Table 2). In lesser amount, muscovite (M), calcite (Cal), grog (Gr), and charred vegetal (Vq) were identified and quantified in the sample (Table 2). Fig. S1 shows a detailed visual picture of the relationship between the matrix percentage (%) and the main types of temper (Q, Fel, M, Fr) related to the different environments where the sherds are coming from.

The matrix-temper relationship is independent of the vessel form, although for Q and Cal tempers it is observed that this relationship could be governed by the vessel function. Additionally, as shown in Fig. 3h, Q and Cal do not positively correlate in the samples from different environments (see Fig. S2).

Multivariate statistics were performed on the whole sample. Technological data were submitted to cluster analysis and principal component analysis (PCA) to define the fabric groups (Fig. 3h).

#### 4.1.1. Ceramic fabrics

Fig. 3h shows a PCA with the seven formed technological groups, which corresponds each other to a different type of ceramic fabric, whereas Table 3 presents the distribution of each fabric per site and environment and Fig. S4 shows the types of shapes of vessels recovered in different environments that refers to each of the technological groups.

Final groups were defined as follows:

- Group 1 (61:139), the largest group, a very fine textured grained fabric, compact to extremely low porosity, with<1% of temper in average, mainly characterized by rounded Q + M + Fr and < Fel (Fig. 3a).
- Group 2 (22:139), very fine to medium textured grained fabric, low to medium porosity, with the highest loads of temper ranging from 5 to 10% average, mainly composed by rounded Q + Fr and < M and < Fel (Fig. 3b).

**Table 2**
Ranges of variation of type of temper (% weighted) (n = 139). References: Q: quartz; Fel: K feldspar; M: muscovite; Cal: calcite; Gr: grog; Fr: rock fragment (igneous); Vq: charred vegetal.

| Environment and quantity of vessels | Matrix (%) | Temper (%) | Range of variation in percentage of the mineral load of the vessels recovered in different environments | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Q (%) | Fel (%) | M (%) | Cal (%) | Gr (%) | Fr (%) | Vq (%) |
| Chaschuil transitional puna (14:139) | 83–100 | 0–17 | 0–11 | 0–2 | 0–6 | 0–1 | 0 | 0–7 | 0–1 |
| Pre-mountain range -adjacent to the northern Abaucán valley- (25:139) | 80–100 | 0–20 | 0–9 | 0–2 | 0–5 | 0–2 | 0 | 0–8 | 0–1 |
| North Abaucán Valley (32:139) | 80–100 | 0–20 | 0–11 | 0–3 | 0–7 | 0–1 | 0 | 0–7 | 0–2 |
| South Abaucán Valley (42:139) | 80–100 | 0–20 | 0–8 | 0–2 | 0–14 | 0–6 | 0 | 0–10 | 0 |
| Antinaco and Vinchina Valley (26:139) | 90–100 | 0–10 | 0–5 | 0–3 | 0–8 | 0–5 | 0–1 | 0–4 | 0–5 |

**Table 3**
Technological groups discriminated by site and environment (n = 139).

| Environment | Archaeological Sites | Technological Groups | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Chaschuil transitional Puna | El Zorro | 4 | 1 | 2 | | | | | 7 |
| | Laguna Salada | 1 | 3 | 1 | | | | | 5 |
| | Ojo de las Loza | | 1 | | 1 | | | | 2 |
| Pre-cordilleran (close to northern Abaucán Valley) | Cardoso | 2 | | | | | | | 2 |
| | Casa del Medio | 1 | 1 | | | | | | 2 |
| | Ojo del Agua-1 | 6 | 2 | 1 | | | | | 9 |
| | Tatón 1 | 7 | 3 | 1 | | 1 | | | 12 |
| Northern Abaucán Valley | Aldea de Palo Blanco | 13 | 7 | 7 | 2 | 2 | 1 | | 32 |
| Southern Abaucán Valley | La Florida | 14 | 1 | 2 | 2 | 1 | 7 | 5 | 32 |
| | LT-V50 | | 3 | 5 | | | 2 | | 10 |
| Antinaco and Vinchina Valley | Eras Viejas-5 | | | | | | 1 | | 1 |
| | La Cuestecilla | 13 | | 5 | 2 | | 4 | 1 | 25 |
| Total | | 61 | 22 | 24 | 7 | 4 | 15 | 6 | 139 |
| Percentage | | 43,9 | 15,8 | 17,3 | 5,0 | 2,9 | 10,8 | 4,3 | 100 |

- Group 3 (24:139), fine to medium textured grained fabric, low to medium porosity, with < 5% temper in average, characterized by rounded to subangular Q + Fr and < Fel and < M (Fig. 3c).
- Group 4 (7:139), fine to coarse textured micaceous fabric, medium porosity, with < 10% temper in average, composed by M + Q + Fr and < Fel (Fig. 3d).
- Group 5 (4:139), very fine to fine textured grained/micaceous fabric, low to medium porosity, with < 7% temper in average, constituted by Q + M + Fr + Fel (Fig. 3e).
- Group 6 (15:139), fine to medium textured micaceous fabric, low to medium porosity, with < 5% temper in average, characterized by M + Q + Fr and < Cal (Fig. 3f).
- Group 7 (7:139), a fine to medium textured micaceous fabric, with < 10% temper in average, constituted by M + < Fr and < Q and < Fel (Fig. 3g).

### 4.2. *NAA groups*

NAA was performed on 139 Grey-Horizon pottery samples from Early Period (see Appendix for elemental concentrations). After an initial exploration of the sample six sherds classified as outliers were removed from the whole data set (LS4, LS5, LF153, PB9, LTV05, PB6). The data set (n = 133) was subjected to principal component analysis (PCA). Fig. 4 shows a PCA diagram differentiating La Cuestecilla (LC) sherds (La Rioja province) from the larger Abaucán Valley and Chaschuil transitional Puna group (58.9% of total variance) for the first two PC s. As showed in Fig. 4, two different compositional groups from LC sherds are formed: Group 1 (G-1), 5.26%, n = 7 and Group 2 (G-2), 3.0%, n = 4 (95% confidence ellipses). The larger Abaucán Valley and Chaschuil transitional Puna group presents itself as a different and single large group.

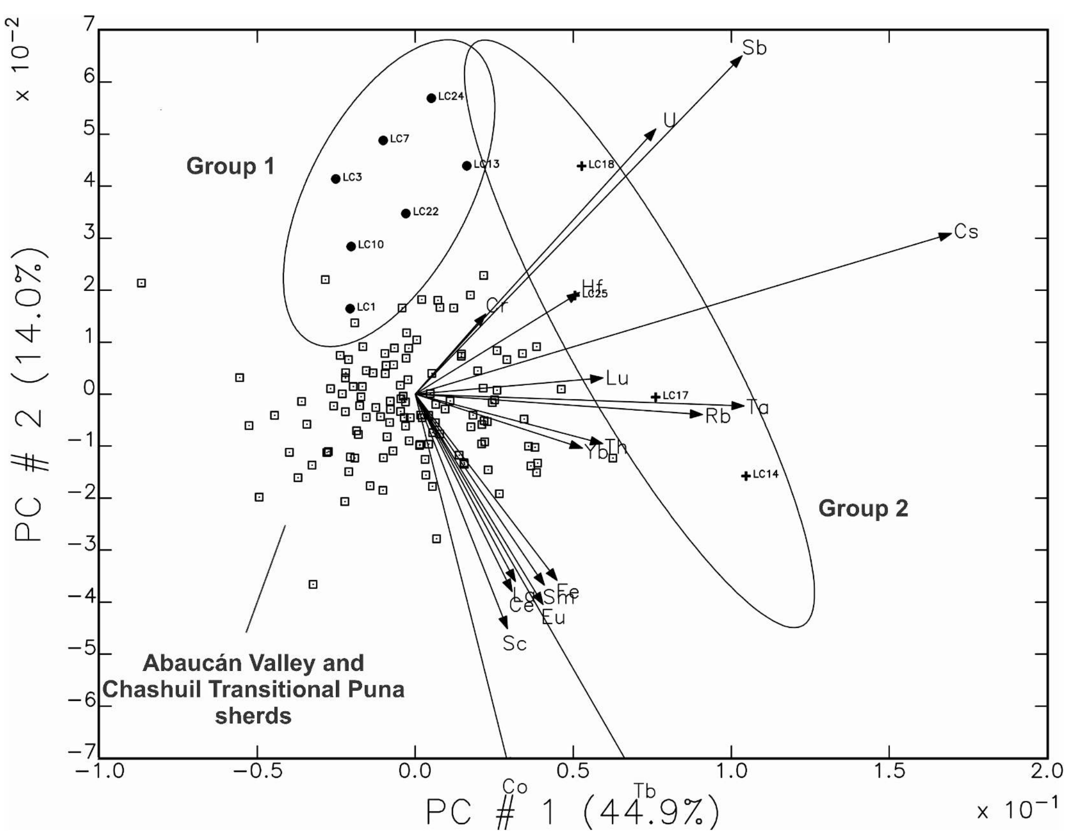


**Fig. 4.** PCA two first components graph with Group 1 and Group 2 (95% confidence ellipses).

The Abaucan Valley + Chaschuil transitional Puna group (n = 122) was subsequently subjected to PCA to explore the internal compositional variability (57.94% of total variance) for the first two PC‘s. The results obtained revealed the presence of six additional ceramic groups: Group 3 (G-3) to Group 8 (G-8) (Tables 4 and 5 and Fig. 5). The largest group, G-4 (23.30%, n = 31), is dominated by sherds with very fine-grained fabrics and exceptionally low temper content (<1% in average); most of the pottery comes from archaeological sites geographically located at northern Abaucán Valley (mainly Palo Blanco), and Precordillera close to Abaucán Valley (Tatón and Ojo de Agua sites). The remaining sherds are from other sites (OLZ, CAR1, LS1, LT-V50) (Table 6). The second-largest group is G-5 (17.29%, n = 26) dominated by sherds with very fine to medium textured grained fabric showing temper content of 5–10% in average; vessels in this group comes mainly from La Florida and LT-V50 archaeological sites geographically located at southern Abaucán Valley. Other sites represented in this group are CM2, EZ, LC, OA, and PB. The third-largest group is G-3 (18.04%, n = 24) and has pottery characterized by very fine to very coarse-grained fabrics with 0–10% temper in average. Pottery from this group comes from sites geographically located at southern Abaucán Valley (LF, LT-V50) as well as northern Abaucán Valley (PB) and Precordillera close to Abaucán valley (CAR, OA), and in a lesser percentage from Chaschuil transitional Puna (EZ, LS, OA) (Table 6).

The fourth-largest group is G-6 (12.03%, n = 16) which is dominated by very fine textured grained fabrics with extremely low temper percentage <1% in average. Sherds in this group are mainly coming from 3 different environments: northern Abaucán Valley (LF site), Precordillera close to Abaucán valley (TT site), and northern Abaucán Valley (PB site) (Table 6). The fifth group is G-8 (9.02%, n = 12) and mostly consists of sherds from LC site and one sherd from EVS site, both geographically located at La Rioja province, with very fine textured grained fabrics. As shown in Fig. 5, this group is partially separated in the PCA plot. Other sites represented in this group are CM, EZ, and LT-V50.

The remaining statistically defined compositional group, G7 (3.75%, n = 5), is too small to warrant a detailed discussion, although it is important to note that it is formed by sherds with fine to very coarse-grained fabrics, coming from 3 archaeological sites LF, PB, and TT. This group, although small, also differentiates very well from the remaining compositional groups. The unassigned sherds shown in Fig. 5 account for 6.01% (n = 6) of the sample, which agrees with the statistical procedures of group assignment.

Additional exploration through bivariate plots of elements (Fe/Cs, Cs/U) shows a ubiquitous and clear separation between G4 groups with the G7/G8 compositional groups (Fig. S3).

**Table 5**
Loadings of variables for the first two PĆs. Eigenvalues (%) and variance explained (%).

| Variables | PC1 | PC2 |
|---|---|---|
| Sc | 0,104732 | 0,176078 |
| Cr | 0,119693 | −0,007916 |
| Fe | 0,159527 | 0,088475 |
| Co | 0,134642 | 0,139972 |
| Rb | 0,267395 | −0,039304 |
| Sb | 0,384400 | −0,714574 |
| Cs | 0,520195 | −0,197637 |
| La | 0,122584 | 0,145587 |
| Ce | 0,125054 | 0,167689 |
| Sm | 0,147516 | 0,158886 |
| Eu | 0,140943 | 0,033852 |
| Tb | 0,242186 | 0,301564 |
| Yb | 0,171580 | 0,067591 |
| Lu | 0,211563 | 0,006191 |
| Hf | 0,138429 | 0,065863 |
| Ta | 0,310902 | 0,052317 |
| Th | 0,182467 | 0,211031 |
| U | 0,294957 | 0,409183 |
| Eigenvalues: | 0,073735 | 0,021635 |
| % Variance | 44,793825 | 13,143471 |

## 5. Discussion

Technological analysis shows that Grey-Horizon pottery presents itself as fine grained, compact, and very homogenous ceramic fabric, mainly tempered with fluvial sands with different felsic minerals and size sorting (Fig. 3a–d, Table 2). Main minerals present are rounded Q, Fel, Fr (mostly igneous), and M (Table 2). Nevertheless, our analysis could determine 7 different types of ceramic fabrics or groups, according to type of temper combination and the temper percentage (Fig. 3f). Some groups, like Group 1, the largest group, are believed to have mostly natural loading of temper (<1% in average) already contained in the primary clays used by ancient potters. Other groups, like Groups 2, 6 and 7, represent specific geographical areas each other (Fig. 3h, Table 3). Additionally, Group 2 and Group 3 do have 5–10% and <5% temper in average, respectively. Ceramic pastes possess light to medium porosity and very fine to medium texture. Interestingly, the composition of these two groups ranges from sherds coming from Chaschuil transitional Puna to southern Abaucán Valley (Fig. 1). Sherds in these groups are moderately tempered, involving the intentional addition of minerals as temper like Q and crushed Fr as it is shown in the bimodal distribution of temper size for these ceramic pastes. On the other hand, sherds in

**Table 4**
Element concentrations and standard deviation (mean + SD) for the pottery compositional groups (all values in ppm).

| Element | Group 1 (n = 7) | Group 2 (n = 4) | Group 3 (n = 24) | Group 4 (n = 30) | Group 5 (n = 26) | Group 6 (n = 17) | Group 7 (n = 5) | Group 8 (n = 10) |
|---|---|---|---|---|---|---|---|---|
| Sc | 12.73 ± 1.28 | 17.64 ± 6.09 | 15.49 ± 1.77 | 15.51 ± 1.81 | 16.96 ± 1.23 | 16.19 ± 2.35 | 16.81 ± 2.00 | 19.50 ± 2.16 |
| Cr | 67.87 ± 28.41 | 42.34 ± 7.77 | 49.08 ± 6.05 | 43.50 ± 5.54 | 52.27 ± 5.36 | 46.87 ± 5.82 | 45.27 ± 11.98 | 50.79 ± 6.37 |
| Fe | 33283.54 ± 2865.79 | 52181.40 ± 15976.56 | 41020.5 ± 2881.29 | 38494.64 ± 3251.37 | 45434.71 ± 3948.04 | 42021.61 ± 3562.53 | 45174.64 ± 4078.23 | 53404.63 ± 9796.13 |
| Co | 8.97 ± 0.79 | 14.33 ± 5.04 | 15.58 ± 1.22 | 14.81 ± 1.74 | 18.01 ± 1.83 | 16.42 ± 2.17 | 16.61 ± 2.83 | 19.65 ± 2.78 |
| Rb | 116.99 ± 28.25 | 299.05 ± 105.68 | 138.97 ± 20.22 | 116.08 ± 19.17 | 159.13 ± 18.97 | 142.39 ± 17.64 | 183.67 ± 22.35 | 157.11 ± 24.25 |
| Sb | 1.00 ± 0.13 | 1.35 ± 0.17 | 0.82 ± 0.25 | 0,59 ± 0.15 | 0.87 ± 0.16 | 0.78 ± 0.17 | 0.85 ± 0.20 | 1.27 ± 0.21 |
| Cs | 9.79 ± 3.57 | 39.54 ± 4.92 | 10.18 ± 1.87 | 7.12 ± 1.53 | 11.71 ± 2.06 | 10.67 ± 1.60 | 18.50 ± 3.55 | 18.67 ± 4.78 |
| La | 35.71 ± 4.46 | 46.23 ± 9.27 | 41.37 ± 3.44 | 40.92 ± 3.93 | 46.27 ± 3.99 | 43.69 ± 4.53 | 49.61 ± 3.74 | 44.93 ± 4.80 |
| Ce | 67.20 ± 8.93 | 87.45 ± 16.62 | 85.55 ± 5.36 | 80.35 ± 11.10 | 92.82 ± 8.09 | 88.39 ± 8.00 | 102.74 ± 8.99 | 84.27 ± 10.57 |
| Sm | 6.38 ± 0.98 | 9.72 ± 2.43 | 7.99 ± 1.05 | 7.56 ± 1.10 | 8.98 ± 0.95 | 8.40 ± 0.58 | 9.96 ± 0.34 | 8.34 ± 0.76 |
| Eu | 1.15 ± 0.16 | 1.86 ± 0.60 | 1.48 ± 0.14 | 1.41 ± 0.10 | 1.57 ± 0.09 | 1.53 ± 0.09 | 1.64 ± 0.14 | 1.97 ± 0.30 |
| Tb | 0.70 ± 0.18 | 1.43 ± 0.69 | 0.77 ± 0.12 | 0.86 ± 0.17 | 1.15 ± 0.18 | 1.20 ± 0.23 | 1.25 ± 0.15 | 1.33 ± 0.33 |
| Yb | 3.03 ± 0.56 | 4.23 ± 1.86 | 2.8 ± 0.3 | 2.67 ± 0.27 | 3.25 ± 0.43 | 2.97 ± 0.26 | 3.31 ± 0.25 | 3.08 ± 0.20 |
| Lu | 0.54 ± 0.10 | 0.66 ± 0.23 | 0.47 ± 0.04 | 0.42 ± 0.05 | 0.53 ± 0.05 | 0.50 ± 0.04 | 0.58 ± 0.03 | 0.54 ± 0.09 |
| Hf | 6.82 ± 0.75 | 8.70 ± 3.43 | 4.69 ± 0.66 | 4.50 ± 0.58 | 5.15 ± 0.60 | 4.95 ± 0.87 | 5.37 ± 0.48 | 5.10 ± 0.70 |
| Ta | 1.09 ± 0.19 | 2.89 ± 0.64 | 1.32 ± 0.27 | 1.01 ± 0.21 | 1.30 ± 0.18 | 1.22 ± 0.16 | 1.76 ± 0.23 | 1.70 ± 0.52 |
| Th | 14.88 ± 4.58 | 23.55 ± 1.72 | 14.61 ± 1.58 | 13.78 ± 1.97 | 15.91 ± 1.29 | 15.74 ± 2.17 | 20.87 ± 1.70 | 14.76 ± 1.81 |
| U | 7.87 ± 3.27 | 5.95 ± 0.81 | 3.93 ± 0.48 | 3.53 ± 0.99 | 4.45 ± 0.91 | 5.02 ± 0.62 | 6.89 ± 0.62 | 4.50 ± 0.92 |

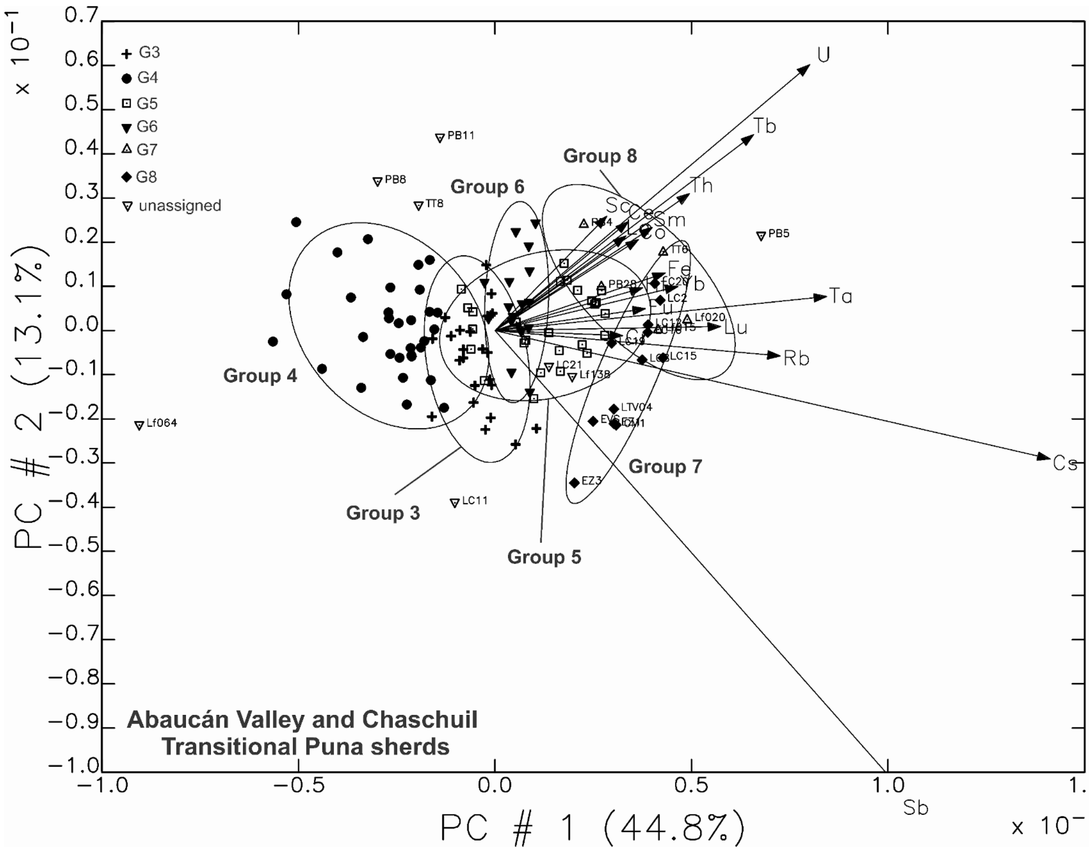


**Fig. 5.** PCA two first components graph showing Groups 3–8 and elemental vectors (95% confidence ellipses).

**Table 6**
NAA chemical groups by site and environment.

| Environment | Archaeological site | NAA CHEMICAL GROUPS | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Unassigned | Outliers | |
| Chaschuil transitional Puna | El Zorro | | | 2 | | 2 | 1 | | 2 | | | 7 |
| | Laguna Salada | | | 2 | 1 | | | | | | 2 | 5 |
| | Ojo de las Loza | | | 1 | 1 | | | | | | | 2 |
| | *Subtotal* | | | *5* | *2* | *2* | *1* | | *2* | | *2* | *14* |
| | *Percentage* | | | *35,71* | *14,29* | *14,29* | *7,14* | | *14,29* | | *14,29* | *100,00* |
| Precordillera (close to northern Abaucán Valley) | Cardoso | | | 1 | 1 | | | | | | | 2 |
| | Casa del Medio | | | | | 1 | | | 1 | | | 2 |
| | Ojo del Agua-1 | | | 2 | 6 | 1 | | | | | | 9 |
| | Tatón 1 | | | | 5 | | 5 | 1 | | 1 | | 12 |
| | *Subtotal* | | | *3* | *12* | *2* | *5* | *1* | *1* | *1* | | *25* |
| | *Percentage* | | | *12,00* | *48,00* | *8,00* | *20,00* | *4,00* | *4,00* | *4,00* | | *100,00* |
| Northern Abaucán Valley | Aldea Palo Blanco | | | 5 | 15 | 3 | 2 | 2 | | 3 | 2 | 32 |
| | *Subtotal* | | | *5* | *15* | *3* | *2* | *2* | | *3* | *2* | *32* |
| | *Percentage* | | | *15,63* | *46,88* | *9,38* | *6,25* | *6,25* | | *9,38* | *6,25* | *100,00* |
| Southern Abaucán Valley | La Florida | | | 9 | 0 | 11 | 7 | 2 | | 2 | 1 | 32 |
| | LT-V50 | | | 1 | 2 | 5 | | | 1 | | 1 | 10 |
| | *Subtotal* | | | *10* | *2* | *16* | *7* | *2* | *1* | *2* | *2* | *42* |
| | *Percentage* | | | *23,81* | *4,76* | *38,10* | *16,67* | *4,76* | *2,38* | *4,76* | *4,76* | *100,00* |
| Northern La Rioja Valley | EVS | | | | | | | | 1 | | | 1 |
| | La Cuestecilla | 4 | 7 | 1 | | 3 | 1 | | 7 | 2 | | 25 |
| | *Subtotal* | *4* | *7* | *1* | | *3* | *1* | | *8* | *2* | | *26* |
| | *Percentage* | *15,38* | *26,92* | *3,85* | | *11,54* | *3,85* | | *30,77* | *7,69* | | *100,00* |
| *Totals* | | *4* | *7* | *24* | *31* | *26* | *16* | *5* | *12* | *8* | *6* | *139* |
| *Percentage (%)* | | *2,88* | *5,04* | *17,27* | *22,30* | *18,71* | *11,51* | *3,60* | *8,63* | *5,76* | *4,32* | *100* |

Group 6, representing the southern sector of Abaucán Valley and La Rioja Valleys, also probably do have naturally tempered ceramic pastes.

Vessels belonging to Grey-Horizon pottery are very thin walled, with 3–4 mm thin in average. Ancient potters probably used to clean, sieve, and mix raw materials, thus cultural selecting the final load of minerals and the size sorting in the ceramic pastes. Ceramic fabrics, expressed in several groups, represent at least at first glance, different types of potter‘s recipes, thus reflecting the technological choices made by ancient potters during the Early Period to produce the vessels across Abaucán Valley.

Concerning the vessel forms, bowls (87:139) are the most representative form and they are distributed along all the groups. The second largest group of vessel forms, urns 22:139), are represented mostly in Group 1 and Group 6 (Fig. S4 Table). It is observed that nonpositive correlation was statistically found between the type of vessel form and each technological group ($x^2$ = 26.815, df = 24, p = 0.313), thus suggesting that potter‘s recipes might be reflecting the influence of several geographical patterns in the different ways of making pottery along the Abaucán Valley than specific recipes for different vessel forms.

Chemical compositional grouping through multivariate statistics suggests the use of different geographical clay sources to produce Grey-Horizon pottery (Figs. 4 and 5). Most of the sample can be divided in two general groups according to a broad geographical differentiation: the Abaucán Valley + Chaschuil transitional Puna (Catamarca Province) and Famatina /Antinaco Valleys (La Rioja Province) (Fig. 4, G-1 and G-2); whereas 8 vessels cannot be assigned to any of the defined groups. This geographical division is reflected in the sourcing of clays for pottery production by ancient potters during Early Period as it is shown in the chemical patterns of compositional groups (Figs. 4–6; Tables 4 and 5). Additionally, G-1 and G-2 groups (17:139) present distinctive geochemical signatures very different to the cases geographically located at Catamarca province (Fig. 4). These groups are related at La Cuestecilla site to a production area where several pottery kilns were found (Callegari et al., 2015; Wachsman et al., 2020). Interestingly, some of this pottery is found reaching the Chaschuil transitional Puna geographical area at Catamarca province.

The Abaucán Valley + Chaschuil transitional Puna group presents an internal compositional variability (Fig. 5). The exploration of this variability allowed define six more compositional groups (G-3 to G-8). Graphs show different distances between G-4 and G-7 and G-8 (Figs. 5 and 6). Groups G-3, G-5, and G-6 are similar groups and share a similar geochemical signature (Fig. 6). Table 6 shows the distribution of the compositional groups by archaeological site and environment.

Before starting the analysis of Groups G-3, G-4, G-5, G-6, G-7 and G-8 (114:139), it is worth mentioning that all these groups do not have any statistical correlation with the technological groups previously defined, both in the whole sample and when we stratify the sample per provenance environment ($x^2$ = 37.424, df = 30, p = 0.165). This lack of correlation would imply that technological groups, as we stated before, are reflecting more the pottér s technical behavior (e.g. different recipes) than the specific geographical sourcing patterning of raw clays as we should expect. It should be remarked that temper load is extremely low (<10%) for most of the analysed sample, which in turn will affect this correlation (see Table 2). However, the differences between the groups are more related with the mineral load and the percentages of matrix in ceramic pastes, although all of them present similar characteristics concerning porosity, texture (fine and very fine), primary forming techniques and firing technology. Thus, these ceramic vessels are homogeneous from a technological view point, independently of their differential mineral load observed in the formed groups. Potters might be selecting clays, mixing them, and perhaps factors like sieving and levigation are affecting the formation of these technological groups. Similar results have been obtained by Falabella and collaborators in central Chile studying the pottery-making practices at household level at Early Ceramic Period (Falabella et al., 2013). Further studies should be done in this area to interpret the effects of mixing clays in the formation of chemical groups.

Concerning the vessel forms there is no positive correlation between compositional groups and specific ceramic forms ($x^2$ = 21.224, df = 20, p = 0.384), thus suggesting that no clay was restricted to produce a specific type of vessel form. Ancient potters produced all vessel forms (bowls, large bowls, urns, jars, vases) using their local clay sources in each geographical area. Also, it does not appear to be any statistical relationship between the defined chemical groups and the vessel thickness (ANOVA, F = 1.107, p = 0.361).

Geochemically, some of these groups, like G-4, represent certain

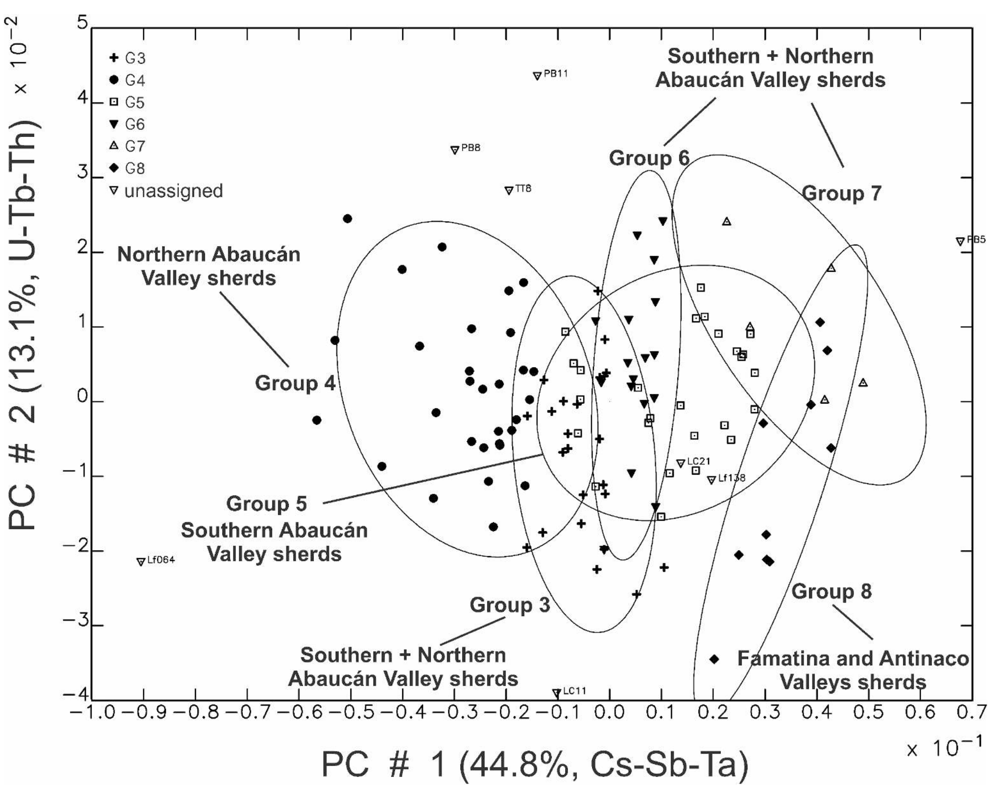


**Fig. 6.** PCA two first components graph showing the Groups 3–8, with the elemental loads for each PC and the geographical assignation to each group (95% confidence ellipses).

geographical area (Fig. 6). Group 4 contains mostly sherds from the locality of Palo Blanco along its 1000 years of life together with *Precordillera* sites like OA-1 and Tatón-1 plus two vessels from Laguna Salada and Ojo de las Lozas sites geographically located at Chaschuil transitional Puna (Fig. 6). According to the “criterion of abundance” (*sensu* Bishop et al., 1982) we consider that the area of pottery production might be the Palo Blanco village at northern Abaucán Valley, and some of these vessels reached the *Precordillera* and Puna

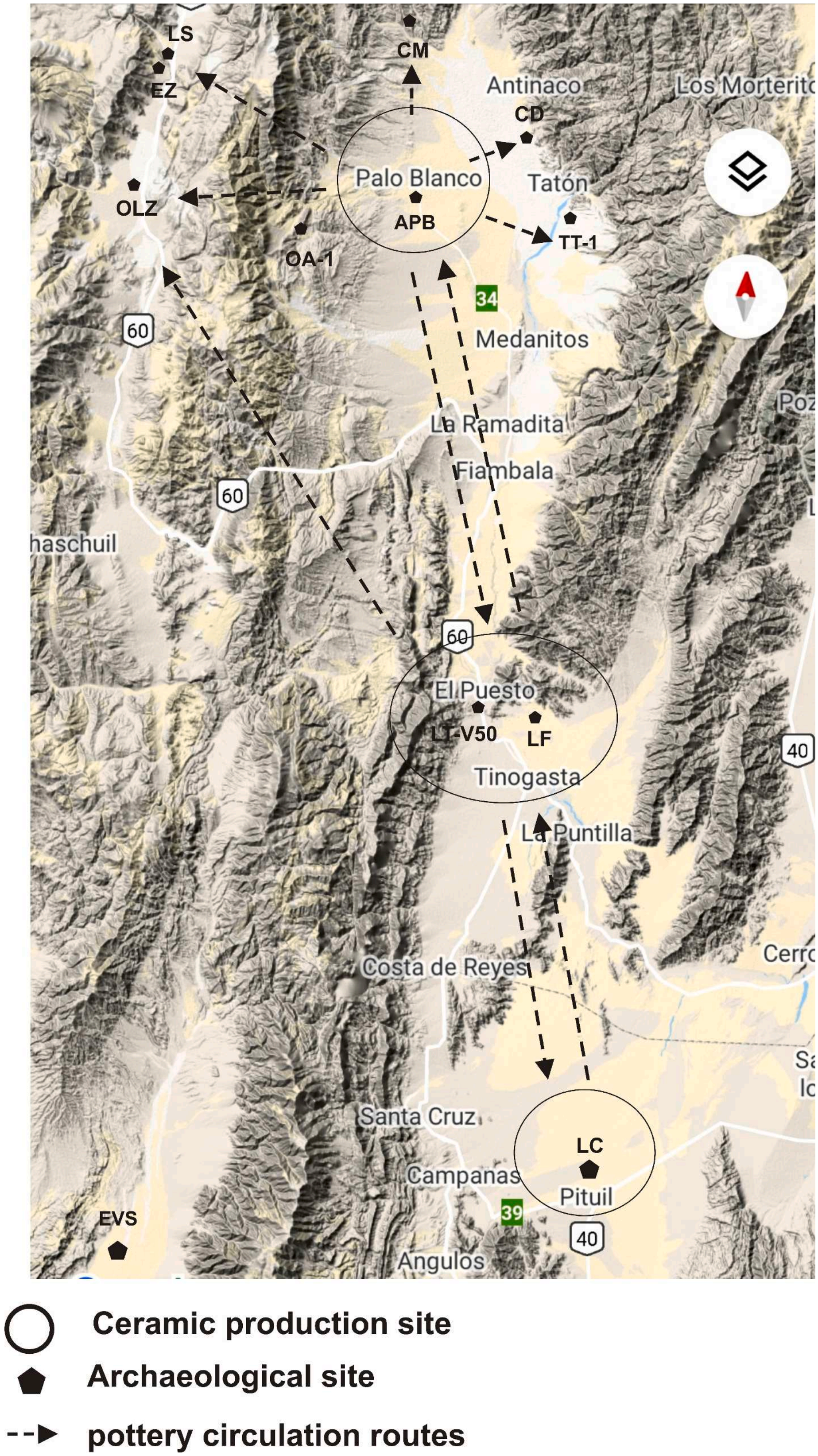


**Fig. 7.** Mobility and distribution patterns for Saujil pottery visualized through NAA analyses.

environments through several interchange mechanisms. These results agree with previous studies concerning the articulation of lowlands Abaucán valley with the Chaschuil highlands through time, where the highlands sites are provided with vessels manufactured at bottom valley sites (Ratto et al., 2002, 2013). Nevertheless, we have to mention that no direct or indirect evidence of pottery production were found in this village yet, such as kilns for ceramic manufacturing and overcooked fragments (Ratto et al., 2013, 2015).

Compositional groups G-3, G-5, and G-6, as we mentioned before, present a different shared geochemical signature (Fig. 6). The observed chemical compositional patterning implies that this pottery was locally produced in the southern sector of Abaucán Valley, using slightly different clay sources and recipes to make the vessels (Fig. 6; Table 4). Sherds in these groups belong mainly to LT-V50 and La Florida archaeological sites. These vessels possess a geographical distributional pattern both to the north (northern Abaucán Valley and Chaschuil transitional Puna sites) and in less proportion to the south, towards La Rioja valleys. Both at LT-V50 and La Florida villages (20 km distance each other) there is direct and undirect evidence of pottery production. LT-V50 village is geographically located within La Troya basin; it was built entirely of earthen materials, *tapia*, presenting a poor state of conservation mainly due to fluvial geomorphic agents (Bonomo et al., 2010). Fourteen pottery kilns were recorded at this village, and 10 of these kilns present circular shape, whereas the rest of the kilns are badly and poorly preserved (Ratto, et al. 2013). Radiocarbonic dates stated that the village was functioning from IV to VIII centuries (Andreoni et al., 2018: Table 1). Besides, the area counts with abundant availability of clay-mud sources for pottery manufacture and fuel (Ratto et al., 2013). On the other hand, La Florida village presents high density of surface Saujil sherds distributed in an area of 10 $km^2$. Several topographical features point to the presence of subsurface architecture, also showing a rectangular pattern in the structures. No kilns were identified here yet, but the presence of overfired sherds and by-products recovered in surface collections at the site indicate that firing has been carried out in the past. TL-dates for some sherds locate chronologically this village during I to IX centuries of the era.

At geochemical level, both sites, LT-V50 and La Florida, are included in one geological province (the Famatina system) with the same geomorphic characteristics (Ratto et al., 2015). Therefore, it is not possible to identify which of the two villages was the focus of pottery production, although the archaeological evidence in one and the other is different. Nevertheless, it is certainly clear that these vessels were manufactured in this geographical area and people moved with the vessels through the north of Abaucán Valley sites (Tatón, Ojo del Agua) reaching in some cases the Chaschuil Puna (El Zorro, Laguna Salada); and with less intensity to the northern La Rioja villages (La Cuestecilla) (Fig. 7).

Other compositional groups (Groups G-7 and G-8) are not so clear to interpret, and they might be reflecting the influence of the temper, as it is shown in the highest loadings for Cs and Rb in the first two PĆs (Fig. 5 and Table 4). Group 7 probably represents travelling vessels, which were manufactured in some unknown place, but there is not enough information to warrant a clear conclusion.

Group 8 also contains sherds from La Cuestecilla site and one fragment from EVS site, both geographically located at La Rioja Province. We argue here that this group represents vessels that travel with people to the north, entering the southern sector of Abaucán Valley but were probably manufactured at La Cuestecilla village (Fig. 7).

It is interesting to observe that some groups, like G-7, G-6, G-8 and G-5 present high loadings for uranium (U) element as shown in Fig. 5 and Tables 4 and 5 for the first two PĆs. The higher loadings of U for these sherds probably indicate that the southern sector of Abaucán valley (G-5, G-6 and G-7) and northern La Rioja archaeological sites (G-8) do have different geochemistry processes acting in the clay banks formation (Ratto et al., 2015). A further and detailed exploration on the U behavior is necessary soon to understand the formation of the compositional chemical patterns in the Abaucán Valley as U mineralization areas have been detected in several mining projects (Hongn et al., 2010; Morello et al., 2011). Previous regional geochemical studies at southwestern Catamarca province show that samples from the Famatina System geological province are characterized by high loads of Eu and Sc at the north, and Ce and Sb to the south (Ratto et al., 2015). Yet, this study points out that there is no differentiation between northern and southern sector of this province at geochemical level. Interestingly, U is one of the elements characteristics of samples belonging to this geological province (Ratto et al., 2015).

Recent ceramic compositional research in NA region involving several valleys geographically located at Catamarca and Salta provinces highlights the importance of exchange networks developed by early sedentary communities (400 BCE–1000 CE) (Lazzari et al., 2017, 2019; Giesso et al., 2019). This research proposes a decentralized model of production and circulation of pottery during Early Period, emphasizing that clays, aplastics (temper) and potters might be circulating across different regions establishing social mechanisms through time. This opens the discussion about the mechanisms acting for the circulation of pottery through different social landscapes, somewhat we are currently observing at the Abaucán Valley during the Early Period for Grey-Horizon pottery coming from residential sites. Contrary to the results of Lazzari et al. (2017), Lazzari et al. (2019), our compositional data support a north–south distribution model (Fig. 7), with no evidence that Saujil pottery has a significant extra-regional scope. Therefore, the technological and compositional data allow us to sustain that there was a "way of doing" pottery typical of the first millennium that materialized in the Abaucán Valley in the Saujil pottery.

## 6. Conclusions

The Grey-Horizon pottery, mostly Saujil ceramic type, from Early Period (I-VI centuries) at Northwestern Argentine was locally produced in several areas along the Abaucán Valley (Catamarca Province) and in the Famatina and Antinaco valleys (La Rioja Province). Saujil pottery has a fine-grained quartz well packed fabric, slightly to moderately tempered with fluvial sands. Ancient potters implemented several recipes according to cultural selection and environmental constraints and availability of clay sources. Technological choices carried out by ancient potters followed regional modalities at least in several geographical areas at Abaucán Valley. Chemical compositional groups support the idea of local production. This chemical patterning suggests that several production sites were functioning at Abaucán Valley during Early Period (Palo Blanco village and LT-V50 / La Florida villages). Sherds from Chaschuil transitional Puna archaeological sites were probably produced at northern Abaucán Valley, whereas the only firmly extra regional production identified in this research is from La Cuestecilla archaeological site (Famatina Valley, La Rioja Province).


## Acknowledgments

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## Appendix I. NAA Elemental concentrations (μg/g)

References: CAR: Cardozo site; CM: Casa del Medio site; EVS: Eras Viejas site; EZ: El Zorro site; LC: La Cuestecilla site; LF: La Florida site; LT-V50: LTV site; OA: Ojo del Agua site; OLZ: Ojo de las Lozas site; PB: Palo Blanco site; TT: Tatón site

| Samples | Sc | Cr | Fe | Co | Rb | Sb | Cs | La | Ce | Sm | Eu | Tb | Yb | Lu | Hf | Ta | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAR1 | 17.22 | 41.60 | 37,181 | 15.320 | 107.45 | 0.520 | 6.19 | 41.43 | 85.30 | 7.620 | 13.90 | 0.970 | 32.20 | 0.46 | 4.34 | 10.50 | 14.83 | 3.42 |
| CAR2 | 15.91 | 51.87 | 37,096 | 13.930 | 138.17 | 0.740 | 11.70 | 41.02 | 82.82 | 7.710 | 13.80 | 10.50 | 30.70 | 0.50 | 4.43 | 10.40 | 15.11 | 3.77 |
| CM1 | 16.81 | 48.34 | 39,228 | 15.580 | 175.40 | 12.40 | 27.61 | 44.31 | 84.59 | 7.120 | 15.70 | 13.60 | 28.90 | 0.51 | 5.05 | 12.60 | 14.65 | 3.65 |
| CM2 | 15.59 | 50.88 | 37,585 | 15.730 | 160.57 | 0.950 | 16.37 | 42.58 | 80.49 | 8.270 | 13.80 | 10.60 | 29.30 | 0.50 | 4.93 | 14.80 | 14.28 | 4.63 |
| EVS | 19.19 | 52.86 | 55,234 | 19.260 | 131.16 | 1.530 | 15.10 | 35.99 | 67.70 | 7.300 | 20.00 | 13.80 | 29.50 | 0.48 | 5.41 | 16.10 | 11.80 | 4.01 |
| EZ1 | 16.49 | 55.80 | 42,282 | 18.190 | 138.08 | 1.460 | 21.56 | 50.25 | 104.69 | 8.950 | 17.20 | 0.870 | 32.20 | 0.79 | 4.66 | 0.96 | 16.67 | 4.29 |
| EZ2 | 13.64 | 43.58 | 36,790 | 14.270 | 119.55 | 10.30 | 13.78 | 39.92 | 80.24 | 7.600 | 15.90 | 0.870 | 25.80 | 0.53 | 4.64 | 10.20 | 12.85 | 3.75 |
| EZ3 | 17.19 | 54.88 | 39,814 | 15.170 | 127.60 | 1.470 | 26.23 | 38.40 | 76.86 | 7.640 | 15.70 | 0.840 | 27.30 | 0.56 | 4.08 | 10.60 | 11.72 | 3.75 |
| EZ4 | 12.98 | 46.08 | 35,428 | 13.890 | 133.66 | 0.860 | 9.07 | 41.20 | 80.64 | 7.380 | 14.80 | 0.690 | 20.10 | 0.58 | 4.65 | 11.90 | 13.77 | 2.80 |
| EZ5 | 15.00 | 46.50 | 39,048 | 14.220 | 143.69 | 11.20 | 10.48 | 45.66 | 85.80 | 8.140 | 16.00 | 0.920 | 27.40 | 0.57 | 3.69 | 0.930 | 14.45 | 5.88 |
| EZ6 | 17.77 | 56.54 | 48,641 | 20.250 | 161.85 | 0.790 | 11.82 | 46.91 | 92.07 | 9.350 | 15.10 | 0.850 | 32.60 | 0.51 | 5.28 | 12.20 | 15.27 | 3.57 |
| EZ7 | 18.49 | 57.41 | 44,280 | 15.360 | 171.93 | 0.890 | 15.17 | 44.58 | 89.09 | 9.090 | 15.60 | 10.10 | 30.80 | 0.53 | 4.23 | 10.90 | 15.59 | 3.35 |
| LC1 | 11.45 | 40.76 | 36,053 | 9.340< | 103.58 | 0.880 | 7.66 | 43.83 | 77.70 | 6.760 | 13.90 | 0.87 | 27.90 | 0.49 | 7.06 | 10.30 | 12.54 | 3.42 |
| LC10 | 13.10 | 45.98 | 33,285 | 10.230 | 117.53 | 10.40 | 7.50 | 32.87 | 62.65 | 6.180 | 12.10 | 0.80 | 27.80 | 0.42 | 5.61 | 0.930 | 12.65 | 5.36 |
| LC11 | 15.70 | 44.56 | 41,507 | 15.320 | 154.80 | 12.10 | 10.78 | 45.02 | 87.26 | 7.870 | 15.30 | 10.00 | 36.10 | 0.56 | 4.36 | 10.00 | 14.01 | 0.93 |
| LC12 | 17.51 | 54.09 | 49,782 | 20.640 | 179.78 | 11.20 | 17.08 | 52.84 | 107.32 | 10.040 | 17.60 | 11.20 | 36.60 | 0.59 | 4.52 | 15.90 | 19.27 | 5.95 |
| LC13 | 11.52 | 46.51 | 28,354 | 8.420< | 174.97 | 10.80 | 14.72 | 39.96 | 79.68 | 7.070 | 0.97 | 0.680 | 37.60 | 0.63 | 6.55 | 12.00 | 25.08 | 9.26 |
| LC14 | 24.14 | 53.03 | 66,308 | 18.110 | 457.32< | 12.80 | 45.75 | 55.77 | 99.39 | 12.010 | 2.34 | 2.43 | 7.010 | 0.99 | 13.44 | 3.49 | 24.22 | 5.21 |
| LC15 | 22.03 | 48.78 | 63,401 | 21.320 | 173.97 | 13.90 | 15.83 | 46.69 | 85.30 | 8.340 | 2.14 | 16.40 | 33.00 | 0.56 | 5.35 | 21.70 | 15.55 | 4.33 |
| LC16 | 20.77 | 44.61 | 60,014 | 18.710 | 153.94 | 11.30 | 16.24 | 42.90 | 78.61 | 8.310 | 2.17 | 1.68 | 30.30 | 0.52 | 5.95 | 2.50 | 14.54 | 4.98 |
| LC17 | 21.50 | 40.15 | 65,525 | 18.750 | 241.05< | 1.400 | 37.90 | 48.46 | 95.18 | 10.340 | 2.42 | 13.40 | 35.20 | 0.60 | 8.82 | 3.18 | 21.11 | 6.68 |
| LC18 | 13.02 | 41.68 | 40,772 | 8.130< | 254.66< | 1.560 | 40.49 | 33.54 | 62.90 | 6.280 | 12.90 | 10.10 | 31.60 | 0.54 | 6.98 | 20.10 | 23.75 | 6.63 |
| LC19 | 21.23 | 41.72 | 57,843 | 22.280< | 142.50 | 11.30 | 13.91 | 46.07 | 83.58 | 8.470 | 2.24 | 16.20 | 32.20 | 0.53 | 5.38 | 19.70 | 15.24 | 3.61 |
| LC2 | 21.99 | 50.16 | 62,977 | 22.770< | 188.25 | 0.980 | 16.93 | 45.60 | 77.02 | 8.940 | 2.28 | 16.00 | 30.00 | 0.55 | 5.72 | 20.60 | 15.81 | 5.62 |
| LC20 | 20.92 | 46.87 | 62,760 | 22.790< | 145.22 | 0.960 | 16.46 | 48.19 | 87.27 | 9.310 | 2.36 | 13.80 | 34.20 | 0.53 | 5.62 | 20.90 | 17.18 | 6.45 |
| LC21 | 16.52 | 42.49 | 48,021 | 14.180 | 124.73 | 11.10 | 11.27 | 31.08 | 49.51 | 6.160 | 17.00 | 12.70 | 25.80 | 0.45 | 8.02 | 19.80 | 12.55 | 6.46 |
| LC22 | 12.78 | 90.92 | 32,989 | 9.330 | 87.04 | 0.97 | 8.56 | 32.11 | 65.16 | 6.920 | 13.00 | 0.95 | 38.30 | 0.70 | 7.21 | 10.50 | 13.95 | 9.18 |
| LC23 | 13.73 | 46.39 | 38,095 | 12.410 | 111.95 | 11.20 | 11.69 | 39.08 | 76.74 | 7.780 | 15.00 | 0.87 | 34.50 | 0.57 | 6.94 | 15.20 | 15.27 | 4.68 |
| LC24 | 15.23 | 94.96 | 33,656 | 9.280 | 100.47 | 11.90 | 15.22 | 34.81 | 55.39 | 4.620 | 0.98 | 0.55 | 23.90 | 0.51 | 7.72 | 14.60 | 13.49 | 9.46 |
| LC25 | 11.91 | 34.49 | 36,120 | 12.340 | 243.17 | 11.50 | 34.03 | 47.14 | 92.33 | 10.270 | 14.00 | 0.95 | 32.20 | 0.49 | 5.56 | 2.87 | 25.10 | 5.28 |
| LC3 | 12.79 | 48.80 | 37,056 | 8.070 | 123.85 | 10.10 | 7.30 | 32.70 | 60.57 | 5.640 | 10.40 | 0.53 | 26.10 | 0.48 | 6.14 | 0.910 | 12.01 | 5.46 |
| LC4 | 15.07 | 52.19 | 39,886 | 13.790 | 150.81 | 1.510 | 10.38 | 40.74 | 79.40 | 7.310 | 12.80 | 0.86 | 34.80 | 0.55 | 4.85 | 10.10 | 12.50 | 4.27 |
| LC5 | 18.20 | 54.38 | 45,623 | 15.530 | 178.45 | 13.00 | 11.25 | 59.56 | 116.20 | 10.890 | 17.00 | 12.3 | 4.330 | 0.61 | 4.36 | 11.10 | 17.54 | 5.45 |
| LC6 | 18.50 | 50.31 | 47,429 | 16.000 | 163.24 | 11.10 | 13.18 | 49.14 | 99.83 | 9.430 | 16.00 | 12.2 | 35.00 | 0.60 | 4.21 | 11.50 | 17.32 | 4.80 |
| LC7 | 12.21 | 107.1 | 31,593 | 8.120< | 111.50 | 0.810 | 7.56 | 33.66 | 69.23 | 7.460 | 11.60 | 0.51 | 30.80 | 0.55 | 7.44 | 10.60 | 14.43 | 2.96 |
| LC8 | 14.67 | 55.10 | 41,022 | 15.250 | 160.49 | 12.00 | 16.35 | 42.64 | 85.81 | 9.140 | 14.90 | 13.3 | 5.380 | 0.91 | 6.91 | 15.10 | 15.52 | 5.31 |
| LC9 | 16.62 | 50.90 | 45,346 | 18.790 | 146.22 | 0.96 | 9.88 | 49.17 | 98.79 | 8.950 | 15.50 | 11.4 | 34.70 | 0.55 | 4.93 | 10.80 | 16.13 | 3.62 |
| Lf001 | 17.09 | 55.12 | 47,221 | 18.700 | 170.46 | 0.80 | 11.84 | 46.21 | 92.92 | 9.850 | 15.40 | 11.2 | 38.40 | 0.61 | 5.00 | 13.50 | 18.65 | 5.56 |
| Lf002 | 17.39 | 53.49 | 47,743 | 19.130 | 171.17 | 0.70 | 11.69 | 46.99 | 94.97 | 9.990 | 16.10 | 12.1 | 32.50 | 0.57 | 5.43 | 14.40 | 15.49 | 4.88 |
| Lf003 | 16.01 | 52.77 | 45,954 | 17.800 | 154.39 | 0.71 | 10.98 | 43.28 | 88.05 | 8.810 | 15.00 | 0.97 | 28.90 | 0.54 | 5.35 | 12.50 | 14.69 | 4.14 |
| Lf007 | 18.54 | 58.36 | 51,082 | 21.000 | 179.28 | 0.90 | 12.43 | 48.54 | 97.35 | 10.040 | 16.70 | 11.2 | 36.00 | 0.58 | 5.85 | 13.90 | 17.18 | 5.15 |
| Lf008 | 15.40 | 48.26 | 42,331 | 14.600 | 179.30 | 0.89 | 14.03 | 42.42 | 86.52 | 9.520 | 13.30 | 0.94 | 35.00 | 0.54 | 6.03 | 13.60 | 15.13 | 4.84 |
| Lf014 | 17.93 | 59.04 | 48,734 | 19.170 | 180.77 | 0.94 | 12.99 | 49.17 | 95.87 | 10.120 | 16.00 | 0.93 | 38.80 | 0.59 | 5.77 | 15.80 | 17.22 | 5.76 |
| Lf015 | 16.58 | 44.99 | 45,953 | 16.070 | 203.23 | 10.40 | 21.21 | 45.65 | 92.66 | 9.940 | 15.20 | 10.20 | 29.60 | 0.63 | 5.07 | 18.00 | 19.52 | 7.53 |
| Lf020 | 16.83 | 43.98 | 46,716 | 16.510 | 209.61 | 10.50 | 22.90 | 45.77 | 95.75 | 10.080 | 15.30 | 14.20 | 36.50 | 0.58 | 5.72 | 21.60 | 19.83 | 6.35 |
| Lf024 | 15.17 | 44.94 | 41,640 | 16.320 | 136.75 | 0.82 | 10.02 | 42.75 | 88.09 | 8.690 | 15.00 | 13.90 | 34.50 | 0.48 | 5.64 | 11.90 | 14.37 | 5.21 |
| Lf026 | 17.05 | 53.12 | 46,771 | 19.090 | 162.89 | 0.89 | 12.29 | 45.85 | 91.85 | 9.550 | 15.90 | 12.70 | 34.00 | 0.60 | 5.45 | 16.30 | 15.95 | 5.64 |
| Lf043 | 17.26 | 54.46 | 46,943 | 18.460 | 172.84 | 0.93 | 12.31 | 50.09 | 96.61 | 10.060 | 16.90 | 11.60 | 37.50 | 0.59 | 6.28 | 13.30 | 16.74 | 5.61 |
| Lf045 | 14.55 | 40.85 | 38,397 | 15.150 | 151.92 | 0.73 | 9.54 | 40.52 | 81.86 | 8.330 | 15.00 | 11.80 | 31.00 | 0.45 | 4.96 | 12.80 | 13.18 | 4.71 |
| Lf048 | 18.12 | 58.65 | 49,338 | 20.190 | 189.58 | 0.57 | 13.40 | 45.61 | 94.32 | 8.650 | 15.30 | 12.20 | 34.10 | 0.54 | 6.18 | 14.40 | 16.00 | 4.66 |
| Lf049 | 15.94 | 49.60 | 42,465 | 16.960 | 152.38 | 0.68 | 10.01 | 42.08 | 87.69 | 7.900 | 13.50 | 0.85 | 25.60 | 0.46 | 3.84 | 12.40 | 14.34 | 4.19 |
| Lf064 | 8.66 | 27.32 | 23,622 | 9.750 | 79.22 | 0.42 | 4.89 | 23.55 | 49.23 | 4.460 | 0.80 | 0.69 | 1.53 | 0.25 | 2.56 | 0.65 | 7.99 | 2.33 |
| Lf065 | 16.50 | 44.16 | 40,425 | 16.090 | 153.94 | 0.74 | 10.42 | 46.53 | 97.14 | 8.820 | 17.20 | 12.50 | 28.30 | 0.45 | 4.87 | 11.90 | 15.31 | 4.26 |
| Lf072 | 15.40 | 48.33 | 43,667 | 16.810 | 154.53 | 0.65 | 9.25 | 42.31 | 87.26 | 7.530 | 13.70 | 0.82 | 27.30 | 0.45 | 4.21 | 11.20 | 13.89 | 3.72 |
| Lf077 | 15.00 | 45.11 | 40,514 | 15.350 | 148.45 | 0.63 | 9.49 | 41.12 | 84.72 | 8.170 | 14.70 | 12.20 | 27.30 | 0.45 | 4.46 | 11.50 | 14.87 | 5.61 |
| Lf087 | 18.52 | 60.70 | 50,440 | 20.380 | 175.12 | 0.93 | 11.83 | 49.20 | 101.20 | 9.510 | 16.30 | 15.90 | 33.00 | 0.54 | 5.19 | 15.20 | 17.38 | 5.03 |
| Lf117 | 13.66 | 45.57 | 40,486 | 15.430 | 121.39 | 0.80 | 9.82 | 43.92 | 95.26 | 8.010 | 16.50 | 12.80 | 29.50 | 0.55 | 6.82 | 15.40 | 17.40 | 4.88 |
| Lf119 | 17.45 | 49.34 | 48,375 | 20.010 | 180.65 | 0.75 | 11.89 | 46.11 | 93.66 | 9.050 | 15.80 | 14.50 | 30.60 | 0.49 | 5.17 | 14.40 | 15.93 | 5.14 |
| Lf122 | 15.56 | 52.88 | 41,833 | 16.110 | 145.62 | 0.83 | 9.32 | 43.55 | 87.58 | 8.010 | 14.60 | 13.40 | 27.90 | 0.52 | 4.51 | 13.20 | 14.63 | 4.79 |
| Lf123 | 14.77 | 43.72 | 41,749 | 16.020 | 122.73 | 0.71 | 10.13 | 37.31 | 79.49 | 7.060 | 15.30 | 0.64 | 26.00 | 0.39 | 4.46 | 18.10 | 13.15 | 4.23 |
| Lf127 | 15.44 | 43.46 | 41,166 | 16.330 | 133.15 | 0.70 | 10.02 | 41.14 | 85.79 | 7.640 | 16.60 | 0.59 | 27.10 | 0.46 | 4.14 | 14.00 | 14.48 | 4.46 |
| Lf128 | 14.56 | 48.24 | 41,535 | 14.870 | 126.51 | 0.83 | 10.33 | 41.20 | 82.23 | 7.560 | 16.10 | 0.64 | 30.70 | 0.46 | 5.27 | 19.80 | 13.65 | 3.76 |
| Lf130 | 15.36 | 47.01 | 42,997 | 16.720 | 140.07 | 0.72 | 9.30 | 47.71 | 93.79 | 7.860 | 16.30 | 10.30 | 26.80 | 0.47 | 4.70 | 14.00 | 14.50 | 4.26 |
| Lf131 | 15.08 | 46.51 | 44,329 | 16.080 | 115.80 | 0.69 | 9.72 | 44.12 | 95.22 | 8.290 | 15.80 | 0.92 | 30.20 | 0.45 | 4.62 | 16.70 | 14.97 | 4.11 |
| Lf132 | 16.24 | 51.53 | 43,147 | 15.820 | 133.06 | 0.67 | 10.40 | 41.71 | 83.13 | 7.670 | 15.30 | 0.84 | 25.50 | 0.43 | 4.69 | 16.30 | 14.42 | 5.21 |
| Lf138 | 12.94 | 36.28 | 35,893 | 13.030 | 314.69 | 0.66 | 16.51 | 29.23 | 64.87 | 6.140 | 12.00 | 0.65 | 31.50 | 0.54 | 4.06 | 46.70 | 13.01 | 5.29 |
| Lf140 | 17.29 | 54.52 | 48,786 | 18.460 | 147.92 | 0.86 | 11.96 | 46.34 | 97.15 | 8.790 | 16.00 | 0.83 | 30.80 | 0.50 | 5.43 | 15.70 | 15.93 | 4.65 |
| Lf146 | 12.72 | 44.63 | 37,677 | 15.480 | 127.09 | 0.60 | 8.62 | 40.63 | 89.20 | 7.260 | 15.20 | 0.76 | 27.70 | 0.46 | 5.94 | 12.70 | 15.00 | 4.39 |
| LS1 | 14.30 | 37.07 | 36,444 | 11.640 | 152.00 | 0.83 | 7.83 | 40.72 | 74.26 | 11.290 | 13.60 | 0.76 | 24.80 | 0.39 | 4.76 | 10.30 | 12.93 | 2.50 |
| LS2 | 14.87 | 46.82 | 39,679 | 14.640 | 139.00 | 0.92 | 9.63 | 32.83 | 83.09 | 11.020 | 14.90 | 0.78 | 27.60 | 0.50 | 4.36 | 12.30 | 13.57 | 3.68 |
| LS3 | 13.87 | 45.68 | 38,838 | 14.770 | 205.00 | 0.97 | 9.15 | 36.85 | 83.06 | 11.240 | 14.00 | 0.62 | 28.70 | 0.40 | 4.39 | 11.60 | 15.12 | 3.57 |
| LTV01 | 14.52 | 45.28 | 41,710 | 16.150 | 141.00 | 0.99 | 8.96 | 41.07 | 84.91 | 7.940 | 15.60 | 10.20 | 26.90 | 0.48 | 4.70 | 12.80 | 15.20 | 3.32 |
| LTV02 | 16.62 | 43.61 | 45,683 | 18.270 | 144.00 | 0.64 | 9.64 | 41.14 | 90.96 | 7.800 | 15.90 | 10.80 | 27.20 | 0.49 | 5.18 | 10.90 | 14.45 | 3.62 |
| LTV03 | 14.50 | 45.29 | 33,102 | 16.490 | 141.00 | 0.82 | 9.30 | 41.66 | 85.62 | 7.770 | 15.30 | 12.00 | 24.60 | 0.47 | 4.49 | 11.40 | 14.61 | 3.72 |
| LTV04 | 18.44 | 63.94 | 50,493 | 20.470 | 195.00 | 1.45 | 16.90 | 50.99 | 97.14 | 9.060 | 17.00 | 0.94 | 30.90 | 0.46 | 3.84 | 14.10 | 14.45 | 4.38 |
| LTV06 | 15.25 | 45.86 | 41,964 | 16.640 | 130.00 | 0.80 | 8.85 | 42.06 | 82.37 | 7.300 | 15.90 | 13.00 | 29.20 | 0.47 | 4.70 | 0.97 | 13.54 | 4.24 |
| LTV07 | 14.31 | 45.84 | 39,859 | 16.160 | 142.00 | 0.84 | 7.95 | 40.62 | 74.84 | 7.150 | 14.40 | 10.60 | 28.20 | 0.44 | 5.09 | 0.89 | 12.73 | 2.92 |

(*continued on next page*)

(*continued*)

| Samples | Sc | Cr | Fe | Co | Rb | Sb | Cs | La | Ce | Sm | Eu | Tb | Yb | Lu | Hf | Ta | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LTV08 | 15.78 | 41.17 | 43,835 | 18.230 | 125.71 | 0.63 | 7.98 | 43.92 | 91.80 | 8.310 | 15.60 | 14.00 | 28.80 | 0.47 | 4.47 | 12.00 | 15.34 | 3.44 |
| LTV09 | 13.13 | 40.53 | 38,086 | 13.860 | 116.82 | 0.72 | 7.70 | 39.91 | 76.18 | 7.440 | 13.40 | 0.66 | 27.20 | 0.45 | 4.03 | 12.40 | 13.20 | 3.39 |
| LTV10 | 14.16 | 45.73 | 39,467 | 15.360 | 122.42 | 0.67 | 8.05 | 37.17 | 76.55 | 7.450 | 15.20 | 0.78 | 28.00 | 0.42 | 4.17 | 12.90 | 17.78 | 3.72 |
| OA1 | 14.58 | 30.74 | 44,187 | 17.660 | 147.00 | 0.48 | 8.45 | 39.53 | 53.36 | 5.680 | 13.80 | 0.64 | 33.50 | 0.55 | 4.61 | 16.10 | 13.24 | 2.40 |
| OA2 | 14.42 | 45.79 | 38,150 | 15.230 | 113.00 | 0.79 | 6.96 | 39.09 | 77.25 | 7.520 | 14.80 | 10.00 | 29.30 | 0.49 | 4.84 | 0.80 | 12.51 | 3.61 |
| OA3 | 18.67 | 44.06 | 42,671 | 17.780 | 90.56 | 0.75 | 6.62 | 47.19 | 91.85 | 8.580 | 15.40 | 0.99 | 28.00 | 0.47 | 4.95 | 10.00 | 16.35 | 3.45 |
| OA4 | 16.73 | 49.15 | 44,256 | 19.240 | 137.38 | 0.78 | 11.03 | 48.03 | 100.41 | 7.260 | 15.60 | 13.90 | 30.60 | 0.48 | 4.78 | 12.80 | 17.82 | 3.15 |
| OA5 | 17.46 | 53.73 | 43,634 | 18.040 | 124.00 | 10.70 | 9.25 | 43.70 | 87.78 | 8.210 | 16.10 | 0.87 | 28.70 | 0.53 | 5.35 | 10.50 | 14.33 | 3.46 |
| OA6 | 14.39 | 43.87 | 37,365 | 14.680 | 105.00 | 0.66 | 6.44 | 38.15 | 74.36 | 7.090 | 14.00 | 11.70 | 28.70 | 0.46 | 5.45 | 0.90 | 11.93 | 3.82 |
| OA7 | 15.74 | 44.37 | 39,182 | 14.940 | 107.00 | 0.71 | 6.87 | 38.04 | 77.15 | 7.010 | 13.90 | 0.92 | 25.10 | 0.40 | 4.30 | 0.84 | 12.10 | 2.16 |
| OA8 | 17.14 | 52.86 | 41,996 | 15.950 | 106.00 | 10.5 | 8.82 | 39.70 | 83.45 | 7.490 | 15.20 | 0.77 | 30.80 | 0.51 | 4.69 | 0.78 | 13.94 | 3.17 |
| OA9 | 17.34 | 53.89 | 40,410 | 18.240 | 132.23 | 0.76 | 7.07 | 42.66 | 82.66 | 7.370 | 14.30 | 0.83 | 26.90 | 0.45 | 3.75 | 16.8 | 17.26 | 3.82 |
| OLZ1 | 14.54 | 41.88 | 35,237 | 12.540 | 117.00 | 0.64 | 9.02 | 41.89 | 82.40 | 7.810 | 14.00 | 0.71 | 24.70 | 0.39 | 5.33 | 11.3 | 13.95 | 3.47 |
| OLZ2 | 16.68 | 46.59 | 39,075 | 14.890 | 147.00 | 12.20 | 10.43 | 44.50 | 82.76 | 6.890 | 0.970 | 0.70 | 23.30 | 0.43 | 4.43 | 14.40 | 14.34 | 3.81 |
| PB1 | 15.62 | 56.43 | 43,540 | 15.610 | 152.00 | 10.90 | 14.26 | 49.84 | 93.36 | 9.610 | 17.50 | 10.30 | 36.10 | 0.64 | 6.03 | 11.10 | 16.18 | 5.24 |
| PB10 | 20.98 | 58.26 | 44,588 | 14.250 | 151.00 | 0.36 | 15.04 | 44.82 | 94.83 | 8.400 | 16.40 | 0.68 | 32.00 | 0.52 | 5.28 | 12.70 | 18.11 | 3.49 |
| PB11 | 21.84 | 53.80 | 43,297 | 16.460 | 118.00 | 0.26 | 8.70 | 47.29 | 107.77 | 8.800 | 0.49 | 12.40 | 30.30 | 0.49 | 4.63 | 15.80 | 21.08 | 5.05 |
| PB12 | 21.01 | 49.28 | 43,126 | 16.130 | 95.00 | 0.22 | 8.11 | 39.89 | 100.84 | 6.570 | 16.40 | 0.60 | 23.10 | 0.35 | 4.86 | 0.50 | 17.69 | 2.77 |
| PB13 | 17.04 | 47.03 | 36,629 | 14.520 | 102.00 | 0.48 | 5.30 | 42.59 | 88.04 | 8.580 | 16.00 | 0.91 | 26.40 | 0.38 | 3.95 | 11.40 | 12.79 | 2.66 |
| PB14 | 16.57 | 54.03 | 41,560 | 17.020 | 123.00 | 0.73 | 6.30 | 51.72 | 94.82 | 8.060 | 14.40 | 11.50 | 29.10 | 0.36 | 5.10 | 10.80 | 17.61 | 1.79 |
| PB15 | 15.91 | 40.10 | 35,126 | 12.140 | 92.80 | 0.45 | 5.04 | 31.54 | 52.35 | 6.310 | 12.50 | 0.76 | 23.30 | 0.40 | 4.06 | 0.75 | 10.09 | 2.99 |
| PB16 | 11.86 | 30.38 | 30,621 | 11.050 | 67.63 | 0.45 | 4.50 | 46.71 | 91.27 | 8.610 | 14.90 | 0.81 | 22.10 | 0.38 | 3.93 | 0.99 | 13.40 | 3.13 |
| PB17 | 17.15 | 48.12 | 46,161 | 19.300 | 123.00 | 0.70 | 8.65 | 41.64 | 73.49 | 7.930 | 14.90 | 11.60 | 26.20 | 0.40 | 5.38 | 11.90 | 13.71 | 4.25 |
| PB18 | 18.04 | 48.61 | 42,283 | 16.540 | 140.00 | 0.66 | 10.41 | 44.47 | 82.19 | 8.600 | 15.30 | 13.80 | 29.80 | 0.49 | 4.81 | 12.10 | 15.21 | 4.81 |
| PB19 | 16.17 | 51.59 | 38,926 | 15.350 | 136.00 | 0.66 | 8.85 | 40.87 | 80.29 | 7.560 | 13.40 | 0.98 | 25.30 | 0.44 | 4.32 | 0.88 | 13.41 | 4.12 |
| PB2 | 14.68 | 50.44 | 36,525 | 14.900 | 119.00 | 0.45 | 9.91 | 36.59 | 76.28 | 7.640 | 14.60 | 0.87 | 27.80 | 0.45 | 5.63 | 0.93 | 12.41 | 4.59 |
| PB20 | 15.71 | 42.75 | 37,095 | 14.610 | 146.00 | 0.58 | 11.51 | 46.52 | 95.10 | 8.600 | 13.90 | 10.20 | 29.30 | 0.43 | 4.97 | 14.00 | 16.82 | 4.22 |
| PB21 | 16.35 | 46.36 | 38,086 | 15.230 | 111.00 | 0.61 | 5.49 | 42.74 | 98.81 | 7.730 | 13.30 | 0.96 | 25.30 | 0.44 | 4.77 | 11.90 | 15.72 | 2.82 |
| PB22 | 13.36 | 42.00 | 35,379 | 13.110 | 127.00 | 0.66 | 10.43 | 37.91 | 78.37 | 6.570 | 12.80 | 0.75 | 28.40 | 0.39 | 3.52 | 0.80 | 15.99 | 5.50 |
| PB23 | 15.08 | 45.42 | 38,566 | 16.070 | 101.81 | 0.60 | 5.39 | 36.54 | 73.44 | 7.060 | 14.80 | 0.67 | 23.40 | 0.37 | 3.04 | 10.10 | 11.04 | 2.64 |
| PB24 | 14.03 | 41.52 | 37,816 | 14.470 | 131.45 | 0.81 | 8.94 | 40.45 | 84.00 | 7.970 | 15.20 | 0.86 | 27.90 | 0.45 | 3.77 | 14.60 | 13.45 | 4.23 |
| PB25 | 13.98 | 44.79 | 38,230 | 13.540 | 122.20 | 0.76 | 5.80 | 37.05 | 71.11 | 7.610 | 13.90 | 0.43 | 27.70 | 0.42 | 4.47 | 10.10 | 12.97 | 6.51 |
| PB26 | 17.76 | 58.75 | 44,382 | 17.610 | 151.25 | 10.60 | 11.49 | 45.42 | 91.71 | 8.500 | 16.90 | 10.20 | 31.40 | 0.55 | 4.61 | 15.50 | 15.17 | 2.51 |
| PB27 | 18.12 | 41.34 | 40,373 | 15.820 | 115.83 | 0.51 | 6.61 | 43.39 | 91.21 | 8.040 | 13.60 | 0.97 | 26.70 | 0.50 | 4.38 | 11.90 | 17.34 | 3.93 |
| PB28 | 15.15 | 36.08 | 40,336 | 14.050 | 181.53 | 0.82 | 14.89 | 51.38 | 107.54 | 9.530 | 16.00 | 12.40 | 32.10 | 0.55 | 5.55 | 16.30 | 21.94 | 6.23 |
| PB29 | 14.76 | 44.05 | 37,138 | 16.010 | 95.35 | 0.75 | 5.03 | 40.29 | 79.62 | 6.890 | 13.40 | 0.95 | 24.00 | 0.41 | 3.46 | 0.90 | 12.16 | 4.12 |
| PB3 | 15.97 | 48.79 | 44,845 | 16.430 | 142.00 | 0.66 | 11.90 | 34.43 | 93.22 | 8.380 | 14.10 | 15.10 | 30.00 | 0.53 | 5.39 | 10.70 | 17.67 | 5.66 |
| PB30 | 15.18 | 40.08 | 37,512 | 14.050 | 110.00 | 0.36 | 6.30 | 43.38 | 74.98 | 8.090 | 13.30 | 0.92 | 27.10 | 0.38 | 4.33 | 0.71 | 15.37 | 3.64 |
| PB31 | 14.83 | 67.76 | 45,646 | 15.180 | 161.00 | 11.70 | 14.08 | 45.96 | 84.37 | 8.240 | 14.70 | 0.62 | 31.60 | 0.46 | 4.98 | 12.60 | 12.27 | 4.24 |
| PB32 | 16.08 | 42.60 | 46,683 | 16.850 | 148.21 | 0.64 | 8.37 | 45.00 | 83.74 | 5.840 | 11.90 | 0.97 | 24.70 | 0.28 | 4.77 | 14.70 | 12.76 | 2.82 |
| PB4 | 15.380 | 35.98 | 42,135 | 15.050 | 162.00 | 0.54 | 15.23 | 51.20 | 102.76 | 9.820 | 18.60 | 13.40 | 33.10 | 0.56 | 5.86 | 15.60 | 19.70 | 6.82 |
| PB5 | 17.14 | 52.66 | 47,607 | 16.520 | 205.00 | 10.30 | 24.98 | 71.00 | 153.33 | 13.900 | 2.16 | 1.68 | 34.10 | 0.67 | 5.25 | 19.90 | 34.26 | 8.58 |
| PB7 | 17.44 | 57.63 | 45,413 | 16.580 | 161.00 | 0.68 | 11.45 | 37.86 | 91.56 | 7.880 | 14.40 | 0.55 | 30.40 | 0.53 | 6.63 | 11.10 | 16.16 | 3.82 |
| PB8 | 22.65 | 50.52 | 45,446 | 23.440 | 119.00 | 0.28 | 5.16 | 45.04 | 66.39 | 9.570 | 2.87 | 12.40 | 32.80 | 0.52 | 4.31 | 0.98 | 4.88 | 4.86 |
| TT1 | 17.15 | 44.10 | 40,244 | 15.170 | 120.00 | 0.51 | 6.66 | 44.85 | 93.91 | 8.730 | 14.50 | 0.82 | 32.40 | 0.48 | 4.80 | 11.90 | 16.53 | 4.60 |
| TT10 | 20.41 | 51.80 | 48,599 | 20.760 | 126.00 | 0.60 | 10.90 | 50.30 | 106.00 | 9.590 | 16.00 | 10.90 | 30.30 | 0.53 | 4.39 | 12.80 | 19.43 | 5.01 |
| TT11 | 18.43 | 56.91 | 46,258 | 18.520 | 153.00 | 0.48 | 10.84 | 48.03 | 95.61 | 8.550 | 16.30 | 10.00 | 30.40 | 0.51 | 4.99 | 12.80 | 18.72 | 5.47 |
| TT12 | 16.46 | 54.42 | 42,972 | 16.900 | 141.00 | 0.52 | 9.62 | 41.82 | 79.68 | 7.430 | 15.60 | 0.77 | 27.80 | 0.44 | 4.62 | 10.60 | 13.95 | 3.72 |
| TT2 | 16.08 | 38.11 | 40,440 | 16.720 | 189.00 | 0.88 | 10.49 | 41.62 | 76.07 | 7.750 | 14.00 | 12.30 | 26.40 | 0.47 | 4.49 | 12.50 | 15.75 | 5.22 |
| TT3 | 14.48 | 37.16 | 36,216 | 12.640 | 118.00 | 0.51 | 7.82 | 35.67 | 72.44 | 6.450 | 15.10 | 0.96 | 26.20 | 0.47 | 4.56 | 10.40 | 11.64 | 3.91 |
| TT4 | 22.19 | 35.14 | 48,417 | 20.960 | 148.00 | 0.73 | 7.28 | 54.22 | 96.12 | 9.600 | 15.90 | 1.77 | 34.20 | 0.52 | 4.23 | 13.80 | 20.24 | 5.27 |
| TT5 | 15.29 | 54.82 | 40,343 | 16.210 | 135.00 | 0.84 | 14.05 | 43.35 | 88.02 | 7.990 | 14.00 | 12.10 | 29.20 | 0.48 | 4.12 | 0.97 | 13.63 | 6.04 |
| TT6 | 20.15 | 65.32 | 50,733 | 21.390 | 162.00 | 0.84 | 18.28 | 54.09 | 115.00 | 10.470 | 16.90 | 12.70 | 34.40 | 0.59 | 4.690 | 16.70 | 23.37 | 7.52 |
| TT7 | 14.79 | 40.10 | 35,028 | 13.560 | 108.00 | 0.38 | 6.46 | 42.95 | 86.28 | 9.190 | 14.60 | 11.10 | 25.60 | 0.39 | 4.17 | 0.94 | 13.97 | 4.06 |
| TT8 | 18.54 | 41.28 | 42,224 | 16.250 | 107.00 | 0.40 | 6.58 | 44.89 | 78.82 | 9.990 | 14.80 | 10.00 | 29.10 | 0.47 | 4.25 | 11.20 | 16.03 | 5.57 |
| TT9 | 15.03 | 44.02 | 37,537 | 14.610 | 131.00 | 0.59 | 7.83 | 39.66 | 76.15 | 6.710 | 13.30 | 0.83 | 25.50 | 0.39 | 4.69 | 10.80 | 13.08 | 4.55 |

## Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2021.102950.

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