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Wari influence in southern Peru: provenance study of middle horizon pottery from the archaeological site of La Real using k_0-INAA

P. S. Bedregal[1] · P. A. Mendoza[1] · M. S. Ubillús[1] · W. Yépez[3] · J. Jennings[2] · E. H. Montoya[1]

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Abstract Fragments of archaeological pottery from a rescue excavation at the site of La Real in Arequipa, Peru, were studied by instrumental neutron activation analysis, k_0 method. Analytical data were processed by multivariate statistical techniques, comparing the chemical composition of the studied samples versus the information available in our database on the chemical composition of archaeological pottery from Conchopata (Ayacucho), Cotahuasi (Arequipa), Huaro (Cusco) and Tiwanaku (Bolivia). The results obtained revealed that most of the samples were likely made locally at La Real, while others correspond to the chemical composition of the different groups considered, showing evidence of the presence of foreign pottery in the site and a small group which were not classified.

Keywords Instrumental neutron activation analysis · Provenance study · Archaeological pottery · k_0 method · La Real · Wari

Introduction

Wari was a pre-Columbian civilization of the Middle Horizon (AD 600–1000), a period of great cultural change in the central Andes. The Wari State was located in Ayacucho, and its influence extended almost the breadth of present day Peru, touching Cajamarca, Lambayeque, Chachapoyas and Piura in the north, and Cusco, and Moquegua in the south [1]. In 1995, salvage excavations at the site of La Real in Arequipa's Majes Valley Fig. 1 documented a rich, largely intact Middle Horizon funerary context. Archaeologists recovered a wide variety of artefacts including textiles, botanical remain, metals and pottery [2]. Some of the ceramic fragments were identified as Wari styles, such as, Ocros, Chakipampa, Viñaque, and others were a combination of local, regional, and Wari styles. The strong level of Wari stylistic influence at La Real begs the question of the provenance of the ceramics found at the site.

The multivariate statistical analysis of chemical composition of archaeological ceramics is a very useful tool for determining the possible presence and provenance of the foreign ceramic styles [3–7], as well as for understanding the kind and grade of influence of wide-ranging civilizations on local groups. Given a representative sample of pottery of different styles from the same period in an archaeological site, the first step is thus to determine the elemental composition of each fragment in a complete and accurate way. For this task, instrumental neutron activation analysis technique based in the k_0 method has particularly advantages in this type of matrix [8, 9]. Once the conditions of both irradiation positions and calibration detector are well established [10], the use of a single comparator simplifies the multielemental determination, getting the quantification of relevant elements for archaeological applications.

This study reports the multielemental quantitative determination of a group of one hundred Middle Horizon fragments from La Real, as well as the results of a multivariate statistical analysis of these determinations. The evaluation includes a comparison of the chemical

✉ P. S. Bedregal
pbedregal@ipen.gob.pe

[1] División de Técnicas Analíticas Nucleares, Instituto Peruano de Energía Nuclear (IPEN), Av. Canadá N° 1470, Lima 41, Peru

[2] Department of World Cultures, Royal Ontario Museum, 100 Queen's Park, Toronto, ON M5S 2C6, Canada

[3] Proyecto Colección Arqueológica La Real, Avenida Los Próceres No 198, J.L. Bustamante Y Rivero, Arequipa, Peru

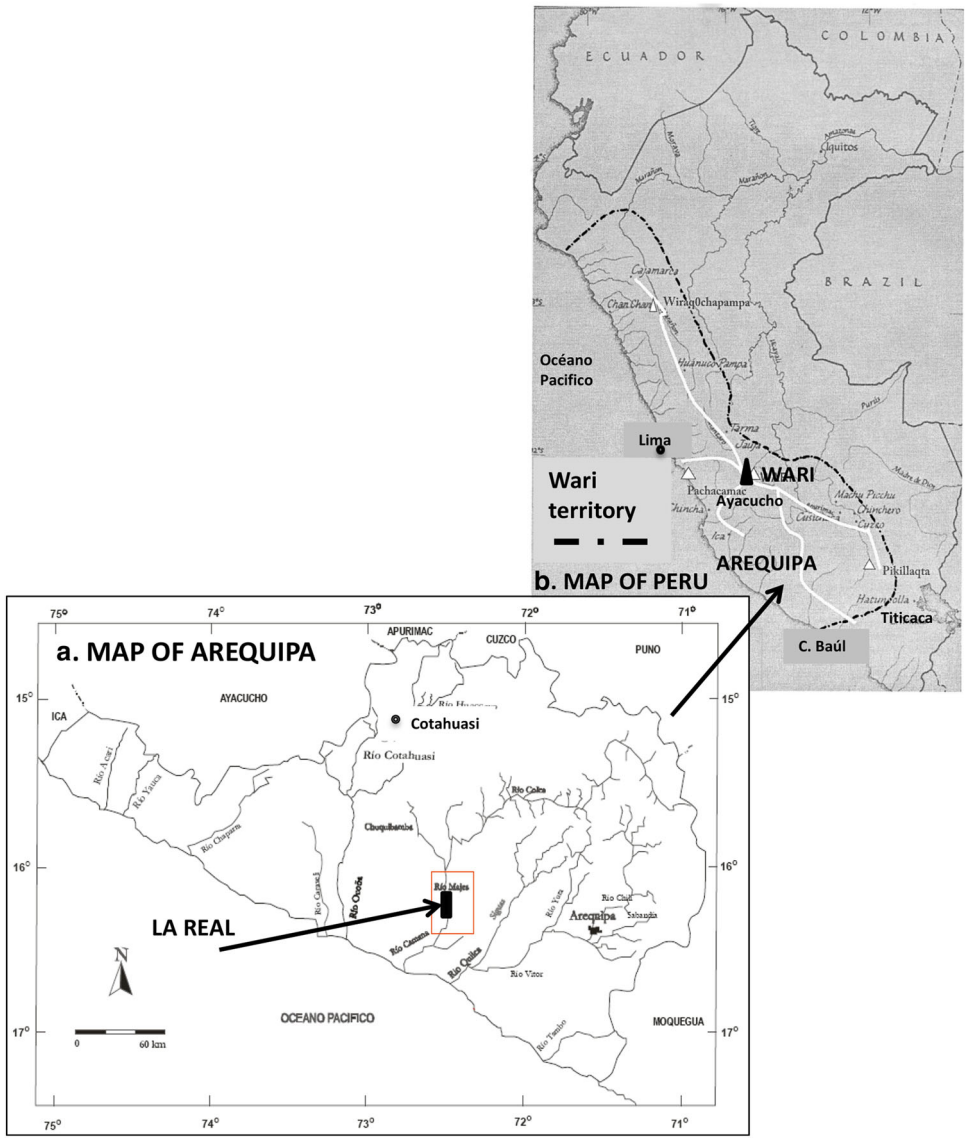

Fig. 1 **a** Map of the Department of Arequipa, indicating the site of La Real. **b** Map of Peru, indicating the capital of the Wari State and the extent of its influence

composition of pottery from La Real site with the chemical composition of groups from our database of Wari style pottery from Conchopata (Ayacucho), three of Huaro, (Cusco), and Cotahuasi (Arequipa), as well as a group from Tiwanaku in Bolivia [11, 12]. Some archaeological implications are proposed as a result of this study.

Experimental

Samples and comparators preparation

One hundred samples of thirteen different styles were selected for this study (Table 1). The styles were largely Wari-related, and characterized by orange or red slips painted in a variety of geometric, zoomorphic, and anthropomorphic designs.

Approximately, 0.700 g of ceramic powder, good enough for two replicates, was extracted from a clean side of each fragment using a tungsten carbon drill. In those cases where the fragment was too narrow for drilling, a small clean portion was cut from the fragment and placed in a vessel with liquid nitrogen that was then broken and milled in an agate mortar. The extracted powder was placed in cleaned glass flasks and dried in a calibrated oven to 105 °C for 16 h. Then, approximately 0.250 g of each sample was weighed and placed in polyethylene (PE) irradiation vials. Comparators were prepared depositing 0.200 mL of sodium ICP standard of 9.650 ± 0.050 g/kg in small disks of filter paper and dried using an infrared lamp.

Table 1 Codes, styles and number of analyzed fragments

Codes	Styles	N° of fragments
6013, 6088, 6095	Atarco	3
6008	Chakipampa (CK)	1
6004, 6009, 6047, 6049, 6084	Chakipampa B (CKB)	5
6038, 6039	Cotahuasi (CH)	2
5, 311, 6023, 6041, 6042, 6051, 6054, 6062, 6064, 6069	Escalonados (ESC)	10
517, 6028, 6040, 6043, 6063, 6070, 6075, 6077, 6078, 6087, 6090, 6096, 6098	HM Chuquibamba (CHU)	13
6019, 6020, 6021, 6022	La Ramada (RAM)	4
6002, 6003, 6005, 6006, 6007, 6010, 6011, 6012, 6014, 6015, 6016, 6017, 6036	Loro (LOR)	13
6001, 6050	Ocros	2
6029, 6032, 6046, 6079, 6045, 6100	Viñaque (VI)	6
6018, 6024, 6025, 6026, 6034, 6044, 6057, 6058, 6060, 6067, 6072, 6080, 6085, 6086, 6094, 6097, 6099	Viñaque La Real (VLR)	17
113, 6027, 6030, 6031, 6037, 6048, 6052, 6053, 6055, 6056, 6059, 6061, 6065, 6068, 6076, 6081, 6082, 6083, 6089, 6091, 6092, 6093	HM Local (HML)	22
6071	Pullhuay	1
6102	Cajamarca	1

Irradiation and measurement

Comparators were inserted between samples and the assemblage was stacked in a PE irradiation container, to be sent for irradiation using the pneumatic transfer system to the irradiation position of the RP 10 nuclear reactor at IPEN, where it was irradiated by 20 min to a nominal thermal flux of 3.2×10^{13}.

After 5 days of decay a first measurement of 5000–6000 s was performed using a HPGe detector CANBERRA GC 1518 (15 % relative efficiency and 1.8 keV FWHM for the 1332 keV ^{60}Co) Comparators were measured by 1000 s after 6 days of decay time. The measurement distance from the detector was 58.2 mm. Under these conditions ^{76}As, ^{42}K, ^{140}La, ^{24}Na, ^{239}Np, ^{122}Sb, ^{153}Sm and ^{175}Yb were determined.

After 15 days of decay time, the radionucles ^{131}Ba, ^{141}Ce, ^{60}Co, ^{51}Cr, ^{134}Cs, ^{152}Eu, ^{59}Fe, ^{181}Hf, ^{177}Lu, ^{147}Nd, ^{86}Rb, ^{46}Sc, ^{85}Sr, ^{182}Ta, ^{160}Tb and ^{233}Pa were quantified using a HPGe detector CANBERRA GC 7019 (70 % relative efficiency and 1.9 keV FWHM for the 1332 keV ^{60}Co) and measuring 10 000 s to a distance of 12.5 mm.

For acquisition and analysis of the spectrum, the program CANBERRA Genie 2000 (v 2.1) was used and for concentrations calculations an in-house visual basic program was employed.

For quality control, a replicate of SRM NIST 1633 COAL FLY ASH was analyzed after a batch of 11 samples and the New Ohio Red Clay reference material was analyzed every 30 samples.

Statistical analysis

Analytical results, expressed in logarithmic units were statistically processed by means of hierarchical cluster analysis; principal components analysis and Mahalanobis distance classification. After a phase of preliminary analysis, the elements Ce, Cr, Fe, Hf, La, Sc, Sm and Th were selected because they led a set of linearly independent principal components, in such a way that the first four components explained the 91.5 % of the observed variance in the data.

An arbitrary 5 % cutoff ($p = 5$ %) was used to evaluate membership probabilities. The reason for this cutoff was to avoid false positives as much as possible, even though this meant risking the rejection of some marginal samples from possible groupings. This criterion was adopted because the different groups in this study are chemically similar. By using this more conservative approach to assigning membership in groups, we eliminated from our conclusions those samples that could not be confidently assigned to a group [12].

Results and discussion

Table 2 contains chemical composition data which define to the reference local group of La Real (LR), as well as a special group conformed by Loro (LOR) pottery found also, in La Real. Data of the reference foreign groups Cotahuasi (CH), Wari Ayacucho (ACW), Tiwanaku (TW),

along with three groups from Cusco (CU1), (CU2) and (CU3) obtained from the laboratory database, are also included [11, 12].

Inspection of the Table 2 data reveals that the elements Cr and Fe are especially useful in distinguishing the eight proposed groups. This can be confirmed in Fig. 2 where a clear separation of the groups is shown. The groups are defined by ellipses of an approximately 90 % confidence level, and concentrations are expressed in logarithmic units.

It can be noticed in the compositional plane defined by the elements Cr and Fe that there is a partial superposition between the ellipses of the group La Real (LR) and CU3 which corresponds to Wari style found in Cusco, due to the chemical similarity. It is also relevant that Loro (LR) style ceramic fragments, define a compact group. This may suggest that they were made with a special grade of standardization, with significant control over materials and manufacturing processes and perhaps within a specific production centre.

Figure 3 shows the distribution of the ceramic groups studied in the plane of two principal components, which describes 78 % of the total variance in the data. It is important to observe that in contrast with Fig. 2, there is a complete separation of the groups La Real (LR) and CU3 in this compositional plane but there is a superposition of the groups CU2 and CU3 as well as LOR and CU3.

The dendrogram shown in Fig. 4 has been elaborated based on 74 of the 100 samples of La Real site and using the four first principal components. It reveals that there is a defined structure in this group. Seven samples of Loro (LOR) style pottery set up as a different group in respect to the remaining samples. This group also includes a Chakipampa B ($n = 8$) style sample (CKB). The next distinct group is small, formed by three samples and because of its size will not be considered further in this discussion. The remaining 63 samples include the 48 samples that form the proposal La Real (LR) reference group, as well as most of the Chuquibamba (CHU) style pottery. As a precaution, these last samples were not included in the conformation of La Real (LR) reference group.

Two well-defined subgroups can be observed with one of these having 12 of the 13 samples in the Chuquibamba (CHU) style. A possible archaeological implication for this separation is that La Real pottery is composed of two well differentiated sub-groups that could correspond to two different centres of ceramic production. Another possible implication is that the Chuquibamba (CHU) style pottery would have been made exclusively in one of these centres.

Table 2 Descriptive statistics of the eight proposed reference groups and number of fragments considered

Ele	La Real (LR) $n = 48$	Loro (LOR) $n = 8$	Cotahuasi (CH) $n = 67$	Wari Ayacucho (ACW) $n = 12$	Tiwanaku (TW) $n = 14$	Wari Cusco Grupo 1 (CU1) $n = 10$	Wari Cusco Grupo 2 (CU2) $n = 7$	Wari Cusco Grupo 3 (CU3) $n = 13$
	Mean ± α	Mean ± α	Mean ± α	Mean ± α	Mean ± α	Mean ± α	Mean ± α	Mean ± α
As	12.6 ± 2.6	38.8 ± 9.3	12 ± 19	12.7 ± 3.8	35 ± 30	16.2 ± 7.3	12.9 ± 8.8	11.7 ± 3.6
Ba	780 ± 180	621 ± 24	1030 ± 150	560 ± 130	930 ± 400	780 ± 190	1250 ± 340	820 ± 230
Ce	75 ± 10	53.0 ± 1.7	94 ± 14	55.6 ± 4.2	82 ± 12	96 ± 15	52.8 ± 9.4	46.5 ± 4.3
Co	14.8 ± 1.6	20.8 ± 4.1	13.3 ± 5.2	11.1 ± 1.6	19.0 ± 7.7	26.9 ± 8.7	16.8 ± 2.0	17.6 ± 6.0
Cr	39.1 ± 4.5	18.1 ± 1.2	20.6 ± 3.8	28.4 ± 3.8	56.9 ± 6.0	105 ± 20	14.5 ± 3.9	31.8 ± 3.8
Cs	9.3 ± 1.8	25.6 ± 1.2	8.8 ± 3.1	8.31 ± 0.75	16.7 ± 7.5	10.7 ± 2.0	5.8 ± 1.3	6.7 ± 1.8
Eu	1.17 ± 0.20	0.90 ± 0.15	1.37 ± 0.20	0.76 ± 0.16	1.22 ± 0.24	1.43 ± 0.20	1.15 ± 0.20	0.93 ± 0.20
Fe	3.73 ± 0.18	4.08 ± 0.10	3.15 ± 0.26	2.51 ± 0.18	4.43 ± 0.29	5.38 ± 0.28	5.54 ± 0.39	4.27 ± 0.31
Hf	7.51 ± 0.67	5.24 ± 0.29	7.66 ± 0.88	4.48 ± 0.19	6.8 ± 1.2	6.9 ± 1.3	4.86 ± 0.87	5.2 ± 1.2
La	39.8 ± 5.7	26.27 ± 0.76	46.6 ± 6.7	26.9 ± 1.9	41.4 ± 4.8	46.0 ± 7.8	25.5 ± 2.3	22.5 ± 1.6
Na	1.56 ± 0.16	1.66 ± 0.64	1.73 ± 0.26	1.39 ± 0.24	1.32 ± 0.27	0.85 ± 0.26	1.46 ± 0.24	1.98 ± 0.43
Rb	103 ± 11	112.4 ± 4.4	120 ± 16	173 ± 17	145 ± 17	148 ± 32	84.7 ± 9.5	78.2 ± 9.6
Sb	1.70 ± 0.37	2.80 ± 0.14	1.2 ± 1.0	1.053 ± 0.097	1.91 ± 0.64	2.12 ± 0.57	0.91 ± 0.24	1.20 ± 0.40
Sc	12.17 ± 0.83	13.92 ± 0.29	10.47 ± 0.95	9.19 ± 0.78	15.3 ± 1.1	17.23 ± 0.59	12.67 ± 0.72	12.54 ± 0.72
Sm	5.8 ± 1.0	4.40 ± 0.069	6.5 ± 1.1	4.57 ± 0.29	6.68 ± 0.75	7.9 ± 1.0	5.19 ± 0.49	4.18 ± 0.25
Th	12.00 ± 0.90	10.86 ± 0.42	17.0 ± 2.3	15.7 ± 1.4	13.7 ± 1.5	17.1 ± 3.3	6.61 ± 0.53	7.53 ± 0.66
Yb	2.12 ± 0.22	2.215 ± 0.081	2.44 ± 0.38	2.15 ± 0.28	3.27 ± 0.29	3.86 ± 0.71	2.90 ± 0.34	2.29 ± 0.25

Concentrations expressed in mg/kg, except Na and Fe in %

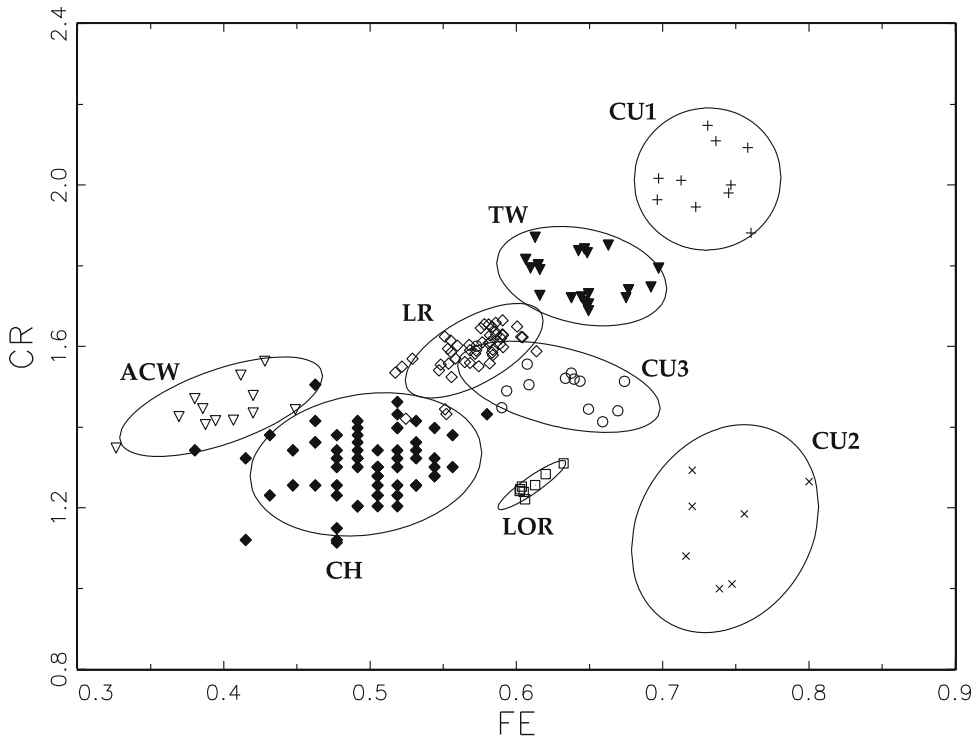

Fig. 2 Representation of the ceramic groups studied in the iron—chromium compositional plane

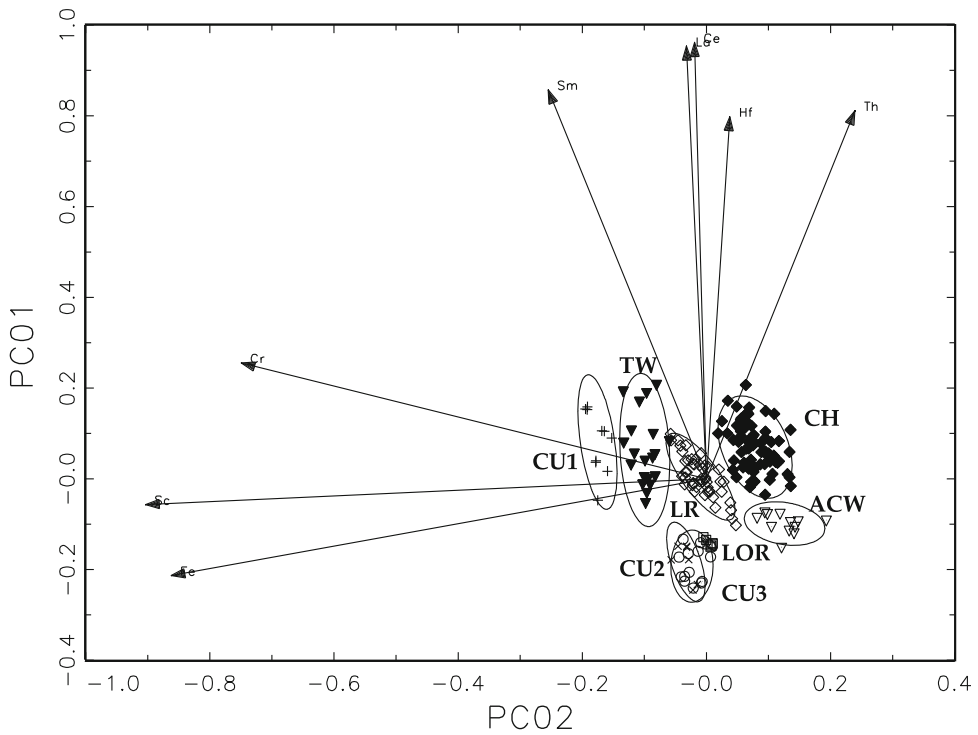

Fig. 3 Compositional distribution of pottery groups in the compositional plane PC1 and PC2, which describe 49.8 and 28.2 % of the observed variance. The ellipses correspond to the 90 % confidence level for each variable

Table 3 presents 21 pottery samples collected at La Real site that have chemical composition that may belong to foreign groups. The last two columns of the table show the second priority of assignation and the membership probabilities, respectively. Thus, the sample with code 6001, an Ocros style sample, has a membership probability of 5.4 % of belonging to the compositional group of Wari from Conchopata, Ayacucho (ACW), and a membership probability of 0.35 % of belonging to group 2 of Cusco (CU2). It is noticeable that 15 of the 21 second membership

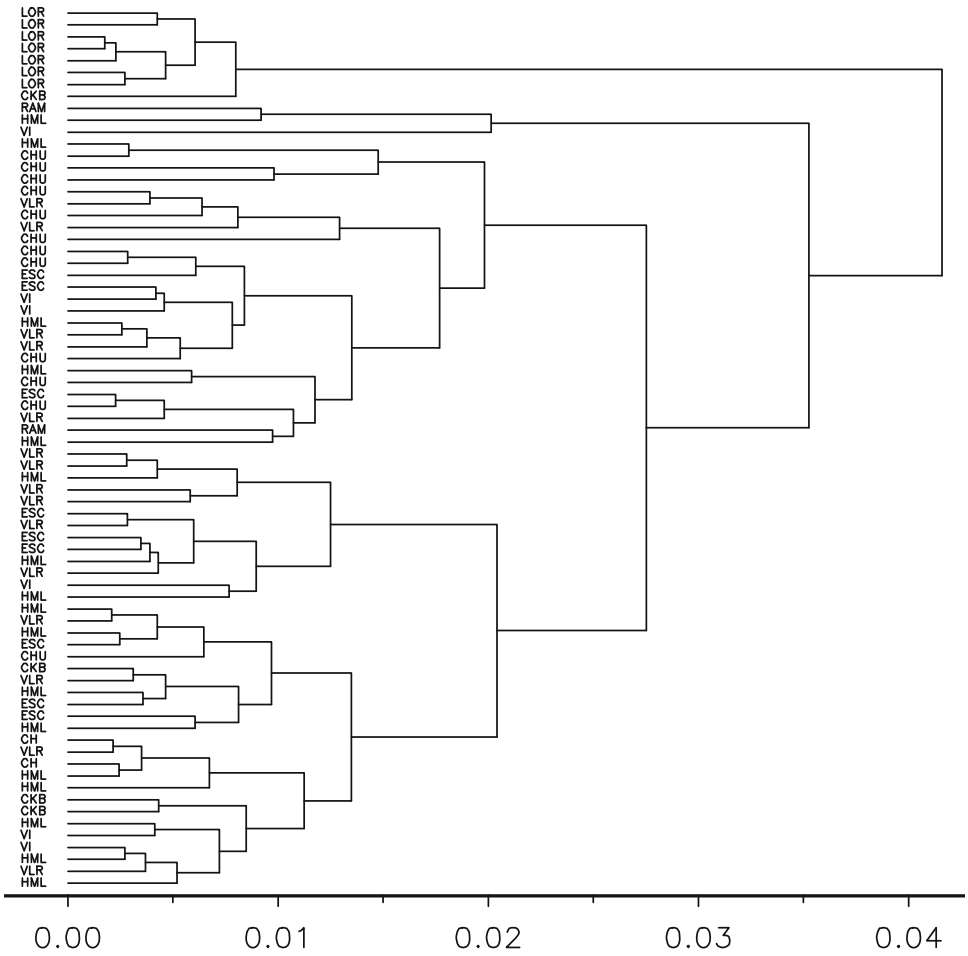

Fig. 4 Dendrogram of the structure of La Real pottery, calculated in terms of Euclidean distance in the compositional space defined by the four first principal components

probabilities of belonging to pottery from Cusco are because of chemical similarities between La Real and Cusco pottery. However, in most of the cases the first option of membership probability was considerably higher.

The sample with code 6091 is a special case, because it is a fragment stylistically classified as Middle Horizon Local (HM Local), but has just as significant and similar probabilities of belonging to the compositional group La Real (LR) as it does to the compositional group Tiwanaku (TW). In this case, it was better to assign this fragment to La Real site based upon the stylistic classification.

The membership probabilities of fragments codified as 6050, 6001 and 6041, in decreasing order of probability, suggest that there was some degree of contact between the Wari State and the local population, in such a way that at least a part of the Ocros style ceramics found at La Real site came from the site of Concohopata in Ayacucho. Similarly, the data in Table 3 suggest that people from La Real site had significant contacts (perhaps commercial) during the Middle Horizon with other centres from Cotahuasi, Cusco and Tiwanaku. It is important to mention that the Wari pottery exchange between Conchopata in Ayacucho and some sites from Cusco has been previously described [11].

Table 4 shows five cases of pottery from La Real that has not been assigned to any of the available reference groups. In the case of sample with code 6009, the membership probabilities for the first two options are meaningful and it would be doubtful to assign such sample to reference group CU2 or LOR. The same implication can be applied for the samples 6011 and 6013. In the case of sample 6037, even though it is a sample HM Local style, it was preferable do not classify it because of the low membership probabilities to both available groups (CU2, 0.53 % and CH, 0.30 %, respectively). Finally, the sample 6055, also HM Local style has 2.5 % of membership probability to the group CU2, and this could be a characteristic caused by the chemical similarity between the groups from Cusco and La Real, so it was preferable do not classify this sample. The feasibility of the characteristic mentioned also generated doubts about the assignment of samples 6003, 6041, 6071, 6084 and 6094 from Table 3.

Table 3 Pottery samples from La Real assigned to foreign reference groups

Code	Style	Assigned to (1)	Prob. (%)	Assigned to (2)	Prob. (%)
6001	Ocros	ACW	5.4	CU2	0.35
6003	Loro	CU2	3.1	LR	0.46
6006	Loro	CH	8.9	CU2	2.9
6007	Loro	CU3	29.2	CU2	2.9
6008	Chakipampa	CU3	34.4	CU2	2.7
6016	Loro	TW	15.9	CU2	6.6
6019	La Ramada	CU1	7.6	CU2	0.38
6021	La Ramada	TW	10.5	CU2	5.0
6036	Loro	CU2	8.8	CU1	0.83
6041	Escalonados	ACW	2.6	CU2	0.47
6050	Ocros	ACW	21.7	CU2	0.35
6052	HM Local	TW	22.6	CU2	5.2
6058	Viñaque La Real	TW	60.9	CU2	5.2
6065	HM Local	CH	36.5	CU2	1.6
6071	Pullhuay	CH	3.8	CU2	2.7
6084	Chakipampa B	CU2	1.9	LR	0.01
6088	Atarco	CU2	6.3	LR	1.9
6091	HM Local	LR	23.5	TW	23.7
6094	Viñaque La Real	CU2	3.6	CH	0.56
6095	Atarco	CU2	5.7	LRO	1.6
6102	Cajamarca	CH	6.5	CU2	1.3

Table 4 Pottery samples from La Real site not assigned to any reference group

Code	Style	Assigned to (1)	Prob. %	Assigned to (2)	Prob. %
6009	Chakipampa B	CU2	6.1	LOR	3.9
6011	Loro	TW	3.0	CU2	2.2
6013	Atarco	CU2	5.5	LOR	3.1
6037	HM Local	CU2	0.53	CH	0.30
6055	HM Local	CU2	2.5	LR	1.3

Conclusions

Seventy-five of the one hundred samples analysed were classified as manufactured locally, possibly in two centres of ceramic production.

Fifteen samples were assigned to foreign groups: 6001 and 6050 (Ocros style) to the group Conchopata, Ayacucho (ACW); 6036 (Loro style), 6088, 6095 (Atarco style), to the group Cusco 2 (CU2); 6007 (Loro style) and 6008 (Chakipampa style) to the group Cusco 3 (CU3); 6006 (Loro style), 6065 (HM Local) and 6102 (Cajamarca) to the group Cotahuasi (CH); 6016 (Loro style), 6021 (La Ramada style), 6052 (HM Local style) and 6058 (Viñaque La Real style) to the group Tiwanaku (TW); 6019 (La Ramada style) to the group Cusco 1 (CU1).

Ten samples were not assigned to any reference group: 6011 (Loro style), 6009 (Chakipampa B style), 6013 (Atarco style), 6037, 6055 (HM Local style), 6003 (Loro style), 6041 (Escalonados style), 6071 (Pullhuay style), 6084 (Chakipampa B style) and 6094 (Viñaque La Real style).

The cases of samples such as 6007 and 6016 (Loro style), 6008 (Chakipampa style), 6050 (Ocros style), 6052, 6091 and 6065 (HM Local), 6058 (Viñaque La Real) constitute clear evidence for the presence of foreign pottery in the archaeological site of La Real.

Further studies of Arequipa ceramics, including other reference groups, will be performed in order to better understand the nature of the Wari State's influence in the region during the Middle Horizon.

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