

ANALYSIS OF ANCIENT POTTERY FROM THE PALATINE HILL IN ROME

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A program of compositional analysis using neutron activation has been performed on samples of Roman
fine ware from the Palatine East excavations in Rome at the University of Illinois TRIGA reactor.
These experiments are ultimately intended to assist the authors in advancing the understanding of the
organization of pottery production and distribution in central Italy during the late Roman imperial
period (4th-5th c. AD). The objectives of this paper are 1) to present an archaeological background of
two regionally-produced fine wares, 2) to discuss the methods of sampling, irradiation and data analyses,
and 3) to demonstrate the preliminary results of our investigation, which included the analyses of Plio-
Pleistocene clays from the Janiculum Hill in Rome.

While students of the Roman economy have made considerable progress in reconstructing
patterns in the long-distance supply of foodstuffs, building material, and craft goods to the
city of Rome, we know relatively little about the role played by the city's immediate
hinterland in its sustenance. A more balanced picture of Rome's economic relations is
essential if we are to attain a clearer understanding of the city's commercial impact on its
region and on the Empire as a whole. To partially address this problem a project involving
the neutron activation analysis (NAA) of regionally-produced pottery recovered in excavations
in the center of Rome was initiated.

The excavations in question are those carried out since 1988 by a joint team of the
Soprintendenza Archeologica di Roma/American Academy of Rome on the site of a late
imperial *domus* (town house) located on the north-east slope of the Palatine Hill.¹ This work
has recovered several large deposits of pottery that were dumped into the structure after its
abandonment in a series of massive fills created between the early fourth and late fifth or
early sixth centuries AD. The overall program of NAA has focused on five distinct classes
of fine-bodied tableware thought to be of local or regional origin on the basis of several
considerations, including the appearance of their fabric, their abundance, and the distribution
of their find spots. The aims of this overall work are to identify distinct compositional groups
within the five classes of pottery, and to identify, to the extent possible, the origins of these
groups through compositional matches with clay sources and ceramics of known provenience
either from Rome or elsewhere in west-central Italy. This paper will communicate the
preliminary results obtained from the analysis of two of these five pottery classes.
The first of these classes (40 samples), termed undecorated fine ware, is by far the most
abundant of the various classes of regionally-produced tableware recovered at the site. It

appears to have been manufactured using the moderately to highly-calcareous clays of the Plio-Pleistocene marine transgression which outcrop in many parts of west-central Italy, including several outcrops in the immediate environs of Rome. Among the forms attested in the archaeological record are various basins, jars, and jugs/pitchers. All appear to have been manufactured rapidly, with little or no recourse to secondary forming operations or finishing of surfaces. The second class of pottery (29 samples), termed color-coat fineware, is identical in fabric, and presumably technology, save that vessel surfaces are coated with an uneven, matte reddish to grayish slip. The range of forms attested is similar to that for the undecorated variety, with the addition of bowls, cups, beakers, and other specialized vessels. In this case there is extensive use of secondary forming operations, such as the turning of bases and the application of handles. Not infrequently, the surfaces are embellished through incision, the creation of decorative patterns in barbotine, and in a few cases, with glass paste inlays. Both classes may have been manufactured by the same workshops, with color-coat fineware representing the higher end of the production scale.

Clay specimens of the Plio-Pleistocene marine transgression were obtained for comparative purposes from two localities on the Janiculum Hill, here termed Cava Aurelia (10 samples) and Villa Pamphili (6 samples), the part of Rome believed to have been the primary locus for the production of ceramic goods during antiquity.² Data are also available for eventual comparative purposes for clays from a number of geochemically similar clay outcrops and fineware from several Roman-period pottery workshops in the territory to the north of the city.^{3,4}

Experimental

Theory: Neutron activation analysis is one of several highly effective methods which can be employed to determine the chemical composition of ancient ceramics and related material, and has traditionally been used to supplement optical and petrographic analysis. Compositional investigations of pottery have been demonstrated to be useful in establishing the loci of source material (i.e. clay outcrops) and/or manufacturing centers when the chemistry of pottery samples of unknown origin are compared to the chemistry of samples (pottery or clay) of a recognized provenience. Several assumptions pertaining to the investigation of provenience of archaeological ceramics using NAA, which widely accepted, are listed: 1) the chemical nature of a given clay source is unique and NAA can sensitively and accurately detect the concentration of the rare earth and trace elements which may be particularly useful in establishing the chemical signature of the clay source, 2) the chemical signature of a sample of unadulterated pottery should reflect the nature of its source, including the degree of variance, and 3) pottery samples which have been demonstrated to have similar compositions are assumed to be products of the same geological source material. *Sample selection and preparation:* Several criteria were considered in the selection of pottery specimens. 1) A group of at least 25 members was desired for each class of pottery in order to establish reliable reference groups for eventual multivariate statistical analyses. 2) Samples were selected from a limited number of stratigraphic contexts in order to diminish broad chronological variability which could potentially bias the compositional analyses; hence, the majority of the specimens are from two large stratigraphic units (PEA 105 = mid 4th c. AD and PEB 180 = early/mid 5th c. AD). 3) Samples were obtained from tins in order to minimize the possibility of accidentally repeating analysis of a single vessel. The pottery samples were prepared in Rome according to standardized procedures. To avoid environmental contamination and chemical interference from the constituents of any slip that

may have been applied, the surfaces of the specimens were removed with a tungsten carbide drill bit. The remaining samples were ground into a fine powder with an agate mortar and pestle and placed into sterile pharmaceutical capsules for transport to the University of Illinois. The clay samples were harvested from the two outcrops on the Jamburum Hill and transported in a raw state to the University of Illinois where they were molded into pellets, fired in an electric kiln at 900°C, and pulverized. All of the pulverized specimens were weighed into polyethylene vials in the irradiation laboratory, dehydrated in an electric kiln for 24 hours at 105°C, reweighed to account for evaporation, and heat-sealed into their containers.

Irradiation: Since the fineware samples are part of a larger overall project involving 200 samples of pottery and clay, irradiation was conducted in four batches of 50 samples under identical circumstances. Hence, a portion of the fineware specimens were irradiated on each of the four occasions. Irradiation for the short-lived elements (Al, Ca, Dy, K, Mn, Na, Sr, Ti, and V) was performed via a pneumatic system. After two weeks the samples were irradiated again for the medium-lived elements (As, La, Lu, Sb, Sm, and U) and the long-lived elements (Ce, Co, Cr, Cs, Eu, Fe, Hf, Nd, Ni, Rb, Sc, Ta, Tl, Pb, Sn, and Th), using a lazy-Susan apparatus. Gamma-ray spectra were accumulated on a Ge-Li detector.

Table 1
Irradiation and counting parameters

Short-lived	Medium/Long-lived	Neutron flux	3.7x10 ¹² n/cm ² /s (500 kW)	3.4 x 10 ¹² n/cm ² /s (1500 kW)
Irradiation time	30 seconds	4 hours		
Decay time	1000 seconds	6-8 days	1 hour	3 hours
Counting time	600 seconds			

Data was converted to a table of concentrations using the program Neutron Activation Data Analysis (NADA). The neutron flux was monitored using solid sulphur for the short-lived experiments and cobalt wire for the long irradiation. Intra-batch accuracy was evaluated through a comparison of the resulting concentrations of our standard reference material (SRM 1632a, SRM 1633a, and Ohio Red Brick) with the values established by the National Institute of Standards and Technology. Our inter-batch compatibility was checked using sets of replicate pottery samples. Three well-known statistical and cluster analysis procedures developed by the Brookhaven National Laboratory and converted for use on a standard PC by the Missouri Research Reactor group were employed to analyze the data.

Results and Discussion

The first objective of our investigation was to establish the relationship between the two classes of fineware which was accomplished by a precursory application of the statistical package, MADSTAT (Table 2). The insignificant differences in the mean concentrations of the two varieties of pottery suggest quite clearly that both varieties were manufactured with

Figure 1. Dendrogram of undecorated (UF) and color-coat (CC) fineware. Distance calculated by squared-Euclidian distance on log-transformed data. Average link. 19 Elements: Al, Ca, Dy, Mn, Na, Ti, La, Ce, Co, Cr, Cs, Ba, Fe, Pb, Hf, Rb, Sr, Ta, Tl, Th

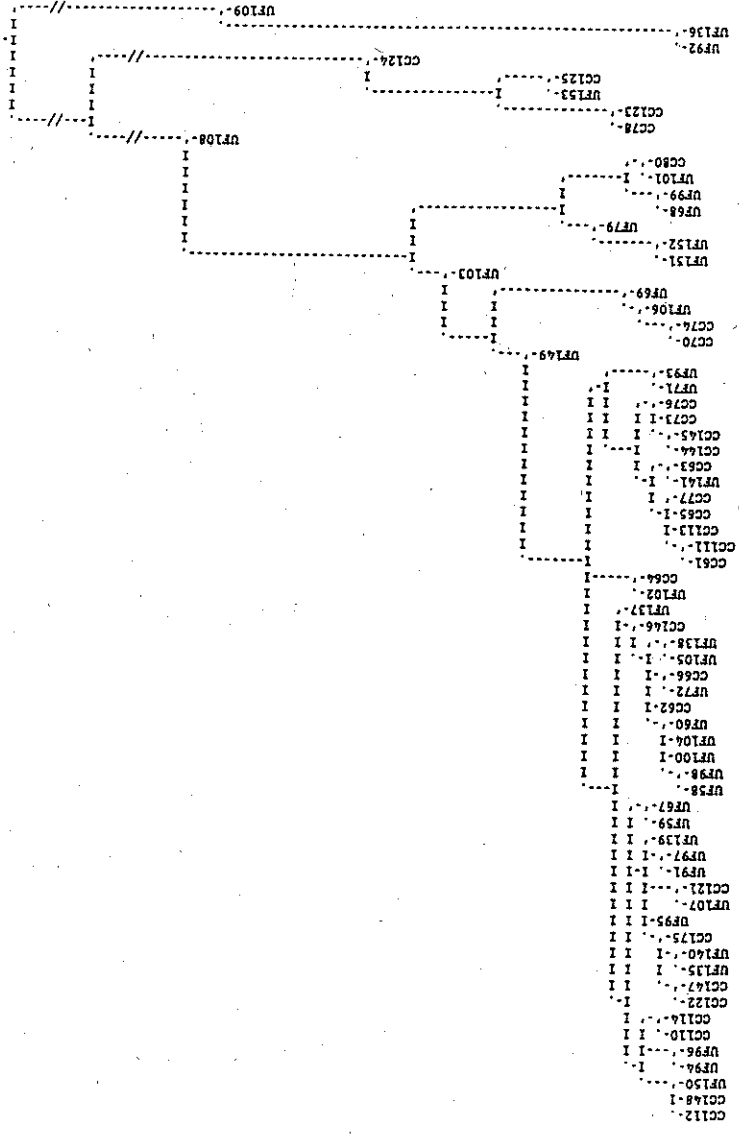


Table 3
Mean values and coefficient of variation of all fineware

Al%	7.04 ± 12.9%	V	96 ± 20.2%	Ce	60.6 ± 12.5%	ND	14.3 ± 21.7%
Ca%	12.3 ± 13.2%	As	10.1 ± 45.6%	Co	10.6 ± 17.4%	Ni	40.5 ± 30.3%
Dy	4.32 ± 15.2%	La	31.3 ± 12.4%	Ct	104 ± 13.5%	Rb	115 ± 20.4%
K%	1.73 ± 21.7%	Lu	0.26 ± 22.3%	Cs	6.03 ± 50.9%	Sc	11.7 ± 10.8%
Mn	621 ± 21.3%	Sb	1.28 ± 45.0%	Eu	1.04 ± 11.7%	Ta	0.96 ± 10.5%
Na	6090 ± 23.4%	Sm	5.39 ± 20.6%	Fe%	3.18 ± 11.7%	Tb	0.67 ± 12.6%
Sr	452 ± 34.1%	U	2.96 ± 35.2%	Hf	3.73 ± 18.8%	Tb	9.58 ± 18.7%
Ti	3310 ± 13.3%						

Working in this fashion specimens CC70, CC74, UF106, and UF69 were observed to have been dissociated from the principal cluster in the dendrogram as a result of low values for Ti, La, Cr, and Ta. Specimen UF103 shows low values for Cs, and Rb, while specimen UF149 has lower concentrations of Mn, Ce, Fe, Ta, and Tb. The overall agreement of the remaining values of these six samples in comparison with the mean group values suggests that they may belong to the core group, but will eventually have to be tested using a multivariate statistical procedure. The sixteen specimens of the lower clusters (UF151 - UF109) posed a somewhat greater dilemma. The frequency of variance for these specimens above or below the mean group values by at least one standard deviation is illustrated in Table 4. It is evident that the majority of these specimens should not be reclassified into the core group which is composed of 53 specimens of fineware, but the significance of their diversity requires attention.

Samples CC78, CC123, UF153, CC124, and CC125 were repeatedly clustered regardless of the selection of elements that are used for cluster analysis. Similarly, specimens UF68, UF101, and CC80 are consistently associated, in this case with the addition of UF99, UF92 and UF136 were consistently set apart with UF109. Specimens UF151, UF152, and UF79 always occur in the same cluster, but are, on occasion, placed in association with the presumed core group. In order to achieve an explanation for the diversity of the sixteen problematic specimens, Table 5 compares the mean compositional values of the suggested core group with the mean values of the four deviant groups. By comparing the resulting ratios, one would hope to be able to claim that either these small groups represent individual source groups, or they are the result of some type of enrichment or dilution factor.

On the basis of these statistics one pattern can be recognized, namely that the values of many of the elements react inversely with the increase or decrease in the value for Ca, often by nearly the same percentage of variance. Group 2 (CC78, CC123, UF153, CC124 and CC125) has an average ratio of 1.31 in comparison with the core group. There is a considerable amount of variability, however, among the individual element ratios, most notably for Co, Cs, Ni, and Th, but also for Dy, K, Na, V, and Sb, suggesting that this may eventually be considered to be an independent source group, rather than an enticed subgroup of the production center that is represented by our core group. Group 3 (UF92, UF136 and UF109) has an average ratio of 0.96, but again, there is a fair amount of capriciousness between the individual ratios, especially for K, Mn, As, Sb, Cs, Hf, Ni, and Rb. On the other hand, the specific ratios of group 4 (UF68, UF99, UF101 and CC80) gravitate regularly around the mean ratio of 1.17. Only U, Cs, Ni, and Rb demonstrate moderate diversity.

Table 4
 Frequency of specimens with multiple values beyond one standard deviation from group mean
 (+/- = above/below S.D.)

	Al	Ca	Dy	K	Mn	Na	Ti	V	La	Lu	Ce	Co	Cr	Cs	Eu	Fe	Nd	Ni	Rb	Sc	Ta	Tb	Tm
151	+						+			+												+	
152	+		+								+												
79	+	-																					
68																							
99	+		+																				
101	+		+																				
80																							
108																							
78																							
123	+																						
153	+																						
124	+																						
125	+																						
92																							
136																							
109																							

Similarly, group 5 (UF151, UF152 and UF79) is rather well-behaved and only V, As, and Sb deviate to any significant degree from the average ratio of 1.15. We would, therefore, tentatively recommend that the dissociation of groups 4 and 5 from the principal cluster on the dendrogram should not be interpreted to assume two independent sources, but that on the basis of their fairly proportional chemistries with the core group, groups 4 and 5 are diverse as a result of an enrichment/dilution factor, the identification of

Table 5

Mean values and coefficient of variation of variation of suspected fineware groups

	Group 1 (53)	Group 2 (5)	Group 3 (3)	Group 4 (4)	Group 5 (3)
Al%	6.84 ± 9.9%	8.40 ± 10.6%	5.98 ± 15.6%	7.87 ± 6.7%	8.61 ± 6.8%
Ca%	12.5 ± 9.6%	9.73 ± 21.4%	14.5 ± 9.4%	11.2 ± 8.9%	11.8 ± 21.6%
Dy	4.15 ± 13.6%	4.92 ± 8.6%	4.14 ± 10.2%	5.24 ± 9.9%	5.24 ± 14.2%
K%	1.75 ± 18.8%	2.00 ± 25.1%	0.98 ± 13.2%	1.62 ± 21.2%	2.01 ± 14.2%
Mn	609 ± 12.1%	864 ± 19.9%	373 ± 56.7%	649 ± 14.7%	752 ± 9.3%
Na	6090 ± 10.5%	5380 ± 17.3%	2180 ± 17.2%	9900 ± 11.0%	6600 ± 4.0%
Si	468 ± 34.4%	278 ± 16.2%	390 ± 22.8%	528 ± 7.8%	475 ± 1.5%
Ti	3210 ± 12.3%	3890 ± 16.1%	3200 ± 4.5%	3580 ± 2.1%	3770 ± 5.5%
V	91 ± 15.5%	136 ± 14.2%	97 ± 21.1%	106 ± 13.2%	118 ± 19.9%
As	9.76 ± 42.0%	13.2 ± 32.5%	17.1 ± 56.3%	8.86 ± 38.1%	5.63 ± 46.4%
Ia	30.0 ± 7.0%	41.4 ± 10.0%	29.2 ± 10.4%	35.2 ± 3.7%	34.1 ± 3.5%
Lu	0.25 ± 19.7%	0.34 ± 12.0%	0.25 ± 35.9%	0.24 ± 17.0%	0.34 ± 20.8%
Sb	1.25 ± 39.5%	1.18 ± 47.4%	1.73 ± 97.2%	1.60 ± 29.4%	0.81 ± 29.1%
Sm	5.24 ± 22.3%	6.51 ± 7.3%	4.87 ± 11.8%	6.08 ± 3.9%	5.70 ± 2.9%
U	2.86 ± 32.8%	3.82 ± 45.3%	2.04 ± 11.1%	3.76 ± 32.5%	3.36 ± 24.7%
Ce	57.8 ± 6.8%	80.6 ± 7.4%	56.4 ± 12.4%	65.8 ± 2.9%	68.5 ± 2.8%
Co	10.0 ± 8.1%	15.9 ± 5.3%	11.1 ± 25.9%	11.1 ± 7.3%	12.5 ± 10.2%
Cr	100 ± 9.8%	125 ± 15.6%	92 ± 21.6%	121 ± 4.2%	123 ± 7.4%
Cs	5.18 ± 11.5%	15.0 ± 41.9%	4.05 ± 7.6%	6.98 ± 8.9%	6.54 ± 7.6%
Eu	1.00 ± 7.5%	1.31 ± 7.4%	1.07 ± 15.4%	1.11 ± 1.4%	1.23 ± 7.3%
Fe%	3.05 ± 8.4%	3.95 ± 7.4%	3.33 ± 17.7%	3.37 ± 6.9%	3.63 ± 6.0%
Hf	3.49 ± 9.6%	4.06 ± 13.9%	5.45 ± 9.2%	4.00 ± 5.0%	4.11 ± 5.3%
Nd	13.5 ± 21.0%	17.6 ± 24.6%	14.3 ± 5.5%	15.9 ± 12.0%	17.3 ± 15.5%
Ni	38.0 ± 24.2%	64.5 ± 11.8%	29.6 ± 46.6%	50.9 ± 26.5%	47.8 ± 26.3%
Rb	110 ± 9.4%	153 ± 8.8%	59 ± 5.5%	169 ± 8.5%	127 ± 7.1%
Sc	11.3 ± 7.3%	14.4 ± 10.0%	11.1 ± 9.7%	12.8 ± 3.1%	13.7 ± 3.3%
Ta	0.94 ± 9.2%	1.10 ± 3.7%	0.89 ± 11.1%	1.07 ± 4.0%	1.12 ± 4.1%
Tb	0.65 ± 10.7%	0.76 ± 13.7%	0.68 ± 8.5%	0.76 ± 13.7%	0.75 ± 11.8%
Tl	9.07 ± 8.0%	14.9 ± 13.1%	7.48 ± 12.3%	10.5 ± 6.1%	10.5 ± 4.2%

which cannot be expressed at this time. The inverse relationship of Ca with many of the elements as stated here and in a recent article on the analysis of pottery from the eastern Mediterranean basin⁵ could prove to be a crucial factor. Groups 2 and 3 may very well represent individual source groups. One significant piece of evidence was observed in the ceramic paste of specimen CC78, namely that traces of black volcanic sand, which is a common tempering agent in Campanian pottery, were noted prior to the sampling process. Whether or not the other four specimens of group 2 contain similar inclusions can only be verified at a future date.

The scattergram (Figure 2) generated by MADPLOT on the basis of Ce/Rb might also shed light upon the nature of the four smaller fineware groups. The five members of group 2 are

loosely clustered toward the upper right-hand region of the diagram. The three members of group 3 all have very low values for Rb and UFI09 is set at a slight distance from the other two data points. Three of the four members of group 4 cluster tightly together, while the fourth member is set mid-way toward the core group. The three members of group 5 occupy a common area just beyond the limits of the core group. If we consider these results, which are similar to the distribution of the same data based upon several other pairs of elements,

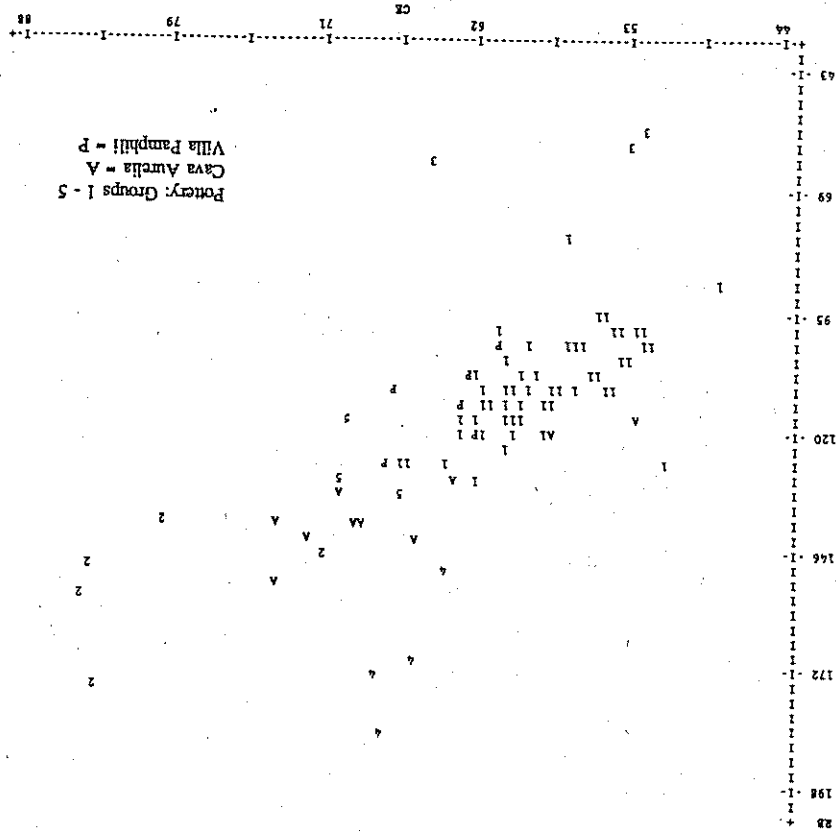


Figure 2. Scattergram demonstrating positions of pottery and clays

such as La/Sc, Ce/Eu, and Cr/La, bearing in mind the statistical implications, the likelihood of multiple source groups is great. While group 2 aligns fairly well with the core group, the overall compositional diversity from the core group is suggestive that this represents an independent source. The cohesion of group 3 is suspicious, but the specimens seem to represent a separate source and may ultimately relate to the two stray members of the core group. Group 4 should almost certainly represent a distinct source with, perhaps, the exception of UP99; however, considering how well this group's overall chemistry corresponds proportionately with group 1, we shall submit that it is a result of dilution. Group 5 appears almost certainly to be a result of dilution, as it is so neatly aligned with the core group.

Relation of pottery to the clays: The same bi-variate diagram demonstrates the association of the pottery and clay specimens. Seven of the ten clay specimens from the Cava Aurelia source cluster rather tightly together in the vicinity of group 5, but three of the members have lower values and appear closer to group 1. The members of the Villa Pamphili source cluster fairly tightly at the high end of the cluster of group 1. The general alignment of the clay specimens with the core group of pottery specimens may be indicative that the pottery was derived from a geochemically similar source, if not specifically these two sources.

The mean concentrations of the clay sources (Table 6) are fairly consistent with the values of the pottery groups, lending credence, at first, to the possibility that the pair of outcrops on the Janiculum Hill were the sources of clay used for the production of some of our fineware. The mean ratios of the Cava Aurelia and Villa Pamphili clays to group 1 of the pottery are 1.12 and 1.07, respectively. However, there is one significant difference between the

Table 6
Mean values and coefficient of variation of Janiculum clays

	Cava Aurelia	Villa Pamphili			
Al ₂ O ₃	8.42 ± 6.6%	7.96 ± 4.7%	Ce	66.4 ± 10.3%	63.6 ± 4.4%
CaO	17.0 ± 3.4%	21.9 ± 7.1%	Co	12.5 ± 5.9%	11.4 ± 26.6%
Dy ₂ O ₃	5.47 ± 10.5%	5.21 ± 9.6%	Cr	125 ± 10.4%	119 ± 3.5%
K ₂ O	1.86 ± 12.5%	1.48 ± 10.0%	Cs	6.75 ± 11.6%	6.44 ± 6.0%
MnO	761 ± 7.1%	887 ± 11.5%	Eu	1.21 ± 5.6%	1.18 ± 3.7%
Na ₂ O	5370 ± 37.7%	5410 ± 6.6%	Fe ₂ O ₃	3.86 ± 12.5%	3.20 ± 10.3%
SiO ₂	431 ± 16.3%	445 ± 35.5%	Hf	3.81 ± 6.3%	3.55 ± 5.6%
TiO ₂	4070 ± 19.6%	3770 ± 7.9%	Nd	12.4 ± 17.4%	12.4 ± 14.3%
V ₂ O ₅	128 ± 15.3%	130 ± 4.2%	Ni	48.4 ± 20.6%	34.9 ± 20.6%
As ₂ O ₃	5.45 ± 23.2%	4.17 ± 27.9%	Rb	136 ± 8.2%	113 ± 7.6%
La ₂ O ₃	32.1 ± 10.3%	32.0 ± 1.9%	Sc	13.6 ± 10.4%	13.1 ± 3.4%
Lu ₂ O ₃	0.27 ± 21.9%	0.25 ± 12.3%	Ta	1.12 ± 11.1%	1.03 ± 7.4%
Sb ₂ O ₃	0.51 ± 45.0%	0.43 ± 23.3%	Tb	0.69 ± 8.7%	0.72 ± 4.1%
Sm ₂ O ₃	5.48 ± 7.0%	5.46 ± 2.2%	Th	10.4 ± 10.3%	9.94 ± 4.1%
U ₃ O ₈	2.77 ± 15.8%	3.04 ± 19.6%			

characters of the clay and pottery groups, namely that there is no longer the inverse relationship between Ca and the other elements in the clay groups. For example, the individual ratios for Ca are 1.36 for the Cava Aurelia group and 1.75 for the Villa Pamphili group. If we were to predict the scores of the majority of elements of the clay groups based upon the Ca values and the observed chemical pattern of the pottery groups, the Cava Aurelia source should have an average ratio of about 0.6, while the Villa Pamphili source should have a ratio of about 0.3. Therefore, unless some unidentified tempering agent was used in the production of the fineware or the clay underwent a meticulous purification process, it seems unlikely that the Cava Aurelia and Villa Pamphili sources were exploited in antiquity for the manufacture of the fineware. But the notion that another source or sources on the Janiculum Hill, such as that which was exploited in the production of ceramic lamps by the *COPPI RES* workshop,² had been used by potters who fabricated fineware vessels is still viable based upon the overall similarities of the values for the clay and pottery groups with the exception of Ca.

Conclusion

The purpose of this paper was to present some of our preliminary hypotheses, achieved by neutron activation Roman fineware recovered at the Palatine East excavations in Rome. Through the use of statistical analysis it has been demonstrated that the clay exploited in the fabrication of undecorated and color-coat fineware was derived from a common source or sources. Cluster analysis revealed five possible source groups, a core group of 53 specimens and four smaller groups of 5, 3, 4, and 3 specimens, and statistical analysis identified the chemical signatures of these groups. The implications of the four minor groups have yet to be determined, but two of these groups (groups 4 and 5) have been suggested to represent enticed/divided sub-groups of the principal core group (e.g. of the same clay source, but with the addition of a tempering agent), while groups 2 and 3 may in fact represent individual source groups. These recommendations must, of course, be verified with the use of a more sophisticated multivariate statistical application, as well as by further optical and petrographic analysis.

Finally, our comparison of the pottery groups with the pair of clay groups from the Janiculum Hill was inconclusive. While the Cava Aurelia and Villa Pamphili outcrops do not appear to have been the specific sources of clay used to manufacture the fineware vessels, the high degree of similarity between the compositions of the pottery and clays does not exclude the possibility that another geochemically similar outcrop on the Janiculum Hill had been exploited in antiquity.

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