Neutron Activation Analysis of Archaeological Pottery from Long Beach

Gary S. Hurd and George E. Miller

Abstract

Archaeological investigations at CA-LAN-2630 produced 642 prehistoric potsherds. Of these, 63 specimens were subjected to neutron activation analysis (NAA) so as to determine whether they were of local origin or imported. Concentration values of 14 elements, Al, V, Th, Co, Ca, Na, La, Sm, Sc, Fe, Ce, Cr, Mn, and Hf, from the sherd specimens were compared to local soils, excavated daub, and to pottery from regional sites. The results indicated that the LAN-2630 pottery was made from local clays.

Introduction

Archaeological investigations at CA-LAN-2630 (Figure 1) on the California State University campus at Long Beach in 1993 resulted in the recovery of 642 potsherds. The pottery from this site has been identified as Southern California Brown Ware (Boxt and Dillon, this double-issue; see Van Camp 1979:67-68; Griset 2009:122). The LAN-2630 ceramic assemblage consists primarily of small, friable body sherds lacking surface decoration, precluding precise evaluations of vessel morphology or function. By applying neutron activation analysis (NAA) to the LAN-2630 assemblage, we sought to understand the selection and procurement of clay in order to garner information about production and exchange. Unlike descriptive studies that focus on stylistic criteria, vessel characterization by clay chemistry typically uses information that may be irrelevant to the potter yet critical to modern analysts. Our objectives were to identify trace element profiles (TEP) for the excavated potsherds and to compare them with local clay sources. It was hypothesized that a concordance of these data could establish the origin of LAN-2630 ceramics. Conversely, a disparity of these data would support an exchange model.

Sherd Selection and Preparation

A stratified sherd sample of just under 10 percent of the total recovered by unit and level was drawn from the study site. Two specimens of daub and two samples of soil from LAN-2630 also were selected for analysis so as to test the possibility of localized pottery production. If the trace element signatures of daub and soil matched those of the earthenware pottery, there would be very strong evidence that the LAN-2630 ceramics were produced locally. Prior to analysis all potsherds were washed in deionized water. Surfaces were scrubbed with a soft bristle brush and dried at room temperature in a covered container to ambient humidity. Prior to washing, catalogue marks (when present) were removed with a tungsten carbide burr. Potsherd surfaces were penetrated with a tungsten carbide bit to remove an approximately 200 mg sample from drill holes. Some very small potsherds were ground to a coarse powder in a mortar and pestle. Polyvials that held the specimens were washed in ethanol followed by a rinse in deionized water. Approximately 100 mg of material was placed in each one-quarter dram polyvial, which was then labeled with a laundry marker and sealed by melting the cap of the vial to its body. Neither the potsherds nor the vials were touched by hand after they had been cleaned.

Neutron Activation Analysis, Irradiation, Gamma Counting, and Standards

All irradiations were performed at the UC Irvine Nuclear Reactor Facility using the TRIGA Mark I reactor. The reactor generates a core neutron density of 2 x 10^{12} neutrons per cm^2 per second at a thermal energy of 250 kw. Trace element determinations for the study samples incorporated the three irradiation schedules discussed below.

A Short-Lived Isotope Determination

Irradiation occurred for one minute or less in the Pneumatic Transfer facility at fluxes from 1 x 10^{11} to 2 x 10^{12} neutrons/cm^2 per second, depending upon the sample size. Gamma ray spectrometry followed a six-minute cooling period, using an HPGe end window detector (Canberra Nuclear) with 30 percent efficiency and 2.2 keV resolution at 1332 keV. Data collection time was 4 minutes. This schedule was utilized to generate data on short half-lived isotopes of titanium (Ti), vanadium (V), aluminum (Al), manganese (Mn), and sodium (Na). There were 78 unknowns and three standards analyzed under this condition.

An Intermediate Lifetime Isotope Determination

Irradiation occurred for 10–15 minutes while rotating in a lazy Susan at a flux of 1 x 10^{12}

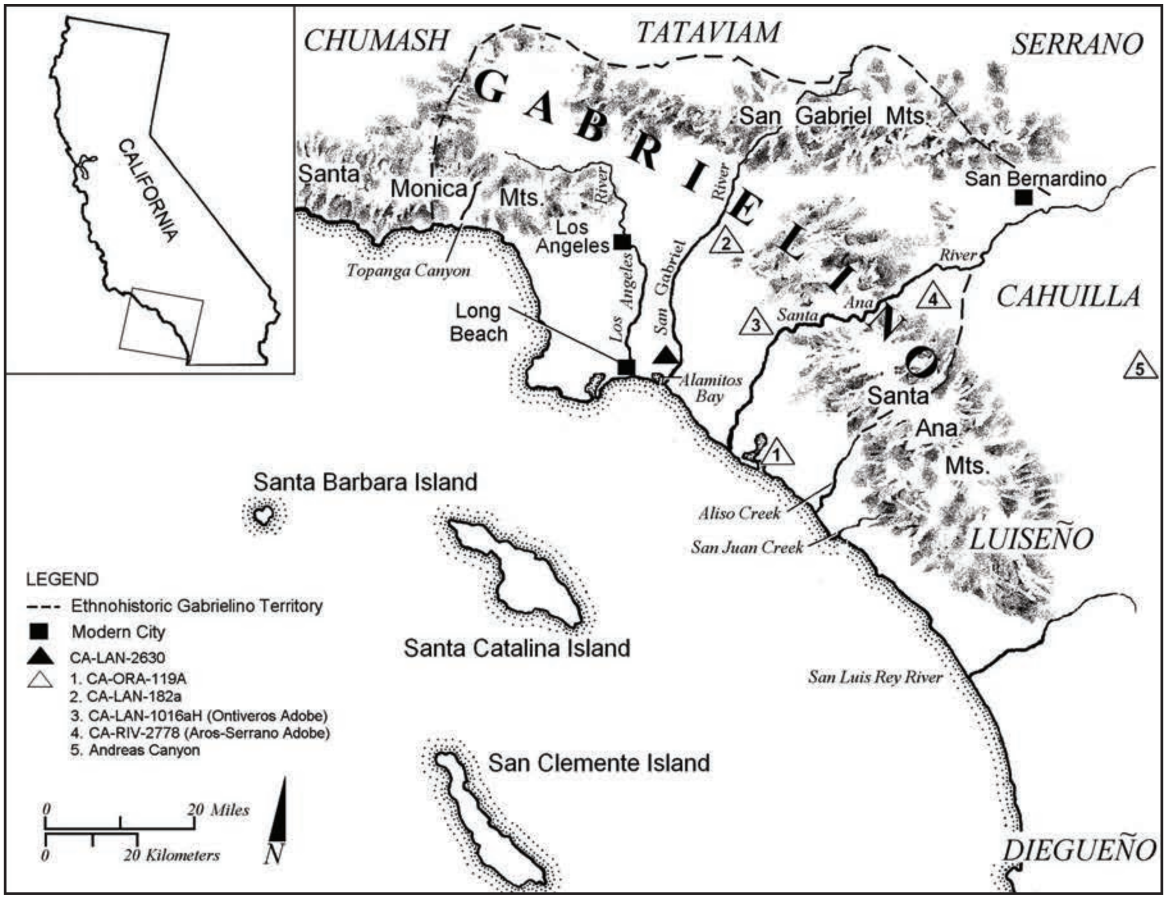

Figure 1. Location of study site CA-LAN-2630 (solid triangle to east of Long Beach) and other locations mentioned in text. Map by Rusty van Rossmann and Matthew A. Boxt.

neutrons/cm^2-second. Gamma ray spectrometry followed using an HPGe Well Detector (Princeton GammaTech) with a 23 mm ID well x 44 mm high, (active volume approximately 115 cm^3), approximately 20 percent efficiency, 2.8 keV resolution; 15 minutes count time was employed. This schedule was utilized to generate data on samarium (Sm), tungsten (W), lanthanum (La), scandium (Sc), and potassium (K). The large number of specimens resulted in the loss of potassium (K) values for a significant number of potsherds. This occurred because the entire data acquisition run of 63 samples allowed the 12.36 hour half-life K-42 to decay below detection range. This problem could be avoided by others needing potassium data by irradiating the sample in two lots, which will nearly double the required reactor costs. There were a number of additional isotopes detected during this data acquisition run. Some were present in only a small number of specimens, some were available with greater accuracy from other analyses, and some had unacceptable errors. The Appendix presents the element concentration assignments and proveniences for the study specimens.

A Long Lifetime Isotope Determination

Irradiation for one to four hours in the lazy Susan at a flux of 1 x10^{12} neutrons/cm^2-second was implemented. Gamma ray spectrometry followed using the same well detector after a decay of two to three days and a count time of one hour. A final data acquisition run was made following a 30-day decay period. Each specimen's gamma spectrum was collected for 4,000 seconds (1.1 hours), using approximately four days of detector time. Data errors were greatly reduced for long half-lived isotopes. Others, in particular, chromium (Cr), cobalt (Co), cerium (Ce), hafnium (Hf), and thorium (Th) measured from the daughter product (Pa-233), were only detectable after the more active short half-life isotopes had decayed below detection limits. Both spectrometer systems are AccuSpec Model A or B boards with 8K channel memory operated at approximately 0.7 keV per channel. The boards are in PC systems and operated by an ASAP (Analyzer Spectroscopy Application Program) package from ND/Canberra Nuclear. This package provides peak areas, isotope identification, and decay computation capabilities, as well as providing for system calibration. The 30 percent detector system is provided with a Gated Integrator Fast Amplifier (Canberra Model 2024) and Fast ADC (8715). It also can be used with a Loss Free Counting module for high count rate correction. Isotopes and the calculated values fell within the standard deviations (Table 1).

Data Reliability

Various procedures were performed to guarantee internal data reliability. The first was to prepare blanks that were run with each lot of specimens. Blanks were empty polyvials that were washed, labeled, and irradiated and counted along with the specimen samples. None of the blanks showed gamma activity above background. One potsherd specimen contaminated by the white paint used during cataloguing was analyzed and showed a significant increase of gamma activity from titanium. This contaminated specimen had approximately 20 times the titanium concentration found in the other samples, but there were no other data

Table 1. Isotopes and Relative Standard Deviations for the Proposed Key Elements.

Element		Half Life	Standard Deviation
Aluminum	(Al)	2.3 minutes	±0.5 %
Vanadium	(V)	3.76 minutes	±3.0 %
Titanium	(Ti)	5.79 minutes	±4.0 %
Manganese	(Mn-56)	2.58 hours	±1.0 %
	(Mn-54)	312.5 days	–
Samarium	(Sm)	47.1 hours	±1.0 %
Tungsten	(W)	23.9 hours	±1.0 %
Lanthanum	(La)	40.27 hours	±1.0 %
Scandium	(Sc)	83.9 days	±4.0 %

abnormalities. We decided to report but not analyze the titanium data. Similarly, comparison of the data generated from potsherds ground versus those drilled revealed that only drilled potsherds returned positive tungsten values. Consequently, data values for tungsten are not reported, as the drill bit was clearly the source of the detected values. Multiple standards were run with each batch of specimens. A linear transformation of peak areas to counts per second per mg provided the data for element concentration calculations relative to the coal fly ash standard specimens. By preparing multiple standards, the standards themselves could be relatively cross-checked against their published element concentrations.

The data resulting from the chemical analysis were used to address the local production hypothesis. We began the current procedure by examining the Spearman rank order correlation matrix (Table 2); from simple inspection we observe two subsets of highly intercorrelated elements, Na, La, and Sm, and Fe, Sc, Cr, Ce, Th, Mn, and Hf, with the remaining elements, Al, Ca, V, Tm, and Co, uncorrelated. This suggests that the intercorrelated subsets represent the element concentrations of minerals within the clay matrix. Regardless of the origin of these subsets, it is necessary that they be reduced to single data points, such as a calculated centroid. In this case with the average subset intercorrelation above .9, we ultimately selected just one isotope from each subset to represent that subset.

Analysis

We next examined the sample distribution of each of the measured isotope concentrations. The uncorrelated elements, Al, Ti, V, Tm, and Co, are basically unimodal and approximately normal (Figure 2 a–e). The exception is the strongly bimodal distribution obtained from the calcium data (Figure 2f). The first intercorrelated subset, Na and La, is strongly bimodal (Figure 2g,h), and the data for samarium appears to be weakly trimodal (Figure 2i). Accordingly, we examined the relationship between Na, La, and Sm by splitting the sample at the inflection point of the sodium distribution, fitting a simple regression line to each of the resulting subsets. The regression lines are very different for the two data subsets. The upper distribution regression (e.g., high sodium values) is Y(La) = 0.45X(Sm)+25 (Figure 3a), and the lower distribution (e.g., low sodium values) is Y(La) = 0.20X(Sm)+42 (Figure 3b). The R^2 for the regression line in Figure 3a is very low, indicating that those data should be interpreted cautiously. However, the overall result indicates that varying amounts of two minerals are contributing to the trace element profiles of the clay matrix. One of these minerals is present in small amounts and has a lanthanum to samarium ratio of 5:1, while the other is more common and has a lanthanum to samarium ratio of 4:1. Naturally, we recognize that some potsherds may contain both hypothetical minerals and in various amounts and that this may account for the appearance of a third mode in the samarium distribution.

Data distributions for the remaining set of intercorrelated elements, Fe, Sc, Cr, Ce, Th, Mn, and Hf, are presented in Figure 4 with iron representing the group. We note clear representations of bimodal, potentially trimodal, element concentration distribution patterns. However, when the data are examined, we find that a single regression line fits both the upper and lower parts of the distribution patterns (Figure 5). We interpret these results to indicate that a single mineral enriches these elements in the clay matrix and that this mineral specie is bimodally distributed. We favor this interpretation over the alternative explanation that these elements constitute the substitution elements in the base clay and that a relatively pure silicate, such as quartz, is bimodally diluting such clay. Such a strong result should have produced obvious textural differences in the potsherds, yet these were not observed. Petrographic analysis might resolve this issue (Plymale-Schneeberger 1993). The elements identified in this study and potential

Table 2. Spearman Rank Order Correlation Coefficient on the NAA Trace Element Data.

	AL	**CA**	**TI**	**V**
AL	1.000	–	–	–
CA	0.420	1.000	–	–
TI	0.102	-0.021	1.000	–
V	0.385	0.275	0.096	1.000
NA	-0.051	-0.076	-0.278	-0.157
LA	-0.005	-0.184	-0.084	-0.094
SM	0.012	-0.174	-0.209	-0.127
SC	-0.053	0.193	0.003	0.070
CR	-0.151	0.188	0.021	0.095
MN54	-0.050	0.189	-0.034	0.036
FE	-0.038	0.186	0.019	0.039
CO	-0.019	-0.077	0.134	-0.065
CE	0.011	0.148	0.049	-0.112
TM	0.196	0.130	0.296	0.029
HF	0.065	0.062	0.078	-0.135
TH	0.028	0.112	0.021	-0.081
	NA	**LA**	**SM**	**SC**
NA	1.000	–	–	–
LA	0.849	1.000	–	–
SM	0.925	0.942	1.000	–
SC	0.262	0.187	0.193	1.000
CR	0.252	0.132	0.142	0.945
MN54	0.245	0.144	0.182	0.815
FE	0.257	0.198	0.205	0.990
CO	0.173	0.272	0.210	0.583
CE	0.231	0.285	0.240	0.900
TM	-0.062	0.050	0.010	0.103
HF	0.244	0.300	0.275	0.725
TH	0.233	0.289	0.266	0.858
	CR	**MN54**	**FE**	**CO**
CR	1.000	–	–	–
MN54	0.773	1.000	–	–
FE	0.926	0.817	1.000	–
CO	0.534	0.476	0.601	1.000
CE	0.795	0.739	0.927	0.691
TM	0.062	-0.051	0.098	0.257
HF	0.584	0.611	0.754	0.602
TH	0.768	0.692	0.881	0.617

Table 2. Continued.

	CE	**TM**	**HF**	**TH**
CE	1.000	–	–	–
TM	0.164	1.000	–	–
HF	0.840	0.239	1.000	–
TH	0.934	0.148	0.811	1.000

mineral species that could serve as sources and are known from Los Angeles County are given in Table 3 (Pemberton 1983).

Comparisons and Interpretations

Published NAA results for coastal southern California ceramics are rare, prompting us to look for reports from inland settlements. Frierman (1987) analyzed four Southern California Brown Ware potsherds, or 45 percent of the total assemblage from CA-RIV-2778 (Aros-Serrano Adobe), including a potsherd from the Ontiveros Adobe (CA-LAN-1016/H). These Historic period potsherds differ by a factor of two to as high as 10 for isotopic concentrations that we found to be significant source identifiers for the LAN-2630 pottery. Since ceramic potsherds had been reported from archaeological sites in the vicinity of LAN-2630, we selected five samples from CA-LAN-182H, the Native American ranchería associated with the Pío Pico Rancho Adobe, which is located roughly 10 km to the northeast. Although these sites are not coeval, we chose LAN-182H because it is related geologically to the study site, within the same sedimentary basin. Indeed, this becomes an important indicator of the regional origins of the LAN-2630 ceramics.

Analysis of the trace element composition of pottery potsherds from LAN-2630 indicates that they can be categorized by the presence of at least three to as many as four minerals that enrich the clay matrix of the pottery; these minerals introduce far

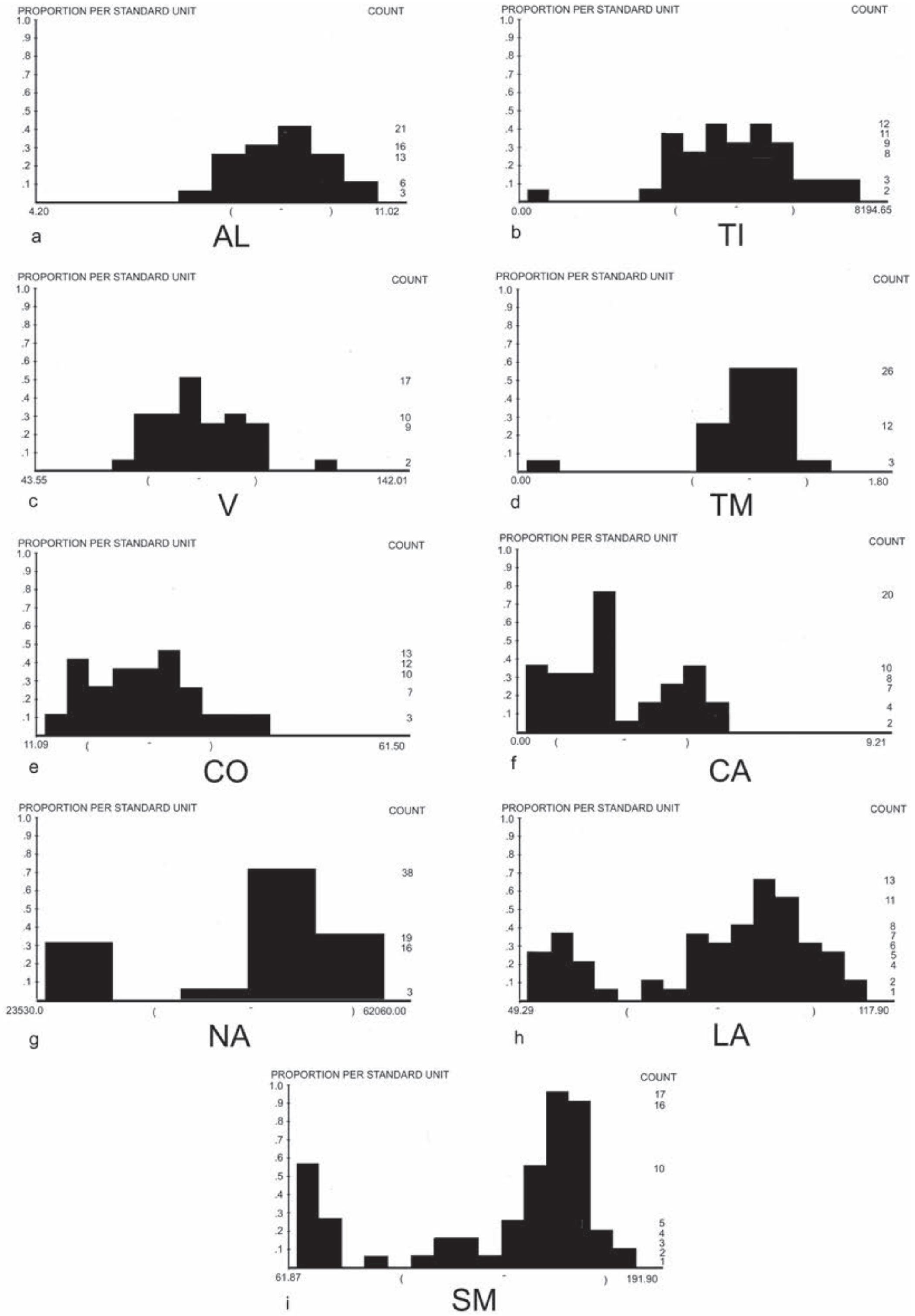

Figure 2. Trace element concentration distributions in the CA-LAN-2630 potsherd sample tested. Aluminium (Al), titanium (Ti), vanadium (V), thulium (Tm), cobalt (Co), calcium (Ca), sodium (Na), lanthanum (La), and samarium (Sm). By Gary S. Hurd and Rusty van Rossmann.

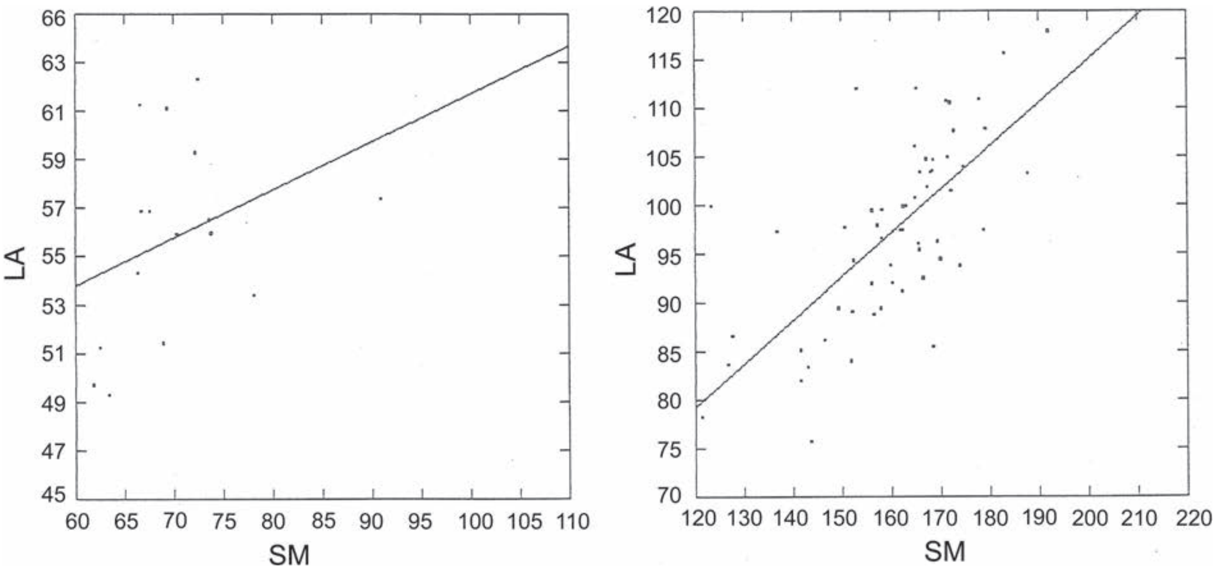

Figure 3. Regression analysis of rare earth element distributions in the CA-LAN-2630 pottery sample tested for sodium (Na), lanthanum (La), and samarium (Sm). Figure by Gary S. Hurd and Rusty van Rossmann.

more variation than the base clay. Partitioning the sample on the inflection points of polymodally distributed element concentrations accounted for most of the sample variance. The partition produced subsets of the sample that included potsherds from LAN-182H, which is geologically comparable but temporally and, in all likelihood, culturally distinct from the study site. The variance in the potsherd trace element profiles is hypothesized to result from two principle sources: (1) the presence of differing amounts of mineral inclusions within the potsherd matrix and (2) the variations in the trace element composition of the actual clays. Thin section analysis of the potsherd sample could be used to further test this hypothesis.

On the basis of NAA, we argue that the study specimens were produced near LAN-2630. There appear to be three elements or groups of elements in the samples that are at least bimodally distributed and independent of each other. Simply splitting the sample at the appropriate inflection points might partition the specimens into interpretable groupings, which account for the majority of data variance. Looking at the contingency tabulation in Table 4, we favor this approach to the data partition. For example, there are a number of near empty cells indicating that this is not merely a random number exercise. A remaining issue is whether such a partition maximally utilizes the sample variance. This is evident when contrasting Figure 6 with the "residual" trend plotted from the unimodal, uncork-related element distributions such as aluminum, vanadium, and cobalt presented in Figure 7. The distant exchange hypothesis may be further tested by the application of Student's t-test to the trace element data from Los Angeles County, Orange County, Riverside County, and LAN-2630.

The Orange County ceramic data were from prehistoric site CA-ORA-119A on the upper Newport Bay (Koerper et al. 1978; Hurd et al. 1990) (Table 5). The Riverside County trace element data derive from Andreas Canyon (Palm Springs) Cahuilla pottery (Hurd and Miller 1973) (Table 6). We are "asking" the data if the trace element compositions of the ceramics

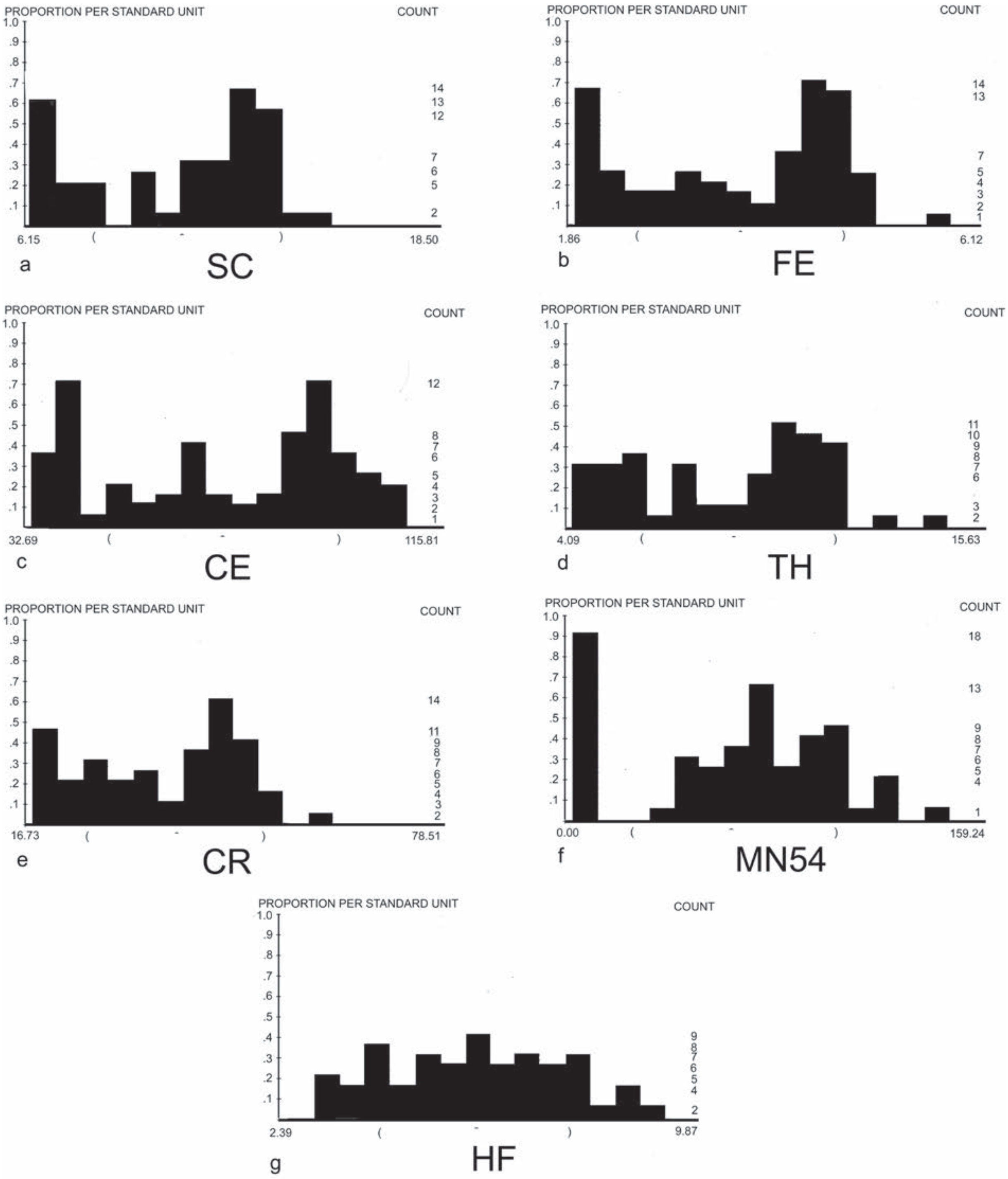

Figure 4. Trace element concentration distributions in the CA-LAN-2630 potsherd sample tested. Scandium (Sc), iron (Fe), cerium (Ce), thorium (Th),chromium (Cr), maganese (Mn), and hafnium (Hf). Figure by Gary S. Hurd and Rusty van Rossmann.

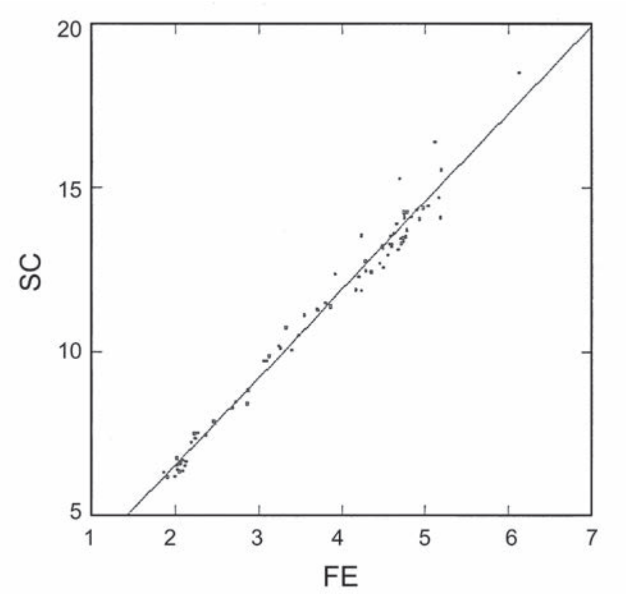

Figure 5. Regression analysis of iron-to-scandium concentrations in the CA-LAN-2630 ceramic sample. By Gary S. Hurd and Rusty van Rossmann.

Table 3. Elements Identified in Sherd Samples and in Minerals from Los Angeles County.

Element		Associated Minerals
Al	Aluminium	Clay, feldspar
Au	Gold	Placer deposits in San Gabriel Canyon
Ca	Calcium	Common from shell, bone, limestone etc...
Cd	Cadmium	With zinc ores, e.g., sphalerite
Ce	Cerium	Monazite, bastnasite, allanite, orthite
Cr	Chromium	Chromite, chromatin, magnesiochromite (especially with serpentine)
Co	Cobalt	Cobaltite, smaltite, erythrite
Fe	Iron	Hematite, magnetite, substitution metal in clay
Gd	Gadolinium	Monazite, bastnasite, gadolinite
Hf	Hafnium	Zircon (1% to 5%)
Ho	Holmium	Monazite, gadolinite
La	Lanthanum	Cerite (25%), monazite (35%) allanite, see cerium
Mn	Manganese	Iron/manganese nodules, many others
Na	Sodium	Ubiquitous
Pd	Palladium	Associated with gold, silver, and platinum minerals
Ru	Ruthenium	Pyroxinite, with platinum ore, pentlandite
Sb	Antimony	Stibnite, or antimonides of heavy metals
Sc	Scandium	Euxenite, gadolinite
Sm	Samarium	Samarskite, monazite (2.8%), gadolinite
Sn	Tin	Cassiterite ($Sn O_2$)
Th	Thorium	Monazite
Ti	Titanium	Common, TiO in white paint
Tm	Thulium	Monazite with thorium
W	Tungsten	From drill bit

Table 4. Contingency Tabulation of Sherds Partitioned Along the Concentration Distribution Inflection Points for (1) Iron, (2) Samarium, and (3) Calcium.

Calcium = Low

	1	**2**	**Total**
1	7	2	9
2	2	1	3
3	17	19	36
Total	26	22	48

Calcium = High

	1	**2**	**Total**
1	5	2	7
2	1	6	7
3	6	10	16
Total	12	18	30

from these different locations could have come from the same clay source, which is another way of asking if the CSULB specimens could have arrived on-site through long-distance exchange from the previously tested sources. Also, this analysis should result in the mutual grouping of the soil and daub samples, supporting the notion that post-depositional processes have not significantly altered the trace element profile of the study potsherds. While recognizing that these data do not categorize the only possible distant pottery sources, we find that these results reject the long-distance exchange hypothesis, favoring the local production theory. Only those elements substantially present for all samples are included in the analysis. Chi square tests on presence/absence data also support the local production hypothesis, although they are not presented. A final test of the local production hypothesis is a one-way analysis of variance applied to the NAA generated trace element data from three independent samples. Here we are asking whether or not locale is a statistically significant predictor of trace element data. The results presented in Table 7 further support a local production hypothesis concerning the pottery of LAN-2630.

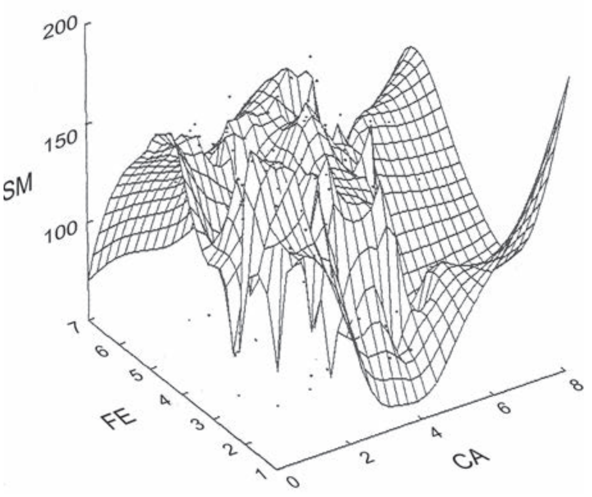

Figure 6. Rugged trend surface from samarium, iron, and calcium concentrations in the CA-LAN-2630 pottery sampled. By Gary S. Hurd and Rusty van Rossmann.

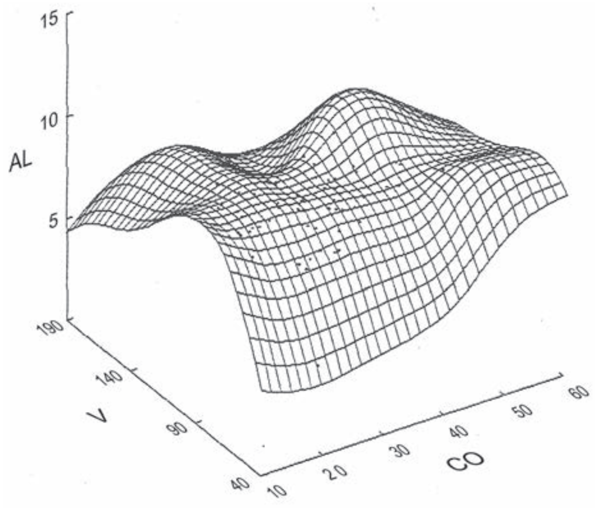

Figure 7: Residual variance trend surface from unimodal distributions of aluminum, vanadium, and cobalt in the CA-LAN-2630 ceramic sample. By Gary S. Hurd and Rusty van Rossmann.

Conclusions

Our analysis revealed that the potsherds from archaeological sites along the San Gabriel River drainage differ significantly from pottery recovered from archaeological pottery within the Santa Ana River system (RIV-2778 in Corona and ORA-119A at

Table 5. T-Test Result for Common Elements Found in Ceramics Recovered from CA-LAN-2630 and CA-ORA-119.

	T	Probability
Mn	3.1	.003
Sc	-2.3	.026
La	16.8	.000
Sm	30.4	.000
Al	-22.4	.000
V	-2.3	.021

Table 6. T-Test Result for Common Elements Found in Ceramics Recovered from CA-LAN-2630 and Andreas Canyon, Riverside County.

	T	Probability
Mn	12.3	.000
Sc	-4.9	.000
La	9.8	.000
Sm	28.9	.000
Al	-1.2	.222
V	-0.197	.848

Table 7. Results of a One-Way Analysis of Variance Testing Locale as a Predictor of Sherd Trace Element Composition.

	F	Probability
Mn	12.6	.000
Sc	3.6	.029
La	152.6	.000
Sm	385.4	.000
Al	355.5	.000
V	2.98	.053

Newport Bay). This provides further support for the argument that the study potsherds from LAN-2630 were produced within the San Gabriel River drainage. It was also noted that the LAN-2630 soil and burnt daub samples share the same chemistry as the potsherds, thus encouraging us to accept the reliability of the potsherd assignments. Our data are unambiguous and lead us to the conclusion that pottery vessels were made within the vicinity of the LAN-2630 archaeological site itself. None of the ceramic samples represent exotic imports.

Acknowledgments

The Pío Pico specimens were recovered during excavations by Cypress College under the direction of Mr. Paul Langenwalter, and permission to use them is gratefully acknowledged. The authors wish to thank the Cahuilla Tribal Council and Tribal Historian Anthony Andreas for providing some of the potsherds discussed in this report. We are grateful to Brian Stokes, Axel Matthias Kern, and Ann Miller for their enthusiasm and tireless efforts at the UC Irvine Radiochemistry Laboratory.

References Cited

Frierman, Jay D.

1987 Southern California Brown Ware. In *Historical and Archaeological Investigation at the Aros-Serrano Adobe, Prado Basin*, by Roberta S. Greenwood. John M. Foster, and Anne Q. Duffield. pp. 79–85. Report prepared by Greenwood and Associates. Report submitted to U.S. Army Corps of Engineers. Los Angeles District.

Griset, Suzanne

2009 Chapter Nine: Native American Ceramics. In *The Archaeology of CA-LAN-192: Lovejoy Springs and Western Mojave Desert Prehistory* by Barry A. Price, Alan G. Gold, Barbara S. Tejada, David D. Earle, Suzanne Griset, Jay B. Lloyd, Mary Baloian, Nancy Valente, Virginia S. Popper, and Lisa Anderson, pp. 115-137. Report prepared by Applied Earthworks, Inc., Fresno, California. Report submitted to County of Los Angeles Department of Public Works, Alhambra, California.

Hurd, Gary S., and George E. Miller
1973 Analysis of Prehistoric Ceramics by Neutron Activation. In *Reports of the Undergraduate Research Fellows to the Regents of the University of California, Irvine*. On file, University of California Irvine Library, Special Collections.

Hurd, Gary, S., George E. Miller, and Henry C. Koerper
1990 An Application of Neutron Activation Analysis to the Study of Prehistoric California Pottery. In *Hunter-Gatherer Pottery from the Far West*, edited by Joanne M. Mack, pp. 202–220. Nevada State Museum Anthropological Papers No. 23. Carson City.

Koerper, Henry C., Christopher E. Drover, Arthur E. Flint, and Gary S. Hurd
1978 Gabrielino Tizon Brown Pottery. *Pacific Coast Archaeological Society Quarterly* 14(3):43–58.

Pemberton, H. Earl
1983 *Minerals of California*. Van Nostrand Reinhold Company, New York.

Plymale-Schneeberger, Sandra
1993 Application of Quantifiable Methodologies in Ceramic Analysis: Petrographic and Geochemical Analysis of Ceramics from Riverside County, California. *Proceedings of the Society for California Archaeology* 6:257–276.

Van Camp, Gena R.
1979 *Kumeyaay Pottery: Paddle-and-Anvil Techniques of Southern California*. Ballena Press Anthropological Papers No. 15. Socorro, New Mexico.

Appendix

Element Concentration Assignment and Provenience for the CA-LAN-2630 Pottery Specimens.

Cat. No.	Unit No.	Depth (cm)	Al (%)	Ca (%)	Ti (PPM)	V (PPM)	Mn-56 (PPM)	Na (%)	La (PPM)	Sm (PPM)	Sc (PPM)	Cr (PPM)	Mn-54 (PPM)	Fe (%)	Co (PPM)	Ce (PPM)	Tm (%)	Hf (PPM)	Th (PPM)
1647	X7	10-20	9.281	3.953	4102.006	78.286	852.091	5.095	103.200	187.700	6.178	24.239	0.000	1.998	14.722	41.257	1.276	3.214	7.674
245	A5	0-10	9.209	4.742	4455.097	79.834	755.949	5.135	85.090	141.500	12.445	47.113	101.867	4.280	16.579	92.522	0.000	5.603	10.997
1150	A1	30-40	9.422	4.651	4303.963	101.994	820.109	2.492	49.290	63.460	11.306	42.410	47.397	3.694	21.974	70.384	1.143	6.557	8.534
243	A5	0-10	9.044	3.915	3763.627	84.140	977.542	2.724	55.900	70.310	6.150	16.731	0.000	1.908	17.896	38.309	0.929	3.456	4.649
247	A5	10-20	10.479	4.831	5380.623	72.964	695.719	2.928	61.250	66.590	9.722	30.324	60.660	3.057	28.896	64.128	1.117	5.407	7.676
1857	A6	0-10	9.625	4.760	4691.828	85.011	908.033	5.187	103.400	165.800	14.677	50.844	115.367	5.162	26.211	108.868	1.384	7.942	12.973
3389	A5	0-10	9.982	5.220	7263.774	91.785	940.337	4.489	86.560	127.600	13.694	50.571	127.947	4.780	29.805	103.311	1.415	9.416	12.138
2918	A4	20-30	9.893	3.378	3668.667	84.382	823.608	5.379	93.710	173.800	11.258	32.157	90.898	3.705	22.875	74.439	1.240	6.071	8.075
1303	A1	20-30	9.766	2.155	4793.476	72.141	945.173	6.005	83.970	151.900	11.834	43.958	81.769	4.231	46.444	87.768	1.391	7.127	10.050
970	A1	0-10	9.638	4.622	0.000	84.044	990.170	5.316	85.440	168.400	10.746	34.220	60.407	3.317	22.051	67.798	1.221	5.955	11.433
2820	A4	0-10	9.443	5.210	3248.703	102.527	761.294	3.863	73.090	106.400	6.679	19.552	46.530	2.088	16.850	40.022	0.960	3.567	4.478
2675*	A4	10-20	9.235	5.860	3560.333	142.008	1361.505	4.954	81.990	141.500	14.436	63.252	127.563	5.33	21.155	62.031	0.841	3.260	7.777
3995	A4	0-10	9.460	5.036	8194.650	102.817	850.869	2.466	57.350	90.940	14.063	45.839	101.943	5.178	25.615	106.853	1.439	7.099	11.591
1123	A1	10-20	9.286	3.195	4818.888	77.609	793.152	5.199	91.170	162.200	14.308	44.140	100.869	4.896	28.862	96.460	1.255	6.931	12.157
2675*	A4	10-20	10.135	0.000	4738.640	106.736	830.419	5.324	110.900	177.800	12.734	34.432	80.849	4.276	31.032	94.887	1.117	9.055	12.472
2754	A4	10-20	9.371	0.000	4281.227	78.818	989.897	5.498	104.900	171.400	6.646	18.575	0.000	2.063	17.870	41.035	1.253	3.765	4.501
2706	A4	10-20	9.022	3.928	5177.328	101.075	819.618	4.993	97.390	161.900	13.894	47.264	113.373	4.654	33.793	94.246	1.323	9.305	11.507
1837	A6	10-20	9.400	4.381	6912.021	94.930	798.268	5.364	115.600	183.000	14.027	53.271	0.000	4.929	37.096	115.812	1.802	8.854	15.627
1847	X7	0-10	9.804	4.988	7610.178	87.237	830.346	5.052	112.000	153.100	13.093	46.081	72.219	4.674	41.929	110.744	1.272	7.675	10.431
2758	V6	30-40	9.897	3.540	6014.582	84.963	801.590	5.365	100.700	164.800	11.862	38.861	82.000	4.162	25.311	89.283	1.321	7.553	15.516
**	Locus 3	99-199	8.725	9.208	5184.016	103.736	712.845	6.206	97.290	136.800	15.250	64.920	106.239	4.689	19.684	95.166	1.320	6.187	10.226
**	Locus 3	99-100	8.640	6.798	4242.440	98.172	837.607	5.809	66.090	114.800	13.533	52.513	94.886	4.230	16.940	61.972	0.942	5.077	7.176
3892	U5.5	40-50	10.322	0.000	6890.621	103.301	834.367	2.567	62.290	72.470	7.219	19.913	0.000	2.189	16.404	41.268	1.365	4.149	5.961
3835	U5.2	20-30	10.008	2.914	4226.390	80.995	958.888	4.944	94.240	152.400	8.279	25.495	0.000	2.684	11.090	50.298	1.127	4.623	6.090
2064	V4	30-40	9.056	0.000	4923.210	78.479	940.707	5.978	101.400	172.100	13.369	58.610	114.140	4.741	30.234	103.625	1.428	8.351	13.595
1885	Y6	10-20	8.963	3.935	3438.623	84.044	1114.577	5.150	93.750	159.800	12.926	45.657	81.309	4.550	39.703	100.258	1.431	6.392	9.865
3189	V2	30-40	8.107	1.798	5549.314	89.128	1089.420	5.406	92.460	166.400	13.182	55.152	159.243	4.597	35.607	94.491	1.140	6.949	11.674

Element Concentration Assignment and Provenience for the CA-LAN-2630 Pottery Specimens (continued).

Cat. No.	Unit No.	Depth (cm)	Al (%)	Ca (%)	Ti (PPM)	V (PPM)	Mn-56 (PPM)	Na (%)	La (PPM)	Sm (PPM)	Sc (PPM)	Cr (PPM)	Mn-54 (PPM)	Fe (%)	Co (PPM)	Ce (PPM)	Tm (%)	Hf (PPM)	Th (PPM)
2323	V7	50-60	9.039	3.390	4558.082	83.511	764.636	5.611	94.430	169.900	14.081	49.570	125.722	4.836	34.059	98.965	1.363	9.345	10.793
2096	V4	20-30	10.594	3.904	5737.726	110.510	907.597	5.476	103.900	174.500	14.365	56.001	134.390	4.975	36.808	108.192	1.601	6.406	11.841
2625	Y10	0-10	9.515	4.690	4711.890	121.203	1019.788	2.556	56.830	66.740	6.628	24.873	0.000	2.127	23.085	39.905	1.424	4.081	5.632
890	F3	20-30	10.348	3.427	3786.364	96.333	977.460	5.536	97.360	178.700	12.343	43.290	76.484	3.909	30.375	80.789	1.364	6.579	9.716
498	N1	0-10	10.305	3.989	7116.653	86.947	975.962	2.882	55.930	73.820	13.418	49.388	115.214	4.700	34.797	95.190	1.434	7.298	11.145
3850	V3	30-40	9.600	4.279	3521.546	75.964	924.691	5.426	83.390	143.000	8.409	25.628	42.158	2.857	13.805	55.052	1.007	4.688	6.300
2830	X4	10-20	10.050	4.684	5804.600	85.495	795.228	4.014	99.880	123.400	13.492	44.564	99.182	4.771	31.593	114.158	1.221	7.443	12.082
1071	I2	10-20	10.445	4.815	5902.235	101.994	946.882	2.617	53.400	78.080	8.458	31.975	48.164	2.721	15.915	51.079	1.153	4.166	6.311
1585	A10	60-70	8.895	4.370	3862.600	75.576	1262.925	5.296	89.060	152.100	12.683	45.565	96.114	4.451	24.963	93.127	1.331	8.258	10.700
3378	X4	10-20	9.431	1.910	5631.110	90.062	1191.914	2.650	56.840	67.610	11.358	42.077	68.284	3.854	43.228	91.158	1.133	5.171	11.154
2726	A4	0-10	10.404	2.000	4958.853	100.586	1104.467	5.453	107.800	179.100	14.242	51.026	98.722	4.744	40.338	105.676	1.386	7.181	11.256
420	Y4	0-10	9.977	2.338	5217.020	96.472	1077.865	5.680	103.500	168.300	8.829	27.703	61.419	2.866	24.226	52.663	1.328	5.026	6.823
150	Y4	0-10	9.956	2.260	5930.175	82.881	1100.105	5.368	96.020	165.500	7.450	27.400	44.513	2.362	21.730	43.028	1.110	4.921	5.589
484	Y4	10-20	11.015	2.345	6405.611	105.848	1026.534	5.529	95.400	165.700	7.864	26.308	0.000	2.455	21.412	43.738	0.967	5.375	5.502
148	Y4	0-10	10.042	2.271	5935.287	97.569	1133.742	2.799	56.480	73.580	6.743	25.025	48.195	2.015	18.569	37.738	1.245	3.018	5.463
149	Y4	0-10	9.580	2.014	6615.212	88.356	1050.225	5.466	104.600	168.500	10.060	34.280	74.068	3.385	25.384	69.883	1.163	6.111	8.449
3695	Z9	0-10	7.187	2.006	5704.503	76.213	689.270	2.463	51.250	62.510	13.216	50.874	83.917	4.483	25.538	87.488	1.149	6.440	10.403
106*	Y4	20-30	8.239	1.686	5447.640	125.144	1330.319	4.591	78.250	121.400	18.500	78.511	127.487	6.122	28.986	86.207	0.976	5.449	10.987
3541	TT5.2	20-30	8.794	2.459	7691.625	89.065	809.867	5.466	117.900	191.900	7.519	29.818	55.344	2.272	21.738	48.515	1.445	4.535	5.790
3587	TT5.5	40-50	9.081	1.879	6439.417	93.594	1095.967	5.083	101.800	167.300	6.303	17.574	0.000	1.861	18.140	38.554	1.409	4.921	4.803
2580	B6	20-30	9.390	2.352	6375.201	87.695	948.342	4.200	85.060	118.900	10.111	35.160	0.000	3.249	26.855	67.565	1.161	6.361	7.860
2070	Z6	20-30	8.789	1.516	3517.598	89.118	910.048	5.032	89.400	149.300	11.457	32.308	71.606	3.794	32.228	74.416	1.082	6.366	9.336
2943	B5	20-30	8.293	2.387	6491.146	78.004	900.862	5.044	97.650	150.600	12.271	43.745	78.855	4.197	43.743	94.269	1.195	5.804	10.319
2146	Z7	0-10	8.664	1.774	3695.325	92.436	1017.604	5.127	106.000	164.800	13.259	47.780	100.486	4.572	61.497	105.955	1.344	9.152	11.906
2961	B5	10-20	8.731	1.803	6298.499	104.655	955.180	2.767	54.300	66.350	6.511	19.239	0.000	2.021	16.035	35.280	1.145	4.240	4.184
2961	B5	10-20	8.018	1.857	4487.970	99.546	801.346	5.210	91.910	156.000	13.154	46.203	85.528	4.492	29.531	90.995	1.219	8.028	10.050
2525	B6	20-30	8.443	1.942	3126.952	89.381	914.485	5.355	97.260	160.300	10.173	37.344	75.134	3.230	42.971	70.373	0.914	5.762	7.882
3247	B5	10-20	7.558	0.992	7188.005	70.002	708.367	2.353	49.700	61.870	6.513	20.735	0.000	2.118	22.339	39.206	0.957	3.447	4.945

Element Concentration Assignment and Provenience for the CA-LAN-2630 Pottery Specimens (continued).

Cat. No.	Unit No.	Depth (cm)	Al (%)	Ca (%)	Ti (PPM)	V (PPM)	Mn-56 (PPM)	Na (%)	La (PPM)	Sm (PPM)	Sc (PPM)	Cr (PPM)	Mn-54 (PPM)	Fe (%)	Co (PPM)	Ce (PPM)	Tm (%)	Hf (PPM)	Th (PPM)
3247	B5	10-20	7.558	0.992	7188.005	70.002	708.367	2.353	49.700	61.870	6.513	20.735	0.000	2.118	22.339	39.206	0.957	3.447	4.945
2198	Z6	20-30	8.028	0.948	4501.961	77.399	721.882	5.217	103.400	168.000	14.242	51.542	103.631	4.783	30.448	98.417	1.223	6.574	12.166
1425	B7	20-30	7.461	0.555	3765.821	71.549	719.836	5.388	97.360	162.300	12.540	40.317	83.687	4.497	28.549	93.663	1.154	7.925	10.301
1462	B7	0-10	7.735	0.804	5044.214	95.721	643.463	4.767	112.000	165.200	9.715	28.653	65.876	3.089	26.503	67.437	1.044	5.693	9.221
1532	B7	10-20	7.731	1.290	5468.243	62.750	702.853	5.105	99.420	156.100	7.798	18.839	59.578	2.472	21.961	51.428	1.020	4.237	5.845
2285	Z6	10-20	7.976	1.023	3781.584	69.229	557.376	5.587	104.700	167.100	13.520	55.304	0.000	4.584	40.917	100.642	1.421	5.926	11.062
2269	Z7	50-60	7.600	0.000	7677.355	74.423	998.815	5.359	96.200	169.300	6.349	17.459	0.000	2.090	19.586	41.059	0.989	3.251	5.006
2090	Z7	10-20	8.502	1.605	5164.020	107.131	988.602	5.407	97.850	157.200	6.321	20.286	0.000	2.046	17.133	37.855	1.026	4.081	5.146
3569	Z9	0-10	8.289	1.895	6405.525	97.861	975.835	4.836	96.520	158.000	10.518	34.553	71.391	3.475	28.214	66.621	1.065	6.156	7.597
1557	C4	30-40	8.141	1.400	5704.691	82.716	689.464	2.580	59.270	72.200	14.073	55.152	106.853	4.752	27.884	110.697	1.277	8.559	11.832
3695	Z9	0-10	8.873	2.439	4714.509	94.332	933.528	5.739	107.600	172.700	14.129	46.627	78.778	4.752	27.995	100.724	1.593	9.868	11.154
2580	B6	20-30	8.358	1.435	5591.196	74.305	769.598	5.075	91.990	160.200	13.587	50.025	82.153	4.624	33.202	92.487	1.323	7.681	11.108
1581	C4	10-20	7.775	1.022	4386.890	67.730	662.630	5.532	99.830	162.400	13.259	48.296	87.369	4.598	28.403	94.153	1.161	7.161	10.069
4056	C4	10-20	8.430	0.968	3631.834	85.134	710.280	5.276	110.500	171.900	6.554	22.613	0.000	2.056	14.667	38.262	1.112	4.353	5.545
1581	C4	10-20	9.214	0.000	3660.208	103.553	757.814	5.190	99.920	163.000	6.372	16.755	43.562	2.027	16.446	38.064	0.837	4.427	4.090
4061	C4	20-30	10.427	2.382	5117.332	85.552	1011.717	5.418	88.810	156.400	13.274	44.686	82.767	4.715	17.175	89.294	1.279	7.619	10.802
4061	C4	20-30	8.225	0.553	0.000	75.755	672.650	5.524	89.420	157.900	12.409	47.143	92.815	4.347	16.155	91.601	0.000	5.886	10.755
1430	C4	10-20	8.004	1.080	5811.880	67.972	626.602	2.538	51.440	68.920	11.117	37.041	68.676	3.541	25.401	73.344	1.332	8.289	9.363
1455	C4	20-30	7.863	1.042	5763.014	93.787	663.211	5.316	110.700	171.200	13.443	52.391	114.907	4.736	34.587	103.019	0.000	8.294	13.595
***	12N0E	110-120	8.130	1.846	6211.094	93.647	814.262	5.532	86.140	146.500	15.529	73.536	112.989	5.192	38.026	78.249	1.082	7.437	10.449
***	12N0E	50-60	8.773	1.889	4455.863	81.217	1081.176	5.454	75.700	143.600	7.340	24.409	0.000	2.236	13.633	32.693	1.031	3.212	4.155
***	8S03	50-60	4.197	0.000	4138.351	43.553	725.050	5.146	83.670	126.800	9.861	46.900	76.653	3.115	19.847	58.151	1.304	4.183	7.105
***	2N0E	20-30	8.264	2.013	4525.430	126.145	962.260	2.486	61.090	69.370	7.491	23.769	0.000	2.225	14.002	38.181	1.463	2.392	5.629
***	FCE-26	0-0	8.560	0.000	6141.527	102.917	1097.466	5.426	99.510	158.100	16.374	67.104	109.307	5.114	33.592	95.970	1.152	5.037	11.952

* Daub.
** Soil sample.
*** Sherds from CA-LAN-182H.