CHEMICAL CHARACTERIZATION OF EARTHERNWARE ON THE ALTA CALIFORNIA FRONTIER

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The research presented in this paper is based on the use of neutron activation analysis to characterize the composition of the pastes in a sample of earthenwares from the missions sites of San Francisco, Santa Clara, San José, Santa Cruz, San Antonio, and San Juan Capistrano, the pueblo of San José, and the presidios of San Francisco, Monterey, and San Diego. Local production at each of the mission sites had been determined through comparison of the ceramics with the bricks and tiles found at the sites. Lead-glazed pottery, believed to have been imported from Mexico, is shown to be compositionally distinct, and apparently obtained from only a few sources in Mexico. Importantly, however, chemical evidence has been obtained that documents the local production of lead-glazed ceramics at two of the missions: San Juan Capistrano and Santa Clara. Thus, glazing technology as well as pottery was exported to Alta California. This latter finding sets the stage for an expanded program of analysis, focusing greater attention on contribution of Mexican glazing technology to California's history.

INTRODUCTION

Throughout what was *Alta California*, archaeologists have found in Spanish- and Mexican-period missions, presidios, pueblos, and ranchos the fragments of hand-modeled and wheel-thrown, unglazed, low-fired earthenwares. Descriptive analyses of the vessels' forms suggest a wide range of functions, including storage, preparation, presentation, and consumption. The extraordinary visual similarities between earthenwares found hundreds of miles apart has been explained by some as the result of intra-colonial or inter-mission trade. Others feel that a more parsimonious answer would be that most of these ceramics were produced—and used—locally (Euler and Dobyns 1958; Evans 1969; Love and Resnick 1983; May 1976; Schulz and Barter 1985). Neutron activation analysis provides objective chemical measurements of adequately high analytical precision so that one may be able to differentiate pottery made from closely spaced, but geochemically different, raw-material resources.

BACKGROUND

Spanish political interests were served first by Catholic missionaries, second by presidio soldiers, and only peripherally by pueblo-dwelling civilians. From Florida to California these borderlands were occupied by Native American peoples with radically different technologies, social organizations, and ideologies. Into these cultures came missionaries, most of whom were Franciscan, whose goal was to Christianize and Hispanicize these peoples. Of the two, religious conversion was preeminent, but the latter would create supporters of the Crown—the missionaries' financial backers—so it too was carried forward. Still, to meet these goals required different strategies depending on the culture of the indigenous people.

In general we can characterize Native Americans in this area as being largely sedentary agriculturalists, such as the pueblo dwellers of the Rio Grande Valley or the Apalachee of Florida, or as being semi-sedentary hunters and gatherers, such as the Karankawa of Texas or the Ohlone of the San Francisco Bay Area of California. Among sedentary agriculturalists we find that missionaries were "invited" into extant communities to build a *doctrina*. In these settings a panoply of new plants and animals, technologies and architecture, customs and ideas were introduced with varying degrees of acceptance.

For all of these changes, these were still "Indian" communities, because their economic focus and social hierarchy remained largely

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unchanged. This is reflected in the ceramics made in these locales. Among the Apalachee, precontact forms of the Lamar ceramic complex continue to be made through the 75 years of Franciscan missionization, yet there is evidence that indigenous potters made ceramics in Spanish forms to meet the demand of priests, soldier, settlers, and local elites (Cordell 2001; Vernon 1988). A similar phenomenon has been chronicled among the Pueblo peoples of New Mexico. There, not only were "colono-wares" made to meet the demand of these elites, but small and medium-sized bowls were exported in forms that had no equivalent in the range of Spanish empire wares (Frank 1991:311).

The situation that developed among the semisedentary peoples of California was radically different. There, the missionaries selected the location for a community that fit their cultural template of the "ideal." At these *reducciones*, the indigenous peoples found a new architecture, new fauna and flora, a new social hierarchy, and a complete new set of social norms that forever altered the lives of Native Californians. The mission system sought to transform these people into Spanish citizens, good Catholics, and loyal subjects of the king. To accomplish this, the missionaries attempted to instill in their neophytes a Spanish ideology which encompassed all aspects of their lives, from world view to language, from clothing to profession, from diet to ceramics (Skowronek 1998).

CERAMICS

Pottery was previously unknown to all but the southernmost groups in California, the rest relying primarily on an extremely well developed basketmaking tradition for their cooking, storage, and transportation needs. But a good Spaniard does not cook in or eat out of a basket. The need for utilitarian ceramics to service the mission Indians led to the development of what is generally referred to as mission-made ceramics, a low-fired earthenware common to California mission contexts. While perhaps not as attractive as the imported Spanish and Mexican ceramics, locally-made earthenware is tangible evidence of the acculturation of Native Californians into the Spanish Empire. It is a native-produced ware made with Spanish technology, in Spanish forms and to service a Spanish lifestyle that was built on the preparation and consumption of domesticated fauna and flora. In California we see them growing wheat—an Old World plant—and not corn as the primary grain. We should remember that California represented a great experiment to "create" *gente de razón* or people of reason, which meant that they ate "human food"; corn was seen among elites in Mexico as fit only for consumption by animals and Indians (Crosby 1972:107). In the case of California, we see wheat-, vegetable-, and meat-based stews called *atole* and *posole*. These were cooked in large copper cauldrons for the neophytes housed in the mission compound and in ceramic pots in the neophyte *ranchería*, but both were served in ceramic bowls and plates (Webb 1952:40-42).

EVIDENCE FOR TRADE

While trade may seem on its face to be a plausible explanation for the similarities between mission-made ceramic wares, it is in fact a problematic solution. Most trade between the missions, pueblos, and presidios would have been overland, since most of the sites were located inland, without adequate waterways connecting them. This would have required ceramics to be moved long distances over dirt roads in carts or in mule-trains—the only transportation technology available at that time. In a situation of this sort, breakage would certainly have been an issue, especially with such fragile, low-fired wares. For example, recent ethno-archaeological work among the earthenware-making *Kalinga* of the northern Philippines has shown that 64% of the earthenwares made today are exchanged within a 10-km (six-mile) radius of their point of production (Stark 1994:187). This small area of distribution may be attributed to a poor transportation network and the low mechanical strength of pottery fired at 600-650 degrees Centigrade (Aronson et al. 1994:102-107). To supply an entire mission population with ceramics would have been a difficult task, to say the least. In terms of labor expenditure, it would have been far more economical for missions to produce their own utilitarian wares, and while it is true that some ceramics were imported to *Alta California* from Mexico, these pieces were exotic items intended for use largely by colonists and soldiers, and are found in their highest concentrations at presidio and pueblo sites (e.g., May 1985). The relative scarcity of these wares at mission sites can be attributed to the fact that few individuals of Hispanic extraction resided there.

Hoover and Costello (1985), in their report on the excavations at Mission San Antonio, noted that inter-mission trade in roof and floor tiles would have been extremely impractical due to the bulk and relative fragility of these earthenwares. This implied the necessity for each mission to possess the technology to fire their own tile. Mission-made pottery, *ladrillos* and *tejas*, are basically the same material—that is, earthenware. Both would have been fired at temperatures above 660 degrees centigrade (Costello 1997:213; Lackey 1982:116-122). By 1781 neophytes at Mission San Antonio were making tiles (Hoover and Costello 1985:123; Webb 1952:108). At Santa Clara, production of roof and floor tiles began in 1791, so the firing technology was in place by this date in the Bay Area. The only other element required to produce pottery would have been skill.

In the 1790s, Father Lausen, president of the California missions, arranged for a number of artisans and craftsmen to be recruited from Mexico to teach the neophytes their skills. The artisans were distributed to different missions throughout California (Kenneally 1965:260; Webb 1952:126). At these locales neophytes from other missions would be sent to learn specific trades. For example, Santa Clara received Cayetano Lopez, a carpenter and millwright, and Miguel Sangrador, a master tanner, leather finisher, and shoemaker. Francis Guest's biography of Padre Lausen (1973:302, 306, 336) states that in 1796 Santa Clara sent neophytes to Monterey to learn tailoring and pottery-making,, ostensibly from Mariano Tapia (Schuetz-Miller 1994:99). In another account written by Engelhardt (1924:121), the potter José Antonio Romero, who was a soldier at the San Francisco Presidio, was to have visited Missions San Francisco, Santa Clara, and Santa Cruz in 1796 (Johnson 1985:54; Langelier and Rosen 1992:87; Schuetz-Miller 1994:91). If these accounts of neophytes as apprentices are accurate, we have all the ingredients necessary for the production of ceramics at Santa Clara and every other mission that made fired-clay bricks and tiles.

PREVIOUS RESEARCH

Chemistry Professor Vance Gritton (Gritton and Tran 1995) of Chapman University measured the chemical similarities between the low-fired earthenwares from four northern California missions using atomic absorption (Gritton and Magalousis 1978). His compositional analysis of these ceramics has led him to conclude that there may have been trade in mission wares between missions San Juan Bautista, San Antonio de Padua, and Santa Cruz. It should be noted that Gritton did not perform any tests on either clay samples or architectural earthenwares from these sites, and any correlations could be due to concentration similarities of the major and minor elements that he quantified, which are grossly similar in clays; or because of the small analytical sample (n = 5 per site). During the summer of 1999, the collections (n = 104 samples) from Mission Santa Clara de Asís were examined using neutron activation analysis, a procedure that has been successfully used to identify the sources of ceramics in other parts of the Americas (e.g., Arnold et al. 1991). It was found that some of the potsherds are chemically identical to bricks and tiles found at the site. This, of course, suggests that the same source of clay was used for both, and that they were both made at Santa Clara. From these initial analyses, sampling has been expanded to incorporate pottery from the mission sites of San Francisco (Dolores), San Jose, Santa Cruz, San Antonio, and San Juan Capistrano; the pueblo of San José; and the presidios of San Francisco, Monterey, and San Diego (Figure 1).

METHODS

The chemical data used in this study are derived from the highly sensitive technique of instrumental neutron activation analysis (INAA). This technique permits many elemental constituents of a ceramic paste to be determined simultaneously with good precision, several being determined at or below the parts-per-million level. This level of sensitivity is often required in order to discover those differences in paste composition that reflect the use of different clay resources within a fairly small geographical area, as well as the specific mixtures of clays and tempering materials that might represent the

Figure 1. Locations of sampled missions and presidios.

'paste recipes' of pottery producers working closely together.

Neutron activation analysis involves the exposure of atomic nuclei in a small sample of the ceramic paste to a source of neutrons. Certain atomic nuclei in the paste capture neutrons and are elevated to a higher energetic state, producing radioactive isotopes. As these energetic radioisotopes decay to stable nuclei, some emit radiation in the form of gamma rays that can be detected, counted, and sorted according to their respective energies, which are specific for the various radioisotopes. By comparing the emissions from the archaeological sample with those from a sample of reference material containing known elemental concentrations, the amount of certain elemental constituents in the unknown ceramic paste can be calculated. Nineteen elemental concentrations are routinely quantified for each sample and have acceptably high analytical precision. All analyses that are part of this study have been carried out at the SCMRE facilities maintained at the National Institute of Standards and Technology.

A total of 725 samples were selected from the mission and presidio sites as potentials for analysis. These specimens were visually analyzed and categorized as to their ware type and method of manufacture at the Santa Clara University Archaeology Research Laboratory. The samples and accompanying data-base were then sent to the Smithsonian Center for Materials Research and Education (SCMRE) where a subset of 503 ceramic samples were selected and prepared for analysis at SCMRE's Nuclear Laboratory for Archaeological Research at the National Institute of Standards and Technology Research Reactor in Gaithersburg, MD. Table 1 lists the samples analyzed in this round of analysis by site and ware type.

Table 1. California mission ceramics analyzed

Total samples analyzed		503
Mission 296	"Mexican" 132	Majolica 75

Site	Mission wares			Mexican Pb glaze	Majolica	Total
	pottery	bricks	tiles			
San Francisco Presidio / Mission Dolores	40	2	9	31	5	88
Mission San Jose	1	1	5	4	6	17
Amesquita Adobe (San Jose)	15	3	2	9	0	29
Mission Santa Clara	73	2	13	14	2	104
Mission Santa Cruz	1	7	0	3	0	11
Monterey San Carlos Cathedral	4	0	7	39	20	72
Mission San Antonio	26	3	7	0	0	36
San Juan Capistrano	48	9	7	23	20	107
San Diego Presidio	3	0	5	9	22	39

The sampling process involved extracting about 1 gram of ceramic material from the edge of the potsherds, bricks (*ladrillos*) and tiles (*tejas*) using a tungsten carbide drill bit. The samples were dried at 105°C for 24 hours, cooled in a desiccator, and nominal 90 mg subsamples taken for analysis. Eighteen samples, 2 comparitor standards (NIST SRM 1633 fly ash), and a check standard (Ohio Red Art Clay), were packaged together and irradiated for 4 hours at a thermal neutron flux of 7.7x1013 n/cm2/sec. in the NIST 20 MW research reactor. Table 2 presents a summery of the experimental parameters, including the 27 elements routinely quantified in ceramics and an estimate of their analytical precision based on the analysis of check standards (Blackman 1986 and Blackman and Bishop 1999).

Table 2. Summary of INAA experimental parameters

Element	Nuclide	Gamma Ray Energy (Kev)	Conc. in Standard SRM 1633	Count	Analytical Precision SRM679
Na	Na-24	1369	0.32 %	1	2.3%
K	K-42	1525	1.61 %	1	8.2%
Ca	Ca-47	1297	4.70 %	1	n.d.
Sc	Sc-46	889	27.0 ppm	2	1.4%
Cr	Cr-51	320	131. ppm	2	3.1%
Fe	Fe-59	1099 & 1292	6.20 %	2	2.9%
Co	Co-60	1173 & 1333	41.5 ppm	2	1.5%
Zn	Zn-65	1115	213. ppm	2	3.5%
As	As-76	559	61.0 ppm	1	6.0%
Br	Br-82	554	8.6 ppm	1	n.d.
Rb	Rb-86	1077	125. ppm	2	9.1%
Sr	Sr-85	514	1700. ppm	2	n.d.
Sb	Sb-122	564	6.9 ppm	1	9.9%
Cs	Cs-134	796	8.6 ppm	2	2.7%
Ba	Ba-131	496	2700. ppm	1	13.2%
La	La-140	1596	82.0 ppm	1	1.4%
Ce	Ce-141	145	146. ppm	2	1.8%
Nd	Nd-147	91	64.0 ppm	2	n.d.
Sm	Sm-153	103	12.9 ppm	1	1.6%
Eu	Eu-152	1408	2.5 ppm	2	2.2%
Tb	Tb-160	879	1.9 ppm	2	12.9%
Yb	Yb-175	396	6.4 ppm	1	4.8%
Lu	Lu-177	208	1.0 ppm	1	6.7%
Hf	Hf-181	482	7.9 ppm	2	3.5%
Ta	Ta-182	1221	1.8 ppm	2	7.0%
Th	Pa-233	312	24.8 ppm	2	2.2%
U	Np-239	106	11.6 ppm	1	15.9%

n.d. not determined

RESULTS

To date 296 unglazed earthernware, 132 lead-glazed, and 75 majolica ceramics have been analyzed. Initial processing of the unglazed earthenware data using cluster analysis revealed an overall pattern of compositional groups unambiguously associated with each individual mission. Additional statistical testing of these groups using Mahalanobis distance and Hotelling's T2 statistic validated these group distinctions. Although few clays have been analyzed from the individual mission sites, it may be inferred that these compositional groups represent local mission production based on the association of brick, tile, and fired adobe samples from each mission with the earthernware pottery from that mission. Similarly distinctive chemical patterns were also present in the samples analyzed from the Presidios of San Diego and Monterey. The only overlap observed for these well-sampled locations is found with the pottery from Mission Dolores and the Presidio of San Francisco, and the samples from Amesquita Adobe in San Jose with both the Santa Clara and San Jose groups.

A binary plot of the concentrations of scandium and chromium that illustrate the compositional distinctiveness of the pottery and architectural earthenwares among several missions is shown in Figure 2. Ellipses have been added to the plot to show the 95 percent confidence interval. Chemical separation of the earthenwares from San Juan Capistrano, San Antonio, Santa Clara and the San Francisco Presidio/Mission Dolores are clearly shown.

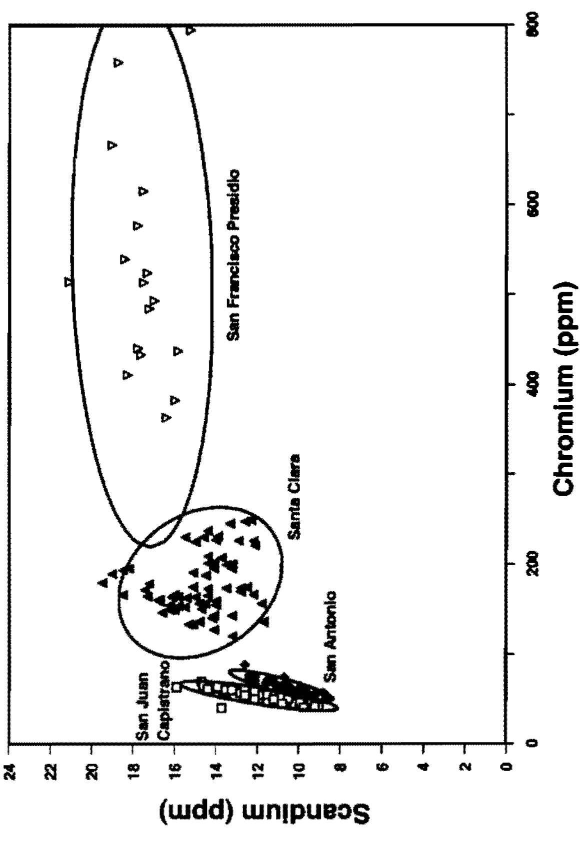

Figure 2. Binary plot of scandium and chromium concentrations at missions San Juan Capistrano, San Antonio, Santa Clara, and the San Fancisco presidio.

The large chromium variation in the San Francisco Presidio/Mission Dolores samples, probably reflecting the presence of particles of chromate in the sand and silt size fractions, forces the other groups closer together. Figure 3, shown without the San Francisco Presidio samples, reveals the separation of the Santa Clara, San Juan Capistrano, and San Antonio groups more clearly. Other combinations of elements serve to separate other locations (e.g., Figure 4).

More can be done with the data already in hand, but a basic finding of local production and consumption of earthenware has been amply demonstrated. Table 3 presents the membership of the compositional groups showing the association of pottery and architectural earthenwares in each mission group. Santa Clara is the only mission, so far examined, where more than a single compositional group was found. Santa Clara 1 is clearly associated with tiles and bricks and represents 63% of the material analyzed from that mission. Santa Clara 2 contains only pottery (22% of the Santa Clara sample) and must be assumed to represent use of a second clay source in the vicinity of the mission. Both the San Jose and Santa Clara 1 mission groups also include samples from Plaza San Antonio and the Amesquita Adobe, a refuse deposit and a home site in the pueblo of San Jose indicating the use of mission made pottery and architectural earthenware at secular habitation sites. Table 4 presents the mean concentrations and coefficients of variation for each of the compositional groups.

Examination of the lead-glazed ceramics added a second dimension to the research. These ceramics were all thought to have been imported from Mexico as the added complexity, expense, and raw material procurement necessities of glazing technology was assumed to be beyond the capacity of mission trained potters. As such, the initial question was from where and from how many workshops in Mexico were these ceramics obtained. While there are suggestions in the data of as many as seven possible compositional groups, it appears that over 55% of the analyzed lead-glazed pottery derives from one major Mexican source. The location of that source is the subject of current investigation. The single most significant finding thus far, however, is evidence for the production of lead-glazed pottery in Alta California. Again with reference to the concentrations of scandium and chromium, Figure 5 displays the 95% confidence ellipses for the San Juan Capistrano, San Antonio and Santa Clara mission earthernware, and the data for the major Mexican lead-glazed group and two smaller lead-glazed groups.

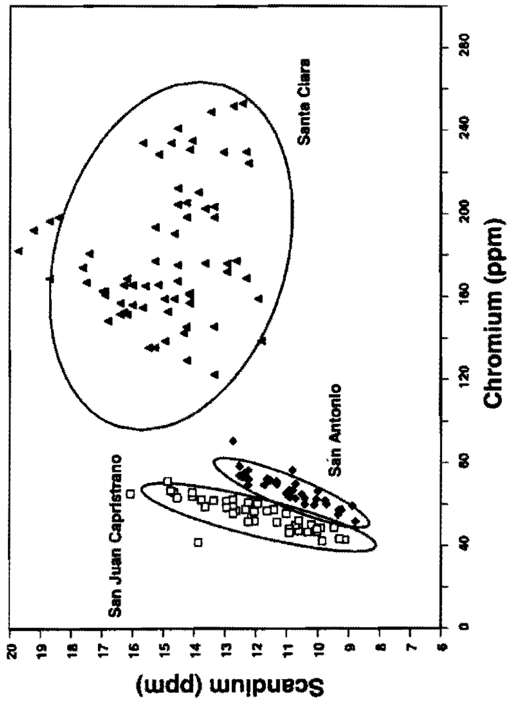

Figure 3. Binary plot of scandium and chromium concentrations at missions San Juan Capistrano, San Antonio, Santa Clara (without San Fancisco presidio samples).

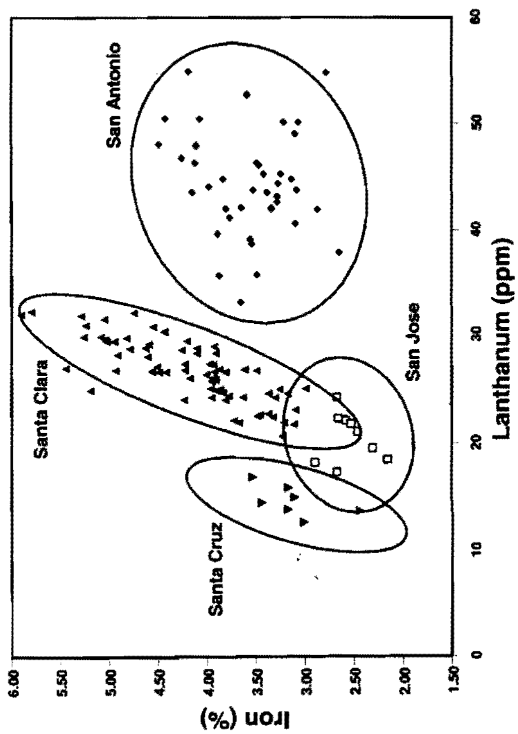

Figure 4. Binary plot of Iron and lanthanum concentrations at missions Santa Cruz, San Jose, Santa Clara, and San Antonio.

Table 3. Mission ceramic compositional groups.

Mission San Juan Capristrano	69%	44
	Ceramics	28
	Tiles	7
	Bricks	9
Mission San Antonio	97%	35
	Ceramics	25
	Tiles	7
	Bricks	3
Mission Santa Clara 1	63%	55
	Ceramics	48
	Tiles	6
	Bricks	1
Amesquita Adobe (San Jose)	80%	35
	Ceramics	25
	Tiles	2
	Bricks	2
Mission Santa Clara 2	22%	19
	Ceramics	19
San Francisco Presidio / Mission Delores	78%	21
	Ceramics	11
	Tiles	8
	Bricks	2
Mission San Jose	80%	6
	Ceramics	1
	Tiles	4
	Bricks	1
Amesquita Adobe	15%	3
	Ceramics	2
	Bricks	1
Mission Santa Cruz	100%	8
	Ceramics	1
	Bricks	7

Table 4. Mean concentrations and coefficients of variation for the four largest mission ceramic compositional groups.

	San Juan Capistrano (N = 49)		**San Antonio (N = 39)**		**Santa Clara (N = 72)**		**San Francisco Presidio (N = 17)**	
Element	Mean	C. V.	Mean	C. V.	Mean	C. V.	Mean	C. V.
Na %	1.44	16.9	1.40	9.8	1.50	13.6	1.80	8.3
K %	1.83	20.0	2.16	13.9	1.64	16.9	0.936	14.6
Sc ppm	12.5	22.6	10.8	10.1	14.7	12.2	17.5	7.8
Cr ppm	54.3	13.7	65.6	11.2	180.	20.8	526.	23.4
Fe %	3.31	19.7	3.57	12.8	4.16	16.6	4.17	7.1
Rb ppm	103.	11.0	103.	13.1	98.1	14.0	46.7	17.3
Cs ppm	4.37	17.4	2.68	13.8	3.77	19.5	2.39	25.6
Ba ppm	749.	24.7	924.	18.8	796.	23.7	516.	38.6
La ppm	28.9	10.6	44.5	11.2	26.7	10.9	22.1	17.2
Ce ppm	54.8	9.1	83.0	18.2	48.3	10.8	43.8	24.0
Nd ppm	23.6	21.5	36.9	11.7	21.1	15.9	20.4	17.7
Sm ppm	4.40	14.1	6.17	12.1	3.94	12.4	3.87	14.0
Eu ppm	0.981	11.3	1.34	7.5	0.973	8.5	1.00	11.2
Tb ppm	0.716	15.9	0.841	13.8	0.657	15.5	0.576	12.0
Yb ppm	2.48	16.2	2.22	17.1	2.01	15.6	2.07	12.5
Lu ppm	0.347	27.1	0.308	26.6	0.280	24.2	0.275	18.0
Hf ppm	7.08	21.1	9.36	16.6	4.06	18.5	6.97	24.3
Ta ppm	0.869	12.8	1.10	11.0	0.784	16.7	0.809	20.6
Th ppm	10.3	10.9	12.6	12.7	9.21	11.7	7.61	15.5

The large lead-glazed earthenware group is clearly distinguishable from the mission groups, and two small groups of four samples each match the earthenware compositions characteristic of San Juan Capistrano and Santa Clara with high probabilities. Those matching the Santa Clara 1 composition were all recovered from Santa Clara Mission and of those matching the San Juan Capistrano composition, three are from San Juan Capistrano and one from the San Diego Presidio. All eight samples have a "red-glaze" finish, in contrast to the commonly occurring brown or green glaze on the pottery from the large lead-glazed group. Table 5 presents the mean concentrations and coefficients of variation for these three lead-glazed compositional groups. It appears that mission potters were also producing lead-glazed ceramics in at least two missions. Although few in number at present, the sample of red-glazed pottery is being expanded to more fully evaluate the compositional relationships and to compare the glaze recipes was well as those of the ceramic bodies.

Beyond the characterization of the ceramic pastes, we have begun to investigate the Pb isotopic ratios of the glazes using lazer ablation ICP-MS. Although still in a preliminary stage of investigation, we can see significant compositional differences between the glazed pottery that was locally produced in Santa Clara or San Juan Capistrano relative to the other so-called "Mexican Glazed pottery." Thus we are finding a covariation between paste and glazing recipes–further attesting to the uniqueness of the production source.

CONCLUSIONS

In conclusion, the initial stage of this research project has shown that all missions, so far examined, appear to have been producing utilitarian pottery to fill their own needs and may have also supplied pottery to near by pueblos and possibly presidios. Further, while the vast majority of more specialized lead-glazed pottery was imported from at least one major production center in Mexico, some small amount was also made at some of the California Missions - Santa Clara and San Juan Capistrano identified to date. It is clear, that a compositionally-based investigation, which is well integrated with more traditional types of archaeological and historical

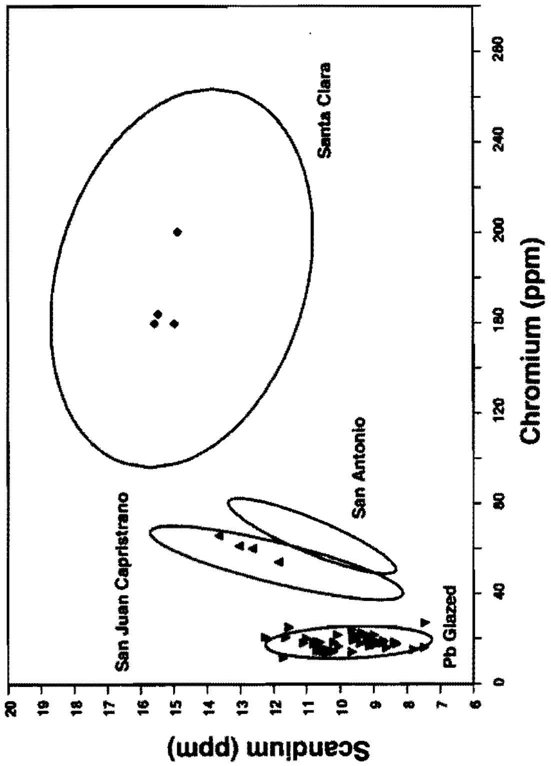

Figure 5. Binary plot of scandium and chromium concentrations for missions San Juan Capistrano, San Antonio and Santa Clara earthernware, and the data for lead-glazed pottery groups.

Table 5. Mean concentrations and coeffiecients of variation for the main Pb glazed group and the two proposed Mission Groups.

	Pb Glazed Group I (Mexican?) (N = 73)		Santa Clara Pb Glazed (N = 4)		San Juan Capistrano Pb Glazed (N = 4)	
Element	Mean	C. V.	Mean	C. V.	Mean	C. V.
Na %	0.787	30.1	1.61	2.6	1.35	20.2
K %	0.464	27.2	1.69	11.6	1.90	12.4
Sc ppm	10.2	12.6	15.2	2.3	12.8	6.0
Cr ppm	17.4	19.3	171.	11.6	61.1	8.0
Fe %	4.08	13.8	4.15	2.1	3.54	6.1
Rb ppm	<10		102.	2.5	111.	1.3
Cs ppm	0.890	14.1	4.15	5.37	4.82	2.8
Ba ppm	738.	21.9	680.	23.1	612.	50.7
La ppm	27.4	11.2	27.0	4.3	28.5	3.7
Ce ppm	45.9	14.6	50.2	4.1	52.6	4.7
Nd ppm	23.8	17.4	22.3	6.6	23.6	9.2
Sm ppm	4.77	14.6	3.34	7.0	4.48	7.9
Eu ppm	1.24	10.5	1.00	2.8	0.994	4.5
Tb ppm	0.649	16.3	0.714	10.1	0.793	17.5
Yb ppm	2.23	16.1	1.99	10.1	2.37	16.9
Lu ppm	0.338	19.8	0.266	16.4	0.343	25.5
Hf ppm	4.82	8.2	4.23	1.9	5.99	7.0
Ta ppm	1.01	15.2	1.12	24.2	0.997	8.6
Tb ppm	3.83	10.3	9.49	4.57	10.9	10.9

data, will provide a wealth of new insights into the organization of local craft production and aspects of larger external trade relationships.

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