Instrumental Neutron Activation Analysis of Palmitopamba Archaeology Project:

Ceramics & Clays

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Introduction

Instrumental neutron activation analysis (INAA) was undertaken on 39 raw clay specimens at the Missouri University Research Reactor Center (MURR). Two reports preceded this one. The first was a preliminary report (Speakman and Glascock 2003) on 56 specimens which included a description of our analytical and statistical procedures. The second report (Descantes et al 2004) included the analytical results of 94 ceramic specimens and 2 clay samples. This third and final report, which replaces the second report, has revisited the group structure of the ceramics and investigated the affinity between the collected clays and the identified ceramic compositional groups.

Results and Conclusion

The original 4-group compositional structure of Palmitopamba, Cosanga, Sierra Inca 1, and Sierra Inca 2 detailed in the second report remained unchanged apart from a few reassignments. Twelve ceramic specimens remain unassigned.

The four compositional groups are visible both in principal component (Figures 1-2) and elemental space (Figures 3-4). Principal component scores were based on a variance-covariance matrix. Seven principal components, which accounted for 91.2% of the variance in the chemical data, were used to statistically test the membership of the ceramic compositional groups.

Generally, a cut-off of 1% was used when deciding membership. Tables 1-5 include the Mahalanobis distance-based probabilities for the memberships of the various groups. Note that because the Sierra Inca 2 group only has four members, it could not be statistically tested as rigorously as the other groups (see Table 4). However, it can be shown to be a distinct compositional group in all of the plots. The membership probabilities of some of the Pamitopamba members in the compositional group of Sierra Inca 1 (see Table 3) are clearly above 1%, but graphically, unequivocally have membership in the Palmitopamba group; this may be related to the relatively small sample size of Sierra Inca 1.

The Cosanga (n=26) compositional group is enriched in rare earth elements compared to the three other groups, which is characteristic of mica-tempered pottery (Figure 1). The Palmitopamba (n=41) compositional group, on the other hand, whose ceramic members are tempered with predominantly with sand and grit, is depleted in the rare earth elements when compared to the other groups. Sierra Inca 1 (n=11) and Sierra Inca 2 (n=4) are compositionally intermediate in their elemental abundances compared to the Palmitopamba and the Cosanga compositional groups. Both Sierra Inca groups are also enriched in the alkaline earth metal element of calcium and the alkali metal sodium. We hypothesize that these four compositional groups represent different clay sources.

The provenance exercise of investigating the affinity between the 41 clays and the four compositional groups produced meaningful results (Table 6; Figures 4-5). Graphically and statistically, the submitted raw clay specimens most resemble ceramics belonging to the Sierra Inca 1 compositional group with several clays exhibiting more than a 10% probability of membership (see Table 6). These results do not reject the hypothesis that the Sierra Inca 1 and Sierra Inca 2 sherds originate from ceramic vessels made with local clays. As stated in the previous reports, we still believe that the Cosanga ceramics are made with exotic clays, and represent ceramics likely made elsewhere whereas the Palmitopamba ceramics likely originate from a local industry using clays that are yet to be identified. We suggest that comparing the locations of the clays and ceramics with high probabilities of membership in the Sierra Inca 1 compositional group will provide interesting insights.

Given that the local ceramics are tempered (that is diluted) with sands, we simulated a hypothetical tempering exercise on the clay samples with sands from the Southwest of the United States to examine how the probabilities of membership might change. An arbitrary tempering concentration of just 30% sands increased the probability that several of the submitted clays have membership in the Sierra Inca 1 compositional group (see Table 7; Figure 6). If you are interested in continuing this avenue of research, we recommend that you consider submitting sands from the region, not to mention clays of a different origins for insights into the production of Palmitopamba and Sierra Inca 2 ceramics.

The spatial, temporal, typological, and compositional relationships described in the second report still hold. All but one (RDL003) of the Cosanga type-sorted ceramics are members of the Cosanga compositional group. Similarly, all of the Yumbo-typed ceramic specimens have membership in the Palmitopamba composition group and were all collected from the site of Palmitopamba except for one specimen (RDL082) which has membership in the Sierra Inca 1 group. In contrast, Cosanga pottery is more geographically widespread, denoting exchange of ceramics. The Sierra Inca 1 ceramics were collected from a diversity of sites; the sample of Sierra Inca 2 ceramics assayed were collected from the sites of Milin Pujili, Azuajatu, and Quitoloma. Finally, all but one (RDL082) of the ceramic members with memberships in the Sierra Inca compositional groups were collected from post-fifteenth century contexts.

In summary, the chemical distinctions between the ceramics submitted are unambiguous; there is a clear four group structure to the data. Based on chemical compositional grounds, we can unequivocally state some of the submitted clay samples definitely resemble the clays that potters used to fabricate Sierra Inca 1 ceramics. A hypothetical sand-tempering exercise with resembling the local ceramics enforced our hypothesis that local clays were used to make Sierra Inca 1 ceramics. We hope you find these results interesting and urge you to consider publishing the results of the data generated so far.

References Cited

Descantes, C. H., R. J. Speakman and M. D. Glascock
2004 *Instrumental Neutron Activation Analysis of Palmitopamba Archaeology Project Ceramics*. Missouri University Research Reactor Center, Columbia, Missouri.

R. J. Speakman and M. D. Glascock
2003 *Instrumental Neutron Activation Analysis of Ceramics and Clays for the Palmitopamba Archaeology Project, Ecuador*. Missouri University Research Reactor Center, Columbia, Missouri.

Acknowledgments

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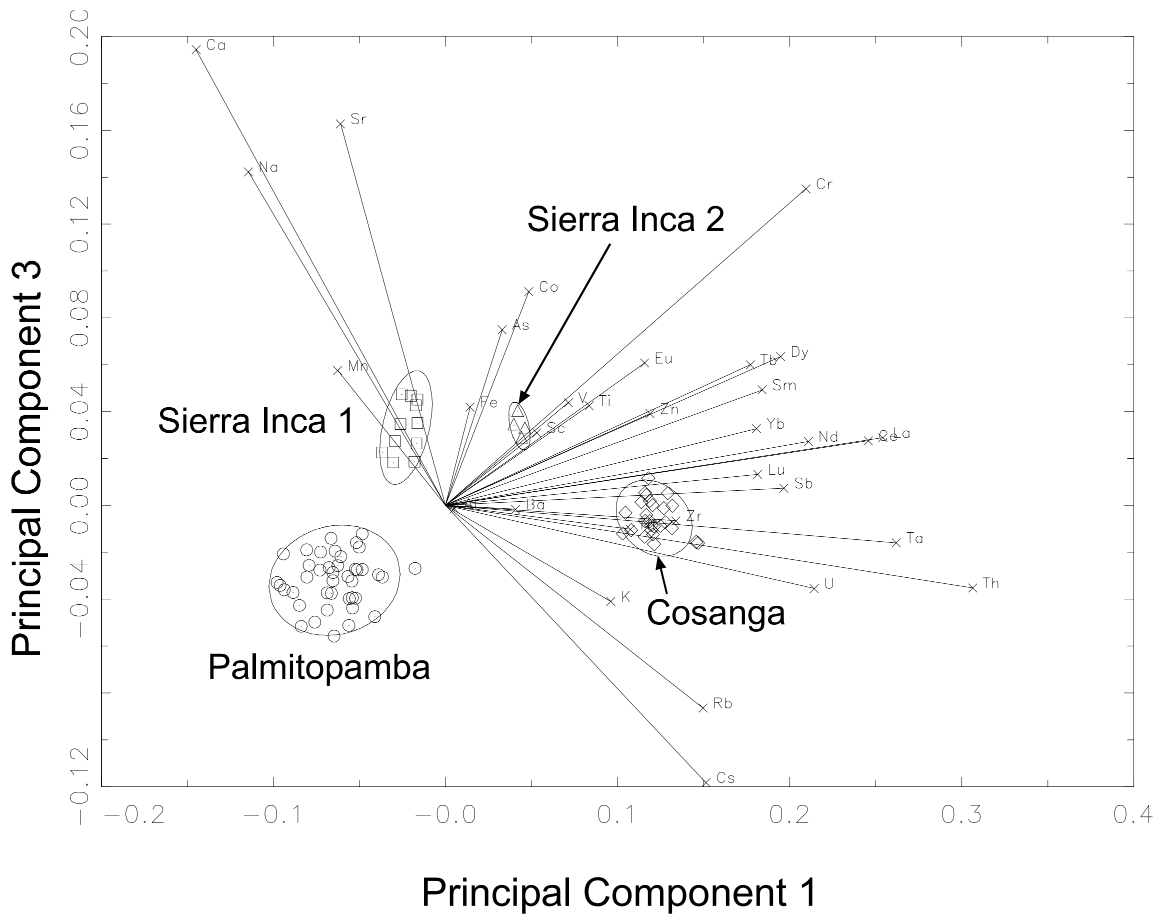

Figure 1: Biplot of principal components 1 and 3 displaying the four compositional groups. Ellipses represent 90% confidence level for membership in the groups. Vectors denote elemental influences on the ceramic data. Unassigned samples are not shown.

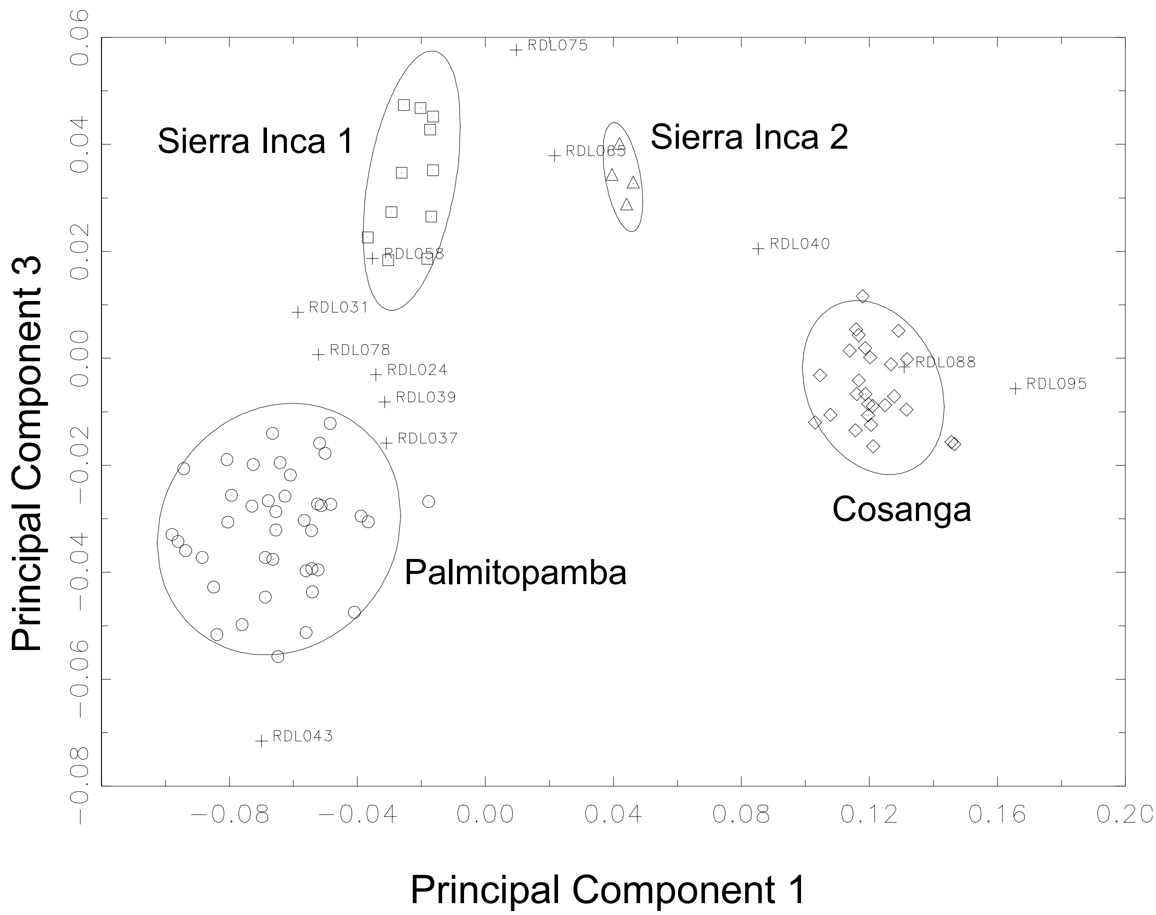

Figure 2: Bivariate plot of principal components 1 and 3 displaying the four compositional groups and unassigned (+) specimens. Ellipses represent 90% confidence level for membership in the groups.

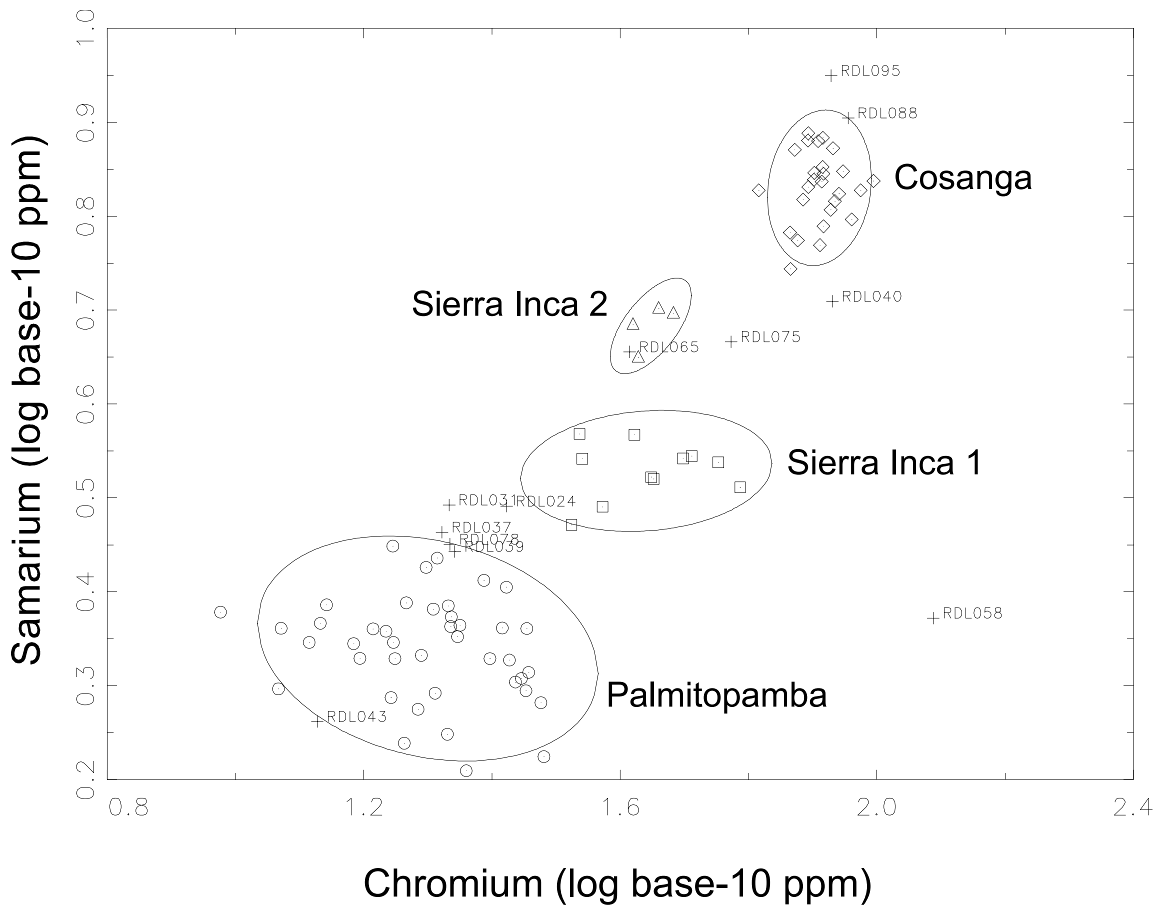

Figure 3: Bivariate plot of base-10 logged chromium and samarium concentrations showing the four compositional groups and unassigned (+) specimens. Ellipses represent 90% confidence level for membership in the groups.

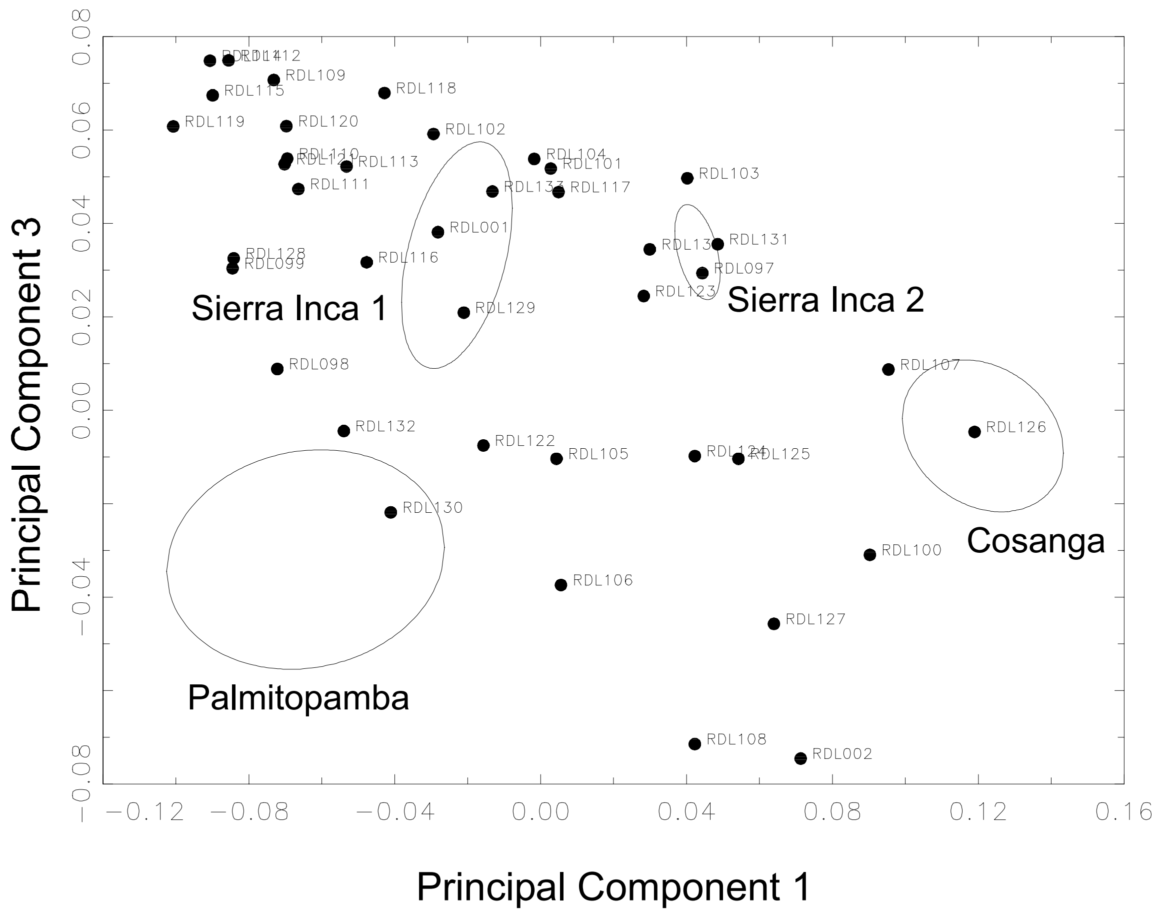

Figure 4: Bivariate plot of principal components 1 and 3 showing the four ceramic compositional groups and raw clay samples (labeled). Ellipses represent 90% confidence level for membership in the groups. Unassigned samples are not shown.

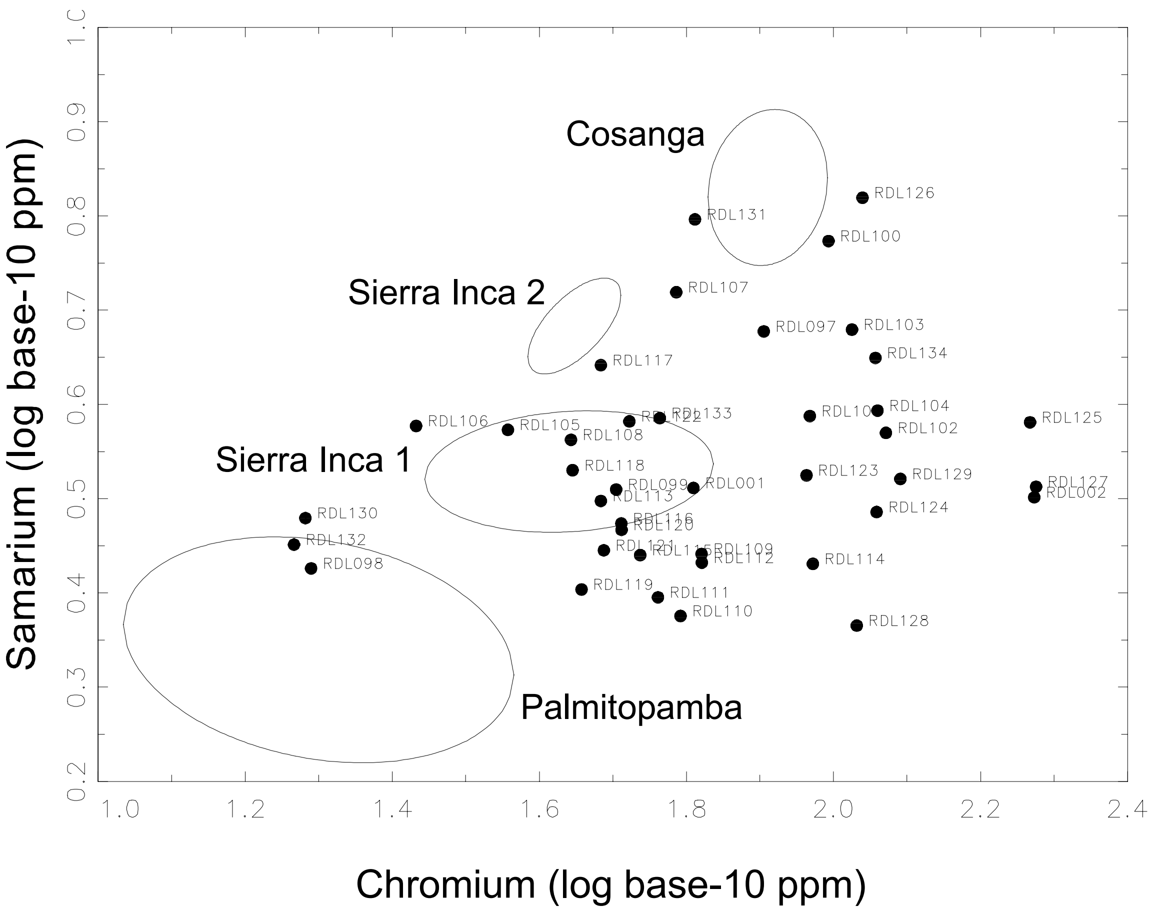

Figure 5: Bivariate plot of base-10 logged chromium and samarium concentrations showing the four ceramic compositional groups and raw clay samples (labeled). Ellipses represent 90% confidence level for membership in the groups. Unassigned samples are not shown.

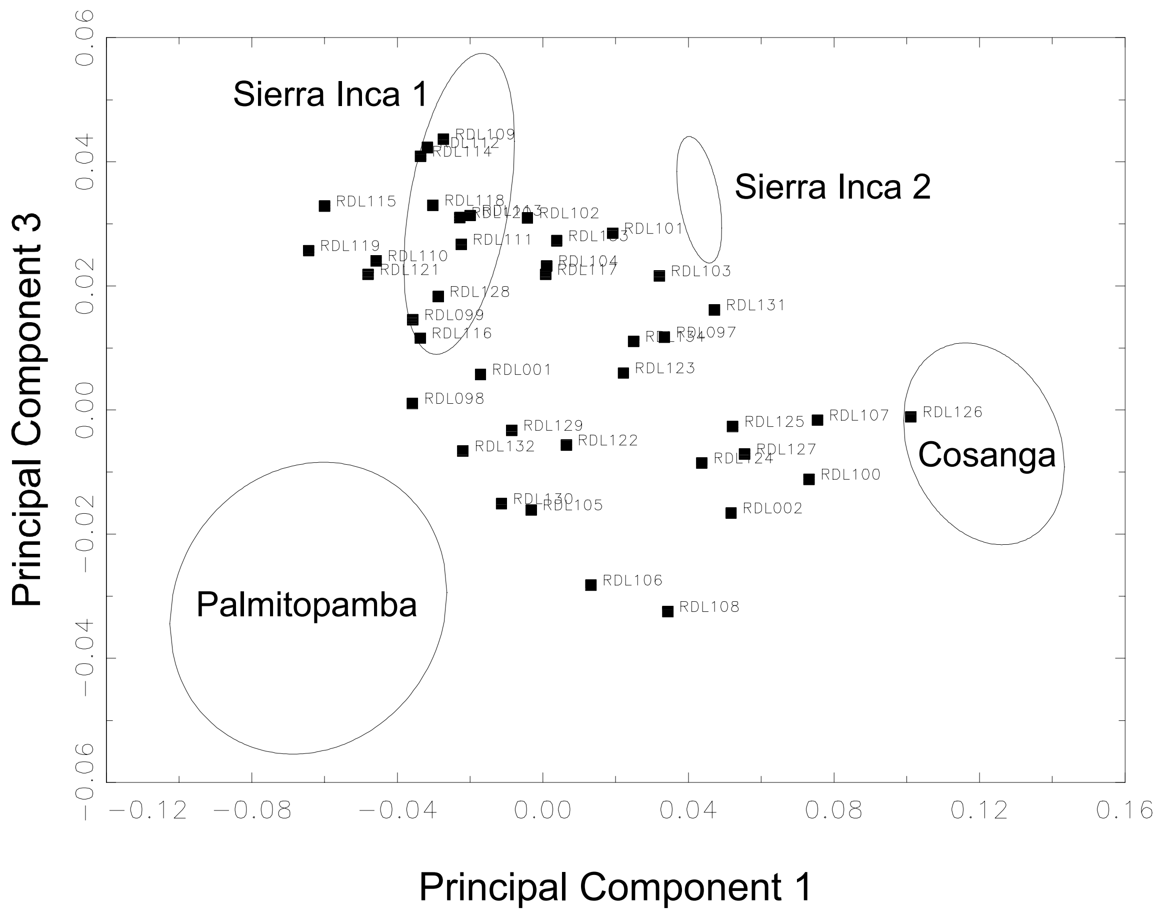

Figure 6: Bivariate plot of principal components 1 and 3 showing the four compositional groups with the 30% tempered clays (labeled). Ellipses represent 90% confidence level for membership in the groups.

Table 1. Mahalanobis Distance Calculation and Posterior Classification for Cosanga Compositional Group Members. Probabilities are jackknifed for specimens included in each group (seven principal components used).

ID. NO.	Palmitopamba	Sierra Inca 1	Cosanga
RDL004	0.000	0.042	60.269
RDL005	0.000	0.046	42.096
RDL006	0.000	0.030	29.863
RDL007	0.000	0.029	83.232
RDL008	0.000	0.028	54.431
RDL009	0.000	0.030	87.805
RDL010	0.000	0.041	24.203
RDL011	0.000	0.042	36.356
RDL012	0.000	0.023	40.656
RDL013	0.000	0.024	54.253
RDL014	0.000	0.028	45.130
RDL015	0.000	0.020	53.352
RDL016	0.000	0.032	95.321
RDL017	0.000	0.031	28.074
RDL083	0.000	0.021	12.339
RDL084	0.000	0.021	19.572
RDL085	0.000	0.028	67.663
RDL086	0.000	0.020	10.611
RDL087	0.000	0.030	21.355
RDL089	0.000	0.037	2.794
RDL090	0.000	0.020	46.481
RDL091	0.000	0.035	21.147
RDL092	0.000	0.035	98.963
RDL093	0.000	0.032	53.252
RDL094	0.000	0.033	95.942
RDL096	0.000	0.036	74.047

Table 2. Mahalanobis Distance Calculation and Posterior Classification for Sierra Inca 1 Compositional Group Members. Probabilities are jackknifed for specimens included in each group (seven principal components used).

ID. NO.	Palmitopamba	Sierra Inca 1	Cosanga
RDL054	0.010	32.955	0.000
RDL055	0.016	74.384	0.000
RDL057	0.005	65.227	0.000
RDL068	0.001	84.325	0.000
RDL069	0.000	49.646	0.000
RDL071	0.070	34.694	0.000
RDL072	0.029	78.205	0.000
RDL073	0.000	77.841	0.000
RDL074	0.000	59.923	0.000
RDL076	0.000	19.017	0.000
RDL082	0.015	1.918	0.000

Table 3. Mahalanobis Distance Calculation and Posterior Classification for Palmitopamba Compositional Group Members. Probabilities are jackknifed for specimens included in each group (seven principal components used).

ID. NO.	Palmitopamba	Sierra Inca 1	Cosanga
RDL003	3.168	0.188	0.000
RDL018	18.282	0.517	0.000
RDL019	16.868	0.232	0.000
RDL020	18.657	0.243	0.000
RDL021	98.380	1.630	0.000
RDL022	32.255	0.520	0.000
RDL023	51.025	0.959	0.000
RDL025	88.523	0.920	0.000
RDL026	44.436	2.052	0.000
RDL027	31.014	2.056	0.000
RDL028	40.154	1.292	0.000
RDL029	77.396	9.378	0.000
RDL030	40.165	3.034	0.000
RDL032	28.689	15.511	0.000
RDL033	18.443	0.677	0.000
RDL034	46.819	0.797	0.000
RDL035	65.816	8.004	0.000
RDL036	58.004	14.387	0.000
RDL038	78.114	3.887	0.000
RDL041	3.113	0.550	0.000
RDL042	90.100	0.924	0.000
RDL044	11.453	3.358	0.000
RDL045	78.960	2.610	0.000
RDL046	77.883	3.972	0.000
RDL047	16.273	2.949	0.000
RDL048	94.388	2.280	0.000
RDL049	41.028	1.041	0.000
RDL050	33.006	4.897	0.000
RDL051	6.180	1.266	0.000
RDL052	94.522	1.568	0.000
RDL053	67.637	13.546	0.000
RDL056	4.502	0.275	0.000
RDL059	81.396	2.122	0.000
RDL060	95.977	5.792	0.000
RDL061	61.647	7.821	0.000
RDL062	85.610	3.635	0.000
RDL063	77.566	2.198	0.000
RDL077	14.512	0.485	0.000
RDL079	86.113	3.243	0.000
RDL080	45.939	0.541	0.000
RDL081	26.220	1.867	0.000

Table 4. Mahalanobis Distance Calculation and Posterior Classification for Sierra Inca 2 Compositional Group Members (seven principal components used).

ID. NO.	Palmitopamba	Sierra Inca 1	Cosanga
RDL064	0.000	0.964	0.000
RDL066	0.000	0.530	0.000
RDL067	0.000	0.785	0.000
RDL070	0.000	0.539	0.000

Table 5. Mahalanobis Distance Calculation and Posterior Classification for Unassigned Ceramic Specimens (seven principal components used).

ID. NO.	Palmitopamba	Sierra Inca 1	Cosanga
RDL024	2.608	7.768	0.000
RDL031	0.041	4.704	0.000
RDL037	14.321	17.011	0.000
RDL039	33.396	43.055	0.000
RDL040	0.000	0.013	0.000
RDL043	0.012	1.914	0.000
RDL058	0.000	5.833	0.000
RDL065	0.000	2.506	0.000
RDL075	0.000	1.827	0.000
RDL078	13.764	20.698	0.000
RDL088	0.000	0.035	0.301
RDL095	0.000	0.012	1.641

Table 6. Mahalanobis Distance Calculation and Posterior Classification for Raw Clay Specimens (seven principal components used).

ID. NO.	Palmitopamba	Sierra Inca 1	Cosanga
RDL001	0.001	9.636	0.000
RDL002	0.000	0.022	0.000
RDL097	0.000	0.098	0.000
RDL098	0.893	2.140	0.000
RDL099	0.000	0.168	0.000
RDL100	0.000	0.026	0.000
RDL101	0.000	0.926	0.000
RDL102	0.000	17.564	0.000
RDL103	0.000	0.142	0.000
RDL104	0.000	2.425	0.000
RDL105	0.001	1.406	0.000
RDL106	0.000	1.230	0.000
RDL107	0.000	0.013	0.000
RDL108	0.000	0.086	0.000
RDL109	0.000	4.591	0.000
RDL110	0.000	9.776	0.000
RDL111	0.000	10.797	0.000
RDL112	0.000	2.037	0.000
RDL113	0.001	18.502	0.000
RDL114	0.000	0.687	0.000
RDL115	0.000	0.637	0.000
RDL116	0.000	17.736	0.000
RDL117	0.000	1.371	0.000
RDL118	0.000	7.474	0.000
RDL119	0.000	0.535	0.000
RDL120	0.000	7.594	0.000
RDL121	0.000	6.994	0.000
RDL122	0.000	4.580	0.000
RDL123	0.000	0.330	0.000
RDL124	0.000	0.104	0.000
RDL125	0.000	0.052	0.000
RDL126	0.000	0.027	0.000
RDL127	0.000	0.025	0.000
RDL128	0.000	2.268	0.000
RDL129	0.000	0.884	0.000
RDL130	0.001	8.163	0.000
RDL131	0.000	0.390	0.000
RDL132	0.808	3.096	0.000
RDL133	0.001	1.505	0.000
RDL134	0.000	0.336	0.000

Table 7. Mahalanobis Distance Calculation and Posterior Classification for Tempered Raw Clay Specimens (seven principal components used).

ID. NO.	Palmitopamba	Sierra Inca 1	Cosanga
RDL001	2.061	24.088	0.000
RDL002	0.000	0.196	0.000
RDL097	0.004	0.288	0.000
RDL098	1.133	20.700	0.000
RDL099	0.001	1.954	0.000
RDL100	0.000	0.101	0.000
RDL101	0.001	1.383	0.000
RDL102	0.001	26.339	0.000
RDL103	0.004	0.410	0.000
RDL104	0.005	5.370	0.000
RDL105	0.019	4.303	0.000
RDL106	0.005	1.694	0.000
RDL107	0.000	0.032	0.000
RDL108	0.001	0.371	0.000
RDL109	0.000	72.350	0.000
RDL110	0.006	61.485	0.000
RDL111	0.001	63.978	0.000
RDL112	0.000	73.839	0.000
RDL113	0.006	88.056	0.000
RDL114	0.000	28.742	0.000
RDL115	0.004	5.074	0.000
RDL116	0.003	28.485	0.000
RDL117	0.017	4.872	0.000
RDL118	0.005	31.226	0.000
RDL119	0.025	4.808	0.000
RDL120	0.009	54.674	0.000
RDL121	0.156	42.764	0.000
RDL122	0.000	3.529	0.000
RDL123	0.059	0.916	0.000
RDL124	0.003	0.254	0.000
RDL125	0.000	0.159	0.000
RDL126	0.000	0.068	0.000
RDL127	0.000	0.136	0.000
RDL128	0.000	22.389	0.000
RDL129	0.015	1.779	0.000
RDL130	0.042	5.876	0.000
RDL131	0.000	0.681	0.000
RDL132	0.244	11.059	0.000
RDL133	0.004	2.588	0.000
RDL134	0.003	0.925	0.000