BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

CHEMISTRY DEPARTMENT
Informal Report

ACTIVATION ANALYSIS STUDY OF PRECLASSIC CERAMICS FROM THE
CAPACHA PHASE (COLIMA) AND EL OPENO (MICHOACAN)

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Several years ago, as a result of correspondence with Dr. Isabel Kelly, we undertook the analysis of two groups of Preclassic sherds from West Mexico, dating to the Formative Period, ca. 1500 B.C. Although these sherds were found in geographically widely separated contexts, they were considered by the archaeologists, Drs. Kelly and Oliveros, to be remarkably similar stylistically. The question was posed whether, by neutron activation analysis, we could establish (or contradict) a possible common clay source origin. The sherds and their proveniences are given in Table 1.

The activation data were originally obtained about two years ago and an interim report to Dr. Kelly in the form of a letter (June 11, 1971) noted that the Colima sherds KE 01, 02, 03, 04, 05, 06, 08, 11 and 12 were similar, while KE 07 and 09 were different (though not much different). Among the Opeño sherds only OP 01 showed any similarity to any of the Colima sherds, and then only to KE 07 and 09. The technique used for matching the compositional profiles was that reported in Abascal et al.¹ — the Potplot-Potstat technique, which depends to some extent on subjective impressions, backed up by statistical analyses.

We have now reexamined the data, making use of the numerical taxonomy program "NADIST"² which generates a matrix of mean Euclidean distance coefficients³ between all possible pairs of samples. The relevant matrix is presented in the appendix. We also employed a second new technique, the scandium-iron correlation (ratio) index, based on our observation that both in the Middle East⁴ and in some portions of Mesoamerica⁵ the scandium and iron in pottery clays tend to be highly correlated with one another, i.e., the concentrations of scandium and iron obey the equation

Table 1

<u>Site</u>	<u>BNL Number</u>	<u>Oliveros-Kelly Provenience, and Dr. Kelly's Comments</u>
El Opeño	OP 01	Tr. 3 (trinchera 3) C-III (Capa III)
	OP 02	" "
	OP 03	Tumba 3
	OP 04	Tr. 3 C III
Villa de Alvarez, Col.	KE 01	8189. Terreno de Jesús Gutiérrez, Villa de Alvarez, Col. Surface, rifled Capacha from rifled burial.
Buena Vista, Col.	KE 02	8207 f. El Barrigón, Buenavista, Col. Surface, rifled Capacha cemetery.
Comala, Col.	KE 03	9610. La Parranda A, Comala, Col. Burial D (designation probably to be changed to Burial #4).
La Cañada, Col.	KE 04	9624. * La Cañada, Comala, Col. Surface, looted Capacha cemetery. Sherd from a painted and incised vessel, whose ornament suggests relationship to Opeño, Mich.
La Cañada, Comala, Col.	KE 05	9626. La Cañada, Comala, Col. Surface, same looted Capacha cemetery. Sherd from another painted and incised vessel which might relate to Opeño.
La Capacha, Col.	KE 06	9652. La Capacha, Col. Panteón de los bules, Pit A. This fragment was packed with sherds from a semi-restorable, cataloged as 9652; it apparently does not belong to that vessel, although included here under the original catalog number.
Caután, Col.	KE 07	9743. * Quintero, Caután, Col. Sherd from a restorable, stirrup mouth vessel. Burial association uncertain. Found immediately beneath the head of Burial #2, but probably belonged to Burial #3 or #4, both of which were adjacent to the vessel and at the same level. This is the only stirrup mouth I've seen from Comala and <u>might</u> be a trade piece.
La Cañada, Comala, Col.	KE 08	9894 F. * La Cañada, Comala, Col. Southeast extension of East extension.
Caután, Col.	KE 09	9918 b. Quintero, Caután, Col. General digging. Sherd which is both smoked and weathered; fine paste suggests non Capacha affiliations. A bare possibility it may relate to one of the Opeño specimens.
Caután, Col.	KE 10	9918 a.* Quintero, Caután, Col. In ornament, this sherd resembles Capacha, likewise one of the Opeño sherds. Otherwise, it does not fit into the Capacha series because of its thinness and red paste. The latter may link it to a later, local horizon, yet well defined.
Comala, Col.	KE 11	9882. d. La Parranda A, Comala, Col. Pit #5.
La Cañada, Comala, Col.	KE 12	9894 g La Cañada, Comala, Col. Southeast extension of East extension. Apparently rose-colored version of Capacha monochrome.

* Sample used up

Table 1

BNL Number	Oliveros-Kelly Provenience, and Dr. Kelly's Comments
OP 01	Tr. 3 (trinchera 3) C-III (Capa III)
OP 02	" "
OP 03	Tumba 3
OP 04	Tr. 3 C III
Alvarez, KE 01	8189. Terreno de Jesús Gutiérrez, Villa de Alvarez, Col. Surface; from rifled burial.
Col. KE 02	8207 f. El Barrigón, Buenavista, Col. Surface, rifled Capacha cemetery.
KE 03	9610. La Parranda A, Comala, Col. Burial D (designation probably to be changed to Burial #4).
Col. KE 04	9624. * La Cañada, Comala, Col. Surface, looted Capacha cemetery. Sherd from a painted and incised vessel, whose ornament suggests relationship to Opeño, Mich.
Comala, KE 05	9626. La Cañada, Comala, Col. Surface, same looted Capacha cemetery. Sherd from another painted and incised vessel which might relate to Opeño.
Col. KE 06	9652. La Capacha, Col. Panteón de los bules, Pit A. This fragment was packed with sherds from a semi-restorable, catalogued as 9652; it apparently does not belong to that vessel, although included here under the original catalog number.
KE 07	9743. * Quintero, Caután, Col. Sherd from a restorable, stirrup-mouth vessel. Burial association uncertain. Found immediately beneath the head of Burial #2, but probably belonged to Burials #3 or #4, both of which were adjacent to the vessel and at the same level. This is the only stirrup mouth I've seen from Colima and <u>might</u> be a trade piece.
Comala, KE 08	9894 F. * La Cañada, Comala, Col. Southeast extension of East pit.
KE 09	9918 b. Quintero, Caután, Col. General digging. Sherd which is both smoked and weathered; fine paste suggest non Capacha affiliations. A bare possibility it may relate to one of the Opeño specimens.
KE 10	9918 a.* Quintero, Caután, Col. In ornament, this sherd resembles Capacha, likewise one of the Opeño sherds. Otherwise, it does not fit into the Capacha series because of its thinness and fine red paste. The latter may link it to a later, local horizon, not yet well defined.
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$$[\text{concentration of Sc}_2\text{O}_3, \text{ ppm}] = K[\text{concentration of Fe}_2\text{O}_3, \%]$$

The index K, expressing this proportionality, has been found to be quite characteristic of homogeneous classes of pottery, and in some cases of broad geographic areas (for example, along the Tigris River⁴), but varies as one moves to other pottery groups or geographic areas. (One should note that K is not the true ratio of $\text{Sc}_2\text{O}_3/\text{Fe}_2\text{O}_3$ but rather 10000 times that ratio.)

Experimental

The experimental procedure used in the sampling, neutron bombardment, counting, calibration and data processing were as described in Abascal et al.¹

Results

The concentrations of the different oxides determined are listed in the Appendix. The appearance of a zero value merely means that the element listed was not determined. The data in this table formed the input to the program "NADIST".

Numerical Taxonomy

The matrix of distances (see Matrix 1) is actually a triangular array of numbers, arranged so that each row refers to specific sample, while the entries to its right in the row are the "distances", i.e., mean Euclidean distances³ between that sample and each succeeding sample. For example, the "distance" between KE 01 and KE 02 is 0.27628, between KE 01 and KE 10 0.39075, between KE 08 and OP 02 0.60146 etc. Note that each distance refers to a pair of samples, and every possible pair is covered.

The distances are the smaller, the closer the match between samples. We may make a rough table of correspondences.

Table 2

Distance	Degree of similarity of paste
0.000	identical samples
0-0.100	almost certainly same clay, highly similar paste
0.100-0.150	very probably same origin
0-about 0.25	may usually be taken as a trial group
0.250-0.300	questionable as to similarity, "grey area"
greater than 0.300	probably not from the same source

This table should not, of course, be used for making decisions rigidly as to group membership. Obviously, other factors must be considered as well as distances.

An examination of Matrix 1 shows that there are a number of "short distances" among the Colima samples. For example

	distance
KE 01 - KE 12	0.14078
KE 03 - KE 05	0.17589

These short distances often seemed to include, as one member of the pair, KE 03, 04, 05, 08, 09 and 11, therefore these were "clustered" to make a trial group, called TGKB

TGKB = samples 03,04,05,08,09,11

Similarly, since DE 01 and 12 were close together, they were called TGKA

TGKA = sample KE 01 and 12.

Finally, all the above were clustered to make a slightly broader combined trial group, TGKC

$$TGKC = TGKA + TGKB$$

We shall return to these trial groups in a moment. At this point it should also be noted that the distances from any of the 12 Colima sherds to any of the El Opeño sherds, tend to be quite large (Matrix 1). The shortest such intergroup distance is KE 09-OP 01 = 0.30316, already in the "grey area". Note also that, of the two Opeño sherds, only 03 and 04 are very similar (distance = 0.21788) to each other.

Let us now consider the trial groups. If we average the concentrations of the different chemical elements over the members of the trial group we can arrive at a kind of "group average" (actually, geometric mean) in sodium, iron, cobalt, etc. and we can treat this group average as though it were a sample, for distance purposes. Thus we can calculate the distance between, for example

$$TGKA-KE\ 01 = 0.07001$$

$$TGKB-OP\ 03 = 0.38120$$

etc.

See Matrix 2.

We first notice in Matrix 2 that TGKA is close to TGKB (dist. = 0.24651) and therefore we may forget about them as separate groups — let us call them subgroups and combine them into TGKC — the broad Capacha-Colima group.

We may now examine the distances between the centroid of TGKC (the average of all the Colima sherds except KE 02, 06, 07 and 10) and all the others: see Row 3 "TGKC" of Matrix 2. We first note that the distance to all the Opeño sherds is large: therefore no Opeño sherd can be a member of Capacha TGKC. We note again that KE 02, 06, 07 and 10 are

at greater distances from TGKC than the individual members of that group, and further no one of the four KE 02, 06, 07, 10 is very close to any other one. Some of these relationships are indicated graphically in Fig. 1, where distances from TGKB and TGKC are shown: note that this is not a cluster diagram but only shows distance from the particular centroid points TGKB and TGKC. Thus, although KE 06 and KE 07 are at about the same distance from TGKC, they are actually quite far (dist = 0.46610) from each other. One can say that Oaxaca and Puebla are about the same distance from Vera Cruz, but that does not make them close to each other!

The measurement of distance between multivariate data points, that is, the Euclidean distance between points in n-dimensional space, is a form of Q-mode numerical taxonomy. We now turn to the inverse, or R-mode technique which seeks to correlate attributes (i.e. element concentrations) within a given group.⁶ As mentioned above, we find that certain element ratios tend to be characteristic of pottery types or, in some cases, of clays from a geographic region.

In Table 3 we give the Sc/Fe ratios (as defined above).

It is interesting that, considering the Sc/Fe ratios, the members of TGKC again form a "tight" group. Likewise, the other four Colima sherds are distinctly different, as we had inferred from the distances. And note the great discrepancy between the Opeño sherds and TGKC, especially OP 01, which was not too far from KE 09 on the basis of distance (= 0.30316). Note also the similarity between OP 03 and OP 04.

Conclusion

The activation analysis data yield evidence for paste similarity among eight of the twelve Colima sherds from the Capacha phase, submitted by Dr. Isabel Kelly. But none of the Colima sherds appears to be related

Table 3
Scandium-Iron Ratios in Sherds

Samples	Sc/Fe*
Ke 01	5.07
KE 03	4.98
KE 04	4.93
KE 05	4.91
KE 08	4.96
KE 09	5.06
KE 11	4.84
KE 12	5.17
<hr/>	
Average (= TGKC)	4.99 $\pm$ 0.11 (Group standard deviation)
KE 02	5.52
KE 06	4.02
KE 07	4.72
KE 10	4.20
OP 01	3.73
OP 02	4.29
OP 03	4.63
OP 04	4.53

* Defined as $10000 \times [\text{Sc}_2\text{O}_3]/[\text{Fe}_2\text{O}_3]$

by clay source to any of the Opeño material. We must conclude that there is no evidence here for "trade pieces", either from Opeño to Colima, or vice versa, or from a third place to both. We are left with "local origin" as the most likely (though unproven) possibility.

References

1. Correlation between Terra Cotta Figurines and Pottery from the Valley of Mexico and Source Clays by Activation Analysis. R. Abascal-M., G. Harbottle and E. V. Sayre. Fifth Symposium on Archaeological Chemistry, American Chemical Society, Dallas, Texas, April 9-10, 1973.
2. NADIST, program for calculating Euclidean distance and mean character difference, written by A. M. Bieber, Jr. This program converts the concentrations to natural logs before calculating distances.
3. Principles of Numerical Taxonomy, R. R. Sokal and P. H. A. Sneath, W. H. Freeman, San Francisco (1963), p. 147.
4. Biblical Studies through Activation Analysis of Ancient Pottery. D. Brooks, A. M. Bieber, Jr., G. Harbottle and E. V. Sayre. Fifth Symposium on Archaeological Chemistry, American Chemical Society, Dallas, Texas, April 9-10, 1973.
5. Scandium and iron are highly correlated in the Mayan X, Y, and Z fine orange pastes. G. Harbottle (unpublished).
6. Sokol and Sneath, op. cit., p. 207.

KE01	,27628	,21757	,30563	,32471	,25322	,43349	,22855	,34133	,39075	,28530	,14078	,47260	,62367	,39211	,736530
KE02	,33009	,35140	,39554	,47925	,51350	,25707	,35514	,48205	,40815	,25577	,42156	,54113	,44251	,40370	
KE03	,23898	,17589	,35662	,37942	,20291	,37813	,42550	,15477	,25290	,50101	,69725	,40236	,41041		
KE04	,18808	,33986	,29555	,19734	,18178	,31223	,15357	,28742	,34511	,55043	,39835	,44441			
KE05	,30205	,33413	,22507	,27756	,37000	,14409	,33652	,47484	,74435	,43655	,48305				
KE06	,46610	,33471	,38717	,41096	,28041	,30980	,48594	,67916	,48657	,42300					
KE07	,35804	,29006	,39902	,32279	,43827	,42568	,71259	,47801	,54870						
KE08	,26173	,35429	,22848	,22051	,39085	,60146	,37737	,34460							
KE09	,20977	,30210	,28531	,30316	,60394	,45800	,48101								
KE10	,35831	,28547	,47717	,75114	,52613	,53670									
KE11	,30060	,45150	,69407	,36263	,42151										
KE12	,44755	,61561	,40895	,35831											
OF01	,44116	,44935	,47627												
OF02	,38479	,41637													
OF03	,21788														

MATRIX 1

UPPER RIGHT OFF-DIAGONAL MATRIX OF MEAN EUCLIDEAN DISTANCES BETWEEN SAMPLES

MATRIX 2

TGKA	.24851 .61590	.17854 .39403	.07301 .35496	.25654	.22498	.28836	.32151	.28825	.43071	.21334	.30074	.33481	.28442	.07078	.45539
TGKB	.06816 .38120	.25798 .40820	.32790	.16409	.09807	.11978	.30383	.29491	.14070	.21842	.32324	.11574	.25249	.39327	.65831
TGKC	.19488 .37871	.28939	.14544	.13170	.16506	.29405	.31781	.12133	.23757	.32326	.14122	.18070	.39450	.63628	.37955

APPENDIX

06/05/73

LISTING OF CAPACHA PHASE COLIMA AND EL OPENO SHEED ANALYSES

CONCENTRATIONS OF OXIDES IN PARTS PER MILLION*

SPECIMEN	NA2O	K2O PERCENT	RB2O	CS2O	BAO	SC2O3	LA2O3	CEO2	EU2O3	LU2O3	HF32	THO2	TA2O5	CR2O3	MNO	FE2O3 PERCENT	COO	NIO	SB2O3
TGKA	28500	1.23	48.7	0.00	786	32.5	18.50	32.2	1.36	0.000	0.00	2.11	0.00	143	1130	6.35	25.7	0.0	0.000
TGKB	29900	1.09	22.9	0.00	742	30.1	23.60	34.4	1.39	0.000	0.00	2.55	0.00	125	919	6.08	21.5	0.0	0.000
TGKC	29600	1.12	28.4	0.00	753	30.6	22.20	33.9	1.38	0.000	0.00	2.43	0.00	130	968	6.14	22.5	0.0	0.000
KE01	24900	1.13	50.3	0.00	703	30.2	19.00	31.0	1.24	0.000	0.00	2.11	0.00	153	1120	5.96	25.9	0.0	0.000
KE02	21300	1.45	45.0	0.00	1130	40.6	18.00	38.1	1.55	0.000	0.00	2.48	0.00	199	641	7.35	21.5	0.0	0.000
KE03	30200	1.04	28.0	0.00	586	33.2	22.00	29.4	1.15	0.000	0.00	2.12	0.00	181	953	6.66	25.5	0.0	0.000
KE04	31900	1.09	24.0	0.00	562	28.8	30.00	35.0	1.42	0.000	0.00	2.68	0.00	112	869	5.84	19.9	0.0	0.000
KE05	29000	1.16	17.0	0.00	620	28.9	21.00	29.9	1.25	0.000	0.00	2.43	0.00	135	921	5.89	20.0	0.0	0.000
KE06	27400	.94	0.0	0.00	844	24.1	16.00	37.0	.83	0.000	0.00	2.70	0.00	96	1880	6.00	20.0	0.0	0.000
KE07	31100	.97	26.0	0.00	382	30.0	31.00	44.0	1.67	0.000	0.00	4.97	0.00	77	797	6.35	19.4	0.0	0.000
KE08	26900	1.01	28.0	0.00	873	30.1	18.00	39.5	1.45	0.000	0.00	2.58	0.00	134	787	6.07	26.9	0.0	0.000
KE09	31000	1.27	0.0	0.00	924	31.4	24.00	42.8	1.88	0.000	0.00	3.30	0.00	79	842	6.21	16.5	0.0	0.000
KE10	45400	1.52	0.0	0.00	857	34.6	0.00	38.7	1.59	0.000	0.00	2.26	0.00	58	1070	8.24	28.0	0.0	0.000
KE11	30800	1.00	21.0	0.00	663	28.2	29.00	32.1	1.26	0.000	0.00	2.35	0.00	135	1190	5.83	22.9	0.0	0.000
KE12	32700	1.34	47.2	0.00	878	35.0	18.00	33.9	1.49	0.000	0.00	2.12	0.00	133	1140	6.77	25.5	0.0	0.000
OP01	25700	1.34	37.4	0.00	1380	28.3	33.00	46.5	1.26	0.000	0.00	6.75	0.00	98	754	7.06	18.8	0.0	0.000
OP02	14800	1.13	64.7	0.00	1850	37.4	31.00	77.0	1.67	0.000	0.00	9.43	0.00	212	1190	8.71	34.9	0.0	0.000
OP03	20100	.80	0.0	0.00	903	36.5	37.00	46.7	1.80	0.000	0.00	4.07	0.00	183	1490	7.87	39.2	0.0	0.000
OP04	21900	.77	37.8	0.00	1170	37.2	19.00	50.8	1.59	0.000	0.00	3.74	0.00	186	1700	8.21	42.2	0.0	0.000

*The value "0.00" in the Table signifies that the analysis for this element was not performed. All entries are in parts per million, except K_2O and Fe_2O_3 , which are given as percent.

Fig. 1