

THE MINERALOGICAL AND CHEMICAL ANALYSIS OF BANESH PERIOD CERAMICS FROM TAL-E MALYAN, IRAN

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Abstract

Surface survey and excavation in the Kur River Basin in the highlands of southwestern Iran have yielded a large collection of Banesh Period ceramics, c.3400 to 2800 B. C. , from low fired, chaff tempered ware to high fired, grit tempered, painted ware. These ceramics provide a body of data from which information may be extracted on ceramic technology, craft specialization, and organization of regional exchange systems during the early stages of urban development in highland Iran.

The initial research has concentrated on Banesh ceramics from the urban context at Tal-e Malyan. Mineral phase identification by optical microscopy and x-ray diffraction was applied to selected samples of raw clay, chaff tempered ware, and grit tempered ware. Instrumental neutron activation analysis for 19 elements was carried out on 50 chaff tempered sherds, 54 grit tempered sherds, and 15 clay objects from two different contexts within the site. The results of these analyses and their implications on questions concerning technology, specialization, and exchange in ceramics will be discussed.

Keywords: CERAMICS, CHEMICAL CHARACTERIZATION, IRAN, MINERALOGY, NEUTRON ACTIVATION ANALYSIS, TAL-E MALYAN.

INTRODUCTION

The chemical characterization of southwestern highland Iranian ceramics, presented in this paper, is one phase of a larger investigation on the chemical and mineralogical characterization of a number of different materials from the early urban center at Tal-e Malyan (3400 to 500 B. C.), and the surrounding Kur River Basin. These materials include obsidian (Blackman, 1978a), chlorite, and clay sealings and tablets (Blackman, 1978b). The objective in studying these materials is to examine the relationship between long distance, regional, and local exchange and the development of urban civilization in the Iranian highlands. The ceramic portion of this investigation is focused primarily on the local aspect of the exchange system.

Johnson (1973) has been able to detect changes in local ceramic production and exchange based on the study of microstylistic differences in ceramics from the Susiana Plain, about 400 km northwest of Tal-e Malyan in lowland southwestern Iran. The present study was initiated to determine if similar patterns could be detected for a comparable time period in highland Iran, using chemical characterization of the ceramic body instead of microstylistics. The main focus of the initial phase of the ceramic study was, therefore, to delineate the chemical variability in the locally produced wares; to determine if locally available clay types could be distinguished based on elemental concentrations; and to determine if correlations between clay type and ware type could be established.

The ceramics chosen for examination were from the Banesh Period, c. 3400-2800 B.C., excavations at Tal-e Malyan. It was during this period that urbanization began in the Kur River Basin, and ceramics from this period were available from well stratified contexts at Tal-e Malyan and from surface survey and excavation elsewhere in the basin.

TAL-E MALYAN: LOCATION AND PHYSICAL SETTING

The archaeological site of Tal-e Malyan is situated within the drainage basin of the lower Kur River in the highlands of Fars Province, Iran (Figure 1.). The lower Kur River Basin is synclinal, surrounded by high, massive, folded limestone mountains, and bisected by a series of low, discontinuous anticlinal ridges. The Kur River flows on the northeastern side of the ridges, while Tal-e Malyan is located in a small internal drainage basin, the Dasht-e Baiza, to the southwest of the ridges and well out on the alluvial valley fill.

Several spring fed marshes are located in the Dasht-e Baiza, however, except around the marshes and in the irrigated fields, vegetation on the alluvium is sparse. The talus slopes and uplands of the folded mountains and anticlinal ridges are better watered and denser brushy vegetation and the remnants of oak-pistachio-almond forest still exist.

BANESH PERIOD: EXCAVATIONS AND CERAMICS

The excavations at Tal-e Malyan have extensively exposed two areas of Banesh Period occupation. These two areas have been interpreted by Sumner (1976:103-09) as serving different functions at the site. Operation TUV, located on a small mound in the northeastern corner of the site covers an area of about 700 square meters. This operation consists of three excavated building levels. These levels appear to represent a domestic complex where small craft activities may also have been conducted. Operation ABC, located near the center of the main occupation area covers an area of about 600 square meters. Four Banesh building levels, each consisting of a large, well built, thick walled structure, were exposed in this excavation. The nature of construction, the elaborate wall decoration, and the many small finds of luxury goods, have led to the interpretation of the buildings as elite residences or non-domestic secular or sacred structures. The ceramics so far analyzed and reported in this paper have all come from stratified contexts within these two Banesh excavations.

The Banesh ceramic corpus was initially divided into two groups based on the temper used in their manufacture. The two temper groups consisted of soft chaff tempered wares and hard grit tempered wares. The temper groups were then subdivided into several forms and decorative styles unique to each temper group.

Within the chaff tempered group three forms: necked goblets; flat trays; and bevel rim bowls were abundant in both excavated areas. Representative samples of each form of chaff tempered ware were selected for analysis. The grit tempered group contained a wide variety of rim forms, but a somewhat restricted number of base forms. In order to reduce the number of variables in the study, it was decided to limit sampling to base forms and decorative styles. Representative samples of the abundant flat bases and the rarer ring bases were chosen from each excavated area. Along with the bases, samples of bichrome and monochrome painted body sherds were also selected. Several rare or unique forms were also included in the sample.

MINERALOGICAL ANALYSIS: METHOD AND RESULTS

The mineralogical analysis of the Banesh ceramics was carried out using both x-ray diffraction and thin section techniques. Selected samples of both temper groups were examined along with unfired clay objects, also recovered from excavation at Tal-e Malyan.

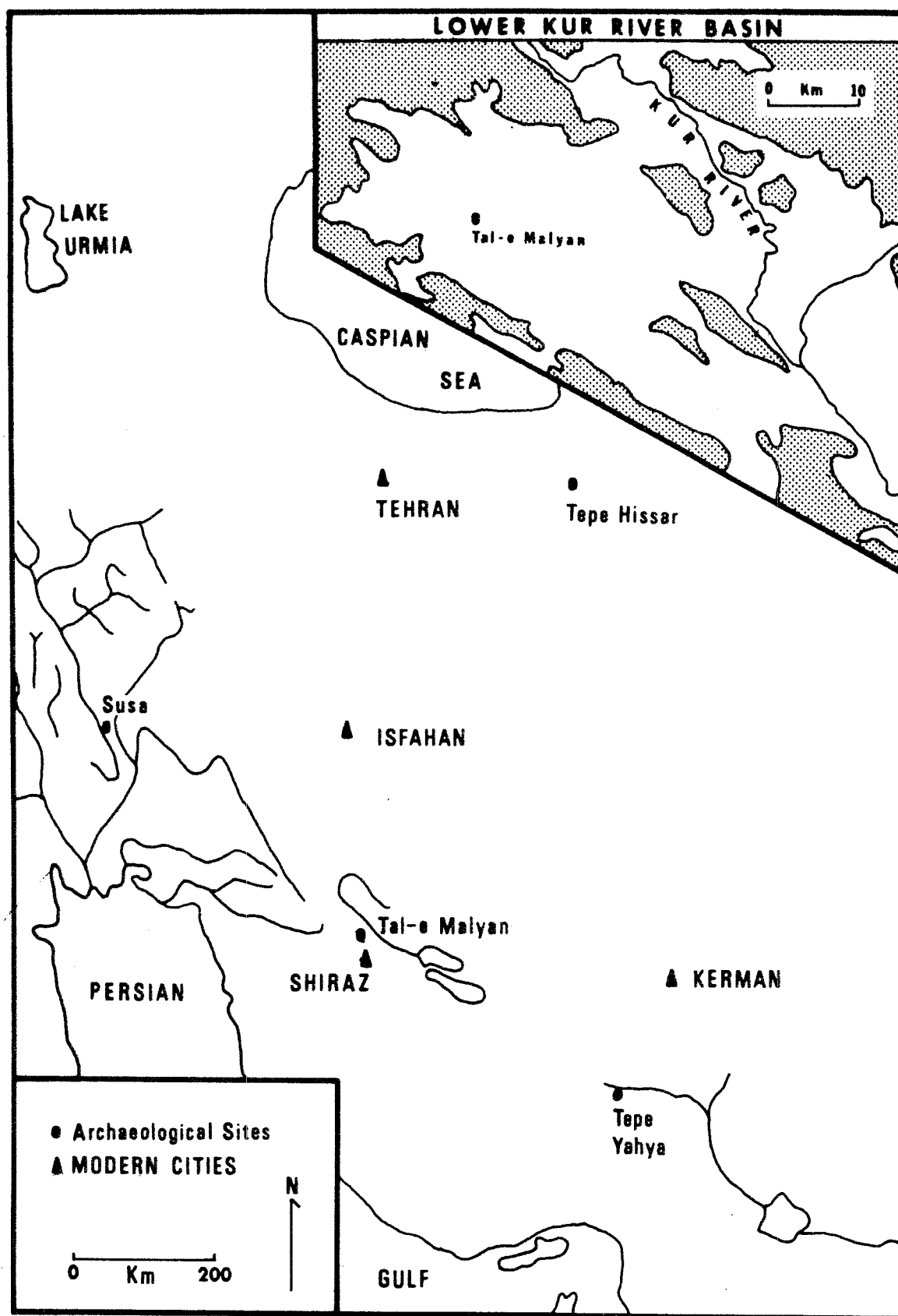


Figure 1: Location of the Site of Tal-e Malyan and the Lower Kur River Basin.

X-ray diffraction analysis of the chaff tempered ceramics showed the major mineral phases to include α -quartz, calcite, dolomite and a poorly crystalline illitic clay or muscovite mica. Diffraction studies of the unfired clay objects yielded a similar composition. The illite/muscovite, present in the unfired clay objects, showed the same broad, weak, ill-defined diffraction peaks noted in the chaff tempered ceramics. The presence of this poorly crystalline phase in both fired and unfired samples strongly suggests that the poor crystallinity in the fired clays was not due to incomplete thermal disruption of the crystal structure, but rather is the natural state of illitic clays in the alluvial valley fill. The presence of dolomite indicates that temperatures in excess of 725°C were not reached during firing and the softness of the ceramics indicates a temperature of probably less than 600°C was employed.

X-ray diffraction analysis of the grit tempered ceramics was conducted on samples of the ceramic body and the temper. The major mineral phases found in the ceramic body included α -quartz, calcite, diopside, and one or more phases, possibly including Ca-plagioclase (anorthite?), cristobalite and spinel. None of the diffraction peaks corresponded to those of any clay mineral indicating a firing temperature high enough to disrupt the clay structure, and the formation of the phases diopside, Ca-plagioclase, cristobalite and spinel indicate temperatures in excess of 900-950°C.

Based on macro and microscopic examination of the grit tempered wares, the tempering material could be divided into three major types. The rarest of the three types consisted of white, friable calcite aggregates. The calcite aggregates, originally limestone grains, had been calcined during firing and subsequently had recarbonated. Calcination of calcite occurs at temperatures of about 750 to 800°C. The other two temper types consisted of dark reddish brown to black, rounded grains and light gray, rounded tabular grains. Diffraction analysis of these two temper types showed the only detectable crystalline phase was α -quartz, indicating firing temperatures sufficiently high to destroy the crystalline structure of the non quartz phases. The resultant material appears to be amorphous or only very poorly crystalline.

Thin section analysis of the grit tempered ceramics showed the two most abundant temper types to be present as well rounded grains. The light gray temper consisted of extremely fine grained quartz in a light grayish matrix of approximately the same size range as the ceramic body. The dark temper, also very fine grained, showed considerable dark reddish brown to black matrix coloration, probably due to amorphous iron compounds (cf Chemical Analysis section). The texture of the grains of both temper types indicated that they were originally fine grained sedimentary rocks. The high degree of rounding of the grains suggests the source of the tempering material was a water laid sand as opposed to a crushed or ground material.

CHEMICAL ANALYSIS: PROCEDURES AND RESULTS

The chemical analysis was carried out by instrumental neutron activation analysis for nineteen elements. The elements determined and the standards used to quantify the results are given in Table 1. Ceramic samples were prepared for analysis by cleaning several areas on the broken edges of the sherds with a tungsten carbide drill bit and then extracting about 0.5 grams of sample with the same bit. Individual samples were thoroughly mixed, dried for 48 hours at 100°C, and 100mg subsamples taken for analysis. Samples and standards were irradiated together for 8 hours at a flux of $5 \times 10^{13} \text{ n cm}^{-2} \text{ sec}^{-1}$ at the National Bureau of Standards 10 Mw reactor. After 14 days decay, samples and standards were counted for 100 minutes using a Ge(Li) detector (FWHM for the 1332.5 Kev gamma ray of ^{60}Co was about 2.10 Kev) and a 4096 channel multichannel analyzer. The data were collected and stored on magnetic tape for later processing using the N. B. S. program, ALSPICE.

Table 1: List of Nuclides.

Element	Nuclide	Half-Life	Energy (Kev)	Standards Used
Ca	Sc-47	3.40	D. 159.4	AGV, GSP, BCR, & 1633
Sc	Sc-46	83.9	D. 889.3	All
Cr	Cr-51	27.8	D. 320.1	DTS, PCC, & 1633
Fe	Fe-59	45.6	D. 1099.2 & 1291.7	All
Co	Co-60	5.26	Y. 1173.2 & 1332.5	All
Rb	Rb-86	18.66	D. 1076.8	AGV, GSP, BCR, & 1633
Sb	Sb-124	60.40	D. 1690.9	AGV, GSP, & 1633
Cs	Cs-134	2.046	Y. 795.8	AGV, BCR, & 1633
Ba	Ba-131	12.00	D. 496.4	AGV, GSP, BCR, & 1633
La	La-140	40.22	H. 1596.2	GSP, BCR, & 1633
Ce	Ce-141	32.50	D. 145.4	AGV, BCR, & 1633
Sm	Sm-153	46.80	H. 103.2	AGV, GSP, & 1633
Eu	Eu-152	12.70	Y. 1408.0	AGV, GSP, BCR, & 1633
Tb	Tb-160	72.10	D. 879.4	AGV, GSP, BCR, & 1633
Yb	Yb-175	4.21	D. 396.3	AGV, GSP, & BCR
Lu	Lu-177	6.74	D. 208.4	AGV, BCR, & 1633
Hf	Hf-181	42.50	D. 482.2	AGV, GSP, BCR, & 1633
Ta	Ta-182	115.5	D. 1221.4	AGV, GSP, BCR, & 1633
Th	Pa-233	27.00	D. 311.9	AGV, GSP, BCR, & 1633

LIST OF STANDARDS

Standard	Concentration	Material Type
U.S.G.S. AGV-I	Flanagan, 1973	Andesite
U.S.G.S. GSP-I	Flanagan, 1973	Granodiorite
U.S.G.S. BCR-I	Flanagan, 1973	Basalt
U.S.G.S. DTS-I	Flanagan, 1973	Dunite
U.S.G.S. PCC-I	Flanagan, 1973	Peridotite
N.B.S. SRM1633	Ondov, et. al., 1975	Coal Fly Ash

Table 2: Concentration means for Banesh Ceramic Samples and Clay Objects.

*concentrations in PPM except where noted
#number of samples in the group

Element*	CLAY OBJECTS (15)#			GROUP I (50)			GROUP II (35)			GROUP III (16)		
	Mean	Sigma	%Sigma	Mean	Sigma	%Sigma	Mean	Sigma	%Sigma	Mean	Sigma	%Sigma
Sc	10.02	1.33	13.30	11.27	1.27	11.24	21.50	2.05	9.53	20.31	3.28	16.14
Cr	243	64	26.34	200	40	20.13	156	17	10.74	171	78	45.45
Fe%	2.85	0.38	13.27	3.18	0.37	11.59	5.27	0.74	14.12	5.25	0.83	15.74
Co	15.28	1.62	10.57	16.98	2.22	13.07	20.14	5.94	29.51	23.86	5.65	23.66
Rb	51.31	7.32	14.26	47.76	6.29	13.17	103	13	12.67	72.04	12.09	16.79
Sb	0.643	0.246	38.32	0.529	0.165	31.22	0.578	0.182	31.49	0.523	0.143	27.34
Cs	3.34	0.50	14.96	2.72	0.45	16.41	26.21	4.21	16.07	5.04	0.93	18.38
Ba	224	43	19.39	425	172	40.37	362	126	34.92	414	192	46.39
La	18.68	1.63	8.71	20.47	2.01	9.82	44.45	4.86	10.94	31.08	4.51	14.51
Ce	37.28	3.76	10.08	41.67	3.93	9.44	89.27	11.74	13.15	62.20	9.91	15.93
Sm	3.32	0.36	10.84	3.63	0.37	10.16	6.71	0.75	11.12	5.37	0.75	13.94
Eu	0.740	0.070	9.46	0.802	0.089	11.09	1.38	0.16	11.46	1.24	0.19	15.40
Tb	---	---	---	0.550	0.097	17.61	0.821	0.142	17.24	0.719	0.138	19.21
Yb	1.54	0.15	9.80	1.69	0.18	10.43	2.67	0.27	10.15	2.37	0.31	13.17
Lu	0.265	0.024	9.05	0.291	0.030	9.83	0.470	0.040	8.61	0.409	0.047	11.56
Hf	2.65	0.36	13.45	2.76	0.13	11.10	5.03	0.44	8.82	4.15	0.69	16.62
Ta	0.673	0.100	14.87	0.740	0.101	13.68	1.48	0.19	12.63	1.22	0.27	21.76
Th	5.17	0.58	11.17	5.76	0.59	10.20	12.68	1.24	9.73	8.36	1.07	12.87
Ca%							5.81	2.43	41.82	7.66	3.97	51.86

Three chemical composition groups were determined for the Banesh ceramics. The means and standard deviations are presented in Table 2. Means and standard deviations are also presented for the Banesh unfired clay objects (Blackman, 1978b) to provide a comparison between the ceramic groups and the local alluvial clays. Group assignments were initially made by eye and the validity of the defined groups was tested using the Brookhaven National Laboratory multivariate statistical program ADCORR. For a full discussion of this program see Oliver (1973) and Bieber, et al (1976).

When chemical groups 1, 11 and 111 were tested for internal consistency, no samples were rejected from membership in the group to which they had been assigned. Intergroup consistency tests showed that the probability of a sample, assigned to one of the three groups, actually being a member of one of the other groups never exceeded 5%. Table 3. presents the condensed results of intergroup consistency tests.

Table 3: Test of Group Coherence

Base Group	Test Group	Probability of Missassignment
GROUP I	GROUP II	0.00%
GROUP II	GROUP III	2.50%
GROUP I	GROUP III	5.00%

All statistical tests thus so far undertaken, confirm the validity of the three chemical concentration groups as defined and reject at a high level of confidence the missassignment of any samples. The groups, therefore, appear to be statistically valid representations of real chemical differences in the ceramic sample. The question that must now be addressed is whether these chemical differences represent real geochemical differences in the clay sources before selection by the Banesh potters, or only apparent differences introduced after selection by either manufacturing techniques (i. e. temper addition) or post-depositional alteration (i. e. dilution or ion exchange).

The clay sources used by the Banesh potters were not composed of clay minerals alone, but were a mixture of clay to silt size particles of a number of mineral phases including quartz and calcite as well as clay minerals. Quartz (SiO_2) and calcite (CaCO_3) are, in general, fairly pure minerals containing low concentrations of trace impurities. The effect of their presence is to dilute the concentrations of trace and minor elements in the clay minerals and therefore to change the apparent chemical composition. If the diluting mineral phases are present before the manufacture of the ceramic, then they must be considered as an integral component of the geological deposit used as a source of ceramic raw material and their effect on the chemical composition of the ceramic body is a valid criterion for distinguishing different sources. On the other hand, if the dilutants are differentially introduced during manufacture or after the ceramic piece has been buried, then they may serve to mask the use of similar clay sources and possibly lead to erroneous conclusions concerning the number of sources utilized.

The same argument is also valid for those mineral phases that enrich the clay body in some or all of the trace and minor elements. If present in the clay deposit before the manufacturing process begins, these minerals may provide valid chemical distinctions among otherwise similar clay sources. If, however, these minerals are introduced during manufacture, in the form of the temper, they could mask similarities in the original raw materials. Each of the above mentioned possibilities had to be examined before the three chemically defined groups could be accepted as representative of different clay sources used by the Banesh potters.

The possibility of post depositional calcium carbonate or silica dilution was examined by optical and x-ray diffraction means. The x-ray diffraction examination showed, as discussed in the section on Mineralogical Analysis, that the ceramic body of both the chaff and grit tempered ceramics contained varying amounts of calcium carbonate and quartz, as did the unfired clay objects. Calcium carbonate was a minor phase or was absent in the grit tempered ceramics, while it formed a major component in the chaff tempered ceramics and in the clay objects. Silica, in the form of α -quartz, was a major component in both ceramic types, and in the clay objects.

Secondary silica precipitation is highly unlikely in the geochemical environment of the Kur River Basin and the α -quartz noted in the x-ray diffraction examination was undoubtedly present in the clays from which the chaff and grit tempered ceramics were made. The geochemical conditions are, however, favourable for the precipitation of calcium carbonate and the crystallization of calcite in pore spaces within the ceramics is a distinct possibility. Thin section analysis of both chaff and grit tempered ceramics showed no evidence of carbonate crystallization in macro or micro pore spaces. The calcite present in the chaff tempered ceramics was evenly distributed throughout the ceramic body as very finely divided particles and pore spaces, even those with communication to the sherd's surface showed no trace of carbonate precipitation. The grit tempered ceramics contained very little or no calcite in the ceramic body. The calcite that was present in the grit tempered ceramic body was, as in the chaff tempered ceramics, evenly distributed. The calcium in the grit tempered ceramics appears to reside predominately in the diopside and anorthite crystal structures and while the calcium may have been in the form of calcite before firing, it appears to have almost totally reacted to form other minerals. The thin section and x-ray diffraction, therefore seem to indicate that the carbonates present in both temper types was present in the original raw materials and not added after deposition.

Possible post depositional ion exchange or leaching effects were examined indirectly by comparing the chemical concentrations in sherds subject to the same burial history. Table 4 presents the chemical concentrations of selected elements for three sherds excavated from the same stratum at operation TUV. Although these three sherds

TABLE 4:
COMPARISON OF SAMPLES FROM THE SAME PROVENIENCE

CONCENTRATIONS of SELECTED ELEMENTS			
Element	Group I MAPØ 94	Group II MAPØ 84	Group III MAPØ 76
Ca%	13.7	5.41	6.38
Sc	11.0	21.4	22.7
Fe%	3.10	5.15	5.46
Co	16.4	34.1	28.6
Rb	48.3	108	61.5
Cs	2.68	24.8	4.43
La	20.6	47.9	28.5
Hf	3.23	4.84	3.91
Th	5.70	13.0	7.44

were subjected to the same chemical environment for the same time period they display significant chemical differences. The results of several such comparisons indicate no important post depositional ion exchange or leaching effects that could explain the observed chemical differences among the three chemical groups.

Post-depositional alteration is not the only way by which clays with the same or very similar chemical compositions might be altered to result in what appear to be recognizably different groups. The intentional addition of inorganic temper could potentially alter the concentrations enough to mask similarities. In the present study, the sampling technique was such that it was impossible to exclude all temper from the sample, and indeed no attempt was made to do so. Therefore, within fairly narrow limits, some temper contamination was included in all the grit tempered samples. To test the possibility that varying amounts of temper could have caused the intra group differences, samples of the two types of temper (cf the section on Mineralogy) were hand picked from a sherd and analyzed. Table 5, shows the results of the analysis of the two tempers and the analysis of the drilled ceramic sample for the same sherd.

TABLE 5:
CHEMICAL COMPOSITION OF THE TEMPER AND WHOLE CERAMIC:
SAMPLE MAPØ 7Ø

Element	Dark Temper	Light Temper	Whole Ceramic
Sc	23.2	26.0	23.1
Cr	210	149	157
Fe%	23.02	2.39	6.01
Co	12.35	3.62	20.2
Rb	87.9	132	112
Sb	1.03	0.989	0.710
Cs	24.6	37.1	32.34
Ba	146	172	221
La	42.4	61.9	49.5
Ce	85.2	126	101
Sm	7.65	8.26	7.55
Eu	1.74	1.44	1.49
Tb	1.13	0.730	0.793
Yb	2.61	3.82	2.93
Lu	0.451	0.614	0.523
Hf	4.39	6.87	5.65
Ta	1.30	2.06	1.83
Th	15.5	17.6	14.64

Using the equation:

$$C = \frac{A - B(x)}{y}$$

Where: C=concentration in the hypothetical clay body
A=concentration in the analyzed drilled sample
B=concentration in the analyzed temper
x=percent temper in the drilled sample
y=percent clay in the drilled sample

TABLE 6:

THE INFLUENCE OF THE TEMPER ON THE CHEMICAL COMPOSITON
OF A HYPOTHETICAL PARENT CLAY BODY

<u>100% Dark Temper</u>						
Temper: Body Ratio						
Element*	5:95**	10:90	20:80	30:70	40:60	50:50
Fe%	5.11***	4.12	1.76	-1.28	-----	-----
Co	20.6	21.1	22.2	-----	-----	-----
Rb	113	115	118	-----	-----	-----
Cs	32.7	33.2	34.3	-----	-----	-----
La	49.9	50.3	51.3	-----	-----	-----
Hf	5.72	5.79	5.97	-----	-----	-----
Th	14.6	14.5	14.4	-----	-----	-----

<u>100% Light Temper</u>						
Temper: Body Ratio						
Element*	5:95**	10:90	20:80	30:70	40:60	50:50
Fe%	6.20***	6.42	6.92	7.57	8.44	9.66
Co	21.1	22.0	24.3	27.3	31.3	36.8
Rb	111	110	107	103	98.7	92.0
Cs	32.1	31.8	31.2	30.3	29.2	27.6
La	48.8	48.1	46.2	44.2	41.2	37.1
Hf	5.59	5.51	5.34	5.13	4.84	4.43
Th	14.5	14.3	13.9	13.3	12.7	11.7

<u>50:50 Dark To Light Temper</u>						
Temper: Body Ratio						
Element*	5:95**	10:90	20:80	30:70	40:60	50:50
Fe%	5.66***	5.27	4.34	3.15	1.56	-0.67
Co	20.8	21.6	23.3	25.4	28.4	-----
Rb	112	112	113	113	113	-----
Cs	32.4	32.5	32.7	33.0	33.3	-----
La	49.4	49.2	48.8	48.3	47.7	-----
Hf	5.65	5.65	5.66	5.66	5.66	-----
Th	14.5	14.4	14.2	13.8	13.4	-----

*concentrations in PPM except where noted

**The ratio of temper to clay body in the drilled ceramic sample

***Calculated concentration in the hypothetical parent clay body.

elemental concentrations were calculated for a hypothetical clay body from the concentration data for the tempers and the drilled sample. The variables in the equation were the light to dark temper ratio and the temper to clay body ratio. Table 6. shows the concentrations calculated for the hypothetical clay body using various temper ratios and temper to body ratios.

No combination of dark and light temper or temper to body ratios could be found that would alter a group III composition to that of a group II or I paste or visa versa.

The results of the dilution, ion exchange, and temper studies all support the contention that the three chemical composition groups are indeed distinctive and probably resulted from the use of three geochemically distinct clay sources to make the ceramics excavated from Banesh levels at Tal-e Malyan.

ARCHAEOLOGICAL IMPLICATIONS

The remainder of this paper will deal with several patterns related to Banesh ceramic production that have emerged from this study. Further research will be needed, however, before any concrete statements can be made concerning the direction and mechanism of distribution and exchange of these ceramics.

CHAFF TEMPERED WARES

Table 7. shows the distribution of the ceramic ware types with respect to the three chemically defined clay groups. The most apparent distributional pattern is that all chaff tempered ceramics, regardless of form or location within the site, belong to a single compositional group, Group 1. Group 1 elemental concentrations and those reported for the clay objects in Table 2 are very similar and it is quite likely that the clay objects and the chaff tempered ceramics were made from the locally available alluvial clays. The extent to which clayey alluvial soils of the same chemical and mineralogical composition are distributed within the Kur River Basin is not known, however these soils are probably fairly wide spread making the location of the production sites, based on chemical characterization alone, very difficult.

Table 7 : The Distribution of Ceramic types by Chemical Group

Ceramic Type	Chemical Group I		Chemical Group II		Chemical Group III	
	TUV	ABC	TUV	ABC	TUV	ABC
Grit Temper						
Bichrome	0	0	10	1	0	0
Ring Bases	0	0	6	0	0	0
Knobby Ware	0	0	5	0	0	0
Monochrome	0	1	8	0	1	2
Flat Bases	1	0	4	0	7	4
Storage Jar	0	0	0	0	0	1
Rosette Relief	0	0	0	0	0	1
<u>Total</u>	1	1	33	1	8	8
Chaff Temper						
Trays	10	10	0	0	0	0
Goblets	10	8	0	0	0	0
Bevel Rim Bowls	6	6	0	0	0	0
<u>Total</u>	26	24	0	0	0	0
<u>Grand Total</u>	52		34		16	

No direct evidence for the production of chaff (or grit) tempered Banesh ceramics have been recovered from Tal-e Malyan. Direct evidence for the production of chaff tempered wares may however, be difficult to recognize. The low temperature to which these ceramics were fired would not require the construction of a kiln and could be accomplished by stacking brush or reeds around piles of the ceramics and burning the fuel in the open (Alden, 1979; 103). This technique would leave only ephemeral evidence of firing and would not result in much, if any, overfired or vitrified pottery. As only a relatively small proportion of the total Banesh occupation has been excavated and much of the remaining area lies under up to several meters of later overburden, the absence of direct evidence from excavation or surface survey, for chaff tempered ceramic production does not rule out its manufacture at Tal-e Malyan. There is, however, strong indirect evidence for chaff tempered ceramic production elsewhere in the Kur River Basin. Alden (1979; 102-114) reports three sites (8G35, 8G37, and 7G16) within 12 km of Tal-e Malyan (cf Figure 1) that appear to have specialized, not only in the manufacture of chaff tempered wares, but in specific forms of this ceramic type. While two of the sites (8G35 and 8G37) appear to have been producing a form of goblet that is chronologically older than those present at Tal-e Malyan, the third site (7G16) was making Banesh trays comparable to those examined in this study. No sites tied to the production of bevel rim bowls or the necked goblets found at Tal-e Malyan were located. Alden postulates that bevel rim bowls may have been produced, as needed, by local households and that an as yet unidentified site that produced necked goblets probably exists. This production site may well be Tal-e Malyan.

The chemical concentration data does not however support or contradict the premise that goblets and trays were made at sites other than Tal-e Malyan and by some undefined mechanism, redistributed to that site. Additional analyses of sherds from Alden's chaff temper ware production sites are needed to attempt to address this problem.

GRIT TEMPERED WARES

As opposed to the chaff tempered ceramics, the grit tempered ceramics are made of clays from all three chemically defined groups (cf Table 7.). The distribution by group is, however, quite uneven with 4% from Group I, 65% from Group II, and 31% from Group III. This distribution pattern appears to show a high reliance on group II composition clay. When the grit tempered ceramics are subdivided by form and decoration, however, a very different distributional pattern emerges. Two types of ceramics, monochrome and flat base, are made of clays of all three groups, while three other types, bichrome, and to a lesser degree of certainty ring base and knobby ware, appear to be made exclusively of Group II clay. This apparent difference in clay utilization related to ceramic type poses some important technological, chronological, and locational questions concerning the production of grit tempered ceramics.

Both Sumner (1972) and Alden (1979) have described at least five sites that show strong direct evidence for grit tempered ceramic production. All of these production sites are situated on or near the talus slopes at the edge of the folded mountain fronts surrounding the basin. No sites showing indications of grit tempered ceramic production were located out in the basin on the alluvial valley fill, although two of the three chaff tempered production sites were found there. Alden proposes that the talus slope location of the grit tempered ceramic production sites is due to the proximity of a fuel supply in the upland forests. The high firing temperatures used in the production of the grit tempered ceramic would require the use of a kiln and necessitate ready access to an adequate and reliable fuel supply. A second possible reason for the talus slope location may be proximity to clay deposits. The chemical data show Group I to be related to the alluvial valley clays and therefore widely available in the basin. Group II and III clays are not closely related to the alluvial clay sources and are probably more restricted geographically. Possible sources for the clays used to produce ceramics of chemical groups II and III could be shale beds in the folded mountains

above the talus slopes. If both fuel and raw materials are to be found on the margins of the basin and not on the alluvial plain, then the economics of transport may be at least partially responsible for the location of the grit tempered ceramic production sites.

The above discussion raises the question of why seek different clay sources for the grit tempered ceramics when the alluvial clays are so ubiquitous and perfectly adequate for the production of chaff tempered ceramics? At least part of the answer may be technological. Group 11 and 111 clays contain an average of 6 - 8% calcium, which, translates to about 16% carbonate content. The alluvial clays contain 32% carbonate or more. The firing temperature of the chaff tempered ceramics was not high enough to calcine the carbonates, however the temperature reached in the firing of the grit tempered ceramics was well above the 725-800°C necessary to drive off the CO₂ from the carbonate. The volume changes and the CO₂ pressure that accompany calcination probably made the alluvial clays unacceptable for high fired ceramic production.

The distribution of the grit tempered ceramic forms and decorative motifs among the chemically defined clay groups needs further discussion. Several hypotheses can be put forth to explain the use of Group 11 clay to make bichrome, ring base, monochrome, and flat base vessels, while Group 111 clay is restricted to monochrome and flat base vessels. These hypotheses include single and multiple production sites, each with synchronic or diachronic uses of the clay types. The single site-diachronic hypothesis requires a shift in clay source utilization through time. Contemporaneous with the shift from Group 11 to Group 111 clays or visa versa, the manufacture of bichrome decorated vessels would have to stop or be introduced. The multiple site-diachronic hypothesis would result in essentially the same set of conditions, only the production site would also change with the change in clay source.

The two diachronic hypotheses are testable archaeologically. The introduction or abandonment of bichrome decoration should be detectable in excavation, while flat base and monochrome vessels should persist in all strata. At operation TUV bichrome, monochrome, flat base, and ring base vessels from unambiguous stratigraphic context were examined. Ceramics made of Group 11 clays were present in strata from building levels 1, 2, and 3. Ring bases were present in all three building levels while Group 11 bichrome vessels and flat bases were present in building levels 1 and 2. Ceramics made of Group 111 clay were, therefore, present in all occupation levels at TUV. Flat base and monochrome vessels of Group 111 clay were also present in all occupation levels. Further, Nicholas (personal communication) states that in the whole sample of Banesh ceramics from TUV, the vessel types used in this study are present in all levels. There is therefore, a complete chronological overlap at TUV both in the clay types and vessel types making a diachronic shift in clay source utilization a highly unlikely explanation for the observed distribution.

The other hypothetical explanations for the observed data involve a synchronic use of the two clay types and thus fit the excavation data. The single site-synchronic hypothesis requires that both Group 11 and 111 clays be accessible from a single site. In addition, a selection process would have to be made resulting in all forms being made of Group 11 clay, while a more limited number were made of Group 111 clays. As no difference in color, texture or quality of the fired clay could be detected between the two clay types, selection based on physical properties seems unlikely. Therefore the selection process would have to be based on traditional or proprietary differential access to clay sources.

In the multiple site-synchronic hypothesis, differential access to clay sources may be motivated by traditional, proprietary, or spatial factors, however the result is two or more contemporaneous sites producing vessels made of one or the other clay at each site. This hypothesis would further require that bichrome and ring base production be restricted to sites with access to Group 11 clays.

Both synchronic hypotheses are testable through stylistic and chemical analysis of ceramics collected through survey and excavation at the grit tempered ceramic production sites. The chemical analysis of this corpus of ceramics is presently underway and when completed will be integrated with Alden's study of the stylistic variation from the same sites.

CONCLUSIONS

This study had demonstrated that three chemically distinct clays were used to make the vast majority of the ceramics of Banesh age found at Tal-e Malyan, and that these chemically distinct clays are probably due to geochemical differences in the clay sources utilized by the Banesh potters. The origin of the clays can only be inferred at this point, however the frequency of occurrence of the various ceramic forms included in this study argues for local manufacture at sites within the Kur River Basin. Importation of ceramics from outside the basin, except on a very small scale, seems unlikely during the Banesh period.

The chaff tempered ceramics seem to have been produced from the alluvial clays available over a wide area within the basin. The producers of grit tempered ceramics seem to have avoided the use of alluvial clays for the most part, possibly because of their high carbonate content. They favoured the use of two other chemically distinct clays, whose sources are probably located in the folded mountains that rim the Kur River Basin. The use of the two clays seems to proceed simultaneously at one or more sites, with Group II clays favoured over Group III clays for a wider variety of vessels. This usage pattern seems to be traditionally or spatially motivated rather than the result of physical differences in the workability or esthetics of the clays.

The chemical characterization of Banesh ceramics from Tal-e Malyan has thus demonstrated that ceramics can be differentiated within a restricted geographical context based on elemental concentrations, and that important implications can be drawn from the chemical data concerning the production of ceramics. An expanded study encompassing Banesh ceramics from other sites in the Kur River Basin is presently underway and coupled with stylistic examination promises to provide important new information on exchange and distribution systems in operation at the local level during the development of urban civilization in highland Iran.

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