Chemical Characterization of Tablets, Sealing Clays, and Source Clays from Tell Leilan, Syria

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Introduction

When attempting to deal with questions involving the emergence and evolution of ancient complex societies, one of the major problems faced by researchers is how to monitor abstract processes from the material remains recovered in excavation. Clay sealings and tablets, which provide multiple independent lines of information: iconographic and/or epigraphic; functional (type of sealing i.e. door lock, bale tag, etc.); and archaeological context have been used in attempts to infer the nature and extent of administrative activities in these early complex societies. Recently, chemical characterization using instrumental neutron activation analysis (INAA) has added a new dimension, clay source provenience, to the information provided by these administrative artifacts. Chemical characterization data for sealing clays from sites in Khuzistan (Blackman 1987); Tal-e Malyan (Blackman and Zeder 1986; Blackman 1989); and Tepe Gawra (Rothman and Blackman 1991) and for a limited number of Proto-Elamite tablet clays from Tal-e Malyan (Blackman and Zeder 1986) have provided productive new insights into the organization and operation of administrative activities both on an inter- and intra-site scale.

This study presents the initial results of the chemical characterization, using instrumental neutron activation analysis (INAA), of a selected sample of clay artifacts: 1) 26 tablets from the early 2nd Millennium contexts at the Lower Town Palace at Tell Leilan (Akkermans and Weiss 1987/88; Eidem 1987/88); 2) two clay artifacts from the Period I Temple on the Tell Leilan Acropolis (Weiss 1985); and 3) 20 sealing clays from mid 3rd Millennium levels at Operation 1, on the Tell Leilan acropolis (Calderone and Weiss, this volume; Parayre, this volume). These artifacts were compared to source clays collected during the 1987 field season within a 15 km radius of Tell Leilan in an attempt to identify a characteristic Leilan area clay composition. Source clays from the Wadi Jaghjagh to the west of Tell Leilan (Fig. 1) and sealing clays from Tell Brak on the lower Jaghjagh, as well as sealing clays from Nineveh in the Tigris River drainage were used to test the discriminating power of the technique. The ultimate objective of the research is four fold: 1) to demonstrate the ability to distinguish epigraphically documentable long distance exchange of information; 2) to document regional information flow between Tell Leilan and other contemporary sites in the northern Habur drainage; 3) to monitor local information flow between Leilan and its hinterlands; and 4) to examine local administrative activities through the analysis of seal impressed clays.

Source clays

The initial working hypothesis was that since the major north-south tributaries of the Habur River (Fig. 1) drain different geological formations, the alluvial clays along these tributaries should reflect this difference in a distinctive bulk chemical composition. Previous research on Halaf ceramics by Davidson and McKerrell (1976) demonstrated that distinctive chemical differences exist between clays available in the Wadi Dara and Wadi Jaghjagh drainages and Dobel et al. (1976) indicated that the clays from the northern Habur River at Tell Halaf could be distinguished from those reported by Davidson and McKerrell. The current research sought to confirm the earlier reported chemical distinctions, to extend the data eastward to the Wadi Jarrah, and to test an even finer level of clay resource discrimination through analysis of source clays from the eastern and western tributaries of the Wadi Jarrah.

To test this hypothesis, alluvial "clays" were collected from three of the main tributaries of the Wadi Jarrah: the Abbas, Qatrani, and Siblah (Fig. 2); and from the Wadi Jaghjagh about 1 km north of Tell Barri. Each of these samples was collected from erosional stream cuts either in uncultivated areas or below the plow zone to avoid possible contamination from agricultural practices. Clay samples were also collected from what appeared to be a large concentration of fine clay in the Operation 4 excavations at the Tell Leilan northern city wall.

From each sampling locality, subsamples of the raw untreated "clay", weighing about 150 g, were wet sieved to separate the silt and clay size fraction from the sand fraction (> 75 microns). This process was done to simulate levigation as few of the sealing clays or tablets appeared to contain a significant sand fraction. Two nominal 100 mg samples of each of the untreated clay and the "levigated" clay from each

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sampling local were analyzed by instrumental neutron activation analysis (INAA) at the Smithsonian Institution's INAA facility at the National Institute of Standards and Technology research reactor using analytical procedures similar to those described in Blackman 1984. Twenty nine elements were sought in the analysis and twenty five were routinely quantified. Table 1 presents a summary of the analytical parameters.

The preliminary evaluation of the chemical data from the source clays using cluster analysis (Fig. 3) shows a clear separation into three chemical groups corresponding to the Wadi Jaghjagh, the western Jarrah tributaries (Siblah and Leilan northern city wall), and the eastern Jarrah tributaries (Abbas and Qatrani). The dendrogram in Fig. 3 is the result of "average link" clustering of a mean euclidean distance matrix based on 19 chemical elements (identified in Table 1). Replicate samples of the "raw clay" are designated R and the "levigated" silt and clay replicates are designated L. It should be noted that, while some changes in the bulk chemical composition are discernible between the raw clays and their levigated counterparts, the differences are not as great as those between different source locals and are insufficient to cause confusion among the three compositional groups. The compositional similarities between the western Jarrah tributary, the Wadi Siblah and the Leilan northern city wall deposits is to be expected. The Wadi Siblah joins the Wadi Jarrah just to the north of Tell Leilan (Fig. 2). The borrow ditch from which the city wall fill at Operation 4 originated is therefore in deposits influenced by both Wadi Jarrah and Wadi Siblah sediments and can be expected to reflect compositions similar to Wadi Siblah clays.

Artifacts

To test the hypothesized discriminating power of chemical characterization in the upper Habur drainage, 25 tablets were selected for analysis, in consultation with Harvey Weiss and Leilan epigraphers Jesper Eidem and Robert Whiting. These tablets are listed in Table 2a. Nine of the tablets sampled were administrative texts, recording local economic activities and therefore assumed to be representative of the local Leilan tablet clays. Local is here taken to mean Tell Leilan proper or possibly dependent secondary centers and towns in the immediate vicinity of Tell Leilan. An additional seven tablets were letters, five of which contained the name of the sender allowing at least a general association with site. One of these letters was from Hammurabi of Aleppo (Weiss 1988). On three of the tablets the senders were associated with sites to the west of Leilan, but still within the Habur triangle (Kahat [Tell Barri?], Eluhut, and Sabbanum or Amaz), and one was from Andarig in the Sinjar region SE of Leilan. The remaining two letters were fragmentary and of unknown origin. Five of the tablets recorded treaties. One was a treaty between Till-Abnu of Leilan and the king of Kahat, thought to be Tell Barri on the Wadi Jaghjagh; a second tablet recorded a treaty between Till-Abnu and Assur on the Tigris River; while a third was between Til-Abnu and an unidentified king. The remaining two treaty tablets were to fragmentary to assign. In addition to the letters, treaties, and administrative texts, two samples were taken from a tablet containing a Sumerian king list. The remaining three tablets were fragmentary and illegible. The tablets selected for analysis, therefore represent a variety of possible source clays from local in origin to potential imports from as far away as Aleppo.

The 21 sealing clays (Table 2a and b) were selected to initiate a study of the administrative functions during Period III (Ninevite V) and Period II times at Tell Leilan. All were excavated on the Tell Leilan Acropolis, with 20 coming from the Operation 1, and a single sealing clay from the Period I Temple. Four of the sealing clays were impressed with cylinder seals (cf. Parayre, this volume), while the remaining 17 had no seal impressions and were selected primarily to assess the variability in chemical composition and closeness of fit with the source clays described above.

Chemical composition data from the analysis of 15 clay sealings from Early Dynastic through Akkadian levels at Tell Brak and 7 clay sealings from Nineveh III and IV levels in the deep sounding at Niveveh (Rothman and Blackman 1991) were also included. This comparison was undertaken to test the discriminating power of the technique, not to imply contact or exchange of materials during these disparate time periods.

Discussion

When the Leilan tablets and sealing clays were clustered with the source clay compositional groups (Fig. 4), five clusters could be readily distinguished. None of the 47 Leilan artifact samples had chemical compositions that clustered with the Wadi Jaghjagh source clay group (labeled Jaghjagh in Fig. 4). The cluster labeled group 1 in Fig. 4 contains the western Jarrah tributary source clays and six tablet samples. The cluster labeled group 2 contains the eastern Jarrah tributary source clays, seven of the unimpressed sealing clays, five tablet samples, and a cylinder seal impressed clay from Leilan period IIa contexts. The cluster labeled group 3 contains eight of the unimpressed Leilan sealing clays samples, three cylinder seal impressed clays from Leilan period IIId, and three tablets. The cluster labeled group 4 consists of seven tablets. The remaining five tablets do not cluster with any of these 5 groups.

Cluster analysis is, however, not a statistical test and has been used here as a graphic presentation and to initially sort the chemical data to provide possible groups for rigorous statistical evaluation. The statistical evaluation of these clusters, presented in Table 3, is based on Mahalinobis Distance measurements in n dimensional space and Hotelling's T2 statistic. The calculations presented in Table 3 were made using seven elements (Na, Cr, Fe, Cs, La, Ce, and Hf) chosen for their discriminating power. The number of samples in any group must exceed the number of variables (elements) by at least one for the test to work. However, at this 1:1 ratio no samples can be excluded from the groups tested. A general rule of thumb is that the sample to variable ratio should be at least 3:1 to achieve reliable results. As determined by the cluster analysis group 2 is the largest group with 23 samples, group 1 and group 3 have 14 samples each, and group 4 has only 7. Harbottle (1988) has shown that with fewer than 10 variables (elements) there is a significant possibility of erroneous inclusion of individual samples or groups of similar samples in test groups and that the most reliable results occur with 10 or more variables (requiring 30 or more samples in the test groups). Erroneous exclusion of samples from test groups, while not addressed by Harbottle, may also be a significant possibility when fewer than 10 variables are used in the test. With these cautions in mind, seven variables were used to allow evaluation of groups 1, 2, and 3. Group 4, with 7 samples was, therefore, too small to evaluate as a group. Table 3 shows the probabilities of all the samples analyzed belonging to one or another of the three larger clay compositional groups (1, 2, or 3).

Before this evaluation was undertaken, however, each of the three larger groups were tested for internal consistency. This analysis involved the removal of each sample from its assigned group, recalculation of the n dimensional centroid of the group without that sample, and comparison of the sample back to the reformed group (jackknifing). The result of this analysis was as follows: 1) group 1 remained as defined by the cluster analysis; 2) in group 2, sealing clay sample LEC010 showed less than a 7% probability of membership in its cluster assigned group (group 2), but about a 75% probability of membership in group 3, and this clay was, therefore, reassigned to group 3; and 3) in group 3, tablet L87 1449 showed less than a 1% probability of membership in group 3, but a 57% probability of membership in group 2, and was reassigned to group 2; and 4) sealing L87 1506 was excluded from all three groups with less than a 1% probability of belonging to any of the three large compositional groups. The final groupings are those presented in Table 3 and differ from the clusters in Fig. 4 only in these three reassigned samples.

Table 3 shows that compositional groups 1, 2, and 3 are internally consistent and readily distinguishable from one another. All three appear to represent clay compositions available at or near Tell Leilan. Compositional groups 1 and 2 are firmly associated with Leilan area clays based on the inclusion of samples of local source clays in the groups. These two groups also contain three administrative tablets each, tablets that were presumed to be records of local transactions and therefore local clays. Group 2 also contains six unimpressed sealing clay samples from Leilan period IIa - IIId contexts. Compositional group 3, while containing no source clays, is made up exclusively of Leilan administrative tablets and sealing clays. The artifact composition of this group would therefore, seem to imply a local Leilan origin for the clay.

All the samples in compositional group 4, with the exception of L87 1441 (6.4% probability of group 3 membership) have probabilities of membership in compositional groups 1, 2, or 3 of less than 5% and most less than 1%. The chemical compositional data coupled with the tablet contents, i.e. letters and treaties, strongly indicates a non-Leilan source or sources for the clays of this group. The remaining five tablets and one cylinder seal impressed clay, listed as "outliers" in Table 3, are not associated with any of the five compositional groups. Each had less than a 2.5% probability of membership in any of the three Leilan compositional groups. The clays from which these artifacts were made are, most probably, not of Leilan origin.

None of the seal impressed clays from excavations at Nineveh had greater than a 1% probability of inclusion in the test compositional groups and only one of the 15 seal impressed clays from Tell Brak on the lower Jaghjagh had greater than a 2% probability of belonging to the test compositional groups. While there was no reason to believe that any of these particular sealings were from the Leilan area, the comparison demonstrates the ready distinction among the clay compositions of these three areas.

Several conclusions may be drawn from the results of the first stages of the analysis of the tablet, sealing, and source clays from the northern Habur drainage. As indicated above the western Jarrah tributaries clays of Leilan compositional group 1 are present just to the north of Tell Leilan where the Wadi Siblah joins the Wadi Jarrah (Fig. 2). The Wadi Qatrani, which joins the Wadi Jarrah about a kilometer south of Tell Leilan, flows within 100 meters of the southern city wall and therefore a source the eastern Jarrah tributary clays of Leilan composition group 2 may be available close to the southern city wall in the Leilan Lower Town. The basis for identifying compositional group 3 as Leilan area in origin lies with the presence of administrative text and unimpressed sealing clays within the group. While source clays for this group remain to be located and sampled, it seems a safe assumption that this group is also a Leilan composition. Seventeen of the 30 Leilan tablet and cylinder seal impressed clays examined in this study have

composition that match either the eastern, the western Jarrah tributary source groups, or the third tablet/sealing clay group. All three groups are readily distinguished from the Wadi Jaghjagh source samples collected near Tell Barri; the Tell Brak sealing clays; and the northern Tigris, Nineveh sealing clays. These three compositional groups appear then to represent clay procurement from three or more sources in the Wadi Jarrah drainage, at or near Tell Leilan. The tablets included in the three compositional groups, therefore, were either written at Tell Leilan, at subsidiary sites along the eastern and western wadis and brought to Leilan, or a combination of both.

Three tablets included in the Leilan compositional groups have epigraphic content that might indicate a non-Leilan origin. Tablet L87 770 — the Sumerian king list, has a firm association with eastern Jarrah tributary clays of Leilan compositional group 2. Most likely this tablet was written or copied at Tell Leilan. The two treaty texts, L87 1331 and 1362 are firmly associated with the western Jarrah tributary clays of Leilan compositional group 1. Although they record treaties between Till-Abnu of Leilan and Assur on the Tigris and Till-Abnu and Kahat (Tell Barri?) on the Wadi Jaghjagh, both were most probably written at (or near) Leilan, possibly as archival copies.

Compositional group 4 is comprised entirely of letter, treaty, and indeterminate tablets, containing no Jarrah drainage source clays and no administrative tablets or sealings. A non-Leilan source or sources has been posited for this group. Only two letters of the seven tablets that make up this group contain sufficient information to indicate a potential origin and this information is contradictory. Tablet L87 1426 is a letter from Jamsi-Hatnu of Kahat, thought to be Tell Barri on the Wadi Jaghjagh about 30 km SW of Tell Leilan, and tablet L87 531 is a letter from Buriha of Andarig in the Sinjar region some 50 km SE of Tell Leilan. Clearly more work needs to be done to resolve the meaning of this group. It should be noted, however, that three tablets with references to Kahat (Barri) were analyzed in this study and none could be associated with the source clays collected about 1 km from Tell Barri or the sealing clays from excavations at Tell Brak about 15 km south of Tell Barri. Furthermore, the Kahat (Barri) tablets were not similar in chemical composition to each other. The Kahat-Barri assignation needs further examination with an expanded sampling of Tell Barri clay artifacts.

The six outlier samples consisted of five tablets and a single cylinder seal impression. Two of the tablets, L79 102 and L87 472 were chemically quite dissimilar from all other samples reported in this study and from each other. Tablet L87 472 is a letter from Hammurabi of Aleppo and would be expected to be readily distinguished from Tell Leilan clays, however, tablet L79 102 is an administrative text dealing with grain disbursements from the period I temple on the Tell Leilan Acropolis. Why this one tablet should be so chemically dissimilar from the other Leilan administrative texts is unclear at this point, although it is the only Leilan Temple tablet so far analyzed. Two of the remaining three tablets in the outlier classification, L87 692, a letter from Hammi-E[puh] associated with Sabbanum and Amaz believed to be N/NW of Tell Leilan and L87 924, a treaty between Till-Abnu and unidentified king appear to have similar compositions. The final tablet, L87 939, a letter from Shukrum-Teshshup, the king of Eluhut probably located to the west of Tell Leilan, is not closely associated with any of the other samples.

The Leilan Period II and III clay sealings present a picture quite different from the tablets. All of the unimpressed sealing clays from the Tell Leilan Acropolis were assigned to either Leilan compositional group 2 or 3, none fell into western group 1 or the Wadi Jaghjagh clay groups. The unimpressed sealing clays, therefore probably represent administrative accounting activities taking place at Leilan. The four cylinder seal impressed clays are separated into chemical compositional groups that vary according to iconographic motif (Parayre, this volume). The period IIa geometric basket weave motif sealing (L87 79c; Parayre seal 3) was assigned to compositional group 2, while the two figurative seated harpist motif sealings from period IIId contexts (L87 188 and 1494; Parayre seal 11) were assigned to compositional group 3. Parayre (this volume) indicates that the two seated harpist impressions were made by the same seal, however the chemical differences between them indicates that they are probably not fragments of the same sealing. The fourth sealing, L87 1506, a period IIId figurative "theme erotique" motif (Parayre seal 14) is rejected from all three Leilan compositional groups at the 99.9% probability level and seems to be of non-Leilan/foreign origin. Additional chemical analysis of seal impressed sealings with the attendant iconographic information, as well as information on sealing function will be important to the final interpretation of the compositional groups.

In conclusion, the preliminary results of the chemical characterization of the source clays and artifacts demonstrate the ability to distinguish between the clays of two of the major Habur tributaries, the Wadi Jaghjagh and Wadi Jarrah, as well as of the northern Tigris drainage, and indicate the strong probability that the other major Habur tributaries will be similarly distinctive. These chemical distinctions present the opportunity to track the flow of information, in the form of tablets, and goods in the form of sealed commodities, across the broad expanse of Northern Mesopotamia. Further, the initial analysis of the clays from the tributaries of the Wadi Jarrah promises even finer distinctions on the intra-regional and even intra-site level.

At present, research is continuing to refine our understanding of the chemical distinctions for the Leilan region clay sources and to expand the source clay inventory to include other major Wadis both east and west of the Jarrah though the analysis of an additional 30 source clay samples collected during the 1989 field season at Tell Leilan. Additional samples of selected seal impressed clays are being collected to examine administrative organization at Tell Leilan in periods II and III.

Element 1	Nuclide (Kev)	Gamma Ray Energy	Conc. in Standard SRM 1633[2]	Count[1]	Analytical Precision SRM 679[3]
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-58	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.
Zr	Zr-95	757	301. 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	3.2%
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	1	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	2.9%
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	5.9%
W	W -187	686	5.5 ppm	1	n.d.

*n.d. not determined. * Elements used in cluster analysis*

- Table 1: I.N.A.A. Experimental Parameters

[1] Count 1: 1 hour after a 5/day decay; count 2: 2 hours after a 30/day decay.

[2] Ondov et al. 1975 and Certificate of Analysis SRMs 1632 and 1633, National Bureau of Standards.

[3] Blackman (1986).

Leilan Object No.	S.I. No.	Type	Content
L.79 102	LEI007	Adm. text	Acropolis Period I Temple - grain disbursements
L.85 149a	LEI006	Adm. text	Dated to limu Ennam-Assur
L.87 156	LEI001	Adm. text	Probably Shamshi-Adad Period
L.87 447	LEI004	Adm. text	Fragmentary
L.87 787	LEI005	Adm. text	Undated, contents unknown
L.87 1436	LEI012	Adm. text	Undated, contents unknown
L.87 1439	LEI013	Adm. text	Dated to limu Habil-Kanu
L.87 1460	LEI019	Adm. text	Undated, contents unknown
L.87 1462	LEI020	Adm. text	Dated to limu Habil-Kanu
L.87 770	LEI022	List	Sumerian kinglist sample 1
L.87 770	LEI023	List	Sumerian kinglist sample 2
L.87 924	LEI024	Treaty	Between Till-Abnu and an unidentified king
L.87 1331	LEI025	Treaty	Between Till-Abnu and Assur
L.87 1362	LEI026	Treaty	Between Till-Abnu and Jamsi-Hatnu of Kahat Barri?)
L.87 1441	LEI014	Treaty	Fragmentary - origin unknown
L.87 1442	LEI015	Treaty	Fragmentary - origin unknown
L.87 402	LEI010	Letter	Fragmentary - to Leilan resident, origin unknown
L.87 472	LEI008	Letter	From Hammurabi of Aleppo
L.87 531	LEI021	Letter	From Burija - ruler of Andarig in Sinjar valley SE of Leilan
L.87 692	LEI002	Letter	From Hammi-E[puh] - assoc. w. Sabbanum and Amaz W/NW of Leilan
L.87 939	LEI003	Letter	From Shukrum-Teshshup - king of Eluhut, prob. West of Leilan
L.87 1426	LEI009	Letter	From Jamsi-Hatnu - king of Kahat, on Wadi Jaghjagh (Barri?)
L.87 1434	LEI011	Letter	Fragmentary - to king of Leilan, origin unknown
L.87 1449	LEI016	Fragment	Illegible
L.87 1451	LEI017	Fragment	Illegible
L.87 1459	LEI018	Fragment	Illegible
L.79 220	LEI027	Sealing	Fragmentary - no inscription - Acropolis Period I Temple
L.87 79c	LEI030	Sealing	Cylinder seal impression, Pd. IIa, geometric, basket weave
L.87 188	LEI029	Sealing	Cylinder seal impression, Pd. IIId, seated harpist (lyre)
L.87 1494	LEI028	Sealing	Cylinder seal impression, Pd. IIId, seated harpist (lyre)
L.87 1506	LEI031	Sealing	Cylinder seal impression, Pd. IIId, "Thème érotique"

- Table 2a: Samples Analyzed: Tablets and Seal Impressed Clays

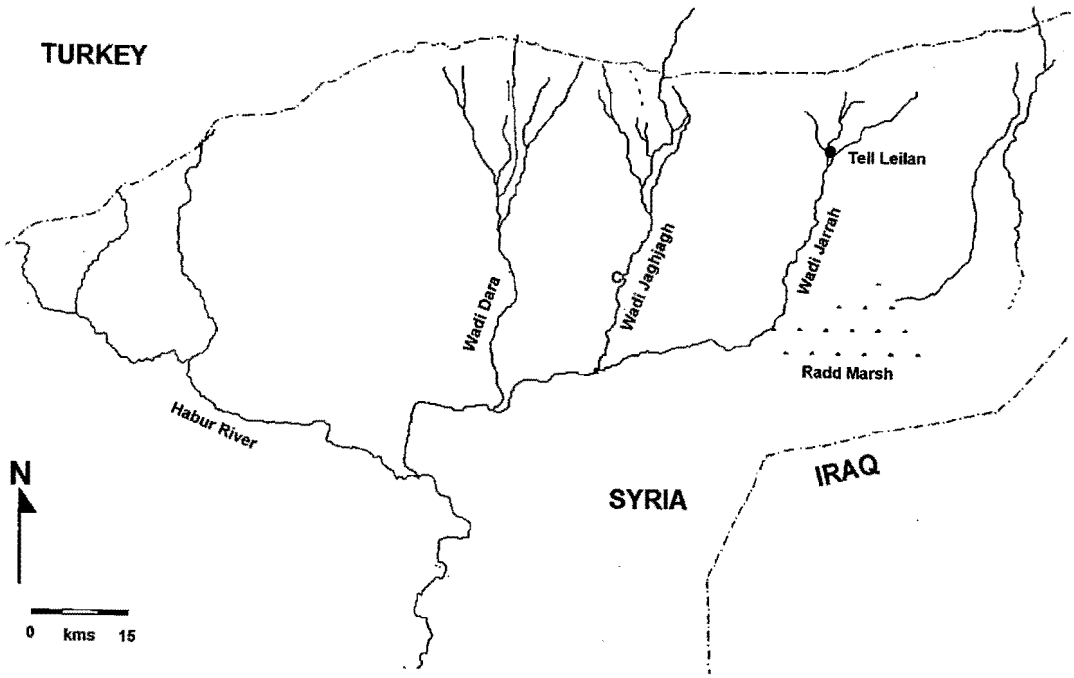
S.I. No.	Location on mound and Period	Sample Description
LEC001	Acropolis Pd. IIId	Unimpressed sealing clay
LEC002	Acropolis Pd. IIId	Unimpressed sealing clay
LEC003	Acropolis Pd. IIId	Unimpressed sealing clay
LEC004	Acropolis Pd. IIId	Unimpressed jar stopper
LEC005	Acropolis Pd. IIId	Unimpressed string cut sealing
LEC006	Acropolis Pd. IIId	Unimpressed jar stopper
LEC007	Acropolis Pd. IIId	Unimpressed sealing clay
LEC008	Acropolis Pd. IIId	Unimpressed sealing clay
LEC009	Acropolis Pd. IIId	Unimpressed sealing clay
LEC010	Acropolis Pd. IIId	Unimpressed sealing clay
LEC011	Acropolis Pd. IIId	Unimpressed sealing clay
LEC012	Acropolis Pd. IIId	Unimpressed sealing clay
LEC013	Acropolis Pd. IIId	Unimpressed sealing clay
LEC014	Acropolis Pd. IIId	Unimpressed sealing clay
LEC015	Acropolis Pd. IIId	Unimpressed sealing clay
LEC016	Acropolis Pd. IIId	Unimpressed sealing clay

- Table 2b: Sealing Clays Analyzed

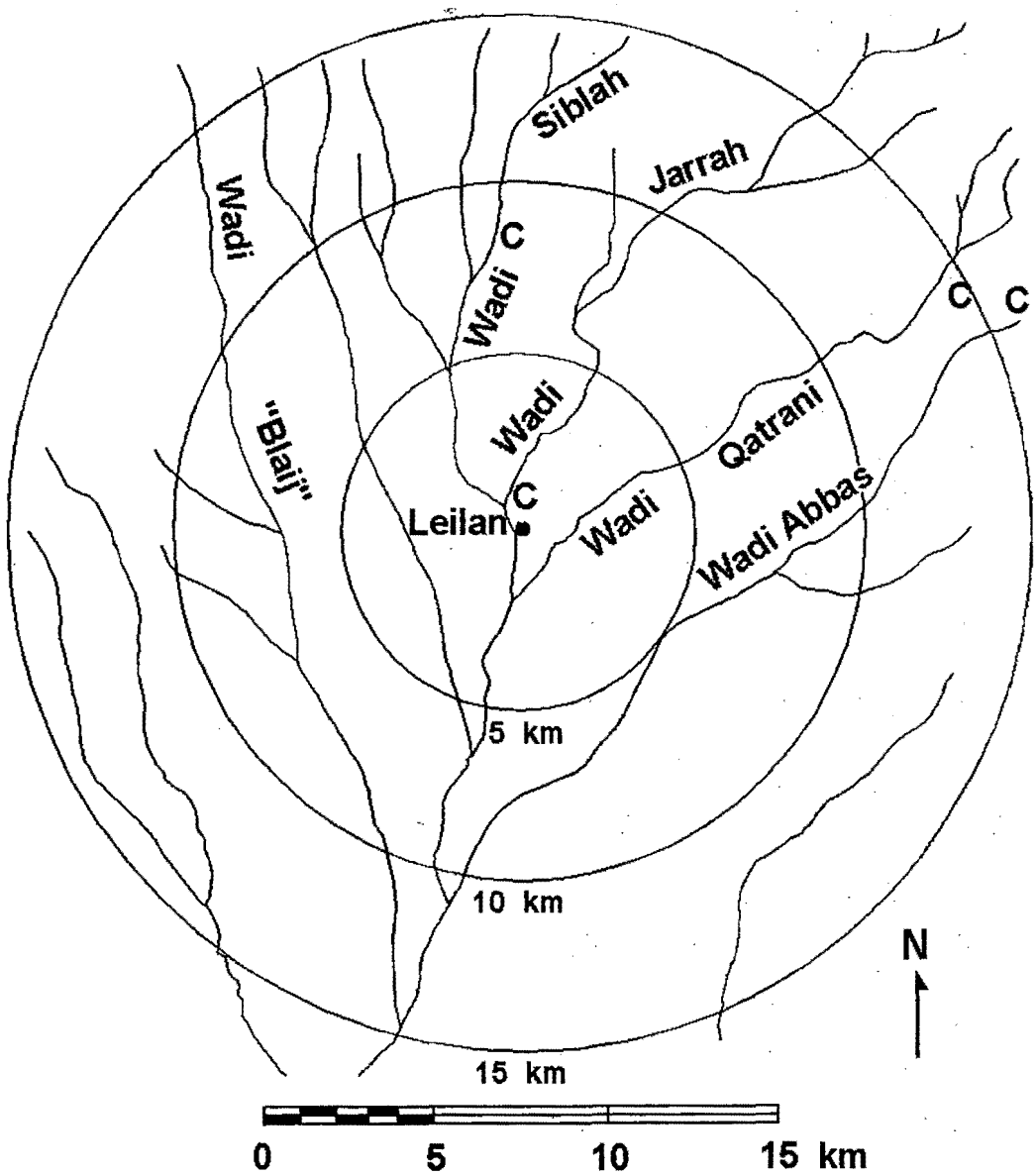
Sample Id. No.	Probabilities of Membership In Compositional Groups			Sample Description
	GRP 1	GRP 2	GRP 3	
Group 1:				
HDC010	82.0	0.0	6.9	Wadi Siblah clay untreated
HDC011	77.2	0.1	4.6	Wadi Siblah clay untreated
HDC015	81.8	0.0	2.5	Wadi Siblah clay levigated
HDC016	90.7	0.0	7.4	Wadi Siblah clay levigated
HDC020	79.0	0.0	13.5	Leilan city wall untreated
HDC021	92.0	0.0	0.7	Leilan city wall untreated
HDC025	97.5	0.0	13.8	Leilan city wall levigated
HDC026	97.5	0.0	2.3	Leilan city wall levigated
L.87 156	78.7	0.0	2.0	Administrative text
L.87 447	73.3	0.0	0.0	Administrative text
L.87 1460	84.6	0.0	3.6	Administrative text
L.87 1459	77.2	0.0	0.2	Tablet - illegible
L.87 1331	85.0	0.0	0.6	Treaty - Till-Abnu and Assur
L.87 1362	81.0	0.0	1.2	Treaty - Till-Abnu and Jamsi-Hatnu
Group 2:				
HDC001	0.0	68.0	1.5	Wadi Abbas clay untreated
HDC002	0.0	85.7	0.7	Wadi Abbas clay untreated
HDC005	0.0	92.1	1.4	Wadi Abbas clay levigated
HDC006	0.0	85.7	1.4	Wadi Abbas clay levigated
HDC030	0.0	77.5	0.4	Wadi Qatrani clay untreated
HDC031	0.0	60.9	0.6	Wadi Qatrani clay untreated
HDC035	0.0	85.3	2.3	Wadi Qatrani clay levigated
HDC036	0.0	72.6	0.1	Wadi Qatrani clay levigated
L.87 787	0.2	52.2	2.1	Administrative text, undated
L.87 1439	0.2	80.3	3.0	Administrative text, limmu Habil-Kanu
L.87 1462	0.0	92.5	0.3	Administrative text, limmu Habil-Kanu
L.87 770	0.1	96.0	0.1	Sumerian kinglist sample 1
L.87 770	0.1	46.8	0.0	Sumerian kinglist sample 2
L.87 1434	0.0	56.0	0.0	Letter - origin unknown
L.87 79c	0.0	63.2	2.8	Cylinder seal impression geometric
L.87 1449	0.0	56.8	0.1	Tablet - illegible
LEC002	0.1	60.0	3.5	Sealing clay, unsealed
LEC004	0.0	59.0	4.1	Sealing clay, unsealed
LEC008	0.0	69.5	1.5	Sealing clay, unsealed
LEC011	0.0	49.4	17.1	Sealing clay, unsealed
LEC012	0.0	86.6	6.7	Sealing clay, unsealed
LEC014	0.0	58.0	5.5	Sealing clay, unsealed
Group 3:				
L.85 149a	0.5	0.6	98.3	Administrative text, limmu Ennam-Assur
L.87 1436	0.3	0.0	71.4	Administrative text, undated
L.87 1494	0.0	0.3	75.8	Cylinder seal impression seated harpist
L.87 188	0.3	0.6	84.7	Cylinder seal impression seated harpist
LEC001	1.9	0.1	80.5	Sealing clay, unsealed
LEC003	0.1	0.6	99.1	Sealing clay, unsealed
LEC005	0.0	3.8	80.2	Sealing clay, unsealed
LEC006	0.0	4.1	89.4	Sealing clay, unsealed
LEC007	0.0	0.4	78.4	Sealing clay, unsealed
LEC009	0.0	4.1	95.6	Sealing clay, unsealed
LEC010	0.1	6.8	75.6	Sealing clay, unsealed
LEC013	0.1	0.6	74.4	Sealing clay, unsealed
LEC015	0.4	0.1	93.6	Sealing clay, unsealed

Sample Id. No.	Probabilities of Membership In Compositional Groups			Sample Description
	GRP 1	GRP 2	GRP 3	
Group 4:				
L.87 1441	0.0	0.0	6.4	Treaty - origin unknown
L.87 1442	0.0	0.0	3.3	Treaty - origin unknown
L.87 1451	0.4	0.0	0.5	Unknown - fragmentary
L.87 531	0.0	0.0	0.0	Letter - from Buriha of Andarig
L.87 402	0.1	0.0	0.1	Letter - to Leilan resident
L.87 1426	0.3	0.0	0.2	Letter - from Jamsi-Hatnu of Kahat
L.79 220	0.1	0.0	4.4	Sealing - Pd. I Temple on Acropolis
Outliers:				
L.87 692	0.7	0.6	1.2	Letter - from Hammi-E[puh]
L.87 939	0.8	0.0	2.4	Letter - from Shukrum-Teshshup of Eluhut
L.79 102	0.0	0.0	0.0	Adm. text from Pd. I Temple on Acropolis
L.87 472	0.0	0.0	0.0	Letter - from Hammurabi of Aleppo
L.87 924	0.0	0.1	0.1	Treaty - Till-Abnu and unidentified king
L.87 1506	0.0	0.0	0.1	Cylinder seal impresion "Theme erotique"
Tell Brak Seal Impressions:				
BRS001	0.0	0.0	0.2	
BRS002	0.0	0.0	1.0	
BRS003	0.0	0.0	1.0	
BRS004	0.1	0.0	1.3	
BRS005	0.0	0.0	0.1	
BRS006	0.0	0.0	0.1	
BRS007	0.0	0.0	0.1	
BRS008	0.0	0.0	0.2	
BRS009	0.1	0.0	0.4	
BRS010	0.1	0.0	0.7	
BRS011	0.0	0.0	0.2	
BRS012	0.0	0.0	1.1	
BRS013	0.1	0.0	6.0	
BRS014	0.1	0.0	0.4	
BRS015	0.3	0.0	1.7	
Nineveh Seal Impressions:				
NVS001	0.0	0.0	0.8	
NVS002	0.0	0.0	0.1	
NVS003	0.0	0.0	0.0	
NVS004	0.0	0.0	0.0	
NVS005	0.0	0.0	0.1	
NVS006	0.0	0.0	0.1	
NVS007	0.0	0.0	0.1	

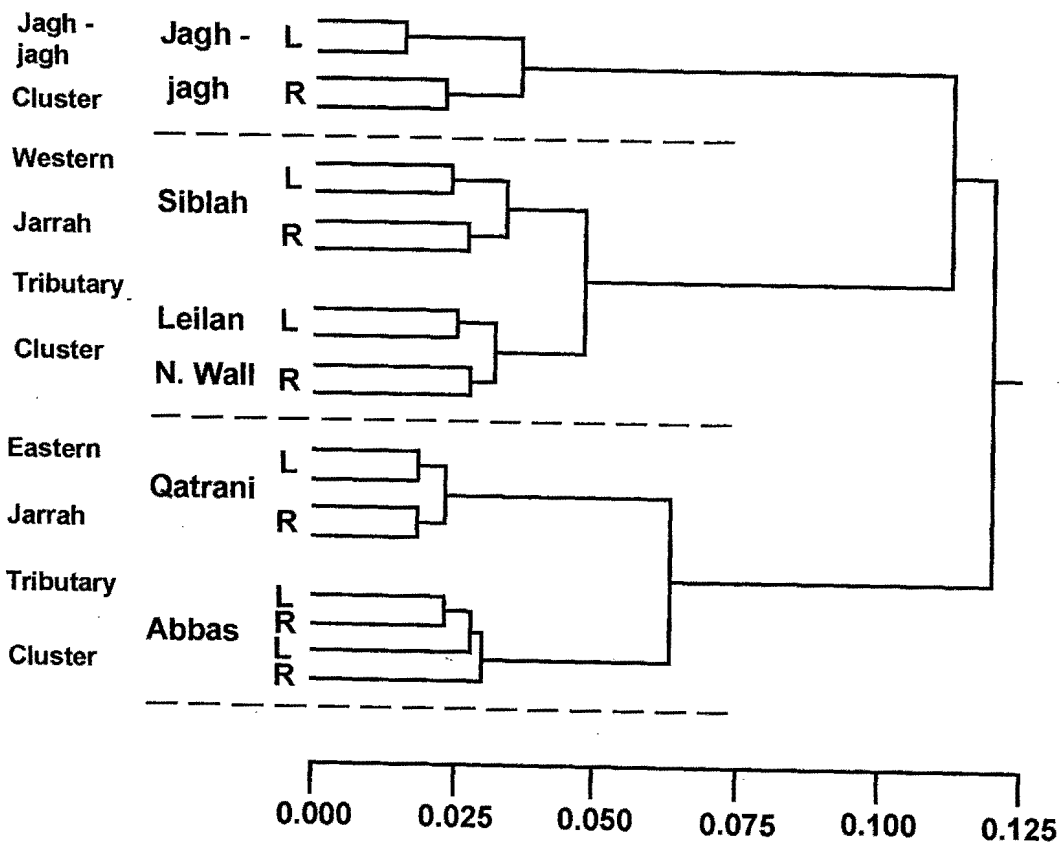
- Table 3: Mahalanobis Distance Calculation and Posterior Classification of Samples using Na, Cr, Fe, Cs, La, Ce, and Hf



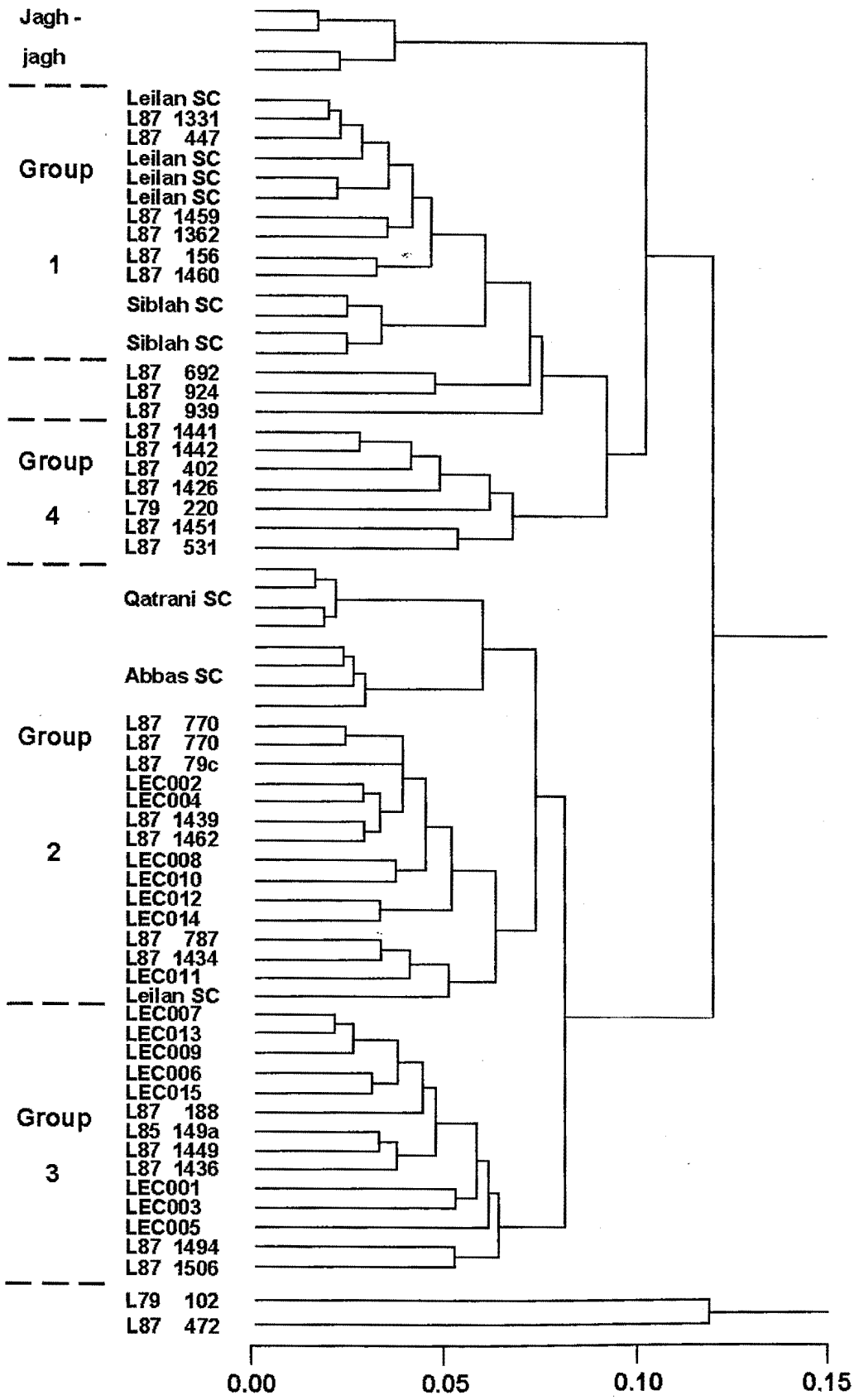
- Fig. 1: Map of the Northern Habur drainage. The sampling site for the Wadi Jaghjagh source clay is indicated by the C on the map.



- Fig. 2: Map of the Wadi Jarrah in a 15 km radius around Tell Leilan. The Wadi Jarrah tributary source clay sampling sites are indicated by the C's on the map.



- Fig. 3: Dissimilarity Cluster Dendrogram of the raw and levigated source clays from the Wadi Jaghjagh and Wadi Jarrah tributaries. L designates the "levigated" samples and R designates the "raw" clays.



- Fig. 4: Dissimilarity Cluster Dendrogram of the source clays and the Tell Leilan tablets and sealing clays.

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