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Mesopotamian Pottery Wares in Eastern Arabia from the 5th to the 2nd Millennium BC : A Contribution of Archaeometry to the Economic history.

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Introduction

Exploration of the Oman coast and its hinterland, which has been carried out since 1985 by the Franco-Italian Mission of the Joint Hadd Project, has provided evidence for the close relations which linked the eastern fringe of the Jaʿalan region and the surrounding countryside during Bronze Age (Cleuziou and Tosi n.d.). Excavations at Raʾs al-Jins RJ-2 and Raʾs al Hadd HD-1 have also allowed a better assessment of the connections between Eastern Arabia and the Indian sub-continent. Various prestige objects from Indus sites reached the coast, and especially Raʾs al-Jins, for example bronze seals, ivory combs, and bronze tools or weapons. There are however other artifacts which demonstrate that contacts existed with other countries too. A dozen fragments of Mesopotamian ceramic vessels fall in this category. They were found at Raʾs al-Jins in levels of Period II (2500-2400 BC) together with black-slipped jars from the Indus valley. This discovery is interesting for two reasons : these fragments are the first evidence of Mesopotamian ceramics located outside the United Arab Emirates during the Umm-an-Nar Period and, secondly, analyses have demonstrated that these pots contained bitumen from Iraq (Cleuziou and Tosi 1994:756).

However, these are not the earliest contacts between Eastern Arabia and Mesopotamia. Ceramic vessels of Mesopotamian style in the United Arab Emirates were identified for the first time some 25 years ago when the famous decorated pots of Jamdat Nasr to Early Dynastic I-II were found deposited in graves of the beginning of the 3rd millennium BC (Frifelt 1970 ; During Caspers 1971). More recently, Ubaid sherds were discovered at some twelve sites along the coast of the United Arab Emirates (see fig.1).

In 1983, H.S. Mynors published the very first analyses of Mesopotamian ceramics found in the Oman Peninsula. In her paper headed "An examination of Mesopotamian ceramics using petrographic and neutron activation analysis", she

studied 19 Early Dynastic III ceramic vessels from the site of Umm an-Nar, and one from a Hafit grave. She demonstrated the closeness of composition between these jars and the pottery from Abu Salabikh in Southern Mesopotamia.

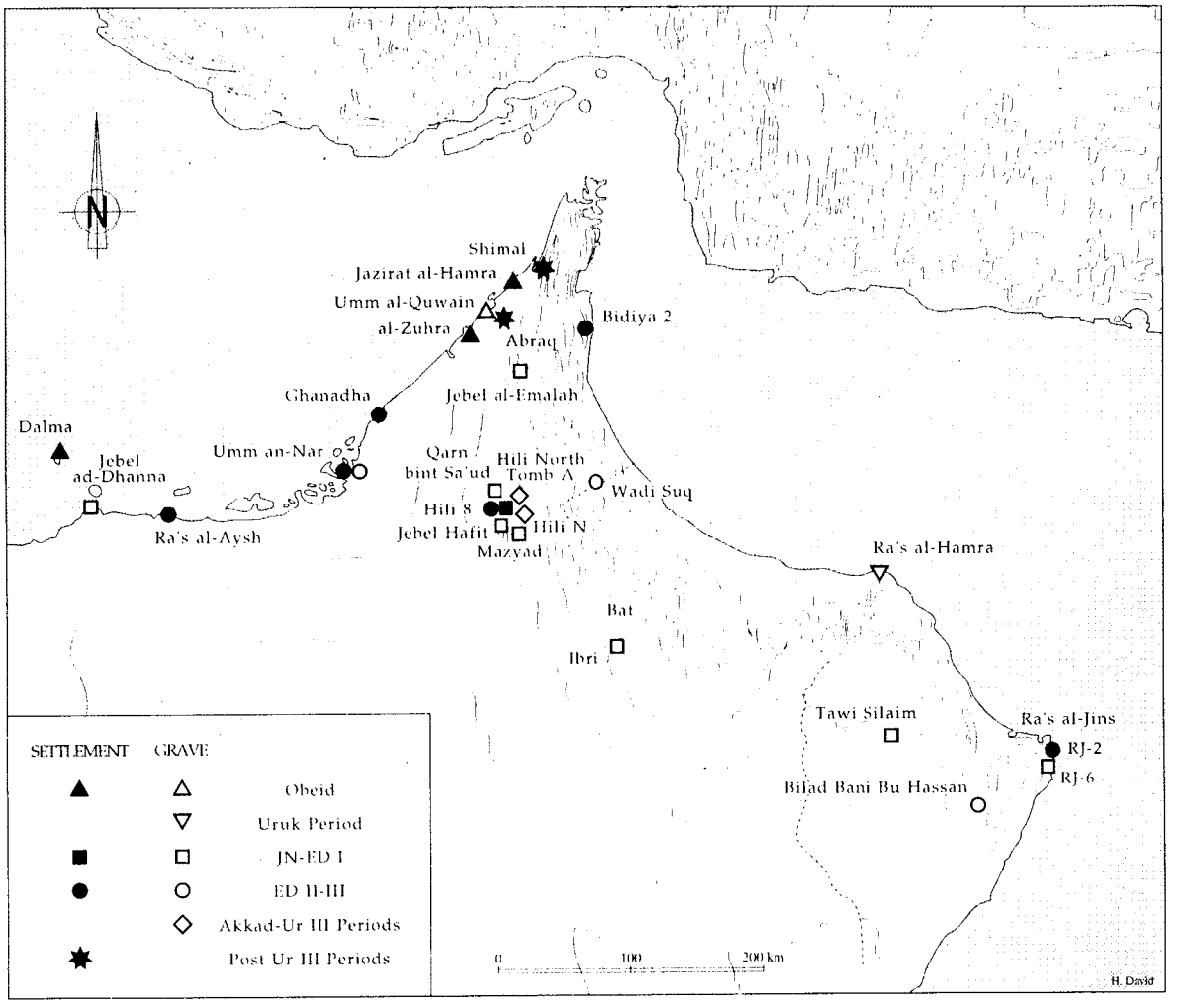

Figure I: Occurrences of Mesopotamian wares in the Oman Peninsula from the 5th millennium to the 2nd millennium BC.

Our petrographic and chemical analyses began in the 1980's along with a general characterisation of protohistoric pottery from the United Arab Emirates and the Sultanate of Oman (Blackman et al. 1989 ; Méry 1991). The results are presented in the following pages. Analyses of 49 pots of Mesopotamian style, which were discovered in 13 different archaeological sites dated from the 5th to the 2nd millennium BC, merely confirm their Southern Mesopotamian origin.

2. The archaeological evidence

The pottery assemblage of Oman gives evidence of relations with Mesopotamia from the 5th until the 2nd millennium BC. For the 4th millennium however, the only available testimony for these contacts is, so far, a single potsherd.

The Ubaid pottery sites (Vth millennium). A small number of Ubaid sherds were found in about 15 fishermen's settlements and one grave, along the coast of the United Arab Emirates (Fig. 1) : Dalma island (Flavin and Shepherd 1993), Ajman (Haerinck 1991, 1994), Umm al-Quwayn (Boucharlat et al. 1991; personal communication C. Phillips), and in the Peninsula of Jazirat al-Hamra (Sites 1, 4, 38, 40, 43, 45, 46, 55, 56, Vogt 1994). These sites are usually characterised by the presence of numerous net-sinkers and a bifacial industry related to Qatar group D (Inizan 1988).

Some of these Ubaid sherds are painted but the decoration is hardly and seldom recognizable : one of them, which is decorated with lozenges painted between two horizontal lines, is dated to Ubaid 3 or 4 (Vogt 1994 : 123) whereas an earlier date (Ubaid 2-3) was suggested for a potsherd from Ajman (Haerinck 1991 : 87).

In the Sultanate of Oman, the earliest Mesopotamian sherds were identified at Raʾs al-Hamra RH-5 (Méry n.d.). One was found in a level dated to the first half of the 4th millennium BC, while the other one was collected from the surface of the site. Neither were decorated.

The Hafit period. Non-Mesopotamian ceramic vessels are exceptional in Hafit graves. So far, the assemblage of Mesopotamian ceramics recovered from Hafit graves amounts to some fifty (complete or uncomplete) pots. Most of them were found in 31 graves which are located in the northern part of the Jabal Hafit (Fig. 1) near the present-day village of Mazyad, and at Qarn Bint Saʿud (Frifelt 1970, 1975, 1979, 1980 ; During Caspers 1971; Cleuziou et al. 1977 ; al-Tikriti 1981). Most of the graves only contained a single vase, three at the most. Mesopotamian ceramic vessels were also discovered in other regions of the Oman Peninsula : at Jabal al-Emalah (Emirate of Ajman), at Bāt and Ibri in the Dhahira, at Tawi Silaim and Maysar in the Sharqiya, and at Raʾs al-Jins on the coast of Jalaʿan (Frifelt 1975 ; Slotta in Weisgerber 1981 ; de Cardi et al. 1994 ; personal communication G. Santini).

The most characteristic shape is biconical, with a large and flat base, a rather low maximum diameter, a high and broad neck, a ridge between neck and upper body and a bevelled rim (Fig. 2 n° 3 and 6). However, many vessels differ from this type, as shown on figure 2 (n° 4 and 5). Only six pots display a well-preserved

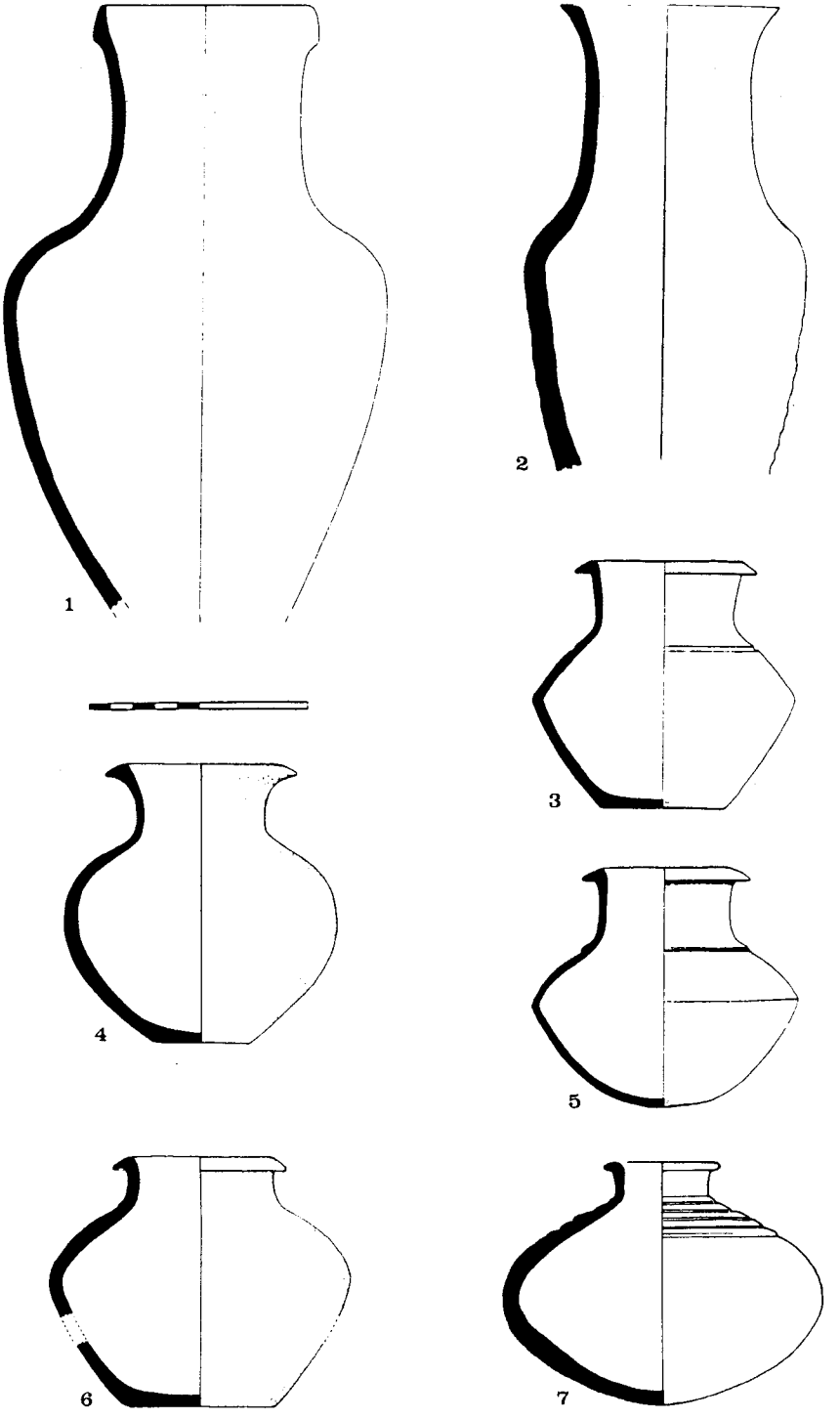

Figure 2: Examples of Mesopotamian vessels found in the Oman Peninsula

polychrome decoration. A plum-red slip was partly applied over a first coat of beige slip, leaving some panels uncoloured. The decoration consists in simple geometric motifs (oblique parallel bands or intersected lines), or vegetal motifs (branches) painted in black on the shoulder of the pot.

Pottery is similarly scarce in the only settlement known for the Hafit Period : the quantity of pottery collected per cubic metre of sediment in the levels of Period I at Hili 8 is very small compared to the levels of the end of the 3rd millennium BC. Among the 100 potsherds of Period I, 40 were classified as Mesopotamian pottery either on account of their shape, or because of the macroscopical aspect of their fabric. 10 flat bases and 3 necks were found associated with local pottery, mainly fine black-on-red ware (Cleuziou 1989 : 51, Fig. 1).

Mesopotamian ceramic vessels of Hili 8 have no exact equivalent among the funerary pots of the Hafit Period, but they too are close in shape to Jamdat Nasr to Early Dynastic I-II vessels from Mesopotamia. Thus, a small pot with cylindrical neck and a cordon and four lugs at the base of the neck was compared to a Jamdat Nasr pottery type (JN47 in Woolley 1956, Pl. 57, quoted by Cleuziou 1989 : 51). This type is still found in Mesopotamia in the Early Dynastic I and II. Another vase with a short neck and banded rim is similar to a type known during Early Dynastic I and II, for example at Khafajah and Tel Razuk (ibid.).

The Umm an-Nar period. Mesopotamian jars with a ring base are attested at Hili 8 in the levels of the beginning of the Umm an-Nar Period (Phases IIa and IIb). They amount to about 25% of the pottery assemblage of this site, and are associated with local pottery such as black-on-red fine and sandy wares (Cleuziou 1989, Méry 1991). No Mesopotamian ceramics were recovered in the grave at Hili M, which is contemporaneous with Phases IIa and IIb at Hili 8 (Vogt n.d.).

Mesopotamian ceramics disappear from the pottery inventory around 2600 BC at Hili 8 and they occur rarely in graves of the end of the Umm an-Nar Period in inland Oman. This is well illustrated by a single Mesopotamian bottle discovered among more than 700 pottery vessels at Hili North, Tomb A (Fig. 2 n°7). Two beakers of late Akkadian type were also discovered at Hili, Tomb B (al-Haddu 1989 : Fig. 9).

Mesopotamian jars are very numerous at Umm an-Nar, both in the settlement and in the graves. They are associated with local and Iranian ceramic vessels (al-Tikriti 1981 ; Frifelt 1991, 1995 ; Méry 1991). A small number of these jars were found deposited in cairns V and VI, they are dated to the outset of the Period of Umm an-Nar (Frifelt 1991: Fig. 180, 181, 207). Ceramic shapes of the Early Dynastic I also occur in levels of Period 0 at the settlement of Umm an-Nar (ibid. Fig. 29 and 32). Mesopotamian jars are more numerous in cairns I and II at

Umm an-Nar. Their high neck and collared rim are typical of the Early Dynastic III Period (Fig. 2 n° 1, and Frifelt 1991: Fig. 86-89, 125-130).

Jars of this type are also found in the settlement, where many of them are coated with bitumen (Frifelt 1995 : Fig. 28, 123). Other types of jars dated to the Early Dynastic III are also represented, like for example bevelled-rim jars (ibid. Fig. 47, 172). Fragments of Mesopotamian jars attributed to Early Dynastic III were also recovered from the settlements at Ghanadha 1 (al-Tikriti 1985 : Pl. 9 and 10) and Ra's al-Aysh (Vogt et al. 1989 : Pl. 7).

The potsherds discovered at Ra'ʾs al-Jins were too fragmentary for us to identify either the complete shape or the type of jars which are found on the coast of the Arabian Sea. All that we know is that these jars were large undecorated vessels with thick walls. One sherd displays an incised sign which was interpreted as the cuneiform sign "Kisal" (Cleuziou and Tosi 1994 : 757).

The Wadi Suq period.The first Mesopotamian sherds found in a context dating to the beginning of the 2nd millennium were discovered in settlement SX-SY at Shimal, where they were very scarce (Vogt, personal communication). More recently, rims of vases attributed to the Isin-Larsa and Old Babylonian Periods were identified at Tell Abrak by Potts (1993 : Fig. 3). Other sherds are attributed to the Kassite and Post-Kassite periods (ibid).

2. The characterization of the pottery fabrics

Macroscopic description. The macroscopic and low-power microscopic examination shows that most of the vessels of Mesopotamian style found in Oman[1] were, whatever the period, made from clays which turned to beige or buff, greenish if fired at very high temperatures. The paste contains numerous black inclusions measuring less than 0.4 mm, the large amount of sand giving a rough texture to the potsherds. There are, however, some exceptions : 1052.B (Fig. 2 n°5) and 1321.A (Frifelt 1975 : fig. 9) are made of fine green fabric, whereas that of 1051.A (Frifelt 1970 : fig 21 C) and 1141.A (Fig. 2 n°3) is fine and orange. Neither present visible mineral inclusions.

Sampling. All in all, 104 samples were selected for the petrographic and chemical analyses[2]. 67 were studied in thin-section and 75 were characterized by X-ray fluorescence. A double petrographic and chemical composition was carried out for 35 samples.

49 ceramic vessels which were discovered in the United Arab Emirates and the Sultanate of Oman were selected (Table 1) for comparison with 55 samples of clays and potsherds from Mesopotamian sites (Table 2). Ten sites of the United

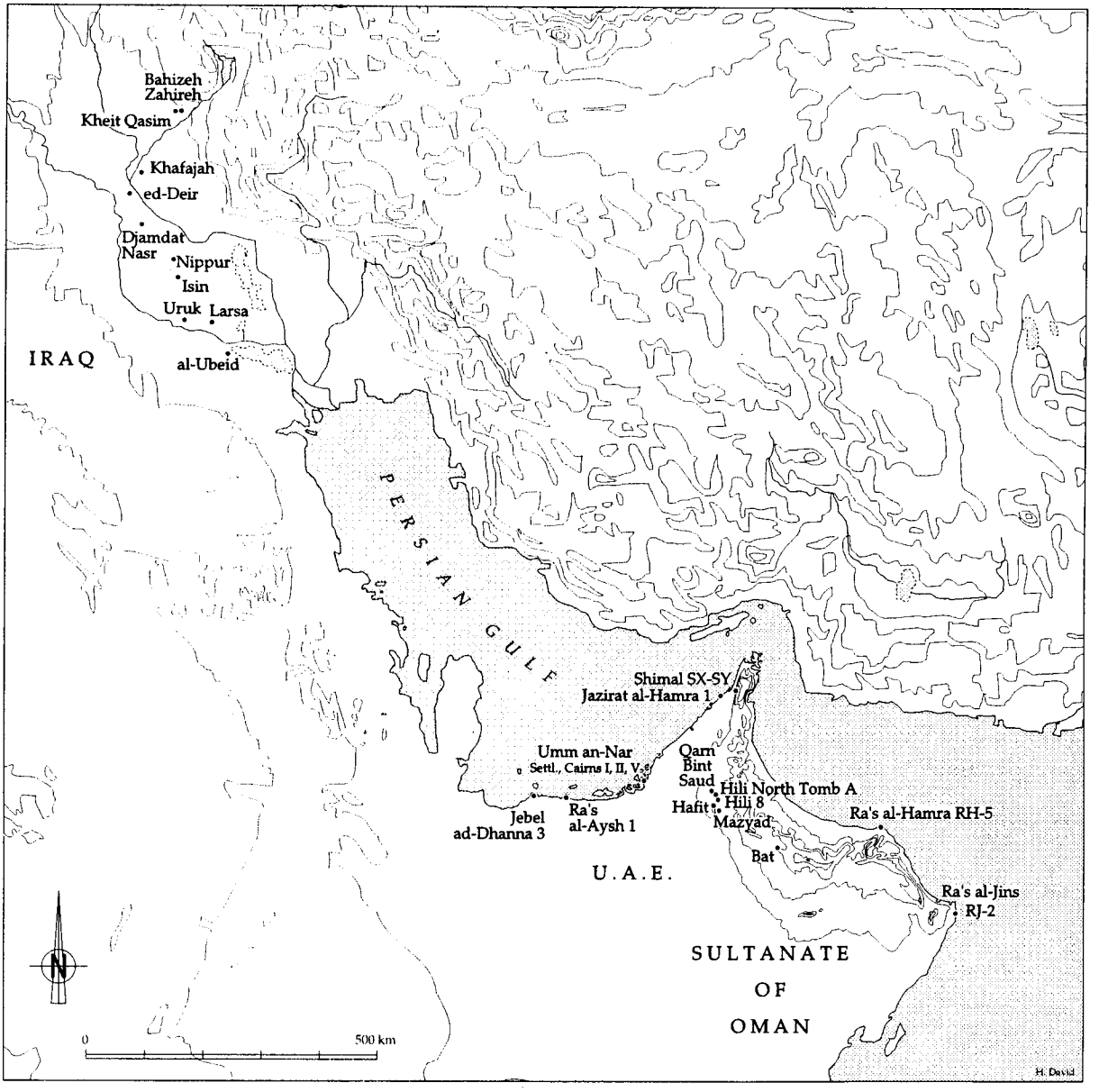

Figure 3:Localisation of the sites from which samples were analysed by optical microscopy or/and by X-ray-fluorescence.

Arab Emirates are represented in the sampling (Hafit, Mazyad, Qarn Bin Saʿud, Hili 8, Hili North Tomb A, Shimal, Jazirat al-Hamra, Umm an-Nar, Jebel ad-Dhanna, Raʾs al-Aish), three sites from the Sultanate of Oman (Raʾs al-Hamra, Bāt and Raʾs al-Jins) and ten from Mesopotamia (el-Ubaid, Uruk, Larsa, Isin, Nippur, Ed-Deir, Djamdat Nasr, Khafajah, Keith-Qasim, Bahizeh Zahireh).

Petrographic composition. 39 ceramic vessels which were discovered in the Peninsula of Oman were studied in thin-section. Three groups of composition were singled out : groups A, H and I. The main difference between A and H is the temperature of firing : a high temperature for the vessels of group A (not below 1000° C) and a low to medium temperature for those of group H. The mineralogical composition of group I is different from that of group A and H, an indication that clays probably came from different sources.

Group A (14 samples). The matrix is sub-isotropic, greenish-brown to dark green (Pl. 1, B), typical of almost overfired calcareous marly clays. The sandy fraction is composed of well sorted inclusions which can be scarce (A624) to quite abundant (200-350 microns, 10-15% of the surface of the thin-section). Inclusions measure less than 175 microns in sample A624 (vessel 1052.B), but they reach 300 microns in other samples. Quartz are the most numerous, with a uniform to shadowy extinction. Their shape is angular, sometimes very irregular. The presence of grains of primary calcite can be recognized from the shape of numerous round holes surrounded by a thin micritic halo. Other inclusions are plagioclases, alkali felspars, micro-cristalline quartz, radiolarite, chert. There are also opaque iron oxides, opacified biotites, sub-automorphic hornblendes (often broken), epidotes, serpentines, muscovites, pyroxenes (with low interference colours) and volcanic fragments.

Group H (21 samples). It is characterized by a low to medium-heated marly clay composition (Pl. 1, A). Only A641, A642 and A1034 (from Umm an-Nar) containing numerous tiny micas in their matrix. Low-heated vessels have a light brown matrix (clay minerals are birefringent) and well preserved grains of calcite in the coarse fraction. Calcite is micritic and clay minerals are no longer birefringent in the medium-heated vessels. Inclusions are abundant and well sorted (200-350 microns, 15-20% of the surface of the thin-section). The composition of the coarse fraction is like the samples of group A except for the presence of many calcareous rock fragments (micro-cristalline calcite, spathic calcite, few foraminifera).

Group I (3 samples). The matrix is composed of a mixture of tiny calcite and micas. In the coarse fraction, quartz, calcite grains and a few volcanic fragments are below 150 microns. This group is quite heterogeneous. Vessel 1051.A belongs to this group.

A625 is unique in thin-section. Its coarse fraction is composed of a mixture of sub-rounded quartz and calcareous fragments.

The results of the petrographic study do not allow us to make a distinction - either in time or in space - among the potteries of Mesopotamian style which were discovered in Oman :

- Group A is represented in 5th millennium contexts (Jazirat al-Hamra), 4th millennium (Ra's al-Hamra), in the Hafit Period (Hafit and Hili 8), at the outset of the Period of Umm an-Nar (Hili 8, Ra's al-Aysh and Cairn V at Umm an-Nar), and in the Period of Wadi Suq (Shimal).
- Group H is represented in 5th millennium context (Jazirat al-Hamra), in the Hafit Period (Hafit, Hili 8), at the outset (Hili 8) and in the second half of the Period of Umm an-Nar (Cairns I and II at Umm an-Nar, Ra's al-Jins RJ-2) and at the end of the same period (Hili North Tomb A).
- Group I is so far only attested among the ceramics of Hafit.

The ceramics which were discovered in the Peninsula of Oman were compared with 27 clays and potsherds from Mesopotamia. Excepting Group I, which was not recognized among our Mesopotamian samples, the ceramics which were found in Eastern Arabia are similar to the samples from Mesopotamia :

- most of the vessels belong to group A. They come from el-Ubaid, Uruk, Larsa, Djamdat Nasr, Khafajah.
- 7 vessels and bricks belonging to group H came from Uruk and Larsa.
- The five samples from the Hamrin basin (Kheit Qasim and Bahizeh Zahireh are different from all the other samples. They are marly clays with a temper fraction which comprise characteristic fragments of cherts, radiolarites and metamorphic rocks containing quartz and micas. This later group was not recognized among the sampling of Oman.

Chemical composition. 75 samples of vessels found in the United Arab Emirates, the Sultanate of Oman and Mesopotamia were analysed by wavelength dispersive X-ray fluorescence for major and trace elements[3]

The samples can be divided into two principal groups according to their contents in calcium and magnesium (Table 3).

The first compositional group is characterised by a high calcium content. This group includes samples from all the sites of the Oman Peninsula which we analysed including the site of Umm an-Nar. This group is heterogeneous and some

samples should be statistically considered as outliers. Averages and standard deviations are given in Table 5. Because the largest variation is in calcium contents, the analyses are sorted in increasing CaO, in order to make the correlations with other elements more obvious.

The second compositional group is characterized by lower calcium contents (between 2.3% and 13.9%) and higher magnesium contents (between 8% and 13.4%). There is no correlation of magnesium with calcium or any other elements. The differences with Group 1 are not significant if the trace contents in Sr and Ba are considered as influenced by burial conditions, a possibility that is indicated by their very high variation. In spite of its higher content in calcium, sample A799 is included in Group 2 because of its high content in magnesium, which distinguishes it clearly from the first group. Except this sample, the second compositional group only consists of samples from the site of Umm an-Nar. In the scattergram (Fig. 4), it can clearly be seen that the group which is high in magnesium has no equivalent among the samples from Southern Mesopotamia which we analysed.

There are also 5 samples from the Oman Peninsula which differ from the two major groups. A167, A549, A625 and A636 are characterised by lower chromium and nickel contents and (excepting A167) by higher potassium contents than the two major groups. The biplot Mg/Cr (Fig. 4) clearly displays these outliers. These samples are clustered at the end of the dendrogram, which means that they did not match the major groups. In this dendrogram, sample A1017 is also clustered at the end, and is thus marked as an outlier. However, because of the typical high content in Mg, we are tempted to attribute this sample to Group 2 (the clustering technique average linkage has a tendency to cluster samples with slightly different compositions at the end). Sample A622 which shows high nickel and chromium contents, also contains more titanium, aluminium and iron. In figure 4, this sample is not separated from the first group.

Major elements Si to K and trace elements Cr, Ni, Rb, and Zr were used for further statistical treatments because they were also determined in the 100 mg samples, and because they were not influenced by secondary effects unlike P, Sr and Ba which had to be excluded for this reason. The scattergram Mg/Cr and the dendrogram (Fig.4) show that the samples from the first group of ceramics found in the Oman Peninsula are comparable to the samples from Southern Mesopotamia (i.e. Uruk, Larsa, Nippur, ed-Deir and Djamdat Nasr).

However, it is not possible to divide this large group significantly, neither is it possible to detect distinguishing local compositional groups among these Southern Mesopotamian sites. Only two samples Ur03 and La04, should be chemically excluded (Ur03 was not studied in thin-section and La04 belongs to

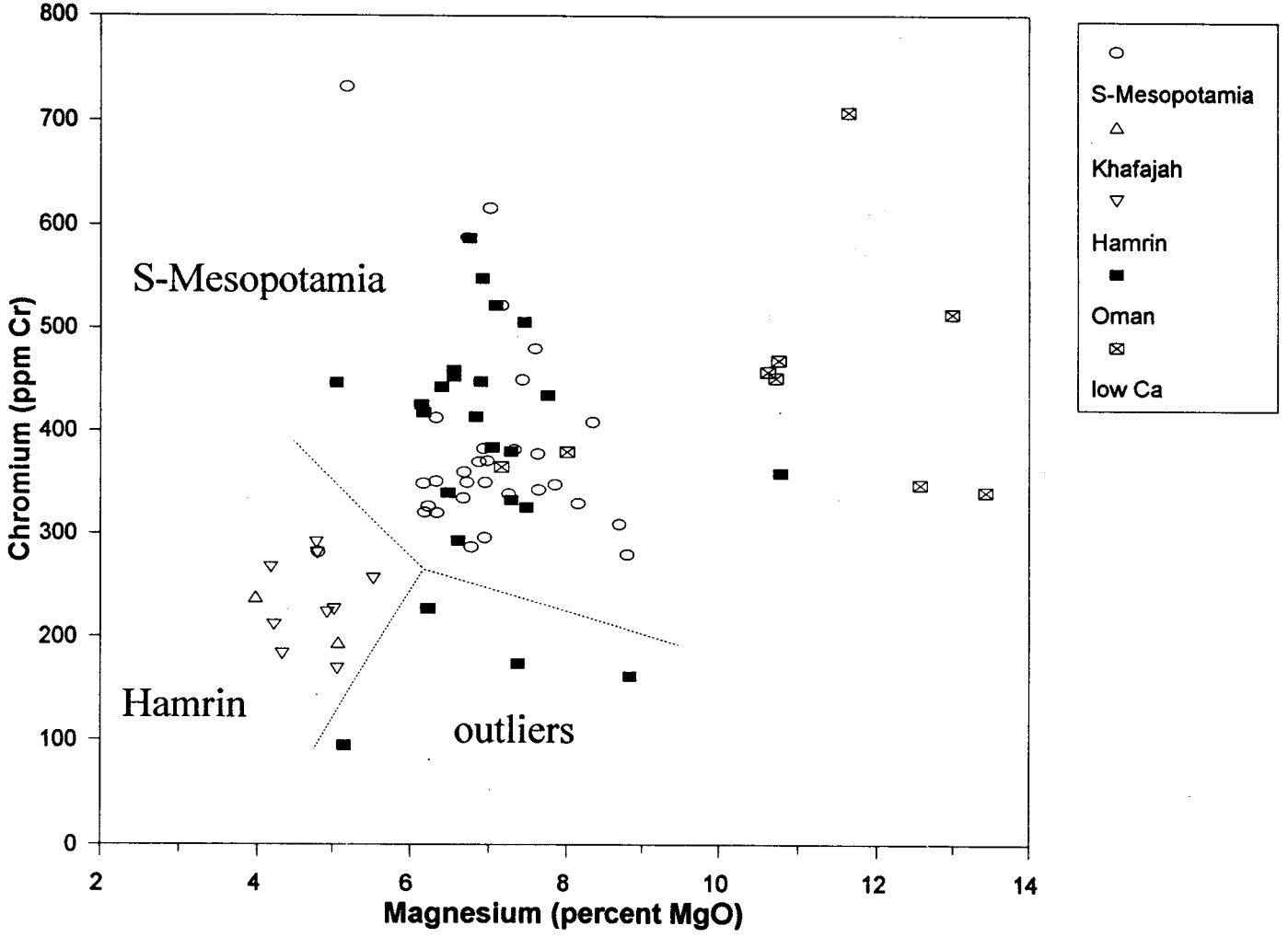

Figure 4: Scattergram of magnesium and chromium. The major groups of Mesopotamian vessels found in Oman fall into the field of Southern Mesopotamian pottery. A second group of vessels is characterised by high magnesium and calcium contents. Both groups are distinct from the Hamrin vessels.

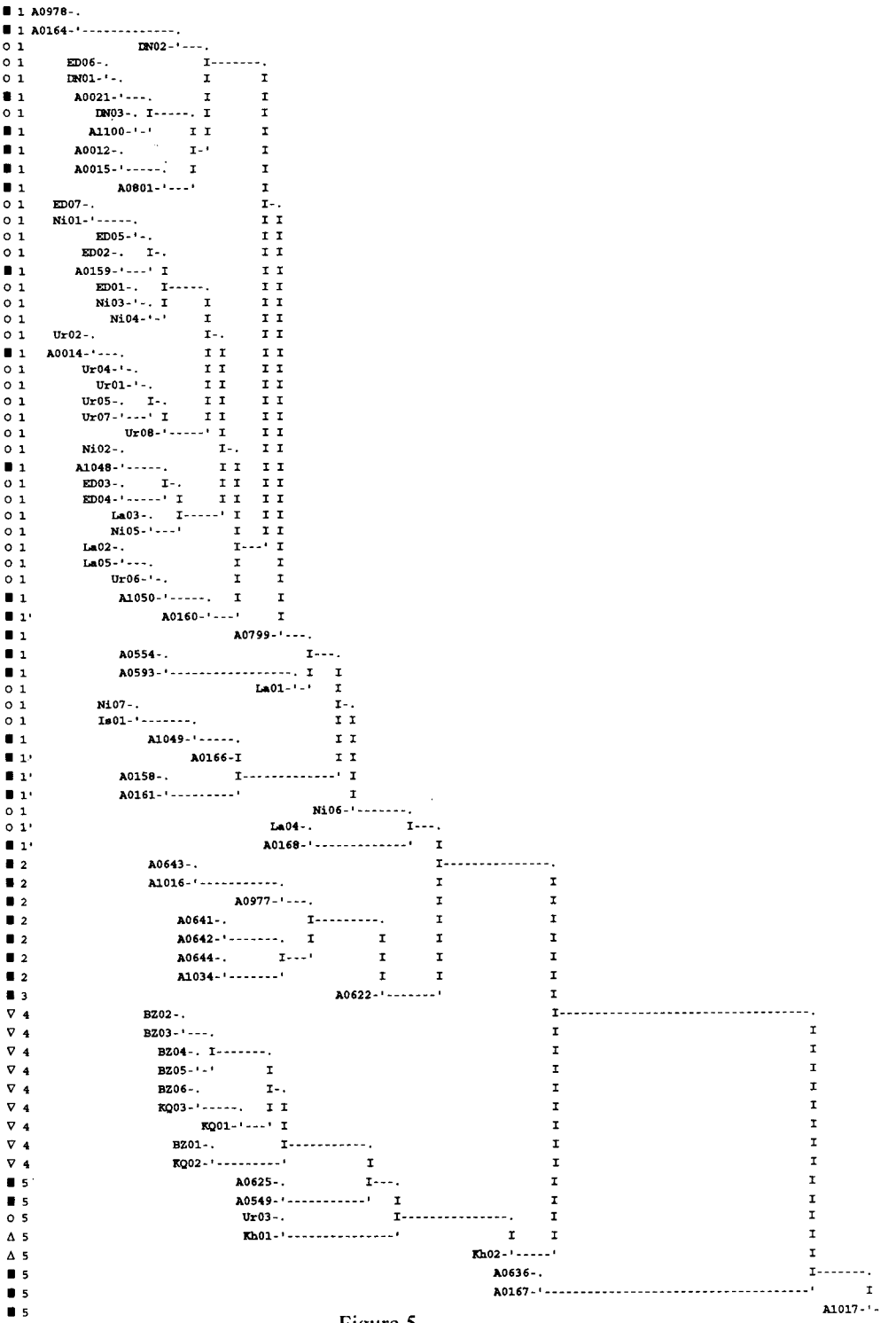

Figure 5.

Fig. 5. Dendrogram made by AGCLUS (Brookhaven Data Handling Programs). Distance measure : euclidian distance used with Si, Ti, Al, Fe, Mg, Ca, Na, K, Cr, Ni, and Zr. Aggregative clustering of a distance matrix using average linkage. Data logged, n=75.
n : samples from the Oman Peninsula, o :samples from Southern Mesopotamia, ▽: samples from the Hamrin region △ : samples from Khafajah.
1 : Mesopotamian major group and vessels found in the Oman Peninsula which are attributed to this major group. **1'** : samples which do not belong to group 1 from Mahalanobis distances, but are very close in composition. **2** : vessels found in the Oman Peninsula which are not attributed to groups 1 or 1'. **3** : outlier, petrographic group I. **4** : Hamrin group. **5** : outliers, mainly because of their chromium and nickel contents.

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petrographic group H). In the dendrogram, Group 1 from Southern Mesopotamia, and ceramics found in the UAE and the Sultanate of Oman are well separated from Group 2 (samples from Umm an-Nar).

When we checked the probability of all samples belonging to the Southern Mesopotamia core group (Table 5, averages) using the Mahalanobis distances, only the samples indicated by a string (1') did not belong to major Group 1. We were not able to distinguish these samples from Group 1 because of the small number of samples and the generally large variations (which can also be detected from the petrographical examination). Group 4, which represents pottery from the Hamrin region, is clearly distinguished, and so are outlier samples numbered 3 and 5 in the dendrogram. It should be stressed, however, that such dendrograms obtained through hierarchical clustering procedures only indicate similarities, and that they cannot be used for making final decisions for or against groupings. The number of samples is too small to allow more efficient statistical treatments.

One clear result from the chemical analysis is that the samples from Kheit Qasim and Bahizeh Zahireh (i.e. from the Hamrin basin) are different from those of Southern Mesopotamia. It is also clear that the ceramics of the second group of Omani vessels have no equivalent among all the analysed samples from Mesopotamia. These Omani vessels are closer to Southern Mesopotamian samples than to Hamrin or Khafajah samples. We can consider, as a theoretical possibility, that these differences are perhaps due to the absorption of magnesium from a possible burial in seawater, and from leaching of calcium in this kind of environment. If this were the case, one should not look for equivalent compositions in Mesopotamia, but for similar secondary changes in potsherds from the site of Umm an-Nar.

3. Conclusions

The results of the chemical and petrographic analyses are coherent :

• - The chemical analyses demonstrate that the main difference between petrographic groups A and H is the temperature of firing. The high temperature of firing of the ceramics from Group A explains the differences which can be observed in the composition of the coarse fraction. This involves, in the first place, carbonates which are dissociated when the pottery is fired at a high temperature, and also the iron-rich minerals e.g. biotites which become opacified or even dissolved in the glass phase. The size of grains and the amount of quartz inclusions are also involved, because they are partly dissolved at high firing temperatures. Therefore, a difference in the composition of the raw materials used for the two groups does not necessarily exist, as stated from the petrographic study alone (Méry n.d.). This shows that the combination of both petrographic and chemical data is needed for the study of calcareous fabrics, because we do not know how fabric A would have looked, had it been fired at lower temperatures.

• - Chemical outliers which were studied in thin-sections clearly have different petrographic compositions from the ones of the main group.

• - Both petrography and chemistry indicate a Southern Mesopotamian provenance for the ceramics found in Oman. It is also true for the second chemical group, which is not petrographically different from the first group, in spite of its high magnesium and low calcium contents. No distinction can be made between the samples from Oman and those from Southern Mesopotamia on the basis of our thin-section studies. The samples from the Hamrin Basin not only have a different chemical composition, but they are also peculiar in their mineral inclusions.

• - For further comparison, we have the results of the instrumental neutron activation analyses carried out by Mynors (1986 : 481) who stresses the closeness between her samples from Umm an-Nar and those of Abu Salabikh (Southern Mesopotamia). However, as Mynors did not include Mg or Ca determinations in her study, we have no means to clear the problem of the group of ceramics with high magnesium contents, from Umm an-Nar. An unpublished Master of Arts thesis by C.L. Coursey (1987) presents mineralogical descriptions of 35 potsherds from Uruk, Jamdat Nasr and Abu Salabikh. As far as can be understood from the descriptions given by Coursey and Mynors[4], the mineral contents are the same as the ones which we found in our samples from Southern Mesopotamia.

• - The thin-sections (see for example plate 1, C-F) and chemical compositions clearly demonstrate that all of the Mesopotamian ceramic vessels which we studied for this paper are quite different from the local or imported potteries which

were studied in Eastern Arabia (Blackman et al. 1989 ; Méry 1991). Where chemical composition is concerned, our conclusion is drawn from the comparison between our own analyses and those made by neutron activation at the Conservation Analytical Laboratory, Smithsonian Insttitution. This comparison is based on at least nine elements determined in both series, including the highest contents of calcium and chromium (Mg and Ni were not determined by INAA). The results are that we were unable to evidence any locally manufactured copy among the Mesopotamian ceramics from Oman which were analysed, no matter what period or what type of pottery. Chemical and petrographic analyses thus confirm the hypotheses which were already suggested some 25 years ago about the transport of Mesopotamian ceramics to the Peninsula of Oman. Our results do not contradict those of Mynors on the pottery of Umm an-Nar. However, new analyses are needed to check whether the samples which she studied do belong to our second chemical group (the one with high magnesium contents), and to ascertain how close they are in composition to the local pottery from Abu Salabikh.

Notes

1. We have studied the ceramics which are kept at the Forhistorisk Museum of Moesgard (Aarhus, Danemark), the Museum of Al Aïn, the British Museum and the Department of Antiquities of Muscat.

2. We wish to express our gratitude to H.E. Saïf bin Ali al-Darmaki (al-Aïn), Sheikh Sultan bin Saqr al-Qassimi (Ra's al-Khaimah), Dr Ali bin Ahmed bin Bakhit al-Shanfari (Muscat) and Dr W. al-Tikriti for their generous support to this study. Samples were kindly supplied by the German Archaeological Institut - Department Baghdad (Uruk), the University of Paris I-Sorbonne (el-Ubaid, Larsa, Djamdat Nasr, Khafajah), A. van As and L. Jacobs (Isin, Nippur, Ed Deir), J.-D. Forest (Kheit Qasim, Bahizeh Zahireh), K. Frifelt (Hafit, Mazyad, Qarnt Bin Sa'ud, Umm an-Nar, Bat), S. Cleuziou and M. Tosi (Hili, Ra's al-Hamra, Ra's al-Jins), and B. Vogt (Ra's al-Aysh, Jebel ad-Dhanna, Jazirat al-Hamra, Shimal).

3. After removal of surface layers and washing with distilled water in an ultrasonic device, fragments of the sherds were powdered in an agate mill. The samples were then ignited, melted with a lithiumborate flux at 1150° C and cast to little discs of 32 mm diameter (1 g sample) or 25 mm diameter (100 mg samples). In the smaller samples, all of the trace elements could not be determined because of a higher dilution by the flux.

4. Microphotographs are either not given, or difficult to read. Thin-sections, which are the best means for a secure comparison, have not, so far, been exchanged.

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sample n.	Registration n.		Period	PG	CG
Hafit	A0021	cairn 3 (french mission), vase 1	Hafit	H	1
	A0622	cairn 22, 1051.A	Hafit	I	3
	A0623	cairn 23, 1052.A	Hafit	I	-
	A0624	cairn 23, 1052.B	Hafit	A	-
Mazyad	A0626	1309.G	Hafit	I	-
Qarnt Bin Sa'ud	A0625	1087.A	Hafit	U	5
Hili 8	A0002	2898 UF1348 period I	Hafit	H	-
	A0007	2878 UF1320 period I	Hafit	A	-
	A0012	2571 UF829 period I	Hafit	A	1
	A0014	2885 UF1320 period I	Hafit	A	1
	A0015	2567 UF820 period I	Hafit	H	1
	A549	no n. UF 280period I	Hafit	-	5
	A0554	2868 UF1345 period IIa-c1	Umm an-Nar	H	1
	A0557	1248 UF106 period IIa-c1	Umm an-Nar	A	-
	A0593	1265 UF108 period I	Hafit	H	1
	A0799	121 surface, attribution period I	Hafit	A	1
	A0801	2684 UF814 period I	Hafit	H	1
Umm an-Nar	A0636	cairn V, 1089.AS	Umm an-Nar	-	5
	A0641	cairn II, 1011.AM	Umm an-Nar	H	2
	A0642	cairn II, 1011.P	Umm an-Nar	H	2
	A0643	cairn V, 1089.O	Umm an-Nar	A	2
	A0644	cairn II, 1011.B	Umm an-Nar	H	2
	A0977	cairn I, 1010.F	Umm an-Nar	H	2
	A0978	settlement, 1014.KL	Umm an-Nar	H	1
	A1016	settlement, 1014.A	Umm an-Nar	-	2
	A1017	settlement, 1014.A	Umm an-Nar	-	5
	A1034	cairn II, 1011.FOb	Umm an-Nar	H	2
Jebel ad-Dhanna 3	A0158	no n.	Hafit	-	1'
	A0159	no n.	Hafit	H	1
	A0160	no n.	Hafit	H	1'
	A0161	no n.	Hafit	H	1'
	A0162	no n.	Hafit	H	-
Ra's al-Aysh 1	A0164	no n.	Umm an-Nar	-	1
	A0165	no n.	Umm an-Nar	A	-
	A0166	no n.	Umm an-Nar	-	1'
	A0167	no n.	Umm an-Nar	-	5
	A0168	no n.	Umm an-Nar	-	1'
Jazirat al-Hamra	A1048	Site 1	Vth mill.	A	1
	A1049	Site 3	Vth mill.	A	1
	A1050	Site 3	Vth mill.	H	1
Shimal	A0739	habitat SX, E19	Wadi Suq	A	-
Hili North, Tomb A	A0076	V77	Umm an-Nar	H	-
Bat	A0845	cairn 1138	Hafit	H	-
Ra's al-Hamra RH-5	A0700	surface	IVth mill.	A	-
	A0704	HXV/AB	IVth mill.	A	-
Ra's al-Jins RJ-2	A1072	RJ2/244	Umm an-Nar	A	-
	A1073	RJ2/980	Umm an-Nar	H	-
	A1074	RJ2/1192	Umm an-Nar	H	-
	A1100	RJ2/767	Umm an-Nar	-	1

Table 1

Site	Sample n.	Registr.	Period	PG	CG
el-Ubaid	Ub01	survey, sherd no n.	Obeid	A	-
	Ub02	survey, sherd no n.	Obeid	A	-
Larsa	La01	sherd PL1.15	ED1	A	1
(ED1 site survey)	La02	sherd PL1.28	ED1	A	1
	La03	sherd PL1.37	ED1	A	1
	La04	sherd PL1.96	ED1	H	1'
	La05	sherd PL1.218	ED1	A	1
Isin	Is01	clay Is10, 850°C	-	-	1
Uruk	Ur01	survey, sherd no n.	Uruk	-	1
	Ur02	survey, sherd no n.	Uruk	-	1
	Ur03	survey, sherd no n.	Uruk	-	5
	Ur04	survey, sherd no n.	EDI	-	1
	Ur05	survey, sherd no n.	EDI	-	1
	Ur06	survey, sherd no n.	EDI	-	1
	Ur07	survey, sherd no n.	EDI	-	1
	Ur08	W21103 brick	Seleucid	-	1
	Ur09	C277 brick	Seleucid	A	-
	Ur10	C278 brick	Seleucid	H	-
	Ur11	C279 brick	Seleucid	A	-
	Ur12	sherd 12	2nd mill.	A	-
	Ur13	sherd B12	1st mill.	A	-
	Ur14	sherd 14	1st mill.	H	-
	Ur15	sherd 30	Ur III	H	-
	Ur16	sherd 30A	Ur III	H	-
	Ur17	sherd 32	Ur III	H	-
	Ur18	sherd 32A	Ur III	H	-
Nippur	Ni01	sherd N93	Kassite	-	1
	Ni02	sherd N123	Old Babyl.	-	1
	Ni03	sherd N, 1150°C	2nd mill.	-	1
	Ni04	sherd N96, 1050°C	Kassite	-	1
	Ni05	sherd N, 1050°C	2nd. mill.	-	1
	Ni06	clay N1, 1150°C	-	-	1
	Ni07	clay N4, 1150°C	-	-	1
Djamdat Nasr	DN01	survey, sherd no n.		A	1
	DN02	survey, sherd no n.		A	1
	DN03	survey, sherd no n.		A	1
Ed Deir	ED01	sherd D3260	2nd mill.	-	1
	ED02	sherd 6124/1	2nd mill.	-	1
	ED03	sherd D1, 1150°C	2nd mill.	-	1
	ED04	sherd D7502, 1150°C	2nd mill.	-	1
	ED05	sherd D3001, 1150°C	2nd mill.	-	1
	ED06	sherd D7501, 1050°C	Kassite	-	1
	ED07	clay D10, 1150°C	-	-	1
Khafajah	Kh01	survey, sherd no n.		A	5
	Kh02	survey, sherd no n.		A	5
Bahizeh Zahireh	Ba01	survey, sherd no n.	EDI	U	4
	Ba02	survey, sherd no n.	EDI	U	4
	Ba03	survey, sherd no n.	EDI	-	4
	Ba04	survey, sherd no n.	EDI	-	4
	Ba05	survey, sherd no n.	EDI	-	4
	Ba06	survey, sherd no n.	EDI	-	4
Kheit Qasim	KQ01	survey, sherd no n.	EDI	U	4
	KQ02	survey, sherd no n.	EDI	U	4
	KQ03	survey, sherd no n.	EDI	U	4

Table 2

Table 3

sample number	major elements SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	trace elements V	Cr	Ni	(Cu)	Zn	Rb	Sr	(Y)	Zr	(Ba)	(Ce)	LOI	total
1st chemical group																							
petrographical group H																							
A0554	56.93	0.794	14.10	7.70	0.136	6.75	9.46	1.70	2.21	0.191	137	587	253	42	77	59	612	22	136	293	38	3.96	100.15
A0978	55.49	0.761	13.48	7.25	0.123	6.56	10.92	3.15	2.04	0.198	132	459	232	74	82	57	312	21	130	255	44	8.34	99.27
A1100	54.58	0.793	13.42	7.33	0.136	6.90	12.03	2.41	2.09	0.279	133	448	247	41	81	54	348	24	141	327	40	4.38	100.26
A0593	55.89	0.797	13.16	7.22	0.127	6.92	12.21	1.46	1.96	0.224	124	548	240	36	66	55	1339	20	131	823	43	7.62	99.88
A0015	55.79	0.688	13.48	6.78	0.120	6.15	12.80	1.85	2.03	0.277	124	426	212	35	75	61	863	20	123	296	40	6.81	99.85
A0801	54.08	0.742	13.11	6.94	0.128	7.09	13.62	2.04	1.98	0.228	126	522	231	40	74	59	795	19	122	274	50	9.15	100.05
A0021	52.86	0.774	13.89	7.35	0.133	6.84	13.78	2.44	1.76	0.152		414	243			49	418		159	259		11.99	99.76
A0159	52.09	0.784	13.39	7.24	0.140	6.40	15.96	1.75	1.96	0.247		443	251			60	655		156	402		9.51	100.29
A0160	50.87	0.733	12.84	6.98	0.125	7.76	17.18	1.44	1.82	0.216		435	228			49	1912		178	1623		10.27	98.58
A1050	50.77	0.781	12.88	6.99	0.128	7.46	17.33	1.86	1.59	0.194	138	506	206	36	68	46	703	20	142	306	39	8.84	99.38
A0161	47.46	0.641	11.78	6.03	0.116	7.29	23.22	1.42	1.61	0.406		380	197			40	1950		163	785		13.67	99.86
petrographical group A																							
A0012	56.27	0.740	13.25	7.04	0.129	6.17	11.65	2.10	2.15	0.459	122	418	227	41	75	54	512	20	132	278	26	5.35	99.70
A1048	50.60	0.815	13.75	7.96	0.158	7.05	15.35	2.03	1.36	0.894	144	384	259	39	87	35	1925	21	129	485	29	2.21	99.35
A1049	50.83	0.744	13.58	7.08	0.126	7.29	17.12	1.64	1.07	0.490	138	333	208	31	78	24	616	22	137	377	61	10.16	100.72
A0014	52.41	0.677	12.58	6.44	0.121	6.48	17.65	1.72	1.72	0.170	123	340	218	19	59	52	914	18	114	268	26	5.15	99.84
no thin sections																							
A0164	55.16	0.753	13.57	7.21	0.120	6.56	11.42	3.01	1.98	0.202	128	453	231	67	78	55	315	19	123	276	43	7.88	99.74
A0168	55.93	0.757	12.77	5.28	0.061	5.05	16.26	1.71	1.99	0.164	219	447	135	36	60	68	1415	17	161	320	25	6.70	88.55
A0166	47.44	0.640	11.87	6.22	0.120	7.48	23.21	1.73	1.08	0.180		326	229			26	3783		203	407		10.55	99.00
A0158	47.59	0.616	11.28	5.77	0.126	6.61	24.36	1.61	1.68	0.321		293	204			43	2070		151	948		14.45	99.48
2nd chemical group																							
petrographical group H																							
A1034	55.83	0.696	13.15	6.77	0.121	12.56	6.88	2.31	1.47	0.182	114	348	236	38	105	39	254	20	125	253	36	7.67	100.89
A0641	55.56	0.817	14.07	7.81	0.146	10.61	6.90	1.71	2.14	0.209		458	265			59	309		166	339		8.94	99.63
A0977	56.65	0.761	13.75	7.29	0.118	8.00	8.00	2.99	2.19	0.219		380	245			57	282		145	288		9.24	99.65
A0644	53.45	0.758	13.15	7.19	0.134	13.44	8.15	1.61	1.86	0.225		341	251			8	213		144	279		13.32	100.57
petrographical group A																							
A0643	53.81	0.803	13.34	7.38	0.161	10.75	9.17	2.66	1.58	0.321		469	242			31	280		168	256		5.59	100.70
A0799	50.72	0.736	13.00	6.87	0.128	10.78	13.86	2.28	1.43	0.187	117	359	226	33	52	35	391	21	132	264	35	5.89	96.37
no thin sections																							
A1017	63.19	0.619	11.78	5.85	0.049	11.64	2.26	2.90	1.55	0.131	71	708	258	33	70	45	211	16	145	221	35	5.44	100.06
A0642	57.88	0.820	14.01	7.60	0.142	10.71	4.60	2.04	1.94	0.210		452	252			53	265		144	294		6.11	99.86
A1016	51.34	0.833	14.47	7.68	0.130	12.99	7.53	3.33	1.44	0.223	104	514	244	38	70	35	263	21	142	238	58	8.83	96.06
outliers in chemical composition																							
petrographical group I																							
A0622	56.27	0.910	15.02	9.11	0.146	7.17	7.54	1.31	2.27	0.227		365	303			83	274		162	283		7.59	100.31
unique																							
A0625	51.29	0.540	10.76	4.25	0.068	7.38	21.71	0.89	2.53	0.555	121	174	105	26	58	66	851	14	116	368	33	17.05	98.84
no thin sections																							
A0636	54.51	0.644	12.79	4.32	0.035	8.84	13.88	1.55	3.20	0.198		162	44			80	1874		209	266		15.28	99.22
A0549	53.69	0.569	10.74	4.23	0.048	6.23	20.15	1.25	2.80	0.262	87	227	74	39	58	68	1996	11	155	319	28	16.84	98.60
A0167	53.62	0.611	11.84	4.34	0.046	5.15	21.67	1.34	1.22	0.131	57	95	59	31	38	23	3490	8	169	501	21	4.15	83.02

sample number	major elements SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	trace elements V	Cr	Ni	(Cu)	Zn	Rb	Sr	(Y)	Zr	(Ba)	(Ce)	LOI	total
Uruk																							
Ur01	53.42	0.711	13.35	6.97	0.130	6.19	15.32	2.01	1.70	0.176	132	321	213	23	76	51	416	19	119	294	47	1.06	100.47
Ur02	52.37	0.708	12.64	6.51	0.133	6.95	16.88	1.88	1.65	0.248	125	350	220	21	65	40	442	21	117	307	15	1.99	98.65
Ur03	61.63	0.594	11.88	6.12	0.104	4.81	10.85	1.52	1.76	0.700	116	282	169	32	78	49	403	19	110	253	33	2.67	98.14
Ur04	52.79	0.681	12.45	6.48	0.140	6.94	16.28	2.08	1.72	0.412	122	383	217	27	54	51	452	18	112	348	39	1.98	95.28
Ur05	52.50	0.677	12.99	6.89	0.147	6.77	16.45	1.58	1.72	0.252	133	287	228	27	82	48	403	19	111	491	34	1.75	99.55
Ur06	52.55	0.774	13.61	7.43	0.138	7.16	14.59	2.06	1.45	0.204	144	522	239	29	62	32	352	21	137	277	49	2.47	100.79
Ur07	52.39	0.722	13.37	7.12	0.136	7.25	15.31	1.58	1.80	0.279	137	339	233	24	72	56	364	22	121	303	39	3.83	99.96
Ur08	50.80	0.765	13.31	7.27	0.128	6.34	17.41	1.77	1.91	0.262		320	196			36	434		138	213			99.81
Larsa																							
La01	53.30	0.867	14.17	7.95	0.141	7.02	12.67	2.35	1.31	0.197	143	616	262	24	58	32	389	22	159	300	54	2.39	100.74
La02	51.17	0.806	13.65	7.29	0.132	7.43	16.26	1.67	1.41	0.160	156	450	256	12	59	44	378	21	136	341	30	0.75	100.74
La03	48.99	0.771	13.35	7.61	0.141	8.15	17.67	1.67	1.45	0.163	142	330	262	20	75	44	376	22	126	307	44	0.62	99.88
La04	59.19	0.841	13.26	5.70	0.130	5.19	11.28	2.37	1.78	0.224	129	732	145	32	51	49	698	21	160	670	37	6.95	99.57
La05	52.45	0.801	14.13	7.55	0.142	7.59	13.85	1.69	1.59	0.174	150	480	265	16	61	53	375	21	141	389	37	1.15	101.05
Tell ed Deir																							
ED01	51.21	0.821	14.13	8.53	0.161	6.16	14.76	1.73	2.21	0.252	137	349	266	35	77	53	428	24	142	312	49		100.55
ED02	50.92	0.844	13.64	8.05	0.161	6.33	15.77	1.96	1.95	0.349	127	413	242	35	76	45	414	23	146	320	45		100.79
ED03	50.78	0.808	14.50	8.45	0.152	6.23	15.25	1.93	1.61	0.268	143	327	255	35	86	36	398	23	141	312	43		101.23
ED04	50.46	0.794	13.89	8.15	0.149	6.72	15.61	2.34	1.61	0.246	141	350	266	21	84	35	399	22	138	291	45		100.90
ED05	49.15	0.805	13.45	8.04	0.155	6.33	17.78	1.89	1.89	0.476	132	351	248	33	75	37	592	21	142	272	41		100.85
ED06	52.08	0.789	14.12	7.75	0.136	6.68	14.09	2.14	1.92	0.255	130	360	250	34	78	43	392	22	140	274	53		100.69
ED07	49.78	0.815	13.68	8.12	0.145	6.87	17.00	1.66	1.72	0.190	147	370	259	41	95	58	406	22	142	310	47		102.53
Nippur																							
Ni01	50.97	0.779	13.30	7.70	0.140	6.98	16.64	1.60	1.61	0.254	130	371	257	13	72	26	337	23	135	231	46		99.37
Ni02	50.22	0.792	13.33	7.99	0.139	7.32	16.86	1.89	1.17	0.248	140	382	265	21	81	19	318	24	137	227	40		101.14
Ni03	50.89	0.776	13.59	7.46	0.135	6.68	16.25	1.59	2.17	0.441	126	335	248	23	84	42	429	23	138	283	52		99.40
Ni04	51.97	0.791	14.53	7.88	0.141	6.95	13.94	1.53	1.83	0.396	141	296	268	49	102	48	336	25	137	297	57		101.07
Ni05	47.85	0.797	13.02	7.84	0.138	8.69	17.93	2.13	1.35	0.221	145	309	254	29	93	24	635	21	143	305	37		100.71
Ni06	49.25	0.718	12.88	7.94	0.139	8.80	16.19	1.10	2.18	0.778	141	280	264	67	112	52	423	21	126	254	41		100.59
Ni07	48.18	0.712	12.10	7.09	0.130	7.65	21.09	1.33	1.23	0.455	107	343	236	34	90	29	593	20	134	279	28		100.68
Isin																							
Is01	47.00	0.694	11.27	6.48	0.120	7.85	23.67	1.47	1.20	0.202	108	348	206	19	77	35	710	19	137	329	45		99.41
Djamdat Nasr																							
DN01	51.28	0.790	13.63	7.56	0.141	7.63	14.45	2.35	1.86	0.270		378	251			45	440		145	353		3.30	100.24
DN02	54.91	0.818	13.57	7.57	0.164	6.73	11.66	2.62	1.74	0.201	142	588	240	31	54	53	437	21	137	321	39	4.35	100.39
DN03	52.56	0.775	13.28	7.29	0.138	8.34	12.71	2.72	1.95	0.214	120	409	251	41	48	55	519	20	133	320	37	4.74	98.86
Khafajah																							
Kh01	54.73	0.702	13.20	6.31	0.112	3.97	15.76	1.92	2.39	0.872	100	238	149	37	59	62	653	19	122	359	54	4.76	99.06
Kh02	52.35	0.649	13.08	5.79	0.104	5.07	14.53	2.88	4.11	1.408	109	194	139	26	71	70	775	18	111	304	38	4.69	93.00
Bahizeh Zahireh																							
BZ01	54.26	0.765	12.84	6.40	0.128	4.78	17.11	0.71	2.72	0.249	95	291	168	44	83	64	582	23	148	427	41	7.16	100.12
BZ02	50.25	0.693	12.56	5.95	0.106	4.33	22.29	0.74	2.82	0.231	110	183	135	37	83	55	643	20	124	309	51	10.52	99.28
BZ03	50.13	0.673	12.00	5.61	0.104	4.21	23.70	0.95	2.36	0.227	100	211	120	22	73	55	619	18	126	354	40	10.61	99.17
BZ04	53.37	0.602	10.85	5.18	0.100	5.02	21.08	0.73	2.12	0.318	109	226	125	22	74	54	614	17	118	496	41	10.42	98.83
BZ05	51.28	0.672	11.83	5.69	0.101	4.79	21.74	0.85	2.69	0.320	113	281	135	26	94	58	794	19	134	681	23	9.92	99.08
BZ06	49.47	0.690	12.36	5.87	0.098	4.92	22.06	1.38	2.60	0.511	108	223	136	37	88	42	638	19	133	332	31	8.57	98.43
Kheit Qasim																							
KQ01	53.11	0.745	13.87	6.63	0.104	5.06	16.82	1.03	2.39	0.207	119	169	138	37	76	77	616	21	131	306	34	4.82	99.88
KQ02	56.43	0.758	13.51	6.57	0.116	4.18	14.62	1.02	2.45	0.309	122	267	148	30	80	78	721	22	141	346	46	6.11	99.10
KQ03	54.91	0.624	11.64	5.45	0.108	5.53	17.97	1.19	2.20	0.342	101	256	134	27	67	62	887	17	127	370	38	8.60	99.07

Table 4

Table 5

sample number	major elements SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	trace elements V	Cr	Ni	(Cu)	Zn	Rb	Sr	(Y)	Zr	(Ba)	(Ce)
Vessels found in the United Arab Emirates and the Sultanate of Oman, 1st chemical group (n = 12, sample A0168 not included)																					
average	52.6	0.74	13.1	6.98	0.13	6.88	15.5	1.97	1.79	0.26	131	429	229	42	75	49	956	21	139	415	40
std dev ±	3.1	0.06	0.8	0.56	0.01	0.46	4.5	0.50	0.34	0.10	7	79	18	15	8	12	629	2	17	220	10
std dev (%)	5.9	8.2	5.8	8.0	7.6	6.7	28.7	25.5	18.9	39.	5.6	19.	8.0	36.	11.	23.	66.	8.	13.	74.	25.
Vessels found in the United Arab Emirates and the Sultanate of Oman, 2nd chemical group (n = 9)																					
average	55.4	0.76	13.4	7.16	0.13	11.3	7.49	2.43	1.74	0.21	102	448	247	36	74	40	274	20	146	270	41
std dev ±	3.8	0.07	0.8	0.60	0.03	1.6	3.17	0.59	0.30	0.05	21	115	12	3	23	16	54	3	14	35	12
std dev (%)	6.8	9.1	5.9	8.4	25.2	14.5	42.3	24.2	17.5	24.	21.	26.	4.7	8.	30.	40.	20.	13.	10.	13.	28.
Pottery from S-Mesopotamia (n = 29; samples Ur03 and La04 excluded)																					
average	51.1	0.77	13.4	7.56	0.14	7.13	16.0	1.88	1.69	0.28	135	378	245	29	88	42	434	22	135	306	45
std dev ±	1.8	0.05	0.7	0.55	0.01	0.73	2.4	0.37	0.29	0.13	12	82	20	12	64	11	92	3	11	52	16
std dev (%)	3.5	6.4	5.2	7.3	7.2	10.2	15.0	19.8	16.9	45.9	8.5	22.	8.0	40.	74.	25.	22.	12.	7.9	17.	36.
Pottery from the Hamrin (n = 9)																					
average	52.7	0.69	12.4	5.93	0.11	4.76	19.7	0.96	2.49	0.30	109	234	138	31	80	61	679	20	131	402	38
std dev ±	2.5	0.06	0.9	0.51	0.01	0.45	3.1	0.23	0.24	0.09	9	43	14	8	9	12	102	2	9	121	9
std dev (%)	4.7	8.2	7.6	8.6	8.8	9.4	15.8	23.6	9.7	31.	8.	18.	10.	25.	11.	19.	15.	11.	7.	30.	22.

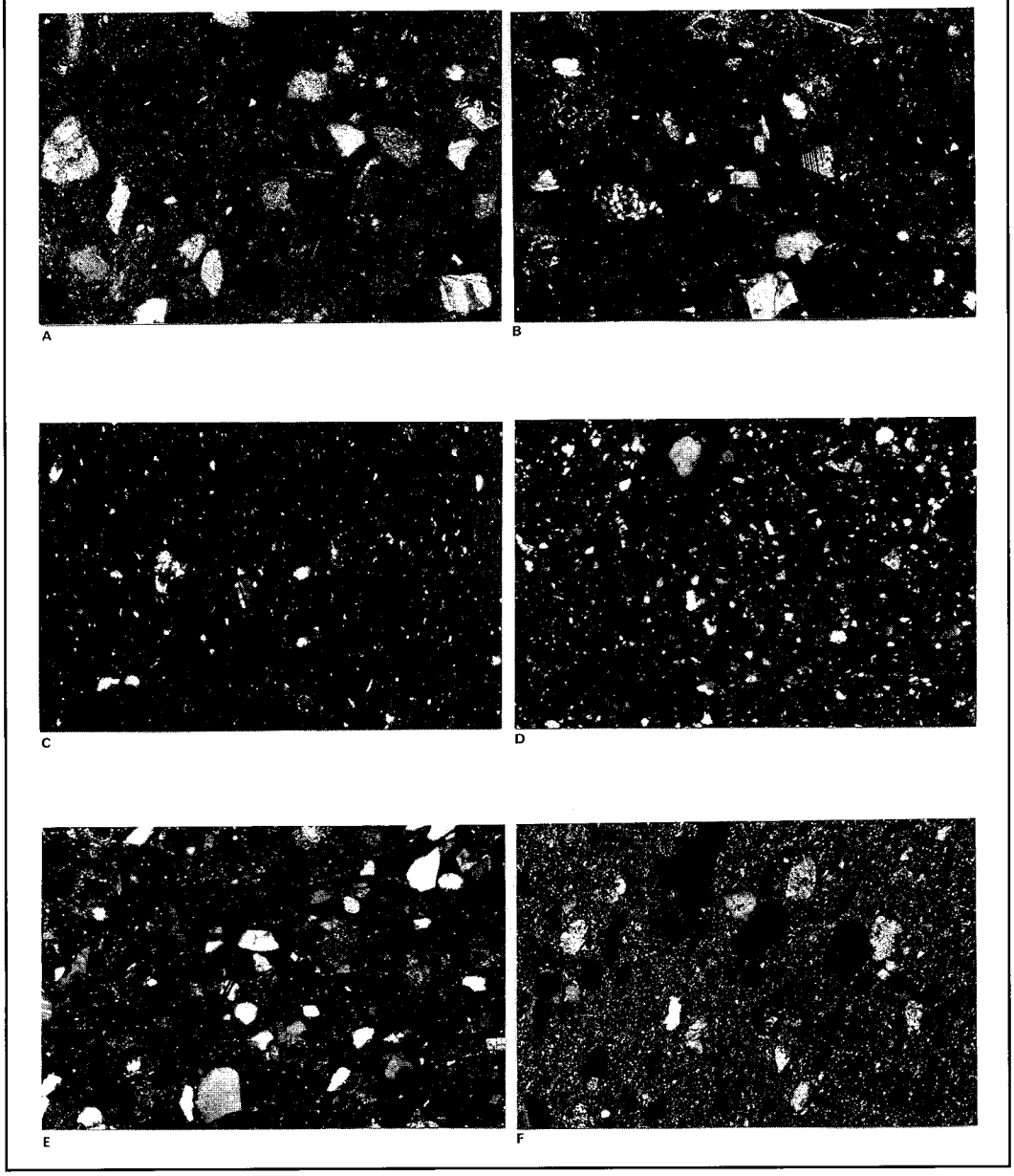

PLATE 1.