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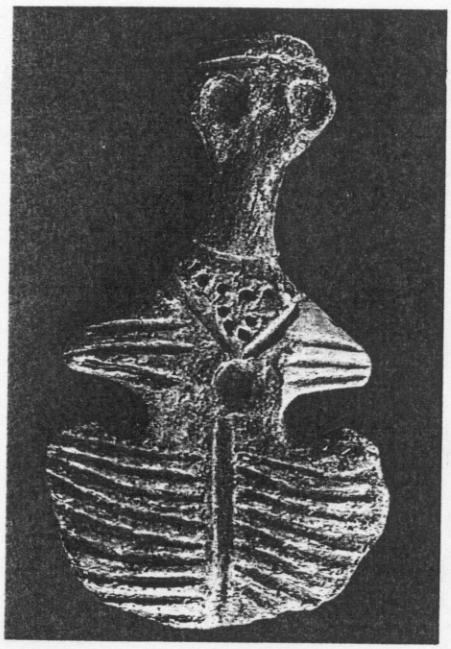

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THIRD MILLENNIUM BC POTTERY AT NAUSHARO, PAKISTAN: FIRST RESULTS OF A MINERALOGICAL AND CHEMICAL PROGRAM

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In 1987, workshop areas of harappean potters were discovered at Nausharo, Pakistan. The discovery of moddled but still unfired vessels is exceptional. In this context, we tried to estimate the degree of variability within the unfired products of a given workshop during the third milennium and to study the evolution of the unfired and fired products in the region through time.

KEYWORDS: CERAMICS, UNFIRED VESSELS, MINERALOGY, X-RAY FLUORESESCENCE, INDUS VALLEY, THIRD MILLENNIUM, WORKSHOP

INTRODUCTION

Located in Pakistani Baluchistan (Fig. 1), the settlement of Nausharo has been excavated by the French expedition directed by J.-F. Jarrige, in collaboration with the Department of Archaeology of Pakistan since 1985. The site was occupied during the pre-Indus periods (2800-2500 BC) and the Indus periods (2500-2000 BC) (Jarrige 1993).

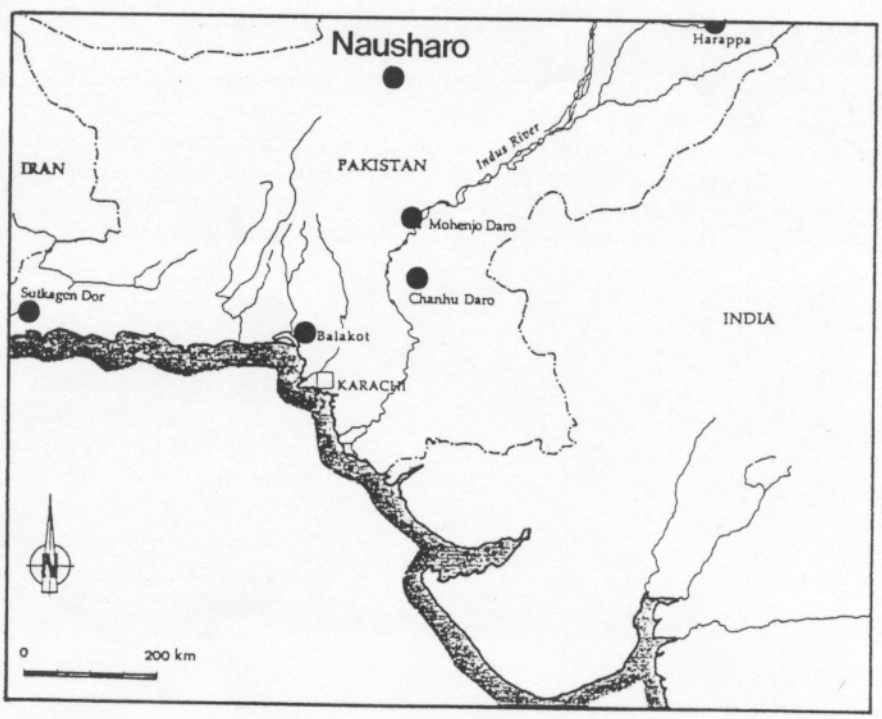

Fig. 1. *Map of Pakistan.*

The discovery of potter's tools associated with unfired clay vessels in a potter's workshop dated from about 2500 BC, i.e., the first phase of the Indus culture at Nausharo, was at the origin of a mineralogical and chemical research program (Jarrige 1988, 1989, 1990; Méry 1994). The main aim of this project was to verify the homogeneity of the workshop's production. We extended our study to the characterization of unfired and fired vessels from pre-Indus and Indus periods in order to detect changes in the ceramic composition through time and to distinguish imported vessels by comparison with the unfired material. Since this unfired material represents a local production, only two clay samples from a contemporaneous potter's workshop far from Nausharo were analyzed in this first phase of our program.

In this paper, we will first present the results of the unfired vessels characterization from the workshop (NS 87 and 89, III, level 4) as our analytical reference group. This unfired material was compared with fired vessels from the same period II (2500-2400 BC), as well as with unfired and fired vessels from Period IC (2700-2550 BC) and Period ID (2550-2500 BC). We also analyzed few samples from Periods IB (2800-2700 BC) and III (2400-2000 BC).

Pottery from Periods IC and ID shows similarities either in shapes and decorations though many vessel types are typical of each period. However, some vase shapes and painted designs, characteristic of the Indus assemblage of Periods II and III, appear at Nausharo as early as Periods IC or ID (Quivron n.d.).

SAMPLING

Whatever the periods, the great majority of vessels found at Nausharo are made of a fine sandy fabric with colors ranging from white to ochre. Our sampling (37 unfired pieces, 99 fired pieces, Tables 1 and 2) is not representative of the whole assemblage even if most of the vessel types have been analyzed. Most of the samples of Periods IC and ID are from complete vessels. It is not the case for the material from the subsequent Period II, though most of them are rims herds and it was possible to recognize the vases shape they are from.

Period IC The IC levels have been excavated in the northern part of the North mound of Nausharo. They are characterized by five superimposed levels of mud-brick dwellings (Tables 1 and 2).

Four unfired vessels and 29 fired vessels corresponding to several types of cups (Fig. 2:B and D), dishes (Fig. 2:E) and pots (Fig. 2:A) have been analyzed among the material from one single level of Period IC. Two vessels are decorated with the typical Period IC "bracket" patterns painted in dark brown (Fig. 2:E). Most of the sampled types were turned most probably thrown shape, with the exception of one pinched bowl (Fig. 2:C). Four sherds of coarse tempered ware have also been analyzed.

Period ID This period corresponds to a single level of burnt structures erected on huge foundation platforms according to a new building method (Quivron 1994).

Several series of identical complete fired vessels have been excavated in one of these houses. Among them, the following vases have been sampled (n=34):

- 12 shallow footed cups decorated with a blank panel of red slip and a single black band at the rim edge (Fig. 2:H). They are a characteristic type of Period ID and were thrown on the hump.
- 17 large dishes (30-35cm across, except four vases which are 40-45cm across) with a decoration of bands painted in red on a white slip (Fig. 2:J) except two of them decorated in the center with worked shell impressions.

Other shapes are globular pots (Fig. 2:F, G and I).

Period II During this period the settlement extends to the south to form, in course of time, a second mound. The structures are constructed according to a predetermined plan, typical of the Indus period.

More than 25 unfired fragmentary vessels have been found in the potter's workshop (level 4 of this excavation trench), associated with potter's tools such as a clay scraper, a bone tool, and several flint blades used during the turning process (Anderson *et al.* 1989; Méry 1994). Moreover, about 200 scraps of clay were uncovered. Some of them were waste from turning vessels when the clay was leather hard, the otherswere the results of scraping. the vessels. A series of pedestal dishes (see Fig. 2:N for comparison) and large bowls with bilateral projecting rims (Fig. 2:M) were found stored after having been formed (probably thrown, certainly turned) and awaiting painting. The only direct evidence of throwing is a centered clay ball (Méry 1994).

23 samples of unfired vessels from this working area have been analyzed as well as one animal figurine, one clay coil and one clay scrap. 13 fired sherds found in association have also been sampled.

Other unfired and fired sherds were selected from two different levels:

- level 3/4; the layer of refuse and broken vessels located above the working area that was to be turned into a level area for a new building (5 fired sherds).
- level 3; several potter's dumps thrown into one of the rooms of this building (8 unfired sherds, 7 fired sherds).

Small dishes and small globular pots (Fig. 2:K), large round bottomed pots (Fig. 2:L), trunconical bowls with bilateral projecting rims (Fig. 2:M), pedestal dishes (Fig. 2:N), cylindrical perforated vessels (Fig. 3:O) and large jars (Fig. 3:P) are among the sampled shapes. Two jars coated with black slip (close to period III types, see Fig. 3:Q, for comparison), one large decorated storage jar and one large bowl with projecting rim, which were manufactured from a micaceous paste, have also been sampled. Most of the analyzed vessel types, like pedestal dishes, perforated vessels, bowls with projecting rims and black-slipped jars are characteristic shapes of the pottery from this first phase of the Indus Culture (Gouin 1990).

Molds and firing-boxes (Méry 1994) have also been sampled, as well as three sherds of coarse ware tempered with grog. Such grog tempers are recorded at Mohenjo-Daro (Dales and Kenoyer 1986: 63).

Other periods We sampled a body sherd from Period IB (Nal style pottery with a geometrical decoration in black, yellow and white) and six sherds of Period III to compare with the material from Periods IC, ID and II. These fragments belong to vessels identical or close to period II types: a pedestal dish (see Fig. 2:M, for comparison), a small cylindrical jar with a flanged rim, three micaceous black-slipped jars (Fig. 3:Q), and one round bottomed pot made of grog fabric (see Fig. 2:L, for comparison).

CHARACTERIZATION OF THE UNFIRED VESSELS

A. Petrographic and mineralogical analysis

The analysis comprised three stages: the observation of thin-sections by optical microscopy, X-ray diffractometry of the raw material, and of the fraction below 20µm.

Our reference group was constituted by the 23 samples of the potter's workshop from period II (level 4). This material has been compared with 8 unfired sherds from period II (level 3), 4 samples from Period IC and 2 samples from period III.

Petrographic analysis Considering the difficulties to prepare thin-sections with unfired clay, some samples were fired to harden them at low temperature (about 250°C). Such a firing facilitates the impregnation of the sample without major effects on micro-structures and minerals, except clay minerals dehydration.

The 19 samples we analyzed (Table 1) were manufactured from a very fine marly clay, poor in organic material and in finely grained iron/manganese oxides. Clay minerals are birefringent. Temper fraction is constituted by quartz inclusions, carbonates (micritic grains, sometimes including shells fragments and foraminifera), associated with some fine biotites and muscovites, and small schisteous fragments (Fig. 7A and B).

Granulometry and abundance of the temper fraction are variable. Three sub-groups have been separated, though some samples could be classified simultaneously into two different sub-groups:

- low tempered fabric, less than 5% in surface, homogeneous granulometry, average 25-200µm, below 200µm (W31, W45, W85, W88);
- intermediate fabric, about 10% in surface, homogeneous granulometry, average 25-200µm, below 350µm (W8, W10, W17, W59, W63, W71, W75, W76, W78);
- high tempered fabric, about 20% in surface, heterogeneous granulometry, average 25-200µm, below 500µm (W3, W22, W68, W69, W80, W82).

Mineralogical analysis The determination of the minerals (except clay minerals) has been carried out by X-ray diffractometry on unoriented powder. The 23 samples we analyzed (Table 1) have very similar compositions: calcite and quartz are predominant; they are associated with traces of feldspars (albite type = sodic feldspars) in several samples. Few samples contain traces of gypsum and halite, because of the vessels burial conditions into a highly saline soil. These observations will be considered for the interpretation of the chemical data.

The powder method is not suitable for a precise determination of the clay minerals, since it is necessary to orientate the preparation on a grooved glass plate (Holtzapffel 1989). We decided to take off 1 gram of raw material (before decalcification) and to analyze the fine silteous fraction (below 20 microns) because:

a) fraction below 2µm is usually richer in expandable clay like smectite and is not representative of the bulk clay mineralogy;

b) as we worked on only 1 gram of matter, it was not possible to sample enough material smaller than 2 microns.

The qualitative determination of the clay minerals is done after three different tests: natural sample, glycolated sample (some clays are expanding) and sample heated to 490°C. Semi-quantitative analysis and internal comparisons were possible since all calculations were done in the same way. However, the precision is probably less than normally (±5%) due to the conditions of our analysis.

The clay mineral assemblage of the analyzed samples is complex (Fig. 4): chlorite and illite are associated with kaolinite and a group of inter-stratified minerals containing smectite layers (expandable complex). Illite and chlorite represent between 40 and 50% of the assemblage: they are primary clays coming directly from the weathering of minerals or rocks. Among secondary clays (weathering clays and soil clays), the expandable complex represents about 40% and the kaolinite only 10 to 15%. Quartz and feldspars are associated to those clay minerals.

Only one sample (W11) shows a different composition (50% of illite and 50% of expandable complex) but it is identical to the other samples in thin-section.

B. Chemical analyses

All analyses have been done by X-ray fluorescence. 22 elements have been characterized (SiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, Cr, Ni, Rb, Sr, Zr, Ba, V, Cu, Zn, Y, La, Ce, Th). The average compositions and standard deviations are shown on Table 3 for each chemical element.

The 14 samples form a homogeneous group (Table 3 and Fig. 5).The standard deviations are low for all elements, except for strontium and phosphorus. We have no explanation for their variations which are not related to particularly high calcium contents. Such a phenomena has also been registered for Mesopotamian ceramics by G. Schneider.

C. Comparison with unfired vessels from Periods IC and II

The number of analyses is small: 5 for period IC, 5 for period II-level 3.

The samples from period IC are not different from the reference group (period II-level 4); those from Period II-level 3 are characterized by an increase of silicon, chromium, nickel, rubidium and zirconium, and a diminution of calcium and strontium (Table 4).

CHARACTERIZATION OF THE FIRED VESSELS

99 samples of fired vessels have been analyzed through petrography and X-ray fluorescence analysis.

A. Petrographic analysis

Three main fabric groups have been recorded among the 93 samples studied in thin-section: marly fabric, grog tempered fabrics and nummulitic tempered fabrics.

Marly fabric (Fig. 8A and B) Most of the observed samples belong to this group (81 samples), already described for unfired vessels. All the variations are represented among the sampling from the relatively low heated vessels to the high heated ones. The first ones are characterized by a light orange colour, with birefringent clays in the matrix and well preserved calcite grains (micritic and sparitic grains). The second ones have a yellow to greenish yellow colour. Their matrix is nearly over-fired, isotropic. The calcite is no more recognizable, except in the shape of holes surrounded by a thin micritic aureole.

In all cases, quartz grains, small micas (muscovites and biotites), flint-like grains, a few weathered feldspars and rock fragments (schists and granitoïds, less than 20µm large), and accessory sphenes, epidotes and brown amphiboles are associated with calcite. Iron oxide grains are frequent in the clayey matrix. All these components correspond to the finest granulometric fraction (less than 10µm) except quartz and calcitic grains. A few samples contain incompletely oxidized organic matter such as remains of vegetal fibers.

According to the granulometry of the temper (mean between 50 and 250µm) and its abundance (ranging between 5% to more than 20%) three sub-groups have been differentiated:

- low tempered fabric (n=18), less than 5% in surface, homogeneous granulometry, average 25-200µm, below 200 µm (E178, E24, E158, E176, E135, E58, E196, E161, E26, E111, E88, E136, E49, E59, E194, E95, E192, E200);
- intermediate fabric (n=44), about 10% in surface, homogeneous granulometry, average 25-200µm, below 350µm (E103, E179, E122, E29, E185, E170, E177, E78, E104, E138, E142, E126, E156, E160, E162, E159, E150, E157, E143, E71, E161, E151, E125, E149, E139, E127, E106, E134,

E140, E133, E131, E132, E83, E186, E109, E77, E180, E174, E187, E169, E129, E22, E27, E182);

- high tempered fabric (n=19), about 20% in surface, heterogeneous granulometry, average 25-200µm, below 500µm (E152, E73, E144, E166, E80, E145, E147, E82, E108, E181, E148, E74, E190, E175, E146, E183, E107, E168, E25).

Marly fabric tempered with grog (Fig. 8C and D) Four vessels (E36, E37, E73, E172) are characterized by an orange matrix similar to the low fired marly fabric. Temper contains micritic and sparitic grains, as well as "over-fired" marly ceramic fragments of various sizes (300-800µm). Grog represents more than 10% of the components. Sample E163 is included in this group in spite of small differences such as the presence of micritic nodules, fragments of biogenic carbonates, and organic matter.

A second microfacies (E75, E86) is characterized by the presence of two types of grog: a greenish "over-fired" marly grog and a reddish less fired marly grog. This temper represents about 20% of the components. Its average granulometry is comprised between 75 and 320µm.

Nummulitic fabric (Fig. 8E and F) Two vessels (E14, E38) have a temper containing well preserved nummulites and discocyclines (about 30% of the components), associated with globigerines. The mineral temper contains very few tiny quartz grains. Organic matter is also visible.

Micaceous fabric (Fig. 8G and H) Six vessels (E76, E87, E117, E154, E199, NS15) are characterized by an uncarbonated matrix, with a very scarse temper containing biotite or muscovite plates, quartz, unweathered feldspars, (mostly plagioclases), and brown amphiboles. The accessory minerals consist of sphene and epidote. Fragments of rocks are too small to be accurately determined.

B . Chemical analysis

In most cases, the quantity of available powder was not sufficient to allow quantitative measurements of all the chemical elements normally determined by XRF. That is the reason why we considered only part of the chemical elements (SiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, Cr, Ni, Rb, Sr, Zr, Ba). Three main groups are distinguished according to the major and minor elements (Table 5): calcium rich composition, calcium hyper-rich composition, aluminous-siliceous composition (see the biplot diagram Al_2O_3/CaO, Fig. 6). These three chemical groups fit with the petrographic groups.

Calcium rich composition This group of 88 samples corresponds to the marly fabric and the marly fabric tempered with grog. According to standard deviations (Table 5), it is a very homogeneous chemical group, characterized by 18% of CaO in average and less than 55% of SiO_2. The most important variations concern silicon and calcium. They are principally due to the variations in the carbonate content. The other characteristics are similar to those of the already described unfired vessels, especially the important variability of strontium which does not appear to be only linked with the variations of the calcium content.

Calcium hyper-rich composition E14 and E38 contain a very high amount of calcium oxide (more than 45%). Compared with the marly composition, the metallic trace elements contents (Cr, Ni, Ba) are lower, and strontium is higher. Both samples are nummulitic fabrics.

Aluminous-siliceous composition This very homogeneous group (all standard deviations are below 1) gathers the six micaceous fabric samples. Its chemical composition is very different from the previous groups: low calcium content (6% CaO) and high aluminium and silicon contents (60% SiO_2, 17% Al_2O_3); high metallic trace elements content (Cr, Ni, Rb, Ba) and low strontium content.

Period	sample	Provenance	Type	Description	Bulk	<20µm XRD	Glycol <20µ	Heated <20µ	Natural >20µ	XRF	Thin section
PIC	W80	NS 92 13 19	"wet ware"	wallsherd	+	+	+	+		comparison	+
PIC	W81	NS 92 13 19	bowl	rimsherd						comparison	
PIC	W82	NS 92 13 19	bowl	rimsherd	+	+	+	+		comparison	+
PIC	W85	NS 92 13 19	pot	base	+	+	+	+		comparison	+
PII level 3	W63	NS 89 III 25	lid	button for prehension	+	+	+	+		comparison	+
PII level 3	W64	NS 89 III 25	pedestalled dish, impressions	wallsherd	+	+	+	+		comparison	
PII level 3	W65	NS 89 III 25	bowl with bilateral projecting rim	rimsherd	+	+	+	+		comparison	
PII level 3	W66	NS 89 III 35	pedestalled dish	rimsherd	+	+	+	+		comparison	
PII level 3	W69	NS 89 III 50	pedestalled dish, shell impressions	wallsherd	+	+	+	+	+		+
PII level 3	W70	NS 89 III 50	perforated vessel	wallsherd	+	+	+	+		comparison	
PII level 3	W73	NS 89 III 60	perforated vessel	wallsherd	+	+	+	+			
PII level 3	W74	NS 89 III 60	pedestalled dish, shell impressions	wallsherd	+	+	+	+			
PII level 4	W75	NS 89 III 61	pedestalled dish, reed impressions	wallsherd	+	+	+	+		core group	+
PII level 4	W3	NS 87 III 37	pedestalled dish	wallsherd						core group	
PII level 4	W8	NS 87 III 37	bowl with bilateral projecting rim	rimsherd	+	+	+	+		core group	+
PII level 4	W9	NS 87 III 37	bowl with bilateral projecting rim	rimsherd						core group	
PII level 4	W10	NS 87 III 37	bowl with bilateral projecting rim	rimsherd	+	+	+	+		core group	+
PII level 4	W11	NS 87 III 37	miniature pot	rimsherd	+	+	+	+	+	core group	+
PII level 4	W17	NS 87 III 37	chuck ?	flatened clay coil + potter's mark	+	+	+	+		core group	+
PII level 4	W22	NS 87 III 37	pedestalled dish	base (upper part)						core group	+
PII level 4	W23	NS 87 III 37	pedestalled dish	base (upper part)						core group	
PII level 4	W30	NS 87 III 37	pedestalled dish	base (lower part)						core group	
PII level 4	W31	NS 87 III 37	pedestalled dish	base (lower part)	+	+	+	+	+	core group	+
PII level 4	W32	NS 87 III 37	pedestalled dish	base (lower part)						core group	
PII level 4	W33	NS 87 III 37	pedestalled dish	base (lower part)						core group	
PII level 4	W39	NS 87 III 37	perforated vessel	wallsherd						core group	
PII level 4	W45	NS 87 III 37	pot, iarge diameter	rimsherd	+	+	+	+		core group	+
PII level 4	W48	NS 87 III 37	pot	rimsherd						core group	
PII level 4	W54	NS 87 III 37	bowl with projecting rim	rimsherd						core group	
PII level 4	W59	NS 87 III 37	perforated vessel	wallsherd	+	+	+	+		core group	+
PII level 4	W68	NS 87 III 37	pedestalled dish	base (upper part)	+	+	+	+		core group	+
PII level 4	W76	NS 87 III 37	pot	rimsherd						core group	+
PII level 4	W77	NS 87 III 37	bowl with projecting rim	rimsherd						core group	
PII level 4	W88	NS 87 III 37	perforated vessel	wallsherd	+	+	+	+		core group	+
PII level 4	W71	NS 87 III 37	clay scrap		+	+	+	+		comparison	+
PIII	W78	NS 92 II	pot, small	base	+	+	+	+	+	comparison	+
PIII	W79	NS 92 II	animal figurine	bottom	+	+	+	+		comparison	
Dhadar potter	W89	NS 88	water's jar	wallsherd						comparison	
Dhadar potter	W90	NS 88	clay							comparison	

Table 1. *List of the unfired vessels samples from Nausharo.*

Table 2. *List of the fired vessels samples from Nausharo.*

Period	sample n°	type (D= maximum diameter)	Description	Fabric	Drawing	Thin-section	XRF
IB	**E196**	"Nal"	wallsherd	marly		+	+
IC	**E014**	?	wallsherd	marly + nummulites		+	+
IC	**E038**	?	wallsherd	marly + nummulites		+	+
IC	**E036**	?	wallsherd	marly + grog		+	+
IC	**E037**	?	wallsherd	marly + grog		+	+
IC	**E176**	"Brandy" cup	complete	marly	D4519	+	+
IC	**E190**	"Brandy" cup	complete	marly	D4492	+	+
IC	**E026**	"Brandy" cup	complete	marly	D4466	+	+
IC	**E179**	"Brandy" cup	complete	marly	D4493	+	+
IC	**E025**	"Brandy" cup	complete	marly	D4449	+	+
IC	**E186**	basin DMax 36 cm	complete	marly	D4513	+	+
IC	**E192**	bowl, open, no foot, D<10cm	complete	marly	D4454	+	+
IC	**E049**	bowl, open, no foot, D10-15cm	complete	marly		+	+
IC	**E182**	bowl, open, no foot, rim D26cm	complete	marly	D4515	+	+
IC	**E180**	bowl, small foot, rim D10-15cm	complete	marly	D4526	+	+
IC	**E185**	cup, no foot, D<10cm	complete	marly	D4544	+	+
IC	**E029**	cup, small foot, everted rim, D10-15	complete	marly	D4464	+	+
IC	**E194**	dish, open, no foot,	wallsherd	marly	D4483	+	+
IC	**E022**	dish, open, no foot, D21cm	complete	marly	D4460	+	+
IC	**E187**	large bowl	no rim	marly	D4512	+	+
IC	**E184**	lid	rimsherd	marly	D4496		+
IC	**E177**	miniature pot	complete	marly	D4498	+	+
IC	**E178**	miniature pot	no base	marly		+	+
IC	**E024**	miniature pot	rimsherd	marly	D4469	+	+
IC	**E175**	pedestalled vase	no rim	marly	D5414	+	+
IC	**E191**	pot	complete	marly	D4495		+
IC	**E181**	pot	base	marly	D4477	+	+
IC	**E170**	pot, globular, flanged rim	complete	marly	D4520	+	+
IC	**E183**	pot, large opening D21cm	complete	marly	D4516	+	+
IC	**E027**	pot, low maximal diameter	complete	marly	D4458	+	+
ID	**E169**	cup, small foot, everted rim	complete	marly		+	+
ID	**E174**	cup, small foot, everted walls	complete	marly		+	+
ID	**E158**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E161**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E157**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E156**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E160**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E159**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E162**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E150**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E151**	cup, small foot, sub-vertical walls	complete	marly		+	+
ID	**E152**	cup, small foot, sub-vertical walls	complete	marly	D4266	+	+
ID	**E145**	dish DEmb 30-35 cm	complete	marly		+	+
ID	**E143**	dish DEmb 30-35 cm	complete	marly		+	+
ID	**E139**	dish DEmb 30-35 cm	complete	marly	D4244	+	+
ID	**E127**	dish DEmb 30-35 cm	complete	marly	D4540	+	+
ID	**E133**	dish DEmb 30-35 cm	complete	marly	D4248	+	+
ID	**E131**	dish DEmb 30-35 cm	complete	marly	D4248	+	+
ID	**E140**	dish DEmb 30-35 cm	complete	marly	D4248	+	+
ID	**E136**	dish DEmb 30-35 cm	complete	marly	D4241	+	+
ID	**E134**	dish DEmb 30-35 cm	complete	marly	D4248	+	+
ID	**E132**	dish DEmb 30-35 cm	complete	marly	D4242	+	+
ID	**E129**	dish DEmb 30-35 cm	complete	marly	D4240	+	+
ID	**E144**	dish DEmb 30-35 cm	complete	marly	D4249	+	+
ID	**E122**	dish DEmb 30-35 cm	complete	marly		+	+
ID	**E126**	dish DEmb 30-35 cm, shell impress	complete	marly	D4243	+	+
ID	**E135**	dish DEmb 30-35 cm, shell impress	complete	marly	D4240	+	+
ID	**E142**	dish DEmb 40-45 cm	complete	marly	D4246	+	+
ID	**E138**	dish DEmb 40-45 cm	complete	marly	D4245	+	+
ID	**E147**	pot, globular, H10-15cm	complete	marly	D4265	+	+
ID	**E125**	pot, globular, H10-15cm	complete	marly	D4234	+	+
ID	**E149**	pot, globular, H10-15cm	complete	marly	D4263	+	+
ID	**E148**	pot, globular, H10-15cm	complete	marly	D4265	+	+
ID	**E166**	pot, pear-shaped	complete	marly	D4276	+	+
II	**E087**	bowl with projecting rim	rimsherd	micaceous		+	+
II	**E117**	transport jar	wallsherd	micaceous		+	+
II	**E154**	very large jar	shoulder	micaceous		+	+

Table 2. (continued)
List of the fired vessels samples from Nausharo.

II-4	**E083**	pot, globular	shoulder	marly		+	+
II-4	**E075**	?	wallsherd	marly + grog		+	+
II-4	**E078**	bowl	rimsherd	marly		+	+
II-4	**E086**	bowl with bilateral projecting rim	rimsherd	marly + grog		+	+
II-4	**E080**	bowl with bilateral projecting rim	rimsherd	marly		+	+
II-4	**E095**	bowl with bilateral projecting rim	rimsherd	marly		+	+
II-4	**E074**	mold	base	marly		+	+
II-4	**E077**	pedestalled dish	rimsherd	marly		+	+
II-4	**E088**	perforated vessel	wallsherd	marly		+	+
II-4	**E084**	pot	rimsherd	marly + vegetal temper			+
II-4	**E108**	pot, globular	base	marly		+	+
II-4	**E107**	pot, globular	base	marly		+	+
II-4	**E082**	pot, round-bottomed	shoulder	marly		+	+
II-4/3	**E106**	bowl with bilateral projecting rim	rimsherd	marly		+	+
II-4/3	**E200**	bowl with bilateral projecting rim	rimsherd	marly		+	+
II-4/3	**E104**	bowl, very everted wall	rimsherd	marly		+	+
II-4/3	**E103**	jar, large	rimsherd	marly		+	+
II-4/3	**E101**	pot	base	marly			+
II-3	**E111**	?	base	marly		+	+
II-3	**E073**	bowl with bilateral projecting rim	rimsherd	marly		+	+
II-3	**E115**	bowl with bilateral projecting rim	rimsherd	marly			+
II-3	**E058**	firing box	rimsherd	marly		+	+
II-3	**E059**	firing box	rimsherd	marly		+	+
II-3	**E071**	pedestalled dish	rimsherd	marly		+	+
II-3	**E109**	pot	rimsherd	marly		+	+
III	**E146**	jar , very large	wallsherd	marly		+	+
III	**E076**	jar, pear-shaped	rimsherd	micaceous		+	+
III	**E199**	jar, pear-shaped	wallsherd	micaceous		+	+
III	**NS15**	jar, pear-shaped	wallsherd	micaceous		+	+
III	**E168**	pedestalled dish	base (lower par	marly		+	+
III	**E163A**	pot, round-bottomed	shoulder	marly + grog		+	+
III	**E163B**	pot, round-bottomed	base	marly + grog		+	+
III	**E172**	pot, tall	wallsherd	marly + grog		+	+

Table 3.
Average composition and standard deviations of the reference unfired samples (Period II - Level 4).
The elements marked with * could not be determined on all samples; LI: loss of ignition.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LI		
Average(%)	47.4	0.68	12.8	5.55	0.09	3.58	25.9	1.14	2.68	0.21	19.6		
Std.dev.	0.8	2.6	3.5	4.2	7.7	1.5	2.8	5.6	3.3	20.6	1.2		
	V	Cr	Ni	Cu	Zn	Rb	Sr	Y	Zr	Ba	La	Ce	Th
Average(ppm)	115	87	65	77	81	86	1460	22	121	310	32	49	13
Std.dev.	4.9	4.4	6.5	4.3	6.2	3.3	17**	3.7	1.8	3.8	27	23	15

Table 4.
Comparison of the average composition and standard deviations of the unfired samples from Periods I and II-3 with the reference samples.

Period	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LI		
II-3	51,8	0,7	13,0	5,8	0,1	3,7	20,8	1,2	2,7	0,2	16,9		
St Dev	0,4	0,0	0,5	0,3	0,0	0,1	0,6	0,1	0,1	0,0	0,2		
IC	48,2	0,7	12,4	5,5	0,1	3,1	25,6	1,4	2,9	0,2	19,7		
St Dev.	0,4	0,0	0,6	0,1	0,0	0,0	1,2	0,1	0,2	0,0			
II-4 (ref.)	47,4	0,7	12,8	5,6	0,1	3,6	25,9	1,1	2,7	0,2	19,6		
	V	Cr	Ni	Cu	Zn	Rb	Sr	Y	Zr	Ba	La	Ce	Th
II-3	111,0	135,0	92,0	75,0	85,0	99,0	650,0	23,0	178,0	312,0	33,0	55,0	13,0
	5,4	6,0	6,0	3,2	5,3	3,2	106,1	0,8	3,3	11,9	8,6	12,6	1,9
I-C	nd	114,0	56,0	nd	nd	62,0	875,0	nd	134,0	329,0	nd	nd	nd
		0,3	0,1			0,6	7,1		0,6	4,9			
II-4	115,0	87,0	65,0	77,0	81,0	86,0	1460,0	22,0	121,0	310,0	32,0	49,0	13,0

SYNTHESIS

The collecting of 136 samples out of several hundreds of complete vases and thousands of potsherds is not representative of the whole pottery assemblage. Nevertheless, according to the macroscopic study realized on location, most of the vessels are made of marly fabrics and only a few of micaceous pastes. Probably other fabric types are missing, either not recognized or not sampled.

Marly fabrics, with and without grog temper Most vessels we studied have a calcium-rich composition. Chemical analysis does not allow us to distinguish between the marly fabric and the marly fabric tempered with grog since the chemical composition of the grog is similar to the matrix itself.

The unfired and fired vessels have very close mineralogical and chemical characteristics: same major components, variability in the repartition, and granulometry of temper. The main difference is the high amount of calcium in unfired vessels (25% CaO in average) compared to the fired vessels (17-20% CaO). This difference could be explained by a secondary absorption of calcium and magnesium carried by percolating waters during the burial. The frequent secondary calcite and gypsum encrustations on the sherds support this argument. Calcium and magnesium would be absorbed in the unsaturated interlayers (especially the smectitic mixed layers) of the raw clays. Once fired, these clays loose that property.

There is not any link between the composition and the shape of the vases associated with the marly fabric without grog. To illustrate this conclusion, two examples follow:

- Among the unfired vessels, two pots (W45, W85), one pedestal dish (W31) and one perforated vessel (W88) have the same microfacies (marly fabric, low tempered, see chapter 1) as well as the same chemical composition (Table 6).
- In period ID, the eleven 30-35cm large dishes with painted decoration have very close microfacies (low tempered marly fabric) with one exception (E145 is richer in temper). The chemical variability of this series is equivalent to the variability of the calcium-rich chemical group from all periods and all shape types, even if we consider the most variable elements like calcium and silicium (Table 7).

Again, there is no link between periodisation and composition of the unfired and fired marly fabrics, tempered with grog or not (Table 8). Among the unfired vessels, the material from our period II reference group (level 4) is identical to the material from period IC. The samples from period III are too scarce to give any conclusion. Among the fired vessels, the material from period II-level 4 is identical to the vessels from the other levels of the same period (level 4/3 and 3). On the other hand, there is no difference between period II material and the vessels from period IC and ID, especially considering th trace elements.

There are however two exceptions:

- Among the unfired vessels, the period II-level 3 material is slightly different from the material, since the amounts of silicon, chromium, nickel, rubidium and zirconium increase whereas calcium and strontium contents are lower. This variation which is not recorded for the fired vessels from the same level cannot be explained so far.
- Among the fired vessels, period III samples are chemically slightly different from the material from the other periods, since the amounts of silicon, chromium, nickel, rubidium and strontium clearly increase whereas calcium content is lower. This variation might be due to the heterogeneity of the sampling since two among the four samples are grog tempered. However, the number of samples is too small to be conclusive.

Micaceous fabric Of the six vessels we analyzed, four were black-slipped jars, one a black-on-red painted very large jar (E154) and one a bowl with projecting rim (E87). The samples form a very homogeneous group both chemically and petrographically. They correspond to similar jars previously analyzed (Table 9) from Nausharo, Mohenjo-Daro, Harappa and several sites of the Oman Peninsula (Méry 1991a; Méry and Blackman in prep.).

This peculiar petrographic composition (metamorphic remains) does not seem compatible with the geology of the surroundings of Nausharo which, according to geological maps, are dominated by tertiary calcareous formations. On the contrary, this composition is compatible with the environment of other Indus sites, especially around Harappa where river sands have a similar mica-rich composition (Banker 1988). Despite the lack of geological samples around Nausharo, these observations suggest the possibility that these vessels were made at other sites in Pakistan.

Nummulitic fabric Two sherds from period IC constitute a third group, very rich in calcium, tempered with a nummulitic sand characteristic of tertiary levels. The question of the origin of this nummulitic ware remains

open for several reasons. On the one hand, this type of fabric is not recorded from other early third millennium sites in Pakistan. On the other hand, the origin of such a nummulitic sand cannot be precisely pinpointed on the available geological maps and there is a lack of geological sand sampling around Nausharo. At least, this ware is generally compatible with the local geology around Nausharo.

CONCLUSIONS

The main results of this study are:

- The homogeneity of the unfired vessels from period II-level 4 taken as reference.
- No major change in the composition of the local marly pottery production between pre-Indus and Indus periods, from 2800 BC (period IC) to 2400 BC (period II). At period III, the tiny change in composition recorded for the fired vessels has to be confirmed by further analyses.
- Whatever the period, no clear links with the typology for the local marly pottery have been found.
- During Indus periods II and III, some vessels, especially black-slipped jars, belong to the group with micaceous fabric. Unlike other Indus sites, this type of clay does not seem to have been commonly used at Nausharo.
- The presence of nummulitic tempered vessels, currently of unknown origin, has been established.

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Type		SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	Cr*	Ni*	Rb*	Sr*	Zr*	Ba*	Ll
Marly	Average	53,43	0,75	13,96	6,25	0,09	3,37	17,46	1,56	2,88	0,25	161,91	110,46	64,1	741,05	164,36	280,1	7,68
	Std deviation	2,4	0,06	0,9	0,46	0,01	0,4	3,46	0,46	0,58	0,15	66	88,13	24,67	269,16	18,84	35,89	4,88
Micaceous	Average	59,54	0,83	17,16	7,36	0,12	3,3	6,35	1,71	3,46	0,18	261,29	256,43	143,14	316,71	166	520	1,59
	Std deviation	1,19	0,03	0,79	0,27	0	0,11	1,14	0,34	0,14	0,03	112,54	183,37	13,06	43,51	11,09	45,18	0,87
Nummulitic	E38	33,81	0,48	9,29	3,92	0,04	4,52	42,63	1,08	3,46	0,77	74	42	35	913	116	83	2,6
Nummulitic	E14	27,74	0,5	9,77	4,26	0,04	5,68	48,3	1,3	1,98	0,44	77	66	41	2438	107	60	29,2

Table 5. *Average composition and standard deviations of the three chemical groups of fired vessels.*
*The elements marked with * could not be determined on all samples.*

Sample	SiO_2 %	CaO %
W31	48.1	25.3
W45	48,5	25,2
W85	47.7	26.6
W88	47.7	25.4
Average	48	25.6
std deviation	0.3	0.6

Table 6. *SiO_2 and CaO contents in various shapes.*

		Period ID dishes	period ID, marly fabric	all periods marly fabrics
SiO_2 %	average	52.45	53.51	53.43
	std dev.	1.27	1.70	2.40
Ca0 %	average	18.53	17.5	17.46
	std dev.	1.82	2.50	3.46

Table 7. *Variability of the chemical composition of a series of dishes from the period ID.*

.	Period	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Cr	Ni	Rb	Sr	Zr	Ba	GV
AVERAGE	1C	54,48	0,78	14,35	6,44	0,09	3,62	15,27	1,76	2,87	0,34	160,45	107,83	65,66	736,14	175,1	289,34	5,46
STD DEVIATION		2,39	0,09	1,04	0,53	0,01	0,41	3,53	0,57	0,66	0,25	27,99	33,39	25,13	198,49	19,16	40,21	3,64
AVERAGE	1D	53,51	0,76	14,1	6,33	0,09	3,17	17,5	1,46	2,9	0,19	148,13	96,25	62,25	675,45	156,85	279,83	8,18
STD DEVIATION		1,7	0,04	0,71	0,36	0,01	0,25	2,5	0,32	0,65	0,04	30,93	35,29	26,78	113,22	11,77	31,97	5,46
AVERAGE	II	51,63	0,72	13,39	5,95	0,09	3,33	20,15	1,62	2,89	0,24	151,46	96,12	61,35	701,54	159,31	269,5	9,2
STD DEVIATION		2,13	0,04	0,79	0,4	0,01	0,37	2,94	0,31	0,42	0,07	45,51	26,47	20,54	101,47	17,29	37,95	4,89
AVERAGE	III	56,02	0,744	13,58	6,17	0,092	3,69	15,75	0,92	2,762	0,27	335	314	84,2	1499,8	188,4	283,8	8,76
STD DEVIATION		2,93	0,06	0,58	0,29	0,01	0,57	3,01	0,62	0,2	0,12	199,96	335,72	20,15	744,92	26,54	14,99	0,95

Table 8. *Evolution of the chemical analysis of calcium-rich compositions according to the chronology.*

sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5
Hili, A47	57.1	17.52	7.53	4	4.92	1.45	3.38	0.92	0.1	0.25
Hili, A800	57.41	17.14	6.92	4.43	7.79	1.1	2.29	0.84	0.16	0.22
Nausharo	59.5	17.16	7.36	3.30	6.35	1.71	3.46	0.83	0.12	0.18

Table 9. *Comparison of the chemical analysis micaceous black-slipped jars from Nausharo and Hili (United Arab Emirates).*

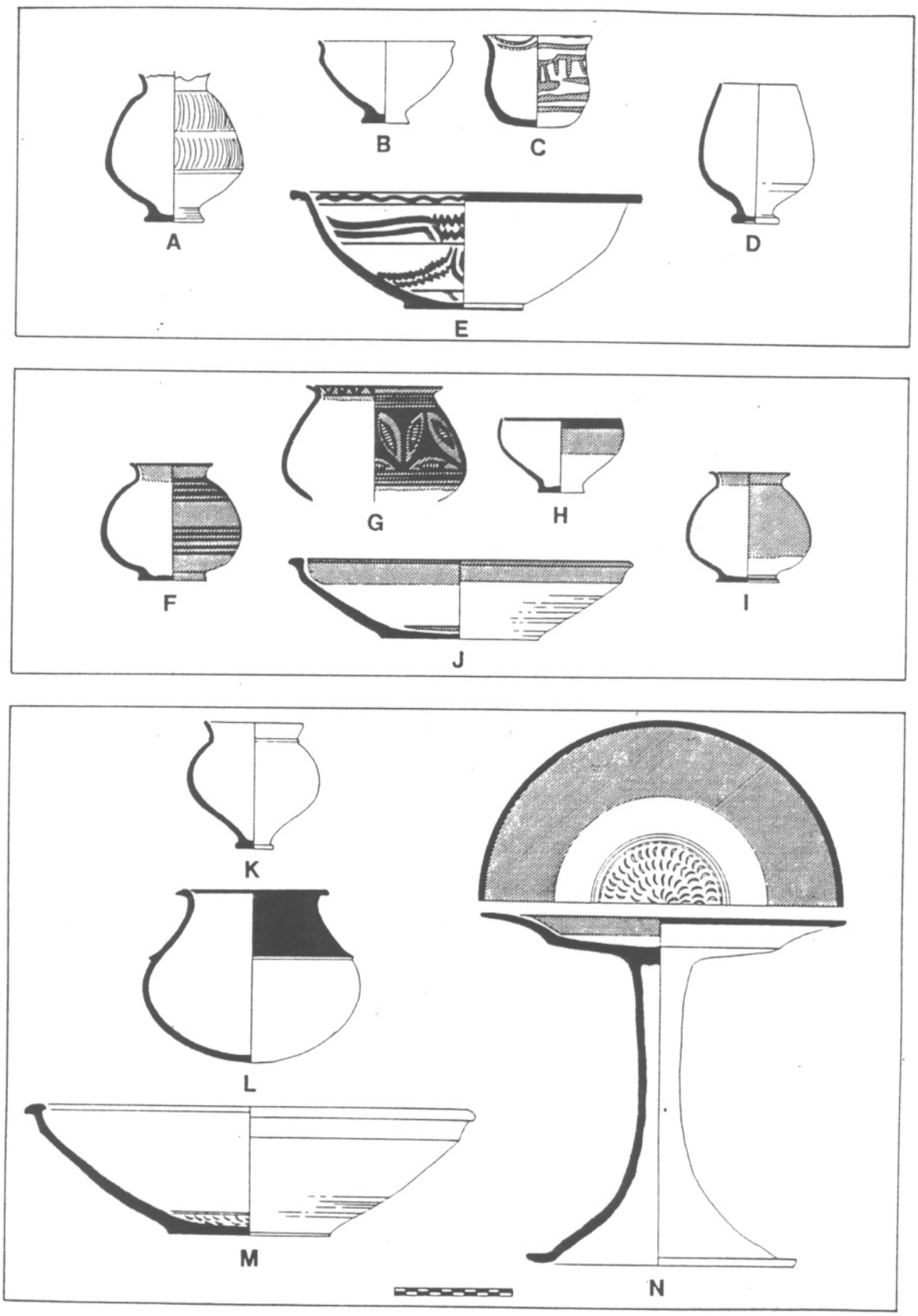


Fig. 2. *Principal sampled pottery types from Nausharo, periods IC (A-D), ID (F-I) and II (K-N).*

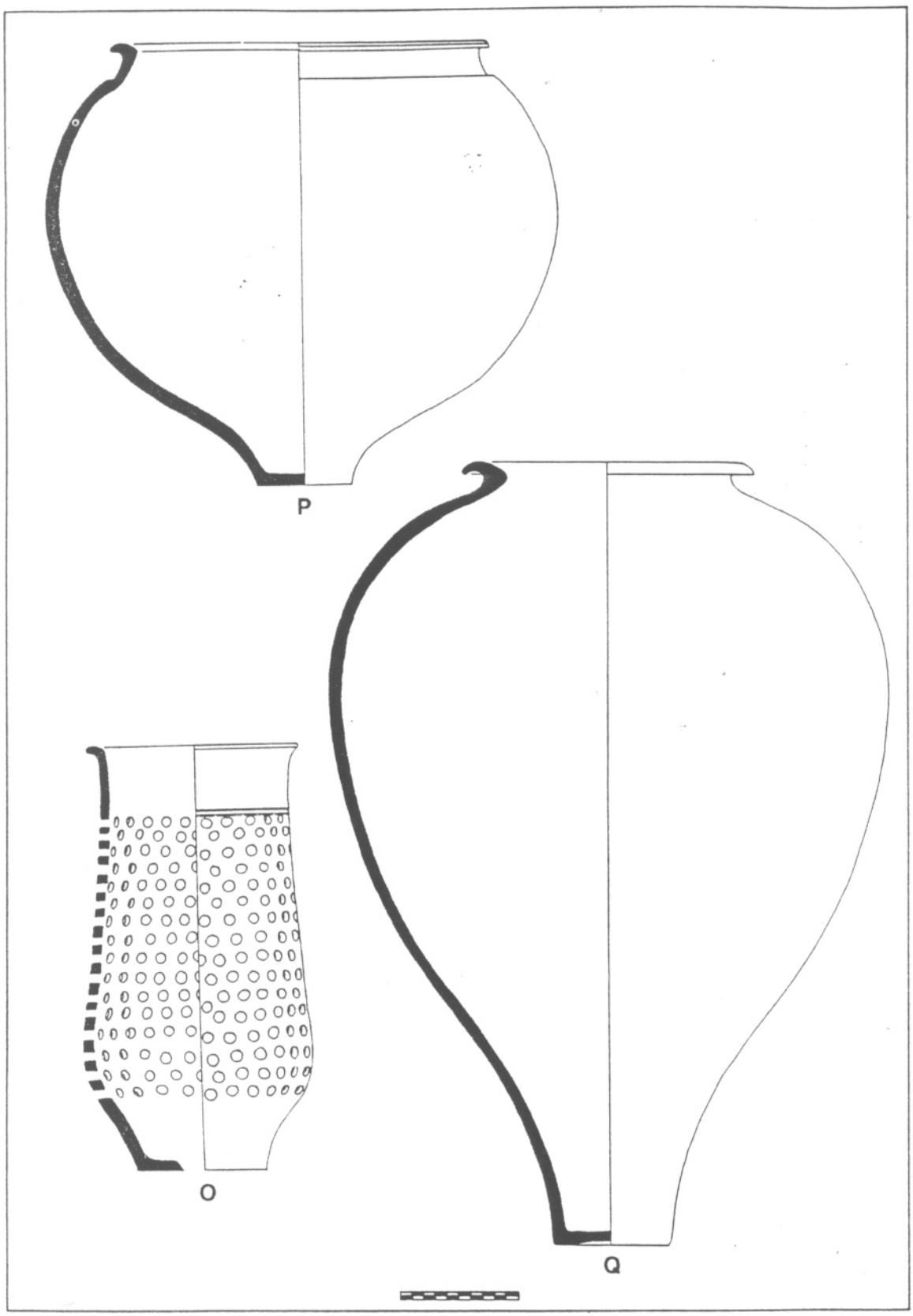


Fig. 3. *Principal sampled pottery types from Nausharo, periods II (0, P) and III (Q).*

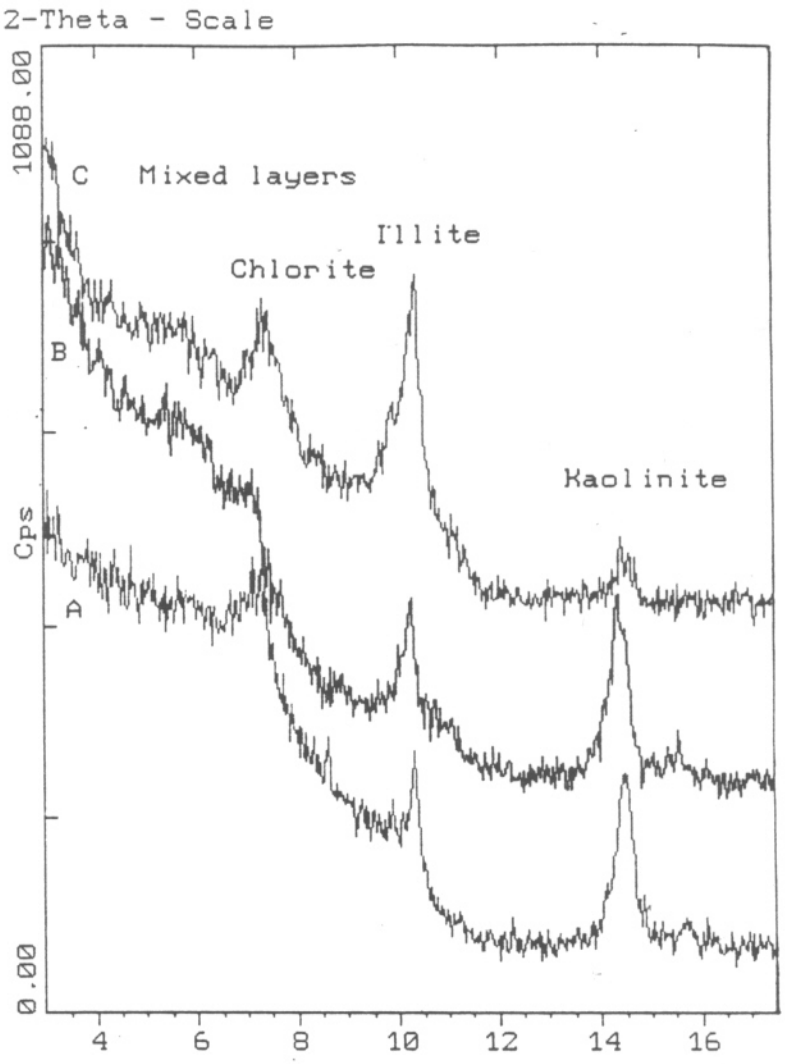


Fig. 4. *X-ray diffractograms: clay fraction (<20 microns). A: natural, B: glycolated, C: heated at 490°C.*

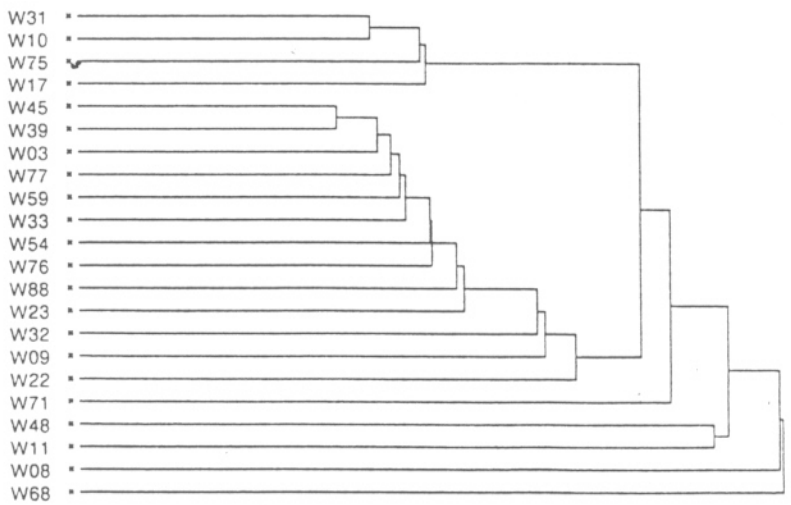


Fig. 5. *Unfired vessels. Dendrogram, chemical analysis, X-ray fluorescence.*

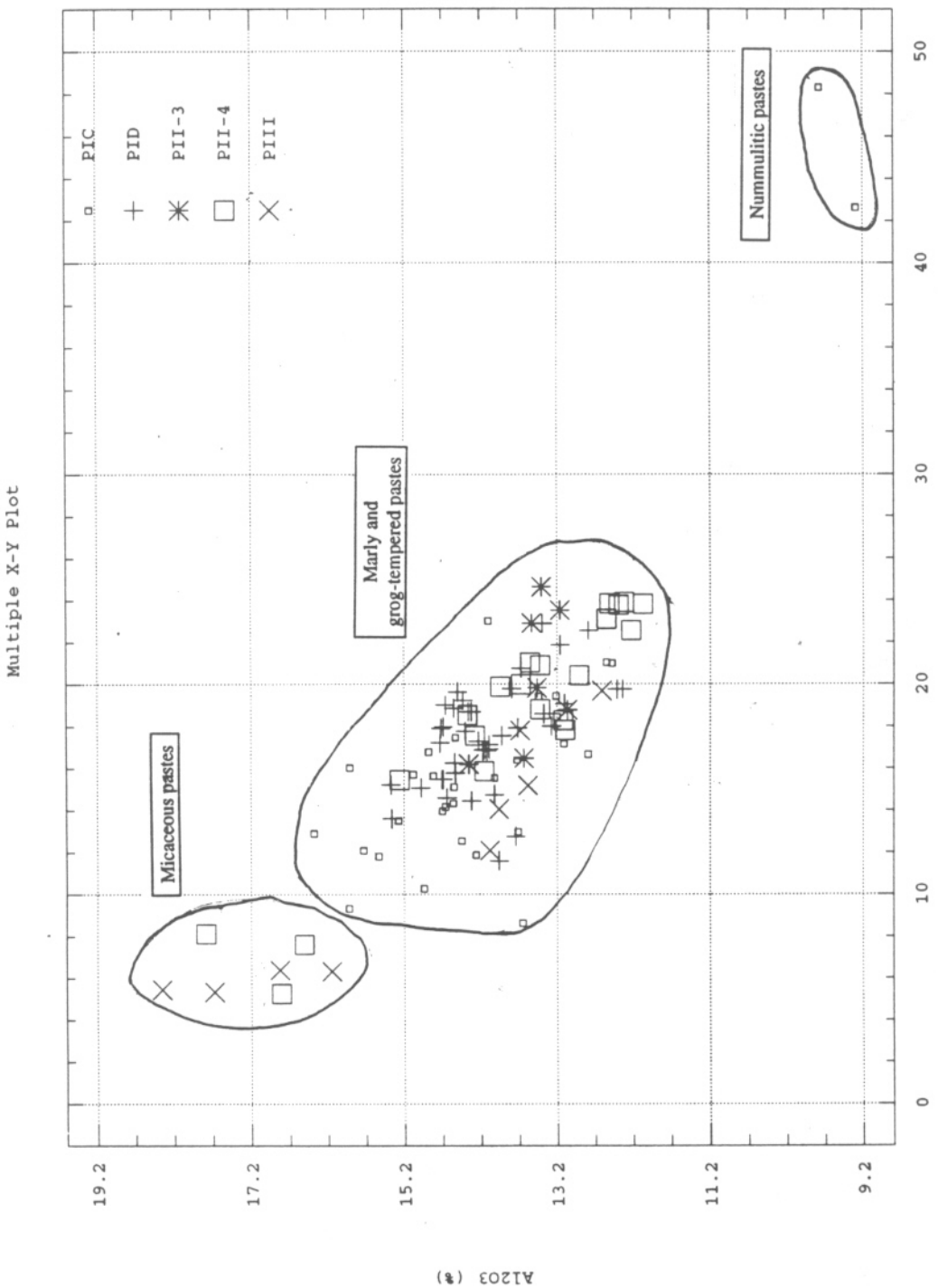
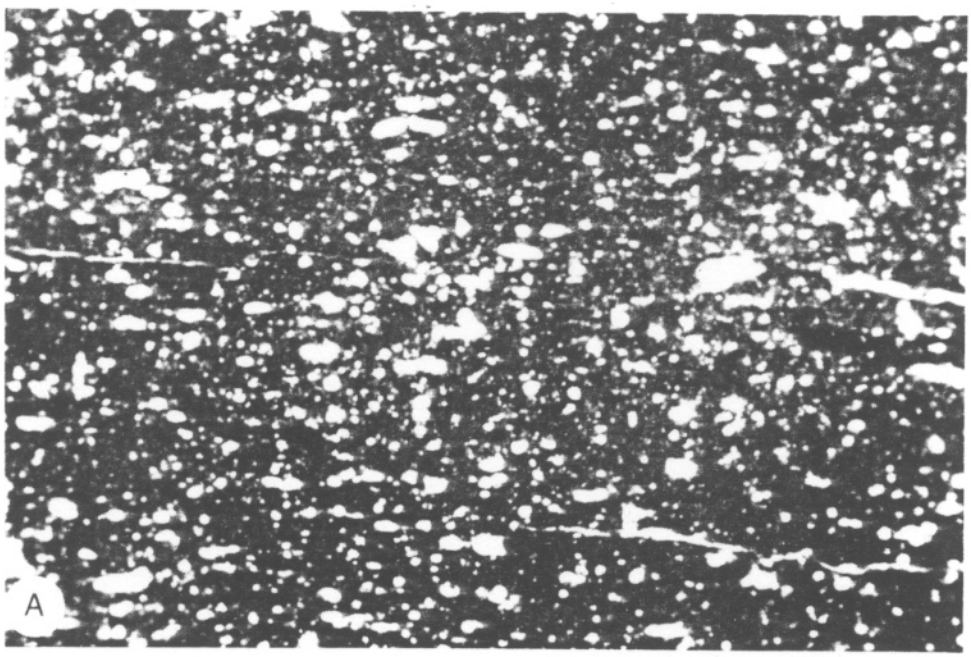


Fig. 6. *Biplot of calcium versus aluminium. Fired vessels from all periods.*



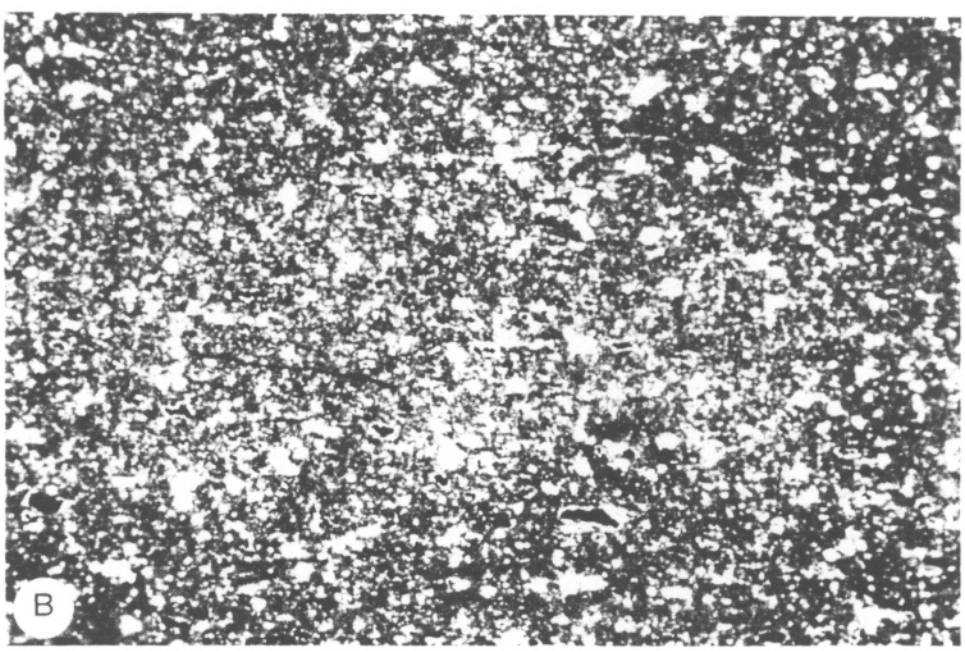


Fig. 7. *Period II, unfired vessels, thin sections X20.*
A: marly fabric, PPL (parallel nichols), B: marly fabric, XPL (crossed nichols).

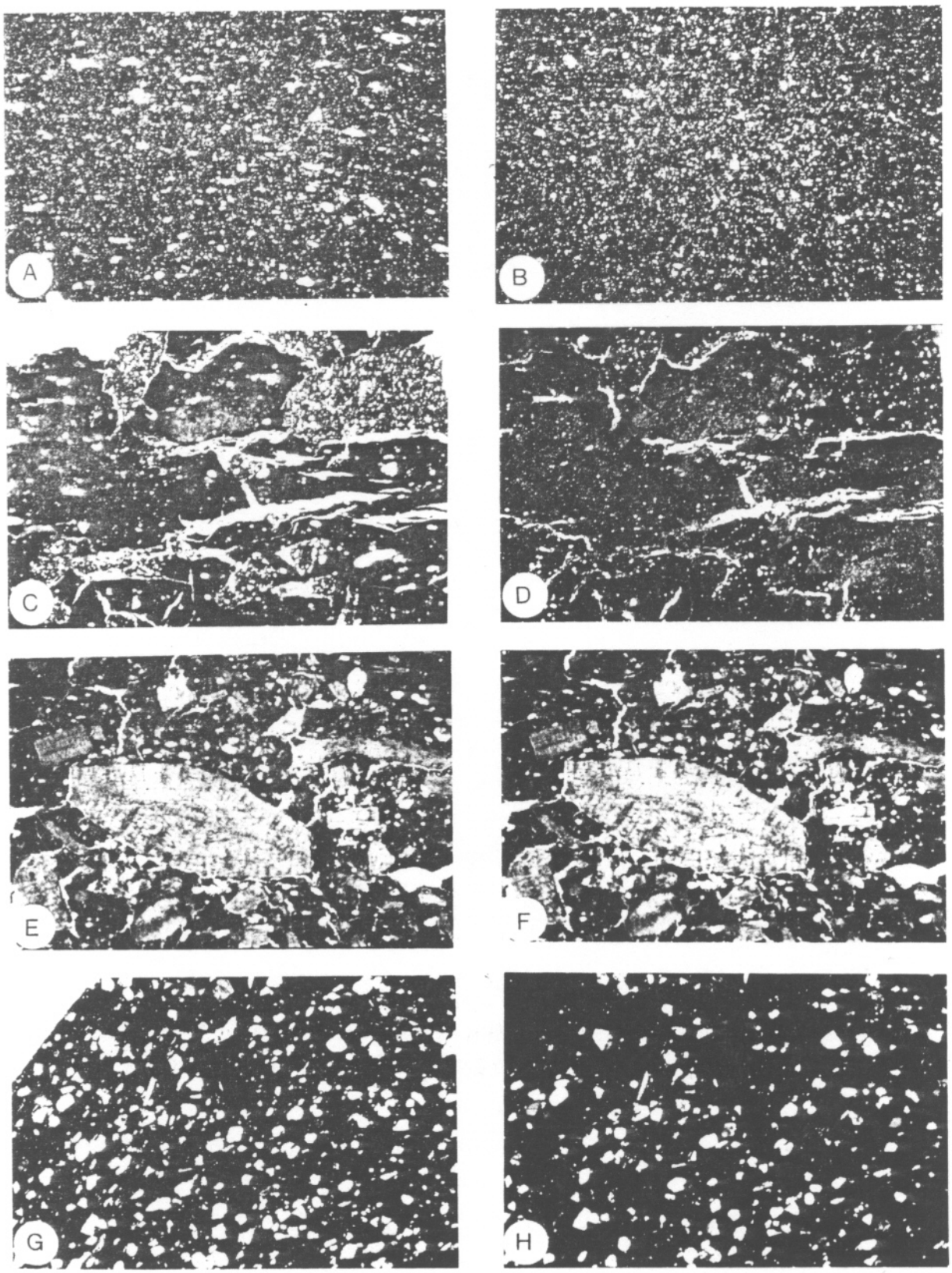


Fig. 8. *Fired vessels. Thin sections X20.*
A: marly fabric, PPL, B: same view, XPL, C: marly fabric with grog temper PPL, D: Same view, XLP.
E: nummulitic fabric, PPL, F: same view, XPL, G: micaceous fabric, PPL, H: same view, XPL.