

## **PETROGRAPHIC ANALYSIS OF POTTERY FROM TELL EL-FARKHA**

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### **INTRODUCTION**

The petrographic analysis of Predynastic samples from Tell el-Farkha aimed to acquire information on how the various pastes were prepared for the vessels and other aspects of their production. While this applied to all of the fabrics, particularly for the Nile clay vessels, it was important to understand how different tempering materials were being used. For the Marl clay fabrics it was essential to establish their variability to see if many different sources were being used to make pottery that would have been brought to the site, as Marl clay is not locally available. However, Marl clay pottery cannot be precisely provenance as it is present on the edge of the Delta and down both sides of the Nile, and includes a number of different limestone formations as the source (NÖRDSTROM & BOURRIAU 1993: 160). Finally, analysis of non-Egyptian fabrics could provide information on the interconnections Tell el-Farkha had with areas of the Levant, both direct and likely indirect. This would supplement the work of CZARNOWICZ (2011; 2012) on the vessel forms. The interconnections between these regions were long and most certainly began during this period based on the presence of Levantine artifacts and architecture in the Delta, and Egyptian artifacts and architecture in the southern Levant. Ceramic evidence is vital for further clarifying this early contact and more precisely locating where foreign vessels were produced that were found in the Delta. Overall, the petrographic analysis was able to provide data on the clay and inclusions utilized to make the pottery paste, a general assessment of firing temperature, and in some cases, a potential provenance.

### **METHODS**

Forty-nine samples of pottery were selected from Tell el-Farkha (Tab. 1). These were chosen by AGNIESZKA MACZYŃSKA, MICHAŁ ROZWADOWSKI, MARIUSZ JUCHA, MARCIN CZARNOWICZ, and MAGDALENA SOBAS from several areas of the kom in order to investigate

atypical Egyptian and non-Egyptian fabrics. Thus, samples of the well-known fabrics were not examined. The analyses were carried out at the Institut Français d'Archéologie Orientale in Cairo in 2011 and 2012<sup>1</sup>.

The petrographic analysis of pottery utilizes a special microscope with polarizing light to examine the clay and inclusions in a sample (REEDY 2008). The sample is glued to a slide and thinned to 30 microns to enable light to pass through the matrix and inclusions. The specific way in which the mineral and rock fragments interact with the light and appear in thin section allows them to be identified. Once the types of minerals and rock fragments are known, this information is related to geologic maps to locate areas where such inclusions would be available as pottery making material. This applies to the clay as well, as different clay types can be seen microscopically and related to soil maps showing their distribution. The combination of location information for the clay and inclusions suggests areas where the pottery was made as typically potters do not travel great distances to acquire their raw materials (ARNOLD 1985: 50). Further, comparison can be made to other petrographic studies of local pottery from specific areas. This is because local raw material resources do not change over extended periods of time. Technological information can also be acquired through petrographic analysis, which can reveal if several clays were mixed together, the types of material used as temper and give an idea of the general firing temperature of the sample.

A full petrographic description of each sample was made and these are reported in the individual reports produced for the Tell el-Farkha project. For this article, Appendix I provides a representative sample description and images (macroscopic and microscopic) for each petrographic group. The thin sections were produced in the standard way utilizing the cross section of the sherd. Petrographic analysis was carried out using typical descriptors (WHITBREAD 1989; OWNBY 2009). This includes the colour of the thin section in plane (PPL) and cross polarized light (XPL). The frequency of inclusions is given as a general percentage estimate and is based on the presence of grains medium-sized to larger, both quartz and limestone, and plant remains. Sorting is based on the consistent presence of grains of similar size (well-sorted) to the presence of grains of many sizes from fine to coarse in size (poorly sorted). Size range is based on the Wentworth scale: very fine (0.0625-0.125mm), fine (0.125-0.25mm), medium (0.25-0.5mm), coarse (0.5-1mm), and very coarse (1-2mm). Grain shape is based on Power's scale of roundness and goes from very angular to well-rounded. Only a single shape range is given for quartz and limestone inclusions, when present; the grains were not separated into those with high sphericity (tend to be more round) and those with low sphericity (tend to be more angular). The inclusions in the paste are divided into those that are common (*i.e.* main inclusions), and those that are less common (*i.e.* additional inclusions). For some of the additional inclusions the exact mineral type could not be specified, typically because the grain is too small, or is not exhibiting enough characteristic features for identification.

<sup>1</sup> Under the ANR Gezira Project and the Parent-Bridge Program Project "The Nile Delta as a centre of cultural interactions between the Upper Egypt and the Southern Levant in the 4<sup>th</sup> millennium BC".

Table 1. Samples

Sample number	Vessel Type	References to CZARNOWICZ 2012: fig	Petrographic Group
#P4	a non-diagnostic sherd		4
#P6	a non-diagnostic sherd		4
#P14	a rim of a bowl		4
#P20	a fragment of a small bowl		1
#P22	a non-diagnostic sherd		5
#P25	undefined		3
#P48	cylindrical jar		4
#P50	cylindrical jar		2
#P52	cylindrical jar		4
#P54	hes-jar		4
#P74	a non-diagnostic sherd		4
#P75	a non-diagnostic sherd		4
#P76	a non-diagnostic sherd		6
#P91	a non-diagnostic sherd		7
#P96	a non-diagnostic sherd		4
#P106	a non-diagnostic sherd		1
#P107	a non-diagnostic sherd		5
#P108	a non-diagnostic sherd		4
#P109	a non-diagnostic sherd		1
#P110	a non-diagnostic sherd		5
#P111	a non-diagnostic sherd		1
#P112	a flat base of a jar(?)		5
#P135	a spout	12.5	1
#P136	a spout	1.4, 12.3	2
#P137	part of keg	2.1, 12.1	5
#P138	a ledge handle	2.4, 8.1	10
#P139	a rim of hole mouth jar	9.4	6
#P140	a ledge handle		8
#P141	a ledge handle	3.1, 8.2	10
#P142	a ledge handle	4.2, 8.3	9
#P143	a ledge handle		9
#P144	w		5
#P145	a ledge handle		1
#P146	a body sherd (jar)	5.1, 13.3	4
#P147	Erani C handle imitation	11.2	1
#P148	a handle	2.2, 11.3	5
#P149	a lug handle	2.5, 13.5	1
#P150	a pillar spout	1.3, 12.2	1
#P151	a ledge handle		10
#P152	storage ledge handle vessel	1.1, 7	10
#P153	a broken ledge handle		10
#P154	buff color sherd with the knob		5
#P155	storage vessel rim		5
#P156	Pijama style vessel body sherd	13.2	1
#P157	a non-diagnostic sherd		1
#P158	a non-diagnostic sherd		1
#P159	a non-diagnostic sherd		1
#P160	ledge handle		8
#P161	large storage vessel painted body sherd	13.4	6

Rock fragments, particularly in Nile clay, are often very small and only in rare cases can a specific type of rock be identified. Rather, they can be categorized as volcanic, plutonic, or metamorphic and the individual minerals in the rock listed.

The results of the current study identified ten petrographic groups, that is sets of samples produced with similar clay and inclusions. A summary of parts of the *chaîne opératoire* for each sample are described as best as possible. Often even in thin section it is difficult to determine what was added by the potter and what might be natural to the clay. Uncertainty is stated clearly when the exact procedures are difficult to discern. Firing temperature estimates are based on several factors, the presence of silica from plant remains indicative of a lower temperature, decomposed limestone suggestive of a temperature closer to 850°C, and the optical activity of the clay matrix, which becomes inactive also near 850°C. These are very general estimates as the chemistry of the clay can affect the temperature at which vitrification occurs. Other factors during the firing such as duration and atmosphere can affect the appearance of the sample. The criteria utilized to give a temperature estimate are given.

## RESULTS

### *Egyptian Petrographic Groups*

#### **Nile clay with plant remains (Group 1)**

The first group comprises thirteen samples produced with Nile clay and some plant remains. The mineral inclusions were all typical for Nile clay, *i.e.* quartz, feldspars, muscovite, biotite, pyroxene, and amphibole. The amount and size of the plant remains could vary. Some of the samples may have added sand temper due to the presence of coarse-sized quartz and feldspar grains. Determining which components are natural and which are added can be difficult as the coarseness of Nile clay depends on where along the river or a canal the clay was collected. There always remains the possibility that the potters would have selected a Nile clay that had natural coarse-sized grains and only in cases where these grains were very common could the addition of sand be inferred with confidence. For most samples, the firing temperature was probably below 800°C as the silica from the plant remains is present and the matrix is optically active. However, some were likely fired above 800°C as the matrix was less optically active.

#### **Nile clay with plant remains and limestone (Group 2)**

Two samples were made with Nile clay and plant remains, plus limestone, which was likely added due to its high amount. The other inclusions were typical for Nile clay being mostly silt-sized to fine-sand sized quartz, feldspars, muscovite, biotite, pyroxene, and amphibole. Both were probably fired to around 800°C as the silica is gone from the plant remains, the limestone is partially decomposed, and the clay matrix is slightly active.

**Limestone-rich clay with Nile clay (Group 3)**

This group contains a single sample. The fabric appears to be a limestone-rich clay with Nile clay as well. The limestone clay undoubtedly weathered from one of the many limestone outcrops along the Nile or at the edge of the Delta. The Nile clay could have been naturally mixed with the limestone-rich clay, perhaps where a wadi meets the Nile. Alternatively, the Nile clay could have been intentionally added. The medium-sized sand grains and few large-sized grains may indicate sand was utilized as temper. The vessel was fired below 800°C as the limestone is intact and the matrix is optically active.

**Nile clay and Marl clay (Group 4)**

Eleven samples were a mix of Nile and Marl clays. The Marl clay has a pinkish color and in most cases the Nile clay appears to be a less than 50 percent of the paste. Some samples had different appearances that suggested various Marl clays were utilized. Whether the Nile clay was naturally present or intentionally added is difficult to determine. As with Group 3, areas near wadis where Nile and Marl clays could naturally mix may have provided the raw materials. Alternatively, there is a long history of potters adding Nile clay to Marl clay to make the latter more workable (REDMOUNT 2003: 213-263). Some of the samples had sand that was likely added due to its size, while others had added plant remains and sand temper, and still others just plant remains as temper. The firing temperature for the majority of the samples was probably between 800°C and 850°C as the matrix is optically inactive. Temperatures below this may have been achieved for a few samples, while a single sample exhibited a scum surface in thin section (OWNBY & GRIFFITHS 2009). Macroscopically most of the samples appeared to have a scum surface.

**Marl clay (Group 5)**

Group 5 comprises nine samples produced with pure Marl clay. In thin section some of these resembled the more pink marls while others had a more yellow color to them. This can be seen in the sherd as well, but the origin of the different colored clays is not known. Importantly, none of these samples were similar to the clays used for the Group 4 samples. Some of the samples appeared to have some added sand, while others had infrequent remains from plants. For all of the samples, the firing temperature was probably between 800°C and 850°C as the matrix is optically inactive.

**Shale clay (Group 6)**

Three analyzed samples were made from a clay derived from eroding shale. There are several shale outcrops in Egypt, but perhaps the best known is the Esna shale of Paleocene date, which is found along the Nile from Esna in the south to Cairo in the north (SAID 1962). Other shale formations are known in the Western Desert oases. One of the samples had added sand and the other two had a small amount of plant remains. The firing temperature for all appeared to be around 800°C as the matrix is optically active.

### **Marl clay with volcanic rock fragments (Group 7)**

One unusual sample consisted of a yellow marl clay with large fragments of volcanic rocks that ranged from dolerite to basalt, which are likely temper. The optically inactive matrix suggests the firing temperature was probably around 800°C due to the presence of calcium carbonate. The origin of this sample is uncertain. The clay is similar to Egyptian marls, but there are marl clays in the Levant as well. The type of dolerite to basalt fragments also exists in both places, along the Red Sea Coast east of Luxor and as small outcrops throughout Egypt and in the area to the southwest of Lake Kinneret in Palestine (BARTOV 1994; SAID 1962). This latter area has eroding Pliocene marls and outcrops of Miocene dolerite and basalt, though the basalt is dominant. Pottery from this area has been noted by COHEN-WEINBERGER and GOREN (2004) for the site of Tell el-Dab'a dated to the Middle Bronze Age, although their description is not exactly the same as the sample seen here. However, the presence of large chert fragments is similar to previous analyses of Levantine samples suggesting that the area remains a possibility (OWNBY 2010). A petrographic analysis of a marl New Kingdom spinning bowl from Karnak identified fresh fragments of basalt similar to those in this sample also as temper (MALLORY-GREENOUGH *et al.* 1998). Further analysis through microprobe suggested the basalt originated in the Cairo area. However, this sample included fragments of metamorphic and granitoid rocks which are lacking in the Tell el-Farkha sample. Comparative analysis to these samples and other information are necessary to give a more specific provenance.

#### *Levantine Petrographic Groups*

### **Foraminiferous Marl (Group 8)**

This group comprises two samples made from a foraminiferous marl clay; that is one with common foraminifera or microfossils. The large, likely natural inclusions, consist of limestone, chert, chalcedony, and iron-rich oolites. The samples were both fired up to 800°C due to the optical activity of the matrix. While foraminiferous clay is common throughout the Levant, the presence of chert and chalcedony suggest Lebanon as a likely production location. Here the Upper Cretaceous (Senonian) formation has chert and chalcedony (BEYDOUN 1977: 322, 329, 332-333). The iron-rich oolites are also a possible indicator for Lebanon as they are known from the Lower Cretaceous shale unit in this same area (DUBERTRET 1962). In fact, this group utilizes similar raw materials to the Early Bronze II and III pottery analyzed petrographically from Tell Fadous-Kfarabida, a site located north of Byblos (BADRESHANY & GENZ 2009). Here the ceramics were made from a ferruginous and foraminiferous marl with variation in the amounts of quartz, limestone, and iron-rich argillaceous inclusions and globules. The appearance of the Tell el-Farkha samples suggests similar materials, but in a location with a greater contribution of chert and iron-rich oolites. Thus, an area where foraminiferous marl clay, possibly the Chekka foraminiferous marls of Senonian-Eocene date, is present along with the Lower Cretaceous unit is the probably place where these samples were produced. Such an area

is along the coast of Lebanon around Beirut, but is found further inland to the north as far as Tripoli. Further comparison to material from this area is necessary to confirm the exact provenance.

### **Dolomite Moza(?) Formation (Group 9)**

The second Levantine petrographic group also has a calcareous clay but in this case, along with limestone and microfossils, are common inclusions of angular and rhombohedral dolomite<sup>2</sup>. As these inclusions are all of similar size, they have been suggested to indicate the addition of a dolomite sand (GOREN 1996: 38, 51). The firing temperature is suggested to have been around 850°C. The presence of dolomitic sand indicates the provenance could be in Palestine. The samples resemble<sup>3</sup> Early Bronze IV pottery produced in the Judean area of Palestine from Moza Formation clay with the addition of a dolomitic sand (GOREN 1996: 38, 51). Though these comparative samples are dated to the Early Bronze IV period, PORAT (1989: 47-48) noted the use of Moza formation clay and dolomite sand in analyzed Early Bronze I material from sites in central Israel, such as Aphek, that do show some evidence for Egyptian contact. Thus, while archaeologically there is little evidence for an Egyptian connection to the Judean area directly, such vessels may have come to Egypt via other sites that had contact with Egypt. Interestingly, this pottery fabric was not seen in vessels from Early Bronze II or III sites, a time when Egypt's involvement in the southern Levant was much reduced. Direct comparison between these samples and those of Moza clay mentioned above would be desirable to confirm this assessment.

### **Marl clay with crushed calcite (Group 10)**

While the previous petrographic group could be fairly easily related to an existing ceramic paste used in Palestine during the Early Bronze Age, the five samples in this group are more difficult to interpret. The marl clay appears similar to the Group 9 samples, but the dolomite sand is not present and foraminifera are less common. Instead, some samples have some large inclusions of dolomite and calcite, while other samples have very few. Along with the dolomite/calcite are fragments of limestone and foraminifera as seen in the other imported groups. Another unique feature of this group is that the appearance of some samples suggests the firing temperature reached 850°C. The use of the foraminiferous Taqiya marl is a possibility for this group (GOREN 1996: 48, 52), but as previously stated foraminiferous marls are also present in Lebanon. In southern Palestine, Taqiya marl used for pottery production has been attested in the Negev during Early Bronze II and Early Bronze IV, and the Coastal Plain during Early Bronze IV. Further, the use of crushed calcite is well-known for Early Bronze Age Palestine. The petrographic work on pottery from Tell Fadous-Kfarabida suggests foraminiferous marl

<sup>2</sup> At temperatures above 500°C dolomite alters to calcite. However, the likely original composition is being referred to here and for the next group.

<sup>3</sup> ANAT COHEN-WEINBERGER examined images of these samples and confirmed their similarity to Moza formation clay and dolomitic sand samples from EBA Palestine.

with angular calcite is also known there for pottery probably produced in the vicinity (BADRESHANY & GENZ 2009: 70-72). Therefore, it is likely these samples are imports, but without further petrographic comparison, an exact provenance cannot be given.

## DISCUSSION

The results of the petrographic analysis revealed a wide range of recipes utilized for producing pottery in the Predynastic Period found at Tell el-Farkha. Nile clay could be utilized without the addition of other materials or with sand, plant remains, and/or limestone added. It is likely differences in firing temperature resulted in the various appearances of these Nile clay sherds. Very few of the sherds appeared to have sand added; rather a more sandy naturally occurring Nile clay was probably used. Several varieties of Marl clay ceramics appear to have come to the site, some with added sand and/or plant remains. In cases where the clay appears to be mostly a Marl clay with a minor amount of Nile clay, this could have been a natural mix or the potter may have added the Nile clay to the Marl clay to make it more workable. The variety in the Marl clay samples analyzed may represent various production locations or the utilization of several different clay beds within the same area. Once again, the lack of information on Marl clay sources in general and their weathering behavior prohibits a better understanding of the raw materials used to produce these vessels. The unusual combination of Nile clay with a limestone-rich clay requires further study but hints at the utilization of a broad range of raw materials. This is also suggested by the production of vessels from a clay weathering from a shale outcrop, possibly from the common outcrops in the oases or from southern Egypt where the Esna shale formation crops out in a few places. The single sample of a Marl clay with volcanic rock fragments, which could be Egyptian, may also signify the use of many different clay resources.

The variety of choices noted for these samples makes clear that the Predynastic potters produced their pastes based on where the vessel was made, its form and its intended function. However, it is likely there were no strict recipes that were adhered to and production was probably based on necessity rather than as an industry. Technologically, the estimated firing temperatures suggest most vessels were probably fired between 750°C and 850°C in keeping with early pyrotechnology.

While, the provenance for these samples cannot be refined beyond a location in Egypt, their consistent low firing temperature and variety provides insight into the development of ceramic technology and contacts within Egypt in the Delta at this time. Although the Nile clay vessels could be local to Tell el-Farkah, most of the other Egyptian vessels were probably not produced at the site. The Marl clay vessels in particular are likely to have been brought to the site from a number of different locations. The lack of information on the variety of Marl clays, which likely vary in terms of geologic age and constituents, prohibits assigning any of them to specific sources. Additionally, there is a strong likelihood that natural mixes of Marl and Nile clays exist. The sources of these clays and their natural constituents are unknown. Such information is necessary for a better understanding of Egyptian pottery in general.

All of the analyzed Egyptian samples were similar to those from previous work and further illustrate the variety of raw materials employed for Egyptian pottery production and the lack of standardization for this period. In comparison with the nearby site of Tell Iswid, also dated to the Predynastic period, the Egyptian samples are quite similar (OWNBY 2012). The Tell el-Iswid Nile clay ceramics were made with the addition of plant remains and limestone, while one fabric consisted of a combination of Nile clay and a foraminifera-rich calcareous clay. The Tell el-Iswid Marl clay samples showed a similar variety to the Tell el-Farkha samples with pink and yellow varieties, some of which contained sand and plant remains. Firing temperatures were also around 800°C.

A petrographic study of Predynastic pottery from the site of Douch in Kharga Oasis revealed many samples produced from a shale clay that could have been acquired locally (OWNBY *in press*). Nile clay vessels at the site had inclusions of plant remains and limestone, while a Marl clay sample had sand temper. The firing temperatures were the same as for the other samples discussed. Comparison to the petrographic descriptions of Predynastic pottery from Maadi also reveals the common utilization of Nile clay with or without plant remains and occasional limestone (PORAT & SEEHER 1988: 222-223). The firing temperatures were estimated to be low, 650°C to 700°C, except for a group of D-ware and black-topped vessels believed to derive from Upper Egypt where the temperature likely reached 800°C and plant remains were absent.

The macroscopic and petrographic analysis of Predynastic pottery from Hierakonpolis, Naqada and Hemamieh revealed a similar range of fabrics (FRIEDMAN 1994: 137-160). Nile clay could be utilized without temper, or include the addition of sand, plant remains and/or limestone. A few Marl clay fabrics were noted from these sites, including mixed Nile and Marl clay fabrics, while some contained sand temper. Pottery produced with shale temper was noted, but may represent a shale clay with remaining pieces of unweathered shale. A similar fabric appears to be common for pottery from Dakhla Oasis dated to the Predynastic period (EDWARDS & HOPE 1989). Thus, the results of this petrographic study and others have revealed important information on the technology of pottery production during the late Predynastic period and the ubiquity of some of these fabrics at sites throughout the Nile Valley and beyond.

Beyond Egypt, the interregional contacts that the inhabitants of Tell el-Farkha may have had can be seen in the several imported fabrics analyzed. Along with the study of vessel forms, it seems clear that pottery from Palestine was reaching Tell el-Farkha, specifically ledge handled storage jars (JUCHA 2008; CZARNOWICZ 2011; 2012). It seems likely that pottery produced in the Judean area from Moza clay was brought indirectly to Egypt. Such indirect movement of vessels may also explain the presence of pottery that is suggested to derive from Lebanon. Although archaeological evidence for contact between Egypt and Lebanon is scarce at this time, there is some indication cedar may have been acquired along with other goods, particularly at the site of Maadi (PRAG 1986; RIZKANA & SEEHER 1989). In fact, analysis of pottery from this site has identified calcareous fabrics with dolomite, crushed calcite temper, and foraminiferous fabrics

(PORAT & SEEHER 1988: 224-225). Notably, various firing temperatures were proposed, similar to the variability in the Tell el-Farkha samples, and most were suggested to derive from Palestine. A few samples contained iron-rich fragments and chert that could indicate Lebanese fabrics (PORAT 1989). Such imports from Lebanon may have come to Egypt indirectly through the areas of Palestine where Egyptian influence is known. Such hypotheses and the provenance assignments for these vessels require further study to confirm. Finally, while the sherds classified as imports petrographically came from non-Egyptian vessel forms, several samples believed to be Palestinian in origin were identified as made of Nile clay. This refers specifically to samples placed in Group 1 and suggests the possibility of local Egyptian copying of foreign vessel shapes. Such imitation was identified at Maadi (PORAT & SEEHER 1988: 225) suggesting a precedent for this behavior.

### CONCLUSIONS

The goal of this study was to highlight the variety of processes to produce pottery found at Tell el-Farkha. Thus, the many petrographic groups are not surprising and have provided additional information on how clay resources were utilized in the Predynastic period. Undoubtedly, this was a time when potters were exploiting different resources and learning what materials worked best for particular purposes. The variety seen also suggests, particularly for the Marl vessels, that pottery at Tell el-Farkha may have come to the site from a number of production locations near limestone outcrops producing Marl clays. Unfortunately, only through further research on the various Marl clay resources in Egypt can more specific information on provenance be provided. The geological prevalence of limestone outcrops in Egypt makes this an especially challenging task. On the other hand, petrographic analysis of the imported samples found at Tell el-Farkha revealed likely production areas in Lebanon and Palestine confirming the impression that the site had interregional as well as regional contacts.

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## APPENDIX I

### IMAGES AND DESCRIPTIONS FOR PETROGRAPHIC GROUPS

This appendix provides a petrographic description and images from a sample representative of each petrographic group. The images begin with a macroscopic view of the fabric at the top, then a plane polarized image of the thin section in the middle, followed by a cross polarized image of the thin section at the bottom.

#### Group 1: Nile clay with plant remains

(Sample #P159)

*Colour PPL:* red

*Colour XPL:* red

*Frequency of Inclusions (estimated):* 20%  
(quartz and OPL<sup>1</sup>)

*Sorting:* fair

*Size Range:* very fine to medium

*Shape Range:* angular to subrounded

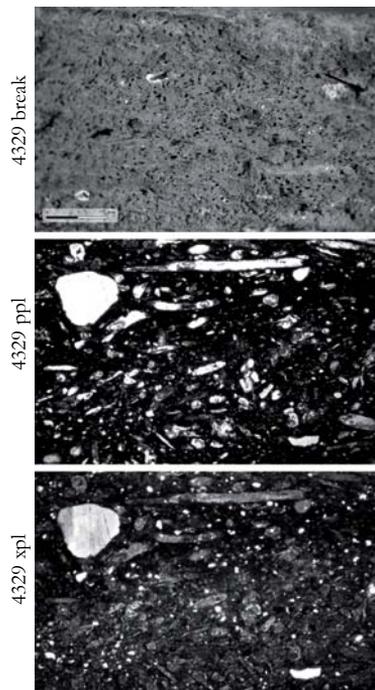
*Main Inclusions:* quartz, K-feldspar, plagioclase, muscovite, biotite, iron oxides, opaques, pyroxene, amphibole, OPL

*Additional Inclusions:* polycrystalline quartz, serpentine, quartzite?, limestone?, zoisite?, grog?, VRF<sup>2</sup>?, MRF?

*Comments:* Nile clay with OPL, low firing temperature

<sup>1</sup> OPL=Organic plant remains.

<sup>2</sup> VRF=volcanic rock fragments; MRF=metamorphic rock fragments



**Group 2: Nile clay with plant remains and limestone** (Sample #P136)

*Colour PPL:* reddish brown

*Colour XPL:* reddish brown

*Frequency of Inclusions (estimated):* 15%

*Sorting:* fair

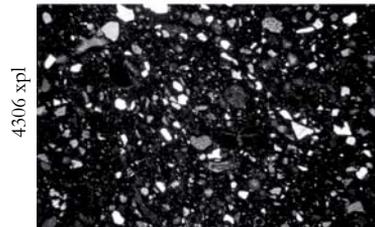
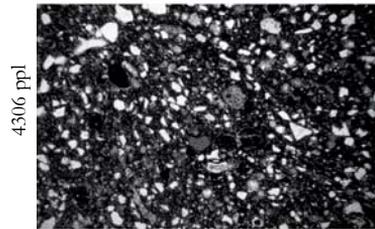
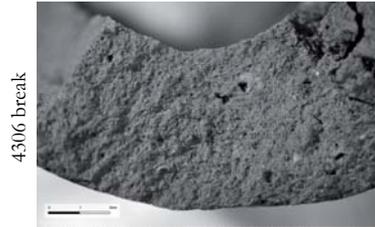
*Size Range:* very fine to medium

*Shape Range:* angular to subrounded

*Main Inclusions:* quartz, K-feldspar, plagioclase, muscovite, biotite, limestone (decomposed), iron oxides, opaques, pyroxene, amphibole

*Additional Inclusions:* polycrystalline quartz, OPL, serpentine, VRF, garnet?, zircon?, gneiss?

*Comments:* probably a Nile clay with limestone; medium firing temperature (limestone is decomposed)



**Group 3: Nile clay with limestone-rich clay** (Sample #P25)

*Colour PPL:* medium brownish tan

*Colour XPL:* medium brownish tan

*Frequency of Inclusions (estimated):* 30%

*Sorting:* poor

*Size Range:* very fine to medium (quartz);

very fine to very coarse (limestone)

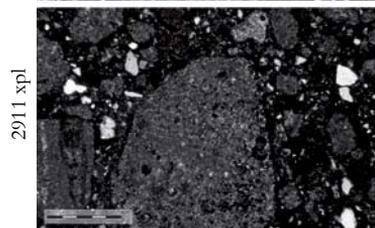
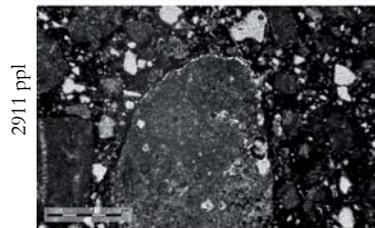
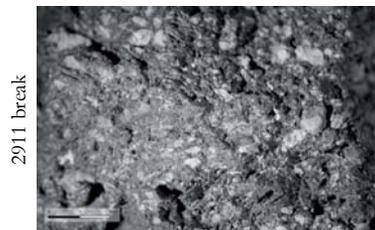
*Shape Range:* angular to subrounded

(quartz); subangular to rounded (limestone)

*Main Inclusions:* quartz, K-feldspar, plagioclase, limestone (micritic and sparry), calcite, iron oxides, opaques, pyroxene

*Additional Inclusions:* polycrystalline quartz, biotite, muscovite, chert, chalcedony, chlorite, clay pellets (Nile), quartzite, plant remains

*Comments:* clay from an eroding limestone and probably some Nile clay and a few plant remains; low firing temperature

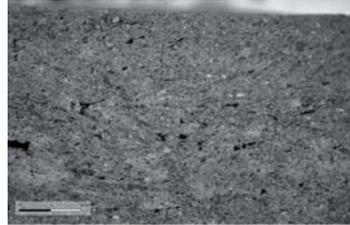


**Group 4: Nile clay and marl clay**

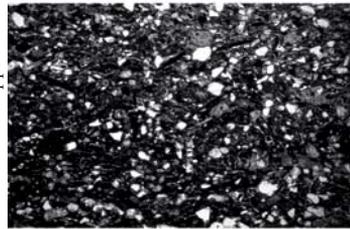
(Sample #P146)

*Colour PPL:* reddish brown*Colour XPL:* grayish red*Frequency of Inclusions (estimated):* 30%*Sorting:* fair*Size Range:* very fine to medium*Shape Range:* angular to subrounded*Main Inclusions:* quartz, plagioclase, K-feldspar, muscovite, biotite, limestone (decomposed), iron oxides, opaques, pyroxene, amphibole*Additional Inclusions:* polycrystalline quartz, chert, serpentine, shale fragments, iron-filled microfossils, sandstone fragments, VRF, OPL, garnet?, gneiss fragment?*Comments:* marl clay with sand and probably some Nile addition; high firing since limestone decomposed

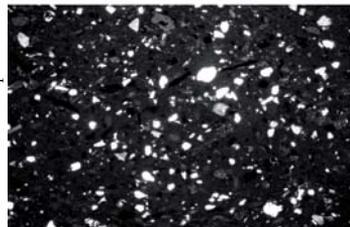
4316 break



4316 ppl



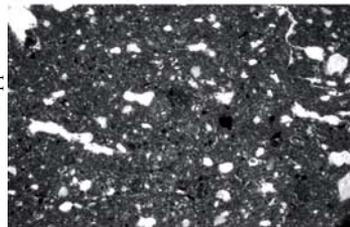
4316 xpl

**Group 5: Marl clay (Sample #P154)***Colour PPL:* light brown*Colour XPL:* grayish brown*Frequency of Inclusions (estimated):* 5%*Sorting:* good*Size Range:* very fine to fine*Shape Range:* subangular to subrounded*Main Inclusions:* quartz, iron oxides*Additional Inclusions:* plagioclase, K-feldspar, biotite, muscovite, chert, opaques, serpentine, amphibole, pyroxene?, amphibole?, OPL?*Comments:* calcareous clay with no added inclusions; medium firing temperature

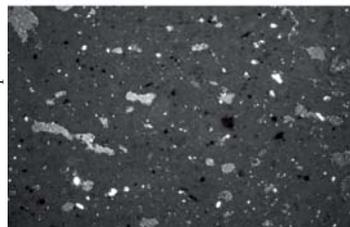
4324 break



4324 ppl



4324 xpl



**Group 6: Shale clay** (Sample #P139)*Colour PPL:* tan*Colour XPL:* reddish tan*Frequency of Inclusions (estimated):* 1%*Sorting:* good*Size Range:* very fine to medium*Shape Range:* angular to subrounded*Main Inclusions:* quartz, iron oxides, opaques*Additional Inclusions:* plagioclase, biotite, serpentine, OPL, pyroxene?*Comments:* shale-derived clay; low firing temperature (optically active)

4309 break



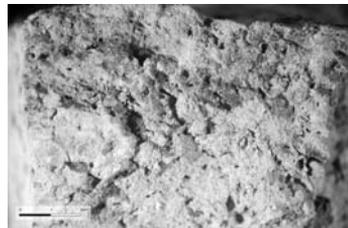
4309 ppl



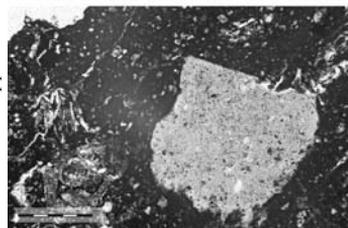
4309 xpl

**Group 7: Marl clay with volcanic rock fragments** (Sample #P91)*Colour PPL:* medium grayish tan*Colour XPL:* dark grayish tan*Frequency of Inclusions (estimated):* 10%*Sorting:* poor*Size Range:* very fine to medium (quartz); fine to very coarse (chert); fine to coarse (VRF)*Shape Range:* angular to subrounded (quartz); very angular to subangular (chert); subangular to rounded (VRF)*Main Inclusions:* quartz, plagioclase, limestone (micritic, some w/chert), iron oxides, opaques, pyroxene, chert (some coarse-sized), VRF*Additional Inclusions:* K-feldspar, amphibole, olivine*Comments:* Marl clay with large VRF (dolerite to basalt, few with olivine which is now iddingsite, ortho and clinopyroxene, mostly tholeiitic in composition, some are holocrystalline and some are hypocrystalline, some are devitrified and weathered); medium firing temperature (limestone decomposed)

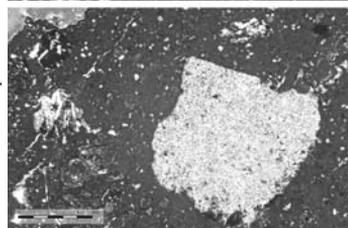
2977 break



2977 ppl



2977 xpl



**Group 8: Foraminiferous Marl**

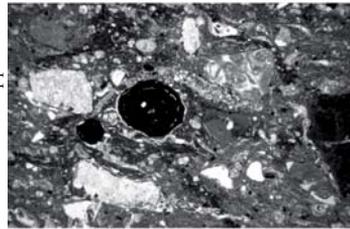
(Sample #P140)

*Colour PPL:* tan*Colour XPL:* tan*Frequency of Inclusions (estimated):* 40%*Sorting:* poor*Size Range:* very fine to very coarse*Shape Range:* subangular to well rounded*Main Inclusions:* quartz, limestone (micritic and sparry), calcite, microfossils (globigerinoids, globigerina, orbulina), chert*Additional Inclusions:* chalcedony, opaques, iron oxides, plagioclase, serpentine, amphibole?, pyroxene?, volcanic glass?*Comments:* marl clay with natural inclusions of quartz, limestone, calcite, and microfossils. The chert and chalcedony are also likely natural. A few iron-rich oolites. Low firing temperature.

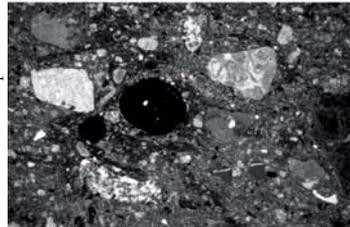
4310 break



4310 ppl



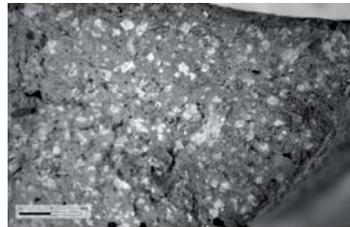
4310 xpl

**Group 9: Dolomite Moza(?) Formation**

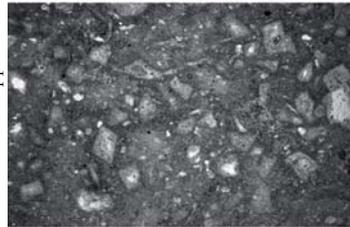
(Sample #P143)

*Colour PPL:* tan*Colour XPL:* dark tan*Frequency of Inclusions (estimated):* 35%*Sorting:* poor*Size Range:* very fine to very coarse*Shape Range:* angular to subrounded*Main Inclusions:* dolomite, limestone (sparry and micritic, decomposed), microfossils (globigerina, globigerinoids, orbulina)*Additional Inclusions:* calcite, quartz, plagioclase, iron oxides, pyroxene?, amphibole?*Comments:* calcareous clay with natural inclusions of dolomite and some microfossils, decomposing so medium firing temperature

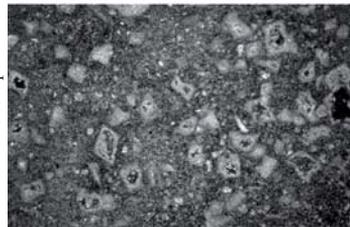
4313 break



4313 ppl



4313 xpl



**Group 10: Marl clay with crushed calcite**

(Sample #P153)

*Colour PPL:* tan

*Colour XPL:* tan

*Frequency of Inclusions (estimated):* 40%

*Sorting:* poor

*Size Range:* very fine to very coarse

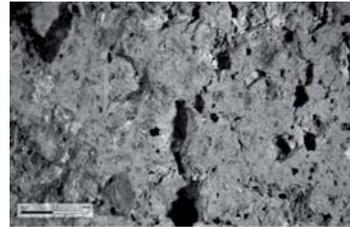
*Shape Range:* very angular to subrounded

*Main Inclusions:* limestone (micritic and sparry), calcite, microfossils (globigerinoids, globigerina, orbulina)

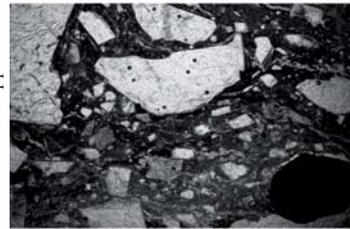
*Additional Inclusions:* quartz, dolomite, iron oxides, serpentine, iron oxide nodule

*Comments:* a dolomitic derived clay, no temper added; low firing temperature

4323 break



4323 ppl



4323 xpl

