CHAPTER EIGHT

8.1 CONCLUSIONS

Apart from three stratified deposits from Ismant el-Kharab, the ceramic material in this corpus was recovered from limited testing and surface collections during the survey of Dakhleh Oasis. Most intact vessels are from cemeteries as these sites provide better conditions for the recovery of intact vessels than settlement sites. The disturbed nature of the three stratified deposits from Ismant el-Kharab which form the last phase (Phase 4) of the chronology also precluded the recovery of intact or restorable vessels. Nevertheless, the overall ratio of intact vessels and those with complete sections to sherd material is satisfactorily high.

The analysis of this published and unpublished material has established a ceramic typology, providing a chronological sequence of vessel forms dating from the eighth–seventh centuries BC to the second century AD. The Vessel Typology is presented in Part II, Section 1 of the thesis and comprises text (1–264) and the drawn pottery forms (Pls 1–88). It has been designed to expedite the processing of material from future excavations in the Dakhleh Oasis and as a comparative typology for use by other researchers in the field of Egyptian ceramics.

The analysis of the ceramic material has also established a catalogue of surveyed sites presented in Part II, Section II (265–464, Pls 89–162). This research was designed to assist in the on-going analysis of the socio-economic development of the oasis by members of the Dakhleh Oasis Project and other researchers. This comparative study of sites and ceramics also demonstrates that, in the oasis, there are many exciting prospects future excavation: these are discussed below.

Nine sites on Map 5 contain pottery from Phase 1, the earliest period in the corpus. Two of these justify particular interest inasmuch as they are settlement sites – SS6 : 33/390-K9-2 (384–7, Pl. 137) and SS14 : 32/390-M4-1 (408–12, Pl. 146). Despite the limited archaeological remains recovered from the tests, the pottery assemblages show that the sites were either occupied, or that some economic activity took place there, at least as early as the Saite Period. The pottery also suggests that these sites may have been active during a single phase. The excavation at other sites (Ismant el-Kharab, Hope 1991 and Ein Birbiyeh, Mills 1998) has illustrated the depth of undisturbed archaeological evidence that remains beneath the sands in the oasis, and the sites, SS6 and SS14, represent a unique opportunity to investigate the socio-economic conditions of the inhabitants in the eighth and seventh centuries BC.

The location in the western sector of Dakhleh Oasis of these two sites is also significant. Both sites were situated close to the entrance of a major trade route that connected the oasis to the Nile Valley – the Darb el-Khashaba (Map 3). This route joins the Darb el-Tawil and debouches into the Nile Valley, some fifty kilometres south of the sites of Amarna and Ashmunein (Map 2). The settlements at SS6 and SS14 would also have been located conveniently close to the main artery that ran through the oasis and connected the Nile Valley, near Thebes, to Farafra Oasis in the Western Desert and regions beyond (Map 2). The comparative material provided by the Nile Valley sites – Ashmunein, Amarna (South Tombs) and Karnak North – for a number of vessels (SS14 1b, 1e and 1k, 1f, 1i and 1j) attests to the use of the Darb el-Khashaba and the Theban route in this period. In addition, the rim sherd (SS6 0b, Form 96) is from a vessel known at the Nile Valley sites, Ashmunein and Karnak North and shows that vessels were brought into the oasis, albeit on a small scale.

In the centre of the oasis, the Phase 1 pottery from the tested tomb at the cemetery site (CS7: 31/405-F9-3, Map 5) reflects the early occupation of the nearby site of Mut el-Kharab (SS20: 31/405-G10-1, Map 4). This large settlement was situated at the hub of the oasis and had links to the south as well as the other routes running through the oasis. The pottery (Pls 102–4) from the cemetery, CS7, has parallels from a number of sites: Form 51 and Form 53 bowls from Amarna (South Tombs), Karnak North and Elephantine, Dorginarti in Nubia, and from the neighbouring oasis of Kharga; Form 31 censers from Elephantine, Matmar and Lahun; Form 32 goblets from Elephantine, Karnak North, Matmar, Amarna(South Tombs) and Ashmunein.

The settlement, SS16: 31/405-M9-1, is situated a short distance to the east of the cemetery, CS7 (Map 5). Flasks from Forms 153 and 154 (Pls 148–9) were recovered from tests in the temple and collected from the surface, and indicate that this site was also occupied during the eighth or seventh century (Phase 1), and possibly earlier. On the surface of the site, sherds of large Form 154 flasks are so numerous that they must have been a local product and were probably made over a considerable period. A sherd from one of these vessels was selected for testing (Sample S3) and the petrographic analysis confirms the local origin of the vessels (Appendix 1, A-5–6 and A-17, Pl. 175). The flasks may have transported the copious quantities of water necessary for the long desert journeys between the oasis and the Nile Valley, or they may have been used for the export of wine from the oasis (Mills 1997, 2). The flasks have been recognised at a number of sites in the Nile Valley (127–9) some of which, including Ashmunein, Amarna (South Tombs) and Karnak North, are situated near the end of trading routes coming from Dakhleh Oasis.

No settlements dating to Phase 1 were discovered in the eastern sector of the oasis during the survey; however, two large cemeteries attest a considerable population in the area at this time. The cemetery of Ein Tirghi (CS15: 31/435-D5-2, Maps 5 and 6) was one of the sites selected for excavation, and the material in the Phase 1 and 2 corpus from this site is quite extensive (Pls 115–123). Some vessels (CS15 14h, CS15 34e and CS15 37a) have possible parallels at Delta sites. These vessels and a number of others also have parallels from Nile Valley sites, particularly at Karnak North.

Only a small number of vessels were recovered from the two tested tombs at the other Phase 1 cemetery site in this area of the oasis – CS19: 31/435-G2-2 (Map 5). However, the vessels are distinctive (Pl. 126), and have parallels in Nile Valley and Delta sites. Three to four hundred tombs were estimated to be located at this site, and it is another site that merits excavation to add to the knowledge of the period and to the corpus of Phase 1 pottery types from Dakhleh Oasis.

The nine sites that date to Phase 1 were located in all the sectors of the oasis (Map 5) and indicate that the population was spread throughout the oasis during the Saite Period. During this time, connections appear to have been maintained with the Nile Valley, particularly with sites from Ashmunein south to Elephantine. A few vessels also indicate contact with the Nile Delta; however, at present, it is not known if the contact was made directly or whether it came through the Valley sites.

It can be seen from the pottery vessels that communications between the oasis and other regions were maintained during Phase 1; however, it is more difficult to conceive how pottery styles were transmitted. Little is known of the craftsmen who made the vessels apart from the fact that, in the Middle Kingdom, the status of their trade was considered to be a lowly one (Lichtheim 1975, 186–7). Tomb paintings suggest that potters were just as much a part of wealthy households as the other servants (Holthoer 1977, figs 4, 6–8, 14–19). Although these representations are also from earlier periods, social structures may not have changed over time. If this is true, the potters in the retinue of officials and other wealthy households would have travelled to new locations such as the Oases, bringing with them pottery styles current in the Nile Valley.

Potters and their craft would also have been essential to armies and other forces: transient people do not usually encumber themselves with relatively heavy ceramic cooking vessels. Whether at new postings or on the move, clay would have been readily available at most locations to make new vessels and the mud bricks for kilns. At different places, local potters may have been enlisted into the armies and, on their return home, would have brought new techniques and styles with them. At times it may also have been necessary for potters to move voluntary to the larger centres in the Nile Valley to search for work. At present, the transmission of pottery styles in the period can only be surmised; however, in view of the small amount of imported pottery in the corpus, it seems more likely that the potters moved rather than that the vessels were transported.

Map 6 shows ten cemetery sites that belong to the next phase, Phase 2 (Persian

Period to the pre-Ptolemaic fourth century BC). Three sites are located in the western sector, five around the settlement of Mut el-Kharab and two, CS15 and CS17 (only two vessels came from this site), further east. As the material in some assemblages was deposited over an extended period and as the transition between Phase 2 and early Phase 3 (Ptolemaic Period) is not clear, Map 7 covers the period from late Phase 2 to early Ptolemaic Period. This map shows that seven sites come into this category including CS7, which also had Phase 1 material.

Altogether seven sites on these two maps – three settlements and four cemeteries – cluster in the western sector of the oasis. The occupation of the settlement sites SS2, SS7 and SS10 appears to have extended over a considerable period and a few sherds indicate that settlement may have started as early as Phase 1 – SS2 Aj (Form 51); SS2 An (Form 175); SS2 Ar and SS7 1y (Form 97); and possibly SS10 0d (Form 38).

The cemetery, CS2: 32/390-K1-1, was situated less than ten kilometres to the east of the settlement, SS7. The large assemblage (Pls 91–3) from the tested tomb indicates this tomb was also in use for some time. It contained two of the Form 52 bowls that have a very distinctive rim formation (CS2 2a and 2ee). In stratified deposits at Buto, this type of bowl is known from the mid-Saite Period through to the fourth century BC (P. J. French, personal communication). Two rim sherds (SS7 1m and SS7 1s), which may be from this form, were also recovered from the settlement site SS7.

In the centre of the oasis, seven cemetery sites form a cluster around Mut el-Kharab and were probably associated with that settlement site. The assemblage from site CS5, the largest in this group of cemeteries (Pls 96–100), contained two Form 87 vessels. From the lack of ceramic parallels from other sites, this spouted form appears to be one of the forms indigenous to the oases of the Western Desert. However, there is a bronze vessel from the Royal Tombs of Kush (Dunham 1957, 28, fig. 8) which is an accurate shape parallel. Another feature also connects the vessels from these far-flung sites: the bronze one from Nubia and one of the spouted jars, CS5 2u (Pl. 20) were both incised on the upper body with a number of characters. Those on the bronze vessel were thought to while the script on the vessel from Dakhleh was unknown (Hope 1981, 237, pl. XXIV).

A Twenty-fifth dynasty presence in Dakhleh Oasis is attested by the smaller stela from the oasis now in the Ashmolean Museum (Janssen 1968, 171–2; Grimal 1998, 340). The spouted vessels (and other forms, such as Form 116) indicate that, after the Kushite kings had retreated into Nubia, contact between these two remote regions was maintained through the network of desert routes.

Three cemetery sites are located a little further east: CS14 (Pl. 114) was a small assemblage containing one of the Form 52 bowls with parallels at Buto. The larger assemblage at CS12 (Pl. 109) included material from Phase 2 (Form 53 and Form 116). It also contained four Form 111 jars that, despite their frequency in this corpus, have been difficult to date. The tomb at CS17 contained two vessels, both of which are difficult to date accurately. In the eastern sector, the tombs at CS15 (115–123) provided a quantity of ceramic material dated to Phase 2.

In summary, fifteen sites in the west and central sectors of the oasis had material dated to Phase 2 or Phase 2/3 and the assemblages from some of the cemetery sites, particularly CS2 and CS5, are quite large. In the eastern sector, the cemetery CS15 was still in use. Comparative material for some of the vessels (particularly Forms 53, 69, 116 and 119) from these sites comes from sites in the Nile Delta, the Nile Valley and Nubia.

There are no standing monuments of the period in Dakhleh Oasis, such as the imposing temple of Hibis in the neighbouring oasis of Kharga. However, the analysis of the ceramic material suggests that, throughout the Persian Period, there was a considerable population in Dakhleh Oasis particularly in the west and centre of the oasis. In addition, the pottery from these sites indicates that contacts between the oasis and other parts of Egypt as far distant as the Nile Delta and Nubia were maintained during this time.

The ten sites listed on Map 8 have ceramic material that can be placed in Phase 3 (Ptolemaic Period). A group of four settlement sites and one cemetery site cluster in the western sector of the oasis. Of these, the settlements of SS7 and SS10 were occupied over western sector of the oasis. Of these, the settlements of SS7 and SS10 were occupied over an extended period and have been mentioned previously in relation to earlier phases. An amphora sherd from the settlement SS8 (Pl. 141) suggests this site may also have been occupied earlier. The other settlement, SS12 (Pl. 145), and the cemetery, CS18 (Pl. 125), contained small assemblages but ones valuable for their additions to the diversity of forms in the corpus.

In the centre of the oasis, the tested tomb at a cemetery (CS9: 31/405-H9-2) in the vicinity of Mut el-Kharab contained only three Form 130 jars. Although this form is without strong parallels, the tomb may be dated to the Ptolemaic Period, possibly early in the period.

The cemetery associated with Ismant el-Kharab, CS13, is located further to the east. A small number of ceramic vessels (Pls 110–3) were recovered from within the tombs but the types are difficult to date accurately. They may, however, prove to be from late in Phase 2 or Phase 3. Still further east, the tomb at cemetery CS17 (also mentioned above) contained two vessels, one of which may be Phase 3 or 4. A temple site, TS3 (Pl. 162) and a settlement, SS15 (Pl. 145) are located in the far east of the oasis. These also have small assemblages but some vessels are possibly dated to Phase 3.

The ceramic material in the corpus from the Ptolemaic Period is scarcer than for other periods and, consequently, the analysis is less conclusive. It may be that later occupation at some sites largely obliterated this material, at least in the material from the limited testing carried out during the survey. The material from some sites, SS7 and SS16, shows that occupation continued into the early Roman Period and later, while site SS2 appears not to have been occupied after the Ptolemaic Period. The temple at TS3 seems to have been in use during the Ptolemaic Period and some material from the deposits, SS17–19, and from the surface suggests that Ismant el-Kharab may also have been occupied at this time.

Phase 4 (Map 9) is dominated by settlement sites. Seven are in the western sector of the oasis: SS1 (Pls 127–8); SS3 (Pls 130–1); SS4 (Pls 132–4); SS5 (Pls 135–6); SS9 (Pls tlements are in the central sector – Mut el-Kharab (SS20, Pls 158–9), SS16 (Pls 147, 149) and Ismant el-Kharab (SS17–9, Pls 150–7).

A few finds from the temple, TS4, situated within the site of Ismant el-Kharab and surface material from the cemetery, CS13, to the north-west of the settlement are dated to Phase 4. Other sites in the central area with Phase 4 material are the temple site, TS1 (Pl. 160), and the cemetery site, CS6 (Pl. 101). The temple TS3 in the east of the oasis contained Phase 4 material as well as Phase 3.

In Phase 4, comparative material can be found at sites outside Egypt as well as at Egyptian sites. Quseir el-Qadim, the port on the Red Sea coast, has provided many parallels for the Series 2 typology (Whitcomb and Johnson 1979 and 1982). In addition to Quseir el-Qadim, parallels for Form 6 cooking vessels come from Carthage (Hayes 1976a), Berenice (Riley 1979), Athens (Thompson 1934), and similar types of cooking pots (Forms 71–2) have been recovered from sites in Palestine (Crowfoot et al. 1957, Lapp 1961 and Hayes 1976). The wider range of comparative material vouches for an increasing uniformity of pottery styles as the Roman Empire increased in territory.

In the finer wares, Form 2 and Form 23 have parallels from Athens (Robinson 1959); Form 24 from Athens, Samaria (Crowfoot et al. 1957) and Hama (Christensen and Johansen 1971); Form 26 from Athens, Samaria and Carthage (Fulford and Timby 1994). Form 35 is an Arretine form that is well known from many sites throughout the Roman Empire (Peacock 1982, 114–28). The twisted handles on the imported jug, L9-1/82/11f (Form 192, Pl. 88), are similar to those on a vessel from Tanis (Boston Museum of Fine Arts 86.719) and others from Egyptian sites (Hayes 1997, pl. 7; Lauffray 1995, fig. 54: 78, pl. 19c). This type of handled-vessel has an earlier West Slope prototype (Crowfoot 1957, fig. 237:1).

During this period, imported wares also became prototypes for the manufacture of local vessels, such as the skyphoi of Form 188. These two-handled cups were made in luxury materials of metal and glass (Henig 1983), and were copied in different ceramic materials from lead-glaze to sigillata wares (Lane 1947, Charleston 1955 and Hayes

1976). Although the context of many of these vessels is not known, they were obviously popular in many parts of the Roman Empire around the first century BC and the first century AD.

There are also standing monuments in Dakhleh Oasis to affirm the integration of the oasis into the Roman Empire. The temple of Deir el-Haggar has been well known since the nineteenth century from the accounts of early visitors to the oasis (Ch. 3, 18). Situated in the west of the oasis, the sandstone temple was built in the first century AD during the reigns of Nero, Vespasian, Titus, and Domitian. This temple has recently been restored as a joint SCA and DOP program (Mills 1990, 20–3, fig. 1, pls IV–V; 1993, 9). The excavation of another sandstone temple, Ein Birbiyeh, in the east of the oasis has revealed scenes of the king, identified as Augustus, offering to deities (Mills 1985, pls II–III and 1998, 87).

The pottery of Phase 4 reflects the uniformity of the Roman Empire and it also signifies the increase in communications and the movement of government officials, armies and business men. Although the finds do not to suggest that either pottery vessels or goods in pottery containers reached Dakhleh Oasis on a large organised scale, more imported wares were recovered in Phases 3 and 4. As well as domestic wares, the handles and sherds from a number of amphorae and jugs (Form 192) were collected from surface surveys, particularly from the large town site known as Amheida (Map 4). These sherds help to envisage the range of vessels brought into Dakhleh Oasis at the time.

Three papyri from Oxyrhyncus also provide evidence for the movement of potters in the third century AD (Cockle 1981, 87–97). These papyri establish the terms of leases taken out by three potters in the course of the third century to make and provide for the lessors a large number of jars for wine vintages. The leases were taken for one or two years and it is to be noted that the lessor guarantees to provide the workshop, potter's wheel, kiln and all the materials. In this way, potters could readily move to more profitable locations to make their livelihood, thereby transmitting different pottery styles and techniques.

This thesis covers a long period from the eighth century BC to the second century

AD and the analysis of the ceramic material shows that during this time, despite changes in political structure and control, contact was retained between the remote region of Dakhleh Oasis and the Nile Valley. In the later phases, particularly after inclusion in the Roman Empire, contacts were more widespread. Throughout all periods, styles and trends from other regions influenced the potters of Dakhleh Oasis, nonetheless, pottery traditions are to a large extent regional and long lasting so, while adopting new styles, the potters kept many of their traditions. Spouted vessels had been popular in the oasis from at least as early as the Old Kingdom, and different types of spouted vessels continued to be made through all phases of the corpus. Lentoid-shaped flasks and barrel-shaped kegs were popular during Phase 1 (eighth to seventh centuries BC) and were made throughout later phases. Large barrel-shaped kegs continued to be made in the late Roman Period and smaller ones are still made by the potters working in Dakhleh Oasis at the present time.

In this thesis I have examined the pottery to see how it was made, endeavouring to understand the throwing techniques adopted by the potters and the way they carried out their craft. It is not yet clear exactly when the kick-wheel was first employed by Egyptian potters. However, the particular method of throwing called Method 3 in this thesis and described in Chapter 6 appears to have been in use by the Nineteenth Dynasty (Arnold 1993, fig. 81). This method of throwing was an efficient and economical alternative technique for making many types of vessels and was used, but not exclusively, in all phases of this corpus. Undoubtedly the use of the stronger and more stable kick-wheel facilitated and developed this particular technique which, once mastered, proved a very long lasting technique which is still practised in Egypt (Pl. 164, Fig. 2).

In conjunction with the study of pottery making techniques, a comparison of vessel types and sites (Ch. 5 and Charts 1–2) has been undertaken. The analysis of these charts suggests that, except for a few specialised types, such as Form 84, it was not the practice to make vessels specifically for funerary use. However, I have proposed that damaged vessels, being less functional, were not discarded but were set aside for use as offering vessels and for burial purposes.

to make vessels specifically for funerary use. However, I have proposed that damaged vessels, being less functional, were not discarded but were set aside for use as offering vessels and for burial purposes.

This thesis has provided a chronological typology for the pottery from Dakhleh Oasis through one thousand years of Egyptian history. The process has endeavoured to clarify the Late Period, a period at first considered to be largely missing from the record in the oasis (Mills 1980, 256). It has furnished a chronological sequence for the surveyed sites and furthered the study of the socio-economic development of Dakhleh Oasis. The study from a technological viewpoint of the pottery from this remote region of Egypt adds to an increasing body of knowledge now being accumulated from Nile Valley and Delta sites. The creation of a database for the ceramic material and the format of the pottery drawings facilitate the electronic transfer of information to other researches working in the field of Egyptian ceramics.

APPENDIX 1

Reconnaissance Petrography of Pottery Sherds and Raw-clay Samples from the Dakhleh (Dakhla) Oasis, Western Desert, Egypt

By P.J. Conaghan

Department of Earth and Planetary Sciences, Macquarie University, NSW 2109

INTRODUCTION

A small representative sample of pottery sherds (11 sherds in all) and two small raw-clay samples (presumed samples of clay used for pottery making – fired under known kiln conditions) from Dakhleh (Dakhla) Oasis, Western Desert, Egypt, were impregnated in polyester resin and thin-sectioned for petrographic documentation and to assess their probable local versus exotic provenance. The rationale of the study was to establish whether the petrographic ingredients that comprise the temper/filler/inclusions of the sherds and raw-clay samples match the petrographic ingredients that are known to be present in the various bedrocks (Figs A-1 to 4) and surficial modern sedimentary veneer of the landscape in the Dakhla Oasis area (as documented by various geologists including Said [1962], Garrison *et al.* [1979], and Staff Members of Sedimentology of Assiut University [1992]).

The thin-sections of the sherds were cut orthogonally to the plane of the sherd in each case, and mainly in a vertical orientation with respect to the reconstructed axis of the pot. As such, the orientation in which the thin-sections were cut is at right-angles to that recommended by most other workers (e.g., Bourriau & Nicholson 1992) who advocate that the thin-sections be cut at right angles to the vertical axis of the pot. The choice of thin-section orientation in the present study was dictated mainly by the limited amount and size of the sherd material. Inasmuch as a preliminary petrographic study of the sherds under a petrographic (i.e., polarising) microscope indicated that clastic grains of phosphatic composition (including vertebrate remains, mainly fish) are present in varying amounts, a chemical test on the sherds was made at the outset of the study to confirm this observation. This test involves the application (by pipette) of an ammonium molybdonate reagent to the surface of the sherd (preferably a cross-cutting [broken] surface of the sherd). If phosphatic material is present in the material being tested the reagent turns yellow. All of the 13 samples tested with this reagent gave a positive result, albeit to varying degrees of intensity. Details of this chemical test in respect of each specimen examined are given below, together with the results of the other petrographic analyses.

By way of preliminary documentation of the sherd and raw-clay samples, the thin-section of each was photographed on both colour-negative and black-and-white film on a Leitz Aristophot facility in both plane-polarised light and under crossed-polars. The resulting colour-print photomicrographs illustrate this appendix (Pls 173-184).

As an aid to the study, the thin-sections were photocopied at twofold enlargement and these photocopies were then used to record petrographic observations made during a reconnaissance study of the thin-sections on a petrographic (polarising) microscope. The colour(s) of each sherd/raw-clay sample were resolved using a "Munsell Color Soil Chart" (limited edition, 1994). In matching the colour(s), the sherd (thin-section) offcuts and other sherd remnants were examined together with the relevant Munsell Color chart under a Maggi Lamp.

A more systematic study of each specimen (using both the impregnated sherd-offcut remnants following the thin-sectioning and remnant un-impregnated sherd fragments) was then made on a Kyowa zoom-binocular microscope (in conjunction with reference to the colour-photomicrographs and petrographic-microscope examination of the associated thin-section) following the analytical format and procedures advocated by Bourriau & Nicholson (1992), and the description of each sample herein follows this format. In particular, the binocular examination was conducted at a magnification of x20 using an eyepiece graticule. This magnification was achieved by using x20 oculars and setting the zoom lens of the microscope at x1. At this setting each numbered division of the eyepiece graticule is equivalent to a distance of 1 mm. This arrangement permitted easy measurement of the size of features encountered in the analyses. Confirmation of some petrographic details made during the binocular microscope analyses required study at a higher magnification than x20. Such observations included determination of the nature of the surface morphology of the quartz sand grains (e.g., presence/absence of surface frosting). The following attribute, relative-abundance, and size/scale conventions (from Bourriau & Nicholson 1992) are used in the descriptions herein (consolidated in Table A1).

MISCELLANEOUS THIN-SECTION PETROGRAPHIC OBSERVATIONS

Some miscellaneous petrographic observations made during the preliminary study of the thin-sections, augmented substantially by additional (and more comprehensive) observations made at the conclusion of the binocular microscope analyses are included for completeness. These petrographic thin-section observations relate to inclusions/ingredients other than quartz (which appears to be predominantly "common" quartz [cf. Folk, 1980] and hence of plutonic origin) and are located at the end of the main binocular descriptions and confirm/revise and extend the binocular microscope observations. An attempt to estimate the proportions of the various petrographic ingredients and textural entities (shrinkage-cracks etc.) was made using a comparison chart for visual percentage estimation (in Scholle, 1979, p. vi) and with the following semiquantitative categories:

Rare (R): 1%
Sporadic (S): 1-5%
Common (C): 5-10 %
Abundant (A): > 10%.

The thin-section petrographic analyses of the samples are consolidated in Tables 2.

Table A1. Descriptor conventions used in the binocular analyses herein (from Bourriau & Nicholson 1992).

Semiquantitative estimates of proportions (i.e., of mineral inclusions and petrographic enclaves):
1 = rare;
2 = medium;
3 = abundant (i.e., particles/enclaves touching each other).

Size/scale attributes:

"Straw" (or siliceous skeletons of same): fine = <2 mm; medium = 2-5 mm; coarse = >5 mm.

Mineral inclusions/enclaves: fine = 60-250 mm (0.06-0.25 mm); medium = 250-500 mm (0.25-0.5 mm); coarse = >500 mm (>0.5 mm).

Wall thickness: 2-4 mm = "thin"; 5-9 mm = "medium"; 10-19 mm = "thick; >19 mm = "very thick".

Structure:

Presence/absence of decomposed limestone particles.
Presence/absence of elongated pores.

Porosity categories:

"open"; "medium"; "dense"; "traces of vitrification".

SAMPLE DESCRIPTIONS

S1 (T/S No. 3): Pottery sherd (Pl. 173 A1a, A1b).

Phosphate test: Positive, strong.
Munsell Colour: No marked colour differentiation between rim and core. Predominant overall colour is 5YR/4.5/2 (= dark reddish grey/reddish grey), but with small patches of 5YR/4/6 (= yellowish red).
Inclusions and enclaves: Quartz sand (no conspicuous bimodal size distribution), mainly fine [2], coarse (well rounded, frosted) [1]; white refractory grains/enclaves (limestone? or altered? limestone; these grains/enclaves commonly have a thin less-refractory [semi-translucent], colourless annular rim), coarse [1], medium [1], fine [1]; other lithic fragments (pale olive/yellow and grey colours), coarse [1]; brick-red hematitic fragments, fine [1]; ?little/no mica; carbonate-fossil grains, medium (includes one radiospherid-like ?calcisphere) [1]; blue mineral grain (?tourmaline), coarse [1].
Straw: None observed.
Porosity: Dense (few pores).
Structure: Some largish pores, weakly elongate parallel to sherd edges, but most are more irregular. Alignment of elongate particles and pores is restricted to the zone adjacent to the inner edge. No suggestion of vitrification.
Wall thickness: Varies from 10 to 15 mm (= thick, and very thick at lip).
Miscellaneous thin-section observations: Some quartz grains show quartz overgrowths. Small, chambered fossil tests (which include: hyaline planktonic and benthonic foraminifera, and ?ostracods) are present, most with coarse carbonate-cement (orthospar) chamber-infills. Similar coarsely-crystalline granular-textured optically-clear carbonate clasts and single-crystal carbonate clasts are present both with and without subtle evidence of enveloping fossil skeletal tissue; their typically coarse internal texture and optically clear character suggest that they too are remnants of microfossil-chamber orthospar-infills. Thus, the skeletal envelopes constitute (probably abraded) remanié fossils. Some chambered microfossil tests (characterised by colourless, isotropic, ?opalised

walls) have optically refractory (?phosphatic) chamber infills. Two small fragments of echinoid skeletal tissue are present. Sporadic small skeletal plant structures defined by opaline lumen-infills etc. are sporadic to common. Typically very finely crystalline and murky carbonate nodules, some with olive-brown to colourless collophane replacement-rims/circumcrusts (isotropic; relief > quartz), and others with enclaves of hematite are present; some contain sporadic quartz sand/silt grains; some are overprinted by hematitic staining. One clast contains a hematite-stained benthonic hyaline foram. Some annularly-structured carbonate/phosphate rock-fragments comprising an outer one- or two-layered halo of murky to olive-brown ?collophane outboard of a colourless cryptocrystalline zone of radially-orientated ?dhallite crystallites (crystallite-fans are length-fast; low birefringence) surrounding a nucleus of granular carbonate are present in sporadic to common proportions together with holes elsewhere in the thin-section of the sherd that are rimmed/lined by a petrographically similar/identical one- or two-layered envelope of phosphatic material. (Some of these holes contain granular carbonate that evidently constitutes remnants of former limestone fragments that have been partially [and in other cases, presumably completely] lost during the making of the thin-section.) Most of the fine-crystalline carbonate clasts resemble caliche in petrographic appearance, the hematitic staining possibly being due to weathering. Small brick-red clasts comprise hematite. Sporadic to common red tabular fissile clasts containing rare quartz silt grains comprise hematitic shale. Typically sand-sized end-rounded flakes of moderately fresh to slightly degraded biotite are common, as are also reddish degraded flakes of biotite, the colour of both being similar to the surrounding ceramic matrix (which circumstance, together with the relatively small size of many of the grains, presumably explain their degree of inconspicuousness in the binocular microscope analysis). Feldspar grains are common, and include plagioclase, microcline, and probably orthoclase. Some of the plagioclase is moderately altered; other grains are fairly unaltered. Rare feldspar grains are almost completely replaced by sericite. One sand-sized degraded muscovite flake was observed, as were several end-rounded tabular polycrystalline grains of degraded ?chlorite (?chlorite schist) and one grain of quartz-mica schist.

Phosphatic clastic grains of various kinds are present including: brown (isotropic in crossed-polars) nodules/ovules (ranging from coarse to fine in size, some containing quartz grains, some containing clusters of fine carbonate crystals); black and reddish-black tabular grains (some with clastic silt inclusions); brown (isotropic in crossed-polars) diamond-shaped fish scales (some showing a zonal pattern of alteration to probable dhallite [length-fast crystallites; low-birefringence] in the interior of the scale), (non-porous) teeth fragments and (porous) bone. Tourmaline is the most common heavy mineral (pleochroic variously in blue-grey and olive-green and green). Sporadic to common elongate shrinkage-cracks are present but are free of firing-related fine crystal growths. The ceramic clay matrix is pervasively hematite-rich.

S2 (T/S No. 6): Pottery sherd (Pl. 174 A2a, A2b).

Phosphate test: Positive, strong.
Munsell Colour: Patchy colour differentiation parallel to edges of sherd, but irregular and not strongly zonal with respect to rim and core. Predominant colour is 5YR/4.5/3 (= reddish brown); patches/enclaves of 5YR/5/6 (= yellowish red).
Inclusions and enclaves: Quartz sand (conspicuous bimodal size distribution), coarse (well rounded, frosted) [1], fine/medium [2]; white refractory grains/enclaves (?limestone or ?altered limestone, some with thin greyish ?reaction/alteration rims) coarse [1], fine/medium [1]; white, cryptocrystalline-lined subspherical/ellipsoidal cavities, fine/medium [1]; no mica observed, but some tabular reddish layered clastic grains could be weathered biotite, coarse [2]; brown and reddish-black fragments (includes one finely-vesicular grain that looks like slag or coke) [1].
Straw: Fine to coarse (see comments under "structure" below).
Porosity: Medium.
Structure: Elongate clastic particles tend to be aligned parallel to the sherd surfaces. Common medium to large (i.e., mm-scale to cm-scale) pores, mostly platy or cylindrical in shape, probably representing moulds of former plant fragments (though no opaline skeletons were observed inside them); some are parallel to the sherd surfaces, especially those near the edges; other ones, especially those in the core area, are discordant to the sherd edges. No suggestion of vitrification.
Wall thickness: 6 mm (= medium).

Miscellaneous thin-section observations: Sporadic quartz grains show quartz overgrowths. Phosphatic clastic grains of various kinds are sporadic to common, including: bone and teeth fragments, diamond-shaped fish scales, nodules/ovules, tabular-shaped black and reddish-black grains, phosphatised thin-walled microfossil fragments (?ostracods, pelagic foraminifera, ?embryonic molluscs). Also present are sporadic granular-textured limestone grains, some with microfossil-shaped outlines, but without remnant microfossil skeletal envelopes. Some or most of these grains probably constitute orthospar-cement microfossil-chamber-infills. Some carbonate/phosphate grains show an annular structure of collophane/dhallite outboard of a carbonate nucleus, similar to that described for sherd S1. Artifact-holes that represent sites where such carbonate/phosphate grains have been partially lost during slide-making also occur (?= "white, cryptocrystalline-lined subspherical/ellipsoidal cavities" of the binocular microscope analysis), invariably with preservation of the outer phosphatic cortex but only sporadic preservation of the some of the granular-textured carbonate core. Rare oxidised glauconite pellets/grains occur. Opaline skeletal plant material is sporadic to common. Grains of hematite are sporadic to common and tabular-shaped fissile hematitic shale (some with included silt grains) is sporadic. Feldspar (both unaltered and altered, mainly potash feldspar but minor plagioclase) is sporadic. Both degraded reddish biotite flakes and brown, less-degraded (still pleochroic) biotite flakes are sporadic to common. Rare tourmaline (variously pleochroic in blue-grey and green), plus rare zircon grains and other, unidentified, heavy mineral species are present. Clay-matrix is of reddish colour and appears to be pervasively hematite rich. Elongate shrinkage-cracks are common but contain no crystal growths. Red colour of both the altered mica and clay-matrix explains reason why mica is not more conspicuous in the binocular microscope analysis.

S3 (T/S No. 10): Pottery sherd (Pl. 175 A3a, A3b).

Phosphate test: Positive, strong.
Munsell colour: Strong core-rim differentiation; predominant colour of core is 5YR/4.5/3 (= reddish brown); convex (outer) edge is 5YR/5.5/4 (= reddish brown/light reddish brown); concave (inner) edge is 5YR/4/8 (= yellowish red).
Inclusions and enclaves: Quartz sand, polymodal size, coarse (well rounded, frosted) [1], medium [2]; white refractory grains/enclaves (?limestone, altered? limestone, or pale phosphatic material), coarse [1], medium [2], fine [1-2]; pale-coloured microcrystalline-lined subspherical/ellipsoidal cavities, coarse [1], medium [1], fine [1]; brick-red, internally very-fine-grained hematite fragments, fine [1]; grey, vesicular slag-like enclaves (these contain rare quartz grains and more common white enclaves), coarse [1].
Straw: Restricted to outer surface/peripheral zone as moulds, coarse.
Porosity: Medium.
Structure: Small to large elongate pores parallel to the original inner and outer surfaces of the pot are concentrated within the peripheral reddish zones; some (typically the larger ones) are moulds of straw; other large ones (mm-scale size) are less platy/cylindrical and may be gaseous cavities of other origin. No suggestion of vitrification.
Wall thickness: 23-24 mm (very thick).
Miscellaneous thin-section observations: Rare to sporadic quartz grains show thin overgrowths. Phosphatic clasts of various types are common, including: teeth and ?bone fragments; diamond-shaped fish scales; ovules/nodules (some containing rare quartz sand grains, and others apparently partly cherty); black and reddish-black semi-equant and tabular grains (that show pull-away shrinkage cracks at their peripheries); and opalised thin-walled and chambered microfossils (pelagic foraminifera) with phosphatic chamber infills. Limestone appears to be absent, the pale-coloured clasts/enclaves of ?limestone/altered-limestone mentioned in the binocular analysis evidently being either phosphatic fragments and/or muscovite/sericite. Rare clasts of quartz sandstone are present, the constituent clastic sand grains lacking rounding, and being cemented together by quartz-overgrowths. Opaline skeletal plant material is common. Red-coloured highly-altered biotite flakes are sporadic to common. Common to abundant tabular-shaped red clasts constitute fragments of hematitic shale (some with quartz silt inclusions). Rare feldspar is present (mostly apparently untwinned and moderately unaltered; one plagioclase and one ?microcline grain observed; one feldspar grain has overgrowth extensions). Coarse to fine clasts of granular-textured sericite are rare to sporadic (= ?pseudomorphed feldspar) as well as rare fine sand-sized

muscovite flakes. Gravel- and sand-sized clasts of frothy/vesicular black and reddish (and isotropic) ?glass with sporadic quartz sand grains are sporadic to common. Putative cavities (mostly sub-spherical; = "pale-coloured microcrystalline-lined subspherical/ellipsoidal cavities" of the binocular microscope analysis) containing thin radial linings and/or random meshworks of stubby to elongate prismatic, green and olive-green, slightly-pleochroic length-slow crystals of moderately high-relief, oblique extinction (probably monoclinic), and lowish/moderate birefringence are common to abundant. Some of these individual crystals show rhombic cross-sections in which the long-diagonal is the slow ray. These crystallographic and optical properties suggest that the crystals are tremolite-actinolite (a hydrous Ca, Fe, Mg silicate), not wollastonite, because wollastonite is colourless and cross-sections of the crystals are nearly rectangular. In many cases these crystal clusters lack radial orientation around the periphery of the cluster and are surrounded by a thin rim of optically-refractory isotropic grey/greenish-grey semi-opaque material that probably comprises collophane. This evidence suggests that such crystal clusters manifest pseudomorphously-replaced former limestone fragments that had a circumcrust or rind of phosphate. Sporadic to common elongate shrinkage-cracks, mainly in the outer (convex-side) zone of the sherd, contain coatings of sparse-to-common euhedral red (semi-translucent) pyramid-terminated fibrous/?bladed and stubby rhomb-shaped crystals that have evidently grown during the firing operation. Stubby rhomb-shaped crystals of the same mineral (probably hematite) occur sporadically within small pores within the ceramic clay-matrix throughout the sherd. The clay-matrix is pervasively hematite-rich.

S4 (T/S No. 5): (Raw clay sample [as dug] from a modern pottery at El Qasr, Dakhla, fired to ca. 900-950° C) (Pl. 176 A4a, A4b).

Phosphate test: Positive, medium-weak except at some specific spots.
Munsell color: Extremely thin oxidised rim (<0.5 mm thick); inside this peripheral zone colour differentiation occurs in elongate patches parallel to the edges of the tablet and involves two colours, enclaves of the one occurring within a background of the other. The thin oxidised rim zone varies in colour from 5YR/5.5/6 (= yellowish red/reddish yellow) to 5YR/5/4 (= reddish brown). Inside the rim zone the predominant colour is 5YR/5/4 (= reddish brown), and within the background of the latter colour occur enclaves of 5YR/5.5/6 (= yellowish red/reddish yellow).
Inclusions and enclaves: Quartz sand, coarse (well rounded, frosted) [1], medium [2], fine [2]; white grains/enclaves (these have sharp discrete edges in this sample and appear to be clastic particles rather than cavity fills), coarse [1], medium [1], fine [1]; red hematitic grains, medium [1], fine [2].
Straw: None observed.
Porosity: Medium/dense.
Structure: Very thin elongate crack-like pores parallel to the edges of the clay artifact (including its short ends) are present (these are best seen in the thin-section). Some (rare) larger (mm-scale) elongate pores (which have irregular outlines and therefore do not appear to represent moulds) are also present). No suggestion of vitrification.
Wall thickness: 7.5-8.5 mm (medium).
Miscellaneous thin-section observations: Gravel-sized clast of quartz sandstone present (the constituent grains of which are not well-rounded, have hematitic "dust" lines and only very sporadic quartz-cement overgrowths/outgrowths). Among the discrete quartz grains in the clay-matrix sporadic ones have minor quartz overgrowths. Fresh white mica (muscovite) is sporadic in grains of all sand sizes (including very coarse sand size), both as single-crystal grains and as coarse-textured polycrystalline grains, and does not show marked rounding (single crystals are present as discrete clasts and commonly retain their pseudohexagonal crystallographic outlines). Rare fine- to medium- granular-textured sericitic clastic grains might constitute pseudomorphed feldspar. Rare altered biotite is also present together with sporadic altered biotite. Feldspar is sporadic to common as fresh to slightly altered (untwinned) orthoclase and rare fresh plagioclase. Two skeletal phosphatic fragments were observed (one probable tooth fragment, the other bone), as well as sporadic other probable phosphatic clasts of non-skeletal origin. Sporadic blackish-red ?phosphatic clasts and red-brown hematitic clasts are present (characterised by tabular, subspherical and other shapes, the tabular ones at least representing fragments of ?phosphatic and hematitic shale respectively). Non-tabular bright red hematite clasts are rare. Annular-structured phosphatic clasts (some with an outer dark-red/brown phosphatic?/hematitic circumcrust) are sporadic to common,

but lack any evidence of carbonate cores and, instead, have hollow cores or skeletal phosphatic material. Possibly former carbonate cores of these structures have been lost during the slide making. The phosphatic material that comprises the bulk of these grains is a turbid pale-honey-brown to clear and colourless isotopic phase (probably collophane), in some cases with patches or enclaves of a clear and colourless cryptocrystalline fibrous mineral (length fast) of low birefringence (?dahllite). In some of these grains the morphology of the inner surface of the rim-phosphate fronting the internal cavity shows a botryoidal character. No limestone fragments were observed in this thin-section. One grain of tourmaline (pleochroic in green) was observed. Sporadic to common elongate firing-related shrinkage-cracks are ubiquitous but lack crystal growth linings. Optical character of the pervasive red-coloured phase in the clay matrix indicates the presence of much hematite.

S5 (T/S No. 8): Pottery sherd (Pl. 177 A5a, A5b).

Phosphate test: Positive, medium-weak.
Munsell Color: Zonal colour differentiation involving an overall predominant colour (5YR/5/4; = reddish brown) within which occur elongate enclaves of different colours (varying from 5YR/6.5/6 [= reddish yellow] to 5YR/7/8 [= reddish yellow]). The colour enclaves are parallel to the original pot edges but are closer to the edges where the sherd is thin (i.e., in section of sherd between original inner and outer surfaces of the pot) and further away from the original pot surface where sherd is thick (i.e., at the top or lid end of the sherd).
Inclusions and enclaves: Quartz sand, coarse (well rounded, frosted) [1], medium (rounded/subrounded, frosted) [2], fine (some grains rounded, some angular) [1]; brick-red hematitic fragments, coarse [1], medium [2], fine [1]; tabular buff-to-cream-coloured, internally very fine grained clastic lithic fragments (in thin-section some of these are identifiable as shale [including fissile shale] fragments; others are isotropic under crossed-polars are probably phosphatic), coarse [1]; white enclaves, coarse (?pseudomorphed ?limestone fragments) [1], medium [1], fine (spherical 'vesicle' infills) [2]; black elongate clastic grains, coarse [1], medium [1], fine [1].
Straw: None observed.
Porosity: Medium.
Structure: Elongate clastic fragments are mostly, but not invariably, parallel to the original pot surfaces. Largish (mm-scale) elongate irregular-shaped pores are present parallel to all original surfaces of the pot (including the concave-downward top/lip of the pot), together with some crack-like smaller pores.
Wall thickness: Varies from 5 to 9 mm (thin).
Miscellaneous thin-section observations: Tabular shale fragments are present in coarse sand-sized clasts. Some (common to abundant) are strongly hematitic. Most contain sporadic/rare quartz-silt and/or very fine quartz sand grains, and some are fissile. Granule- and coarse sand-sized grains of hematitic quartz siltstone are sporadic to rare. Sporadic tabular-shaped polycrystalline grains of muscovite are present, as well as one granule-sized monocrystalline grain of degraded (?white) mica. Sporadic highly altered ?biotite is present. Rare somewhat altered feldspar is present (orthoclase and plagioclase). Rare to sporadic phosphatic grains are present, including: one possible bone fragment and tooth fragment; finely-textured isotropic honey-brown annular-structured (?collophane) grains containing a central cavity (no carbonate observed) are sporadic, some containing centripetal weakly-birefringent fibrous crusts of ?dahllite (= "spherical vesicle infills" of the binocular microscope analysis); sporadic black and reddish-black semi-opaque grains, some of which are tabular-shaped and contain sporadic tiny quartz silt grains (= ?phosphatic and hematitic shale fragments) are present. Rare (unidentified) heavy mineral grains are present. Sporadic to common elongate firing-related shrinkage-cracks are present but lack crystal growths. The clay-matrix is hematite-rich.

S6 (T/S No. 11): Pottery sherd (Pl. 178 A6a, A6b).

Phosphate test: Positive, medium (sherd has cream-coloured original surfaces).
Munsell color: Sherd has a very thin (<0.5 mm-thick) pale-coloured periphery, especially on the original outer surface of the pot; predominant overall colour is 5YR/6/3 (= light reddish brown); thin outer edge is 5Y/8/3 (= pink).
Inclusions and enclaves: Quartz sand, coarse (well rounded, frosted) [1], medium (well rounded, frosted) [1], fine (angular/subangular to subrounded) [2]; brick-red hematitic fragments, medium [1], fine [2]; white enclaves/fragments (?pseudomorphed ?limestone fragments; some have an internally fibrous appearance), coarse [1], medium [1], fine (infilled subspherical "vesicles") [2]; black clastic fragments (mainly subspherical/ellipsoidal ?phosphatic/glauconitic pellets or ?charcoal), medium [1], fine [1]; orange-buff-yellowish-coloured tabular-shaped clastic grains, medium [2]; vertebrate skeletal fragments (phosphatic, ?bone), coarse [1].
Straw: Cylindrical moulds containing skeletal opaline elements are present and are ca. 2-5 mm long (hence fine/medium).
Porosity: Medium.
Structure: Pores are mainly sub-mm- and mm-scale crack-like features parallel to elongate clastic grains and pull-away (shrinkage) "aureole" pores adjacent to some clastic particles (especially phosphatic ovules and some ?mica). Elongate clastic grains and crack-like pores define a "swirly" fabric that is, in the main, not geometrically related to the original pot surfaces. No suggestions of vitrification.
Wall thickness: 8 mm (thin).
Miscellaneous thin-section observations: No overgrowths observed on the detrital quartz grains. Phosphatic grains are sporadic to common and include: ?bone and teeth fragments and diamond-shaped fish scales; sporadic to common ovules/nodules, including fine-textured honey-brown grains (these are isotropic in crossed-polars); and sporadic to common black and reddish-black tabular and semi-opaque grains (?phosphatic/hematitic shale). Opaline skeletal plant fragments are sporadic to common. White mica is sporadic as coarse to fine degraded monocrystalline grains [some showing the typical pseudo-hexagonal outline of the crystal parallel to (001)], and as sporadic to rare polycrystalline (mainly sericitic) grains some of which contain rare quartz-crystal enclaves and possibly constitute mica-schist (though no foliation planes were observed in these grains). Other sericitic grains show rectilinear shapes/outlines reminiscent of possible former feldspar phenoclasts suggesting that such grains could constitute mica-pseudomorphed feldspar. Sporadic red, highly-altered biotite flakes occur. Sporadic feldspar is present, mainly moderately fresh orthoclase; some fresh plagioclase also present. Rare grains of quartz sandstone are present (in which the constituent quartz grains are not well-rounded and quartz overgrowth cement is present). Tabular and semi-equant grains of hematitic shale are sporadic to common, many of the tabular grains showing fissility (and thus confirming their identity as hematitic shale). Semiequant bright red hematite grains are sporadic. Sporadic to common annular ?phosphatic hollow-'nodules' are present, many with an internal free-floating thin selvage-ring (= "white .. infilled subspherical 'vesicles'" of the binocular microscope analysis). Common firing-related elongate shrinkage-cracks are present but lack crystal growths. The clay-matrix phase throughout the thin pink rim zone has optical characteristics identical to those of a non-red-coloured clay-matrix phase that is interspersed with red-coloured (hematitic) clay-matrix in the core zone. This non-red coloured phase has a murky honey-brown colour in plane-polarised light and clearly contains little/no hematite.

S7 (T/S No. 12): Pottery sherd (Pl. 179 A7a, A7b).

Phosphate test: Positive, weak (sherd has cream-coloured original surfaces).
Munsell color: Thin pale peripheral zone is present on all original pot surfaces of the sherd, but especially on the original inner surface and narrow top edge where (in both places) it is ca. 1 mm thick; on the original outer pot surface it is very thin (ca. 0.25 mm). Predominant overall colour of the core zone is 2.5YR/6/1 (= reddish grey). Thin periphery zone is 5Y/8/1.5 (= white/pale yellow).
Inclusions and enclaves: Quartz sand, coarse (well rounded, frosted) [1], medium (well rounded, frosted) [1], fine [2]; black clastic grains (?phosphatic; smaller ones are subspherical/elliptical, larger ones are tabular and rounded/subrounded), medium [1], fine [1]; red hematitic grains;

larger ones tend to be tabular), medium [1], fine [1]; cream-/orange-coloured tabular clastic grains (internally very fine grained), coarse [1], medium [1]; siltstone-like clots/enclaves/fragments, coarse [1], medium [1], fine [1].
Straw: None observed.
Porosity: Medium.
Structure: Largish (but mainly mm-scale and sub-mm-scale), mostly elongate (but semi-irregular-shaped) open pores (which are not crack-like), are present and are generally parallel or subparallel to the original pot surfaces (including the original pot end). In thin-section other small thin (sub-mm-scale crack-like) pores are evident, mainly present as pull-away shrinkage features adjacent to clastic grains, especially elongate black grains that are probably phosphatic. No suggestion of vitrification.
Wall thickness: 4-5 mm (thin to medium).
Miscellaneous thin-section observations: No overgrowths observed on detrital quartz grains. Phosphatic grains of various kinds are present, including: sporadic to rare ?bone and teeth fragments; sporadic to common, variously murky and clear (isotropic in cross-polars) ovules/nodules and rock fragments, some with hematitic enclaves and/or quartz sand/silt grains; and rare to sporadic black (opaque) and reddish-black tabular grains of ?phosphatic and hematitic shale (some containing sporadic quartz silt grains). Sporadic to rare tabular hematitic shale fragments are also present, but no bright-red semiequant hematite grains were observed. Sporadic to common degraded biotite is present but no muscovite was observed. Sporadic opaline skeletal plant material is present. Rare grains of fine quartz sandstone and siltstone are present, as well as largish grains of mixed-composition sandstone comprising quartz, phosphate-pellets, and tabular hematitic grains (the latter appear to be mainly degraded biotite). Rare orthoclase, plagioclase, and microcline feldspar are present. Large and small enclaves/clasts of vesicular/frothy brown (hematitic) isotropic ?glass are common, some containing quartz sand/silt grains. No limestone fragments were observed. Very sporadic to rare firing-related pull-away shrinkage-cracks are present, but none contain crystal growths associated with the firing. One tourmaline grain (pleochroic in brown and olive-green) was observed. The clay-matrix is non-hematitic.

S8 (T/S No. 9): Pottery sherd (Pl. 180 A8a, A8b).

Phosphate test: Positive, medium-weak.
Munsell color: A thin more-homogeneously coloured peripheral zone is present on all original pot surfaces in the sherd. This zone is ca. 0.75 mm thick on the outer and top edges, and is ca. 0.5 mm thick on the original inner pot surface. The overall colour inside this peripheral zone is 5Y/6.5/1 (= grey/light grey). The thin peripheral zone is 5Y/8/1.5 (= white/pale yellow).
Inclusions and enclaves: Quartz sand, coarse (well rounded, frosted) [1], medium (rounded, frosted) [1], fine (angular to rounded) [2]; red hematitic grains, medium [1], fine [1]; black, subspherical/elliptical clastic grains (?phosphatic), medium [1], fine [1-2]; white/orange enclaves/fragments, coarse (infilled 'vesicles') [2], medium [1], fine [1] (clastic versus diagenetic genetic nature of many of these is difficult to resolve because of the whitish background colour of the sherd); glassy, "frothy" enclaves, coarse [1]; red-black enclave/fragments with internally sucrosic/granular texture, coarse [1].
Straw: None seen (but in thin-section some opal-filled plant fragments are evident).
Porosity: Medium.
Structure: Sporadic/rare, largish (mm-scale) pores (mainly elongate but also rare irregular-shaped ones) are present, and are mostly parallel to the original pot surfaces, including the original top of the pot. More abundant smaller (sub-mm-scale) crack-like pores are also present and although these are mostly parallel to the original pot surfaces they also define a "swirly" fabric to some extent that is unrelated to the pot surfaces. No suggestions of vitrification.
Wall thickness: 5 mm (thin) in wall; original top (lip) of pot is 10 mm thick.
Miscellaneous thin-section observations: No unambiguous overgrowths observed on the detrital quartz grains. Phosphatic grains present include: sporadic tabular and semi-equant black (opaque) and reddish-black (semi-opaque) grains; sporadic grey to pale brown tabular grains that are refractory in crossed-polars when viewed with substage condenser lens inserted (= ?bone fragments); sporadic/rare colourless fragments (apparently isotropic) with linear internal pattern (= ?tooth fragments); sporadic/common black and reddish-black semi-opaque grains with abundant

clots of opaque material (?hematitic phosphate); sporadic honey-brown and reddish-brown grains/ovules (near isotropic), some with tiny carbonate crystals present as inclusions. Also present are sporadic to common frothy/vesicular reddish-brown and brown (isotropic) grains (= ?glass), some with sporadic quartz grain inclusions. Rare/sporadic fresh orthoclase, perthite, and plagioclase feldspar are present. One olive-green rounded elongate grain of altered ?chlorite or glauconite was observed. Sporadic/rare opaline plant structures are present. Very rare zircon and tourmaline (pleochroic in red-brown) are present. Sporadic cavities or hole-artifacts (mainly within the peripheral zone of the sherd) are lined with colourless prismatic fine crystals (which have moderate birefringence and are length-fast; hence, not tremolite-actinolite); small pockets, narrow haloes around some clastic grains (including quartz grains), and dispersed single crystals of the same mineral appear to also occur in the clay matrix, mainly in the core zone. Rare loose-knit crystal-clusters of micro-rosettes of what appears to be the same mineral occur in isolated enclaves that could constitute firing-altered former rock fragments (?limestone). Longitudinal sections of this mineral show maximum birefringence of about second-order blue-green, thus precluding wollastonite. A generally thin veneer of internally fine-clastic-textured mixture of very fine mica (mainly biotite), carbonate crystals/grains, and hematite grains is present discontinuously, especially within shallow to deep embayments/hollows on the original periphery of the pot (including on the original outer, inner and top surface of the pot). Sporadic silt- to gravel-sized enclaves of the same material occur within the immediately adjacent peripheral zone and would appear to constitute infillings of original air-pockets/cavities that were physically connected to the outer surfaces of the pot. This raises the possibility that this material was applied as a slip finish. Sporadic to common firing-related elongate shrinkage-cracks are present but do not contain crystal growths. The clay matrix has a murky honey-brown colour in plane-polarised light and a refractory appearance under crossed-polars with the substage-condenser lens inserted, suggesting that it could contain high amounts of phosphate.

S9 (T/S No. 2): Pottery sherd (Pl. 181 A9a, A9b).

Phosphate test: Positive, weak.
Munsell color: Sporadic, extremely thin peripheral zone (<0.2 mm thick) of 5YR/7/6 (= reddish yellow); otherwise predominantly the one colour throughout (5YR/5.5/3 = reddish brown/light reddish brown), but with some elongate enclaves of 5YR/7/6 (= reddish yellow) that parallel the original pot surfaces.
Inclusions and enclaves: Quartz sand, coarse (well rounded, frosted) [1], medium (angular to rounded, some grains frosted) [1], fine [1]; brick-red hematitic grains, fine [1]; cream/white tabular clastic grains (glassy to porcellaneous/vitreous appearance), coarse [1], medium [1]; black and red fragments/enclaves with internally sucrosic/granular and vesicular texture (?slag/coke), coarse [1]; white enclaves/clasts, coarse [1], medium (some appear to be infilled 'vesicles') [1], fine [1]; black clastic grains (?phosphatic), coarse [1], medium [1], fine [1].
Straw: Conspicuous, mainly platy-shaped large (medium to coarse) moulds could manifest the former presence of leaf material; rare tubular/cylindrical moulds of ca. 0.2 mm diameter could be moulds of grass (= "medium" size in the straw size-classification used here).
Porosity: Medium.
Structure: Sporadic/common platy/elongate pores are present, mainly mm- and sub-mm-scale sized; most are parallel to the original pot surfaces but some (= ?leaf-moulds) are disposed at high angles to these surfaces. No crack-like pores are present except for sporadic pull-away ones on the edges of some platy clastic grains. No suggestion of vitrification.
Wall thickness: 5-9.5 mm (medium).
Miscellaneous thin-section observations: No overgrowths observed on detrital quartz grains. Phosphatic grains present include: sporadic black (semi-opaque) and reddish-black (red in plane-polarised light with substage-condenser inserted) (= ?hematitic phosphate), and sporadic fissile tabular grains, some with quartz silt grains (?hematitic phosphatic shale); sporadic black tabular opaque grains (opaque even with substage-condenser lens inserted); sporadic tabular black and grey refractory grains; rare diamond-shaped fish scales and ?bone fragments; sporadic tabular honey-brown isotropic grains with linear internal structure (= ?tooth fragment). Also present are red tabular hematite grains, including fissile grains (= hematitic shale) and semi-equant hematite grains with sporadic quartz grain inclusions (= silty hematitic mudrock). Rare fresh feldspar grains

are present including plagioclase, ?microcline and ?orthoclase. Opaline skeletal plant material is sporadic to common. Also present are sporadic grains of frothy/vesicular grey-brown isotropic ?glass. One grain of tourmaline (pleochroic in greenish blue-grey) was observed, and very rare small grains/flakes of white mica, including some small polycrystalline sericitic grains (= ?pseudomorphed feldspar). Very rare tiny grains of possibly caliche-like limestone occur (mostly present in the thin-section as grain-plucked holes with only partial retention of bits of the original grains). Rare to sporadic quartz sandstone are present, including one variety with diagenetic phosphate matrix/cement. Rare to sporadic annular phosphate/?carbonate rock-fragments/nodules are present but with the very-finely crystalline ?carbonate cores mostly absent (due to plucking during slide-making). A thin surficial clayey veneer with accessory silt grains and containing less hematitic pigment is present around the periphery of the original surfaces of the pot suggesting it might constitute a 'slip' finish. Rare elongate firing-related shrinkage-cracks are generally confined to grain-edge pull-away cracks and internal fissility-surface cracks. They do not contain crystal growths. The clay-matrix is more or less pervasively hematite-rich except for sporadic enclaves that are not as well as the peripheral ?slip-finish veneer.

S10 (T/S No. 13): Pottery sherd (Pl. 182 A10a, A10b).

Phosphate test: Positive, strong.
Munsell color: Strong colour differentiation between rim zone and core: rim zone varies from ca.3 mm to <0.5 mm thick, but is thin/semi-absent only very sporadically along one (i.e., the original inner) pot surface (in the sherd this surface is the less regularly planar one). Rim zone colour is 2.5YR/6/6 (= light red). Outer zone of core is 2.5YR/5/4 (= reddish brown). Inner part/zone of core tends more toward 10YR/7/1 (= light grey).
Inclusions and enclaves: Quartz sand, coarse (well rounded, frosted) [1], medium (subrounded to well rounded, some grains at least are frosted) [1], fine (angular to subrounded) [2]; mainly white, some olive-green/grey, enclaves/fragments, coarse (some appear to be infilled 'vesicles') [1], medium (some are infilled 'vesicles') [2], fine (some are infilled 'vesicles') [2]; dark-coloured lithic-like enclaves/fragments (internally with siltstone-like texture), coarse [1]; dark-coloured spongy/vesicular-like-textured grains (some contain quartz-grain inclusions), coarse [1], medium [1]; dark-coloured tabular-shaped clasts (?phosphatic), coarse [1], medium [1], fine [1]; light-coloured tabular-shaped clasts (?phosphatic; one, at least, has an organic/cellular structure), coarse [1], medium [2], fine [2]; brick-red/orange hematitic clasts, coarse [1], medium [1], fine [1].
Straw: None observed, but elongate moulds/half-moulds on outer and inner original pot surfaces of sherd could be "straw" or plant-stems (medium size) and some of these that show flat capsule-shapes (ca. 1-2 mm long) could be seeds.
Porosity: Medium.
Structure: Some tabular- and irregular-shaped mm-scale-long "large" pores are present, mainly parallel to the original pot surfaces. Also present are abundant small, thin crack-like elongate pores and pull-away (shrinkage) cracks adjacent to clastic grains. The latter pull-away shrinkage cracks are both parallel and discordant to the original pot surfaces depending upon the orientation of the associated elongate clastic grains. These clastic grains are statistically parallel to the original pot surfaces but there are numerous departures from this relationship. The axis of the (unimpregnated) sherd shows a deep, 16-17-mm-long gaping (ca. 1 mm wide) crack, presumably a dehydration/shrinkage crack. No suggestion of vitrification.
Wall thickness: 10 mm (thick).
Miscellaneous thin-section observations: Rare quartz grains show thin overgrowths. Diagenetic phosphatic clastic grains of various types are present including: tabular-shaped black semi-fissile ones (?phosphatic shale), translucent grains (either colourless or honey-brown) and turbid (some are pelletoidal-like internally) refractory ovules/nodules (some containing quartz sand grains and/or carbonate enclaves). Organic phosphatic grains include rare small brown diamond-shaped fish scales, sporadic (non-porous) teeth fragments and rare (porous) possible bone fragments. One coarse clastic limestone fragment observed with recrystallised (granular) core and thin circumcrust of ?phosphate. Sporadic to rare skeletal plant material is manifested by opaline organic structures. Rare semiequant non-fissile bright-red, and sporadic to rare tabular brick-red clastic grains are hematite and hematitic shale respectively. Sporadic to rare grey, refractory tabular clasts containing sporadic quartz silt grains are possibly phosphatic clay-shale. Sporadic to common red-

brown and black spongy/frothy clastic grains of large and small size (some containing quartz sand grains) are opaque (isotropic) in crossed-polarised light and appear to be vesicular glass (slag). Sand-sized grains of pseudo-hexagonal and spindle-shaped white mica are sporadic to common; coarse polycrystalline white mica is sporadic as are finely-crystalline sericitic grains. Relatively fresh biotite is sporadic and degraded biotite is common. Rare heavy mineral grains include zircon and possibly other species. Rare feldspar included plagioclase, ?orthoclase and perthite. Annular phosphate/?carbonate nodular grains and hole-artifacts of such grains are sporadic. Some problematical grains consist of colourless, clear granular ?phosphate containing loose meshworks of relatively large prismatic crystals that have relatively high relief and high birefringence. Sporadic clasts of quartz, feldspar etc. have thin phosphatic circumcrusts. Sporadic to common elongate shrinkage-cracks (including grain-edge pull-away cracks) are present but do not contain firing-related fine crystal growths. Outer red-coloured rim zone of sherd is pervaded by hematite.

S11 (T/S No. 4): Pottery sherd (Pl. 183 A11a, A11b).

Phosphate test: Positive, medium.
Munsell color: Extreme zonal colour differentiation is present between the outer (= more planar, convex) pot surface and the inner (= less regularly planar, but generally concave) pot surface. Outer zone (which averages ca. 5 mm thick) is 5YR/6/6 (= reddish yellow). Inner zone (which varies in thickness from ca. 8 to 12 mm) is 5YR/5.5/1 (grey).
Inclusions and enclaves: Quartz sand, coarse [absent], medium (well rounded, frosted) [1], fine (subangular to rounded) [2]; brick-red/orange-coloured hematitic grains, coarse [absent], medium [1], fine [1]; white/cream clasts/enclaves, coarse [1], medium [1], fine [2] (the coarse examples appear to be possibly of polygenetic nature, for example: one porcellaneous-white example has the unambiguous morphological attributes of a clastic fragment [with both angular and rounded corners/edges] but its dull to silky lustre and internally finely fibrous crystalline texture suggest that the constituent mineral could be wollastonite, and hence the feature is a ?wollastonite-pseudomorphed limestone clast; a second coarse example is light buff/cream, subspherical, soft [recessive on slabbed surface] and looks slightly spongy and/or with tiny darkish inclusions); white-lined 'vesicles,' coarse [1], medium [1], fine (concentrated mainly within the inner non-red zone of the sherd) [2]; black ?phosphatic clasts (mostly tabular/platy in shape, but some are subspherical/subequant), coarse [absent], medium [1], fine [1]; light-coloured tabular clastic fragments, coarse [1], medium [1], ?fine [1].
Straw: None observed.
Porosity: Medium.
Structure: Sporadic, elongate mm-scale- and sub-mm-scale-long open (widish) pores are present mainly in the border zone between the red and grey zones and are parallel to the original pot surfaces. Abundant small thin crack-like pores occur throughout both the red and grey zones and define "swirl"-like patterns that are locally (near the irregular bulges on the inner [concave] surface of the sherd) at a high angle to the original pot surfaces. Elongate clastic grains are involved in the "swirl" pattern. The broken surface of the sherd has a glossy lustre, evidently including the fused clay matrix ceramic phase (inspected at ¥20 and at much higher magnifications), suggesting a degree of vitrification.
Wall thickness: 6.5-8 mm (medium).
Miscellaneous thin-section observations: Rare detrital quartz grains show thin overgrowths. Diagenetic phosphatic grains present include: rare tabular honey-brown refractory-looking (but not isotropic) grains (?phosphatic clay-shale); sporadic brown isotropic grains; sporadic to common black opaque tabular grains (some showing fissility), and reddish-black fissile semi-opaque grains (= ?phosphatic hematitic shale); semi-equant honey-brown and red-brown refractory grains (not isotropic), some containing ?carbonate inclusions; plus other petrologically more complex grain types. Organic phosphatic grains include sporadic honey-brown diamond and rectangular fish scales; rare phosphatised thin-walled microfossils with carbonate and opaque (?oxidised ?glauconite) chamber infills; colourless and pale honey-brown (some isotropic; some with silver birefringence) skeletal fragments (teeth and ?bone fragments). Sporadic to moderately common fresh feldspar includes orthoclase, plagioclase, and perthite. Sporadic altered and highly-altered reddish biotite flakes occur and rare tiny flakes of fresh muscovite. Rare quartz siltstone grains (= quartzite; constituent quartz grains not well-rounded; quartz-overgrowth cement) are present.

Very finely crystalline carbonate and carbonate/phosphate rock-fragments or nodules are sporadic, commonly with a somewhat turbid optical character (?caliche), most with thin circumcrusts of phosphatic material, as well as sporadic to common slide-making hole-artifacts of the same kinds of grains. Rare heavy mineral grains include zircon and tourmaline, the latter pleochroic in brownish olive-green and pale brown. Sporadic subspherical and ellipsoidal-shaped grains of granular-textured limestone occur, some with thin circumcrusts of phosphate. Hole-artifacts of the same grains are sporadic, recognizable by the partial retention of the granular carbonate cores. Semi-equant, non-layered brick-red hematite grains are rare to sporadic, some with sporadic inclusions of quartz silt (= hematitic silty mudrock). Red-brown tabular fissile hematitic shale grains are sporadic, some with sporadic inclusions of quartz silt. Opaline skeletal plant material is rare. Common to abundant elongate shrinkage-cracks include both grain-margin pull-away cracks and fissility-gapes (the latter confined to fissile grains). These cracks lack firing-related crystal growths. Outer (convex-side) red-coloured peripheral zone of sherd has solidly hematitic clay-matrix; clay-matrix in inner (concave side) zone is darker but with small hematitic patches.

S12 (T/S No. 7): (Raw-clay sample from House No. 3, Ismant El Kharab, fired to ca. 900-950°C under oxidising kiln conditions) (Pl. 184 A12a, A12b).

Phosphate test: Positive, weak with spot reactions.
Munsell color: Strong and very sharply defined colour differentiation between the periphery of the tablet and its core. Edge zone (1 mm and less thick) is 5YR/5/4 (= reddish brown); core zone is 5YR/6/6 (= reddish yellow).
Inclusions and enclaves: Quartz sand, coarse (well rounded, frosted) [1: but quite rare], medium (variously angular and subangular to rounded) [1: but more abundant than coarse], fine (angular to subrounded) [1; but more abundant than medium]; black clastic grains (?phosphatic; in thin-section some are subspherical), fine only [1]; brick-red hematitic grains, medium only [1]; white/cream enclaves/fragments (some are white-lined subspherical/elliptical cavities or 'vesicles'), medium [1], fine [1].
Straw: None observed.
Porosity: Dense.
Structure: Some long thin cracks (many mm long) are present at one end in the central part of the fired clay artifact. Some rare gaping semi-equant to elongate/bladed pores are also present with their long dimension parallel to the artifact surfaces (these are mostly not lined by any white mineral encrustation). Sporadic thin pull-away cracks are present along the margins of elongate/tabular (probably phosphatic) grains. Red-brown blotches that show a pattern of increasing size and decreasing relative frequency and concentration inwards from the artifact's peripheral zone appear to manifest some kind of reaction product produced by the firing. No suggestions of vitrification.
Wall thickness: 7.5 mm (medium).
Miscellaneous thin-section observations: Rare detrital quartz grains show thin overgrowths. Organic phosphatic grains include: one honey-brown tabular concavo-convex skeletal grain with margin-parallel and margin-orthogonal linear structures, probably a piece of tooth or phosphatised molluscan shell; sporadic honey-brown diamond-shaped (isotropic/near-isotropic) fish scales; Diagenetic phosphatic grains include one phosphatised thin-walled microfossil (?embryonic gastropod) with oxidised ?glauconitic cavity infills; sporadic black and reddish-black opaque/semi-opaque ?hematitic phosphatic shale fragments; tabular honey-brown isotropic grains, some with quartz silt inclusions are possibly phosphatic clay-shale. Also present are rare tabular grains of red-brown and brown fissile hematitic and limonitic clay-shale (some with sporadic quartz silt grains). Rare coarse to fine flakes of moderately-fresh biotite and sporadic degraded biotite. Sporadic to rare feldspar includes fresh orthoclase and plagioclase. Rare polycrystalline grains of fine white mica (sericite) could be altered feldspar crystals. Rare tiny detrital flakes of white mica are also present. Red, optically bright, semi-equant non-layered hematite grains occur, one containing a hematite-pseudomorphed rhomb of former ?siderite, others containing rare quartz silt grains. Rare opaline skeletal plant material is present. One clast of quartz-sandstone is present. One polycrystalline volcanic/hypabyssal rock-fragment was observed comprising mainly feldspar laths. One tourmaline grain observed (pleochroic in blue-green). Subspherical cavities are present and are lined by a honey-brown semi-isotropic phosphatic-looking material that in places shows a

pattern of radial extinction shadows under crossed-polars suggesting that cryptocrystalline fibrous crystals are present (?dahllite); these cavities could manifest remnants of formerly solid phosphatic ovules/nodules whose centres have fallen out of the thin-section during slide preparation; however, the inner edge of the cavity-lining is typically sharp and regular, suggesting that the adjacent holes are not artifacts of the slide making. Most of these small nodular structures have relatively thick circumcrusts of silty hematitic clay and some nodules have a core of hematite. Rare elongate shrinkage-cracks are confined to fissility gapes in fissile grains and do not contain firing-related crystal growths. The clay-matrix of the fired raw-clay sample is hematite rich.

S13 (T/S No. 1): Pottery sherd (Pl. 179 A13a, A13b).

Phosphate test: Positive, weak-medium intensity.
Munsell color: Rim zone varies from 5YR/6/3 (= light reddish brown) to 2.5YR/7/1 (= reddish black). Core is predominantly 5YR/6.5/3 (= light reddish brown/pink) but with seams and patches of 5YR/4/6 (= yellowish red) and 5YR/6/8 (= reddish yellow).
Inclusions and enclaves: Quartz sand, coarse (well rounded, probably frosted) [1; but very rare], medium (well rounded, frosted) [1; but quite rare], fine (mostly angular) [1; but much more abundant than the medium and coarse sand]; black clastic grains (variously: tabular-shaped; semi-equant but not rounded; and subspherical), medium [1], fine [1]; brick-red hematitic grains, coarse [1], medium [1], fine [1]; white/cream enclaves/grains (some of these, including all/most of the "coarse" ones, appear to be white-/cream-lined elongate and irregular-shaped vugs), coarse [1], medium [1], fine [1].
Straw: None observed.
Porosity: Medium.
Structure: Sporadic mm-scale gaping pores are present, mostly elongate and subparallel to the original pot surfaces, but some are quite irregular in shape. Rare pull-away cracks are present peripheral to elongate ?phosphatic grains (these grains are isotropic in thin-section). No suggestions of vitrification.
Wall thickness: 2.5-5 mm (medium/thin).
Miscellaneous thin-section observations: No overgrowths observed on the detrital quartz. Diagenetic phosphatic grains include: rare reddish-black semi-opaque tabular (and fissile) and semi-equant fragments of hematitic ?phosphate and phosphatic hematitic shale; rare colourless to pale honey-brown isotropic fragments lacking obvious organic structure; rare honey-brown (and near-isotropic and refractory-looking in crossed-polars) grains with sporadic quartz silt; rare pelletoidal brownish refractory and near-isotropic grains. Organic phosphatic grains are confined to rare diamond-shaped fish scales. Rare opaline skeletal plant material is present. Sporadic to rare grains of frothy/vesicular reddish-black isotropic ?glass are present, some containing quartz sand/silt grains. Rare bright-red semiequant grains of hematite are present as well as rare very small tabular grains of possible hematitic shale. Rare small grains of feldspar occur (no twinning observed). Sporadic red flakes of degraded biotite are present, as are rare small flakes of somewhat degraded white mica and sporadic polycrystalline grains of sericite. White mica remnants at edges of some cavities presumably manifest formerly intact white mica grains that have fallen out of the thin-section during slide preparation. Firing-related shrinkage cracks are absent. Elongate cavities lack diagenetic mineral-growth linings. Clay-matrix is hematite-rich.

DISCUSSION

Some apparent inconsistencies occur in some samples between the results of the binocular microscope and thin-section petrographic microscope analyses. For example features described in the binocular study as white-/cream-lined 'vesicles' in many samples are found in the thin-section study to be either annular phosphate/carbonate nodules in which the carbonate cores have been lost during slide-making but with retention of the outer phosphatic rim, or polycrystalline grains of white mica that have also experienced grain plucking during slide making except for remnants around the former grain edges that still adhere to the surrounding clay-matrix. Similarly, there is petrographic overlap in the appearance of certain inclusions, thus making it difficult in some cases to confidently identify some of the ingredients. For example, the distinction between degraded biotite and hematitic shale is difficult because both are red-brown in colour, typically with tabular grain-shape ± evidence of cleavage/fissility. The distinction is aided by the presence of sporadic quartz silt grains in some fragments of hematitic shale. Thus, tabular grains of red-brown colour were routinely scrutinized for the presence of quartz silt grains with clastic texture as diagnostic evidence of the sedimentary clay-shale vs mica-mineral genetic affinity of the host tabular grain.

In general there is good correspondence between the two types of analyses but the binocular microscope analysis is not able to effectively identify the petrographic/mineralogical affinity of many grains types (other than quartz), especially polycrystalline grains. This problem is exacerbated in regard to the present materials because many of the more common rock-fragment ingredients are of a microcrystalline or cryptocrystalline nature and the genetic affinity of such grains can be difficult even in thin-section under the petrographic microscope. For this reason more reliability is placed here on the results of the petrographic-microscope thin-section analysis.

In terms of the provenance significance of the petrographic composition of these samples there is a high correspondence between the mineral and organic constituents of the samples and the occurrence of these mineral and organic constituents in the local geological landscape and cultural setting.

Of particular significance is the presence in all samples of phosphatic ingredients, and in particular of vertebrate bone and teeth fragments (present in 12 of the 13 samples, i.e., in all except S13) and fish scales (present in at least 9 of the samples, including sample 13) and phosphatised microfossils, including probable pelagic foraminifera. Phosphatic ingredients, including abundant vertebrate remains (mainly fish scales, teeth and bones and shark teeth) together with diverse other phosphatic sedimentary material is present in the Late Cretaceous "Phosphate Formation" (previously known as the "Phosphatic beds") in the south-facing escarpment of the Abu Tartur Plateau of the Dakhla Oasis region (cf. Said 1962, Ch. 6; Garrison *et al.* 1979; Staff Members of Sedimentology 1992). As illustrated in Fig. 13 (from Garrison *et al.* 1979, fig. 2) the Phosphate Formation is underlain by the Nubia Formation (including the Nubia Sandstone at the base and the Variegated Shale at the top) and is overlain in turn by the Dakhla Formation (comprising mainly shales) and this in turn by Tertiary chalky limestone (Kurkur Formation). The apparently geologically "exotic" ingredients in the present samples (such as polycrystalline mica grains etc.) presumably occur in the local sedimentary bedrocks (e.g., the Nubia Sandstone) and were sourced into those sediments at the time of their deposition. Alternatively, some of these ingredients, especially mica flakes/grains, could constitute present-day wind-borne dust particles that have been sourced from more distant areas beyond the Dahkla Oasis. Control thin-sections of phosphatic sedimentary rocks from the Phosphate Formation from the Dakhla Oasis region were studied herein for comparison of their ingredients with those of the pottery sherds and raw-clay samples.

Apart from the opaline skeletal plant remains in the samples, all of the other organic remains and diagenetic types of phosphate seen in the samples studied here are present in one or other of the various geological formations of the Abu Tartur escarpment (including the thin-walled microfossils, mainly pelagic foraminifera) and the phosphatic ovules/nodules. Similarly, the limestone fragments that occur in some of the samples, and the hematite grains and hematitic shale fragments can be accounted for by rocks in this escarpment. White and red clays are still exploited from the Variegated Shales formation near the base of the escarpment as is crushed quartz sandstone (the "La silice" of Henein 1997, p.33) for ceramic use by local potters at Dakhla (Henein 1997). Similarly, the frosted coarser grained quartz sand that is present in many of the samples is indicative of a source from modern wind-blown (and hence frosted) sand that is abundant in the local landscape. According to Henein (1997) the modern potters of the Dakhla Oasis area use ash from the bread ovens as a filler in their pot-making clays. This ash is produced from the combustion of local straw and other plant material, and would explain the opaline skeletal remains of such plant material seen in the present samples. Similarly the presence of fragments of frothy/vesicular glassy material in the present samples (= ?slag) presumably also comes from such ash and results from the combustion of other materials in ovens.

Firing-related mineral-growth ("thermal metamorphic") enclaves.

Most texts and research articles that deal with the petrographic aspects of pottery/ceramics (e.g.: Hope et al. 1981; Rice 1987; Bourriau & Nicholson 1992; Aston 1996; Arnold & Bourriau 1993) focus on the mineral and organic (i.e., plant) "inclusions" that either: (1) occur naturally within the source-clay from which the artifacts were made, or; (2) are deliberately added to the source-clay by the potter as filler/temper.

Many of these workers refer to the presence of "decomposed limestone" in the pottery sherds, and Aston (1996, p. 2) elaborates some of the chemical processes that accompany, and some of the products that form, as pots that contain lime and/or limestone fragments are fired. He states, *inter alia*: "The firing of Nile silt vessels is more straightforward and less problematic than marl clays since when marls are fired to temperatures above 850° C, the calcium carbonate within the clay breaks down into calcium oxide whilst carbon dioxide is given off. ($CaCo_3 \rightarrow CaO + CO_2$). Unfortunately calcium oxide is hygroscopic and absorbs moisture from the atmosphere as it cools. This produces quicklime and gives off heat in the process which causes volume expansion and sometimes results in cracking of the pot. ($CaO + H_2O \rightarrow Ca(OH)_2$). The problem is overcome by firing the clay to temperatures over 1000° C since at that temperature the calcium liquidifies and new compounds such as calcium silicates or calcium ferrosilicates are formed. These are not hygroscopic and no quicklime is formed."

The most common form of calcium silicate is wollastonite ($CaSiO_3$) and it forms at temperatures at or in excess of 450°C in the presence of both calcium carbonate ($CaCO_3$) and silica (SiO_2; present in pottery-making materials either as quartz or opal [e.g., opal as in plant phytoliths and in other structural-infillings within plants]), according to the reaction: $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2\dagger$. Wollastonite is a white (less commonly greyish), relatively soft (Mohs hardness = 5) and typically finely fibrous mineral with either vitreous or silky lustre (the latter is typical in fibrous varieties). According to Berry & Mason (1959, p. 243), in a system that contains calcite and only minor amounts of reactive silica, the silica will be completely converted into wollastonite and the remaining calcite will simply recrystallize; and "if the temperature continues to rise, the wollastonite and calcite react together to give complex silicate-carbonate minerals and ultimately larnite, Ca_2SiO_4."

In sherd S3 (and possibly also sherd S8) enclaves/grains of what could comprise microcrystalline tremolite-actinolite [$Ca_2(Mg,Fe)_5(OH)_2(Si_4O_{11})_2$] occur as loose-knit crystal clusters that define what appears to be former detrital grains, typically surrounded by a very thin zone of turbid grey-green optically-refractory isotropic material that could comprise collophane. These enclaves/grains commonly have subspherical shapes but also irregular shapes and in some cases sporadic crystals of the same mineral encrust platy shrinkage cracks within the clay-matrix. In sherd S3 a thin zone of radially-orientated crystals is present in some examples of these enclaves, followed centripetally by a core of randomly-orientated crystals. Rare textural evidence that the growth of such crystal clusters extends outward beyond the former margin of the precursor detrital grain suggests that, at least in these cases (if not more generally), the crystal clusters constitute pseudomorphed fragments of limestone and that in some cases crystal growth continued irregularly outward beyond the former margin of such grains. Incomplete preservation of these relatively soft and texturally-fragile thermal-metamorphic enclaves/grains is typical (due to "grain"-plucking, and in the case of the calcite cores of annular phosphatic/carbonate nodules, possible also dissolution) in both the thin-sections and the slabbed sherd-offcuts resulting from the thin-section preparation. "Grain-plucking" during slide making is also no doubt enhanced by the presence in some of the sherds and fired natural-clay samples of (pull-away) shrinkage-cracks between mineral-grains/inclusions and the enclosing ceramic clay-matrix as well as fissility gapes in fissile grains. Thus, it is difficult to assess the possible cavity-fill versus limestone-replacement origin of enclaves that lack at least partial retention of (kernel-like) former limestone fragments. This difficulty is compounded by the separate thin-section observation that unaltered limestone fragments occur in some of the sherds, commonly with highly-rounded subspherical to ellipsoidal-shapes.

No definite wollastonite was encountered in the samples studied here, and in particular those that contain limestone fragments. However, some limestone fragments are rimmed by an amorphous to cryptocrystalline circumcrust that in most cases appears to comprise phosphate (collophane and/or dahllite). Whether or not some of these circumcrusts contain wollastonite formed as firing-related reaction-rims is very difficult to assess. The phosphatic circumcrusts would appear to manifest the products of diagenesis, either in the original source rocks or in the modern weathering profile.

Another mineral-growth product that is confined to sherd S3 is fibrous, bladed, and (in thin-section outline) rhomb-shaped euhedral crystals of a translucent to semi-opaque red mineral that would appear to be hematite. It occurs in sherd S3 as fibrous and bladed encrustations on the surfaces of elongate shrinkage-cracks and less commonly in micro-cavities throughout the clay-matrix.

CONCLUSIONS

The petrographic ingredients of all pottery sherd and raw-clay samples studied here from Dakhla Oasis are consistent with available local geological and cultural sources. This indicates that the pottery sherds are probably of local provenance, i.e., they were made locally from local materials as is the custom at Dakhla at the present time (cf. Henein 1997). The marked variation in iron (hematite) content among these separate samples, manifested primarily by their individual colour, is presumably a function of the relative proportions of (red) hematitic clay-shale mixed with clay-shale material of other colour, including white colour. Clay-shales of both these colours occur locally in the Variegated Shale Member of the Nubia Formation toward the base of the Abu Tartur Escarpment.

ACKNOWLEDGEMENTS

Best-quality thin-sections of the samples studied here were made free of charge by Tom Bradley, Department of Earth and Planetary Sciences (DEPS), Macquarie University. David Durney, also of DEPS, kindly translated relevant sections of Henein (1997) from the original French for this study. Emeritus Professor Peter Howard (also of DEPS) kindly made available for this study rock samples of the Phosphate Formation from the Abu Tartur escarpment collected by him in 1992 at the Abu Tartur Mine. Thin-sections of these samples were also made free of charge by Tom Bradley.
These samples are archived in the DEPS at Macquarie University (sample numbers MU52511-52514).
Figures A-1 and A-2 are figs 1 and 2 (Garrison et al. 1979); Fig. A-3 is fig. 10 (Said 1962); Fig. A-4 is from Arnold and Bourriau (1993).

REFERENCES

Arnold, D. and Bourriau, J. (eds). (1993). *An Introduction to Ancient Egyptian Pottery*. Deutsches Archäologisches Institut Abteilung Kairo. Verlag Philipp Von Zabern, Mainz am Rhein.

Aston, D.A. (1996). *Egyptian pottery of the late New Kingdom and Third Intermediate Period (Twelfth-Seventh Centuries BC). Studien zur Archäologie und Geschichte Altägytens, Band 13.* Heidelberger Orientverlag.

Berry, L.G. and Mason, B. (1959): Mineralogy: Concepts, Descriptions, Determinations. W.H. Freeman & Co., San Francisco.

Bourriau, J.D. and Nicholson, P.T. (1992). Marl clay pottery fabrics of the New Kingdom from Memphis, Saqqara and Amarna. *Journal of Egyptian Archaeology* **78**: 29-91, Colour pls 1-4, pls V-XVIII.

Folk, R.L. (1980): *Petrology of Sedimentary Rocks*. Hemphills, Austin, Texas.

Garrison, R.E., Glenn, C.R., Snavely, P.D., and Mansour, S.E.A. (1979). Sedimentology and origin of Upper Cretaceous phosphorite deposits at Abu Tartur, Western Desert, Egypt. *Annals of the*

Geological Survey of Egypt IX: 261-281.

Henein, N.H. (1997). *Poterie et Potiers d'Al-Qasr, Oasis de Dakhla.* Institut Français D'Archéologie Orientale.

Hope, C.A., Blauer, H.M. and Riederer, J. (1981). Recent analyses of 18th Dynasty Pottery. *Studien zur altägyptischen Keramik.* Verlag Philipp Von Zabern, Mainz am Rhein.

Rice, P. M. (1987). *Pottery Analysis, A Sourcebook.* University of Chicago Press, Chicago.

Said, R. (1962). *The Geology of Egypt.* Elsevier, Amsterdam.

Scholle, P.A. (1979). A Color Illustrated Guide to Constituents, Textures, Cements, and Porosities of Sandstones and Associated Rocks. American Association of Petroleum Geologists Memoir 28.

Staff Members of Sedimentology, Department of Geology, Assiut University (1992). International Symposium and Field Workshop on Phosphorites, Field Guide Book. Department of Geology, Assiut University

SAMPLE No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
1) Quartz fine	2	2		2	1 (sa-sr)	2 (a-sa)	2	2 (a-r)	1	2 (a-sr)	2 (sa-r)	1 (a-sr)	1 (a)
Quartz medium		2	2	2	2 (r/sr,f)	1 (wr, f)	1 (wr, f)	1 (r-f)	1 (a-r, some f)	1 (sr-wr, some f)	1 (wr, f)	1 (a-sa-r)	1 (wr, f)
Quartz coarse	1 (wr, f)	1 (wr, f)	1 (wr, f)	1 (wr, f)	1 (wr, f)	1 (wr, f)	1 (wr, f)	1 (wr, f)	1 (wr, f)	1 (wr, f)	absent	1 (rare wr, f)	1 (wr, ?f)
2) Feldspar	✓ C p, m, ?o	✓ S o, p	✓ R o, p, ?m	✓ S - C ?o, p	✓ R o, p	✓ S o, p	✓ R - S o, p, t, m	✓ R - S o, p, t?	✓ R p, ?m, ?o	✓ R ?o, p, t	✓ S - C o, p, t	✓ S - R o, p	✓ R ?o
3) Biotite 'fresh'	✓ C	✓ S - C		✓ R - S	absent	absent	? ✓ R	not seen	not seen	✓ S	not seen	✓ R	not seen
Biotite degraded	✓ C	✓ S - C	✓ S - C	✓ S - C	✓ ?S	✓ S	✓ S - C	not seen	✓ S	✓ C	✓ S	✓ S	?✓ S
4) Muscovite	✓ R		✓ R	✓ S	✓ S	✓ S	not seen	not seen	✓ R	✓ S - C	✓ R	✓ R	✓ R
5) Muscovite				✓ S	✓ S	✓ R	not seen	not seen	absent	✓ S	not seen	not seen	not seen
6) Sericite	✓ R		✓ R - S	✓ R	?✓ R	✓ S - R	not seen	not seen	✓ R	✓ S	not seen	✓ R	✓ S
7) Glauconite		✓ R						?✓ R				?✓ R	
8) Heavy minerals	✓ R t, u	✓ R t, u, z		✓ R t	✓ R u	not seen	✓ R t	✓ R z, t, u	✓ R t	✓ R z, u	✓ R t, z	✓ R t	not seen
Opaline plant fossils (modern)	✓ S - C	✓ S - C	✓ S	absent	absent	✓ S - C	✓ S	✓ R - C	✓ S - C	✓ S - R	✓ R	?✓ R	✓ R
9) Vesicular glass		✓ S	✓ S - C q	absent	absent	? R	✓ C q	✓ S - C q	✓ S	✓ S - C q	not seen	not seen	✓ S - R q
10) Marine invertibrate microfossils	✓C ci, p, o?, hpf, hbf, ech, ?ost, ?m	✓ S - C p, o, gi, hpf, ?m	✓ R o, pi, hpf		absent	? ✓ poss plant frag-ments ?p, ?o	not seen	not seen	not seen	✓ R ?m, ?p	? ✓ R hpf, p, g, ci	✓ R p, g	not seen
11) Diagenetic phosphate	✓ S - C qs, c	✓ S qs, c	✓ S - C qs, ch	✓ S - C	✓ R - S	✓ S - C	✓ S - C qs, **he**, ch	✓ S - C c, he, qs,	✓ S qs	✓ S - C qs, c	✓ S - C c, qs	✓ S qs	✓ S qs
12) Organic phosphate	✓ S t, ds, b	✓ C t, ds, b	✓ S - C t, ds, ?b	✓ R - S ?b, t	✓ R ?b, ?t	✓ S ?b, t, ds	✓ S - R ?b, t	✓ S ?b, ?t, ?ds	✓ R ?b, ?t, ds	✓ S ds, ?t, ?b	✓ S ds, b, t	✓ S ds, t	✓ R ds

Table 2: Binocular Microscope (i.e., quartz data) and Thin-section Petrographic Microscope Analyses (all other data)

SAMPLE No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
13) Bl/red-black ?phosphatic-hematitic shale	✓ C qz	✓ S - C qz	✓ S - C	?✓ S	✓ S qz	?✓ S - C	✓ R - S qz	✓ S	✓ S	✓ S - C qz	✓ S - C	✓ S	✓ S - R
13) Hematitic shale (tabular)	✓ S - C qz	✓ S	✓ C - A qz	✓ S - R	✓ C - A qz	✓ S - C	✓ S - R qz	not seen	✓ S qz	✓ S - R qz	✓ S qz	✓ R qz	? ✓ R
14) Hematite	✓ R - S	✓ S - C qz	✓ R	✓ R	✓ R	✓ S	not seen	absent	✓ R qz	✓ R qz	✓ R - S qz	✓ R qz	✓ R
15) Clay shale		✓ R	✓ S - R		✓ S qz					✓ S - R ?p, qz	✓ R ?p, qz	✓ R ?p, qz	not seen
16) Caliche-like limestone	✓ C - ?A qz, cc, he	✓ S - R qz, ?cc, he	absent	absent	absent	absent	absent	absent	?✓ R qz	not seen	✓ S qz, cc (16a)	not seen	absent
17) Limestone granular-tex-tured	✓ C + ortho	✓ S + ortho	absent	absent	absent	absent	absent	absent (except in ?slip)	absent	✓ S - R cc	✓ S (17a)	not seen	absent
18) Chert and chalcedony	✓ R		✓ R				not seen	?✓ R			✓ R	✓ R	not seen
19) Quartz sandstone	✓ S - R +dpm	✓ S + hc	✓ R +dpm	✓ S	absent	✓ R	✓ R		✓ R - S +dpm			✓ R +?dpc	not seen
20) Quartz siltstone	✓ S - R		✓ R		✓ R - S +hc	✓ R +dpc	✓ R				✓ R		not seen
21) Metaphorphic	✓ R chl, qm	?✓ R chl											
Volcanic										?✓ R		✓ R	
22) Other clastic ingredients					22a		22b	22c	22d	22e			

Table 2: Thin-section Petrographic Microscope Analyses (cont'd)

SAMPLE No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
13) Bl/red-black ?phosphatic-hematitic shale	✓ C qz	✓ S - C qz	✓ S - C	?✓ S	✓ S qz	?✓ S - C	✓ R - S qz	✓ S	✓ S	✓ S - C qz	✓ S - C	✓ S	✓ S - R
13) Hematitic shale (tabular)	✓ S - C qz	✓ S	✓ C - A qz	✓ S - R	✓ C - A qz	✓ S - C	✓ S - R qz	not seen	✓ S qz	✓ S - R qz	✓ S qz	✓ R qz	? ✓ R
14) Hematite	✓ R - S	✓ S - C qz	✓ R	✓ R	✓ R	✓ S	not seen	absent	✓ R qz	✓ R qz	✓ R - S qz	✓ R qz	✓ R
15) Clay shale		✓ R	✓ S - R		✓ S qz					✓ S - R ?p, qz	✓ R ?p, qz	✓ R ?p, qz	not seen
16) Caliche-like limestone	✓ C - ?A qz, cc, he	✓ S - R qz, ?cc, he	absent	absent	absent	absent	absent	absent	?✓ R qz	not seen	✓ S qz, cc (16a)	not seen	absent
17) Limestone granular-textured	✓ C + ortho	✓ S + ortho	absent	absent	absent	absent	absent	absent (except in ?slip)	absent	✓ S - R cc	✓ S (17a)	not seen	absent
18) Chert and chalcedony	✓ R		✓ R				not seen	?✓ R			✓ R	✓ R	not seen
19) Quartz sandstone	✓ S - R +dpm	✓ S + hc	✓ R +dpm	✓ S	absent	✓ R	✓ R		✓ R - S +dpm			✓ R +?dpc	not seen
20) Quartz siltstone	✓ S - R		✓ R		✓ R - S +hc	✓ R +dpc	✓ R				✓ R		not seen
21) Metaphorphic	✓ R chl, qm	?✓ R chl											
Volcanic										?✓ R		✓ R	
22) Other clastic ingredients					22a		22b	22c	22d	22e			

Table 2: Thin-section Petrographic Microscope Analyses (cont'd)

23) 'Nodules', rock-fragments, hole-artefacts	✓ S	✓ S - C	✓ S - C	✓ S - C 23a	✓ S 23b	✓ S - C 23c	not seen	✓ S 23d	?✓ R -S 23e	✓ S 23f	✓ S - C 23g	✓ S - C 23h	absent
24) Cavities and or enclaves	absent	absent	✓ C - A 24a	absent	absent	absent	absent	✓S qz	absent	absent	absent	absent	absent
25) Crystal growths	absent	absent	✓ R - S	absent	absent	absent	absent	absent	absent	absent	absent	absent	absent
26) Shrinkage cracks: elongate	✓ S - C	✓ C	✓ S - C (26a)	✓ S - C	✓ S - C	✓ C	✓ S - R	✓ S - C	✓ R	✓ S-C	✓ C - A (26b)	✓ R (26c)	absent
27) Nature of clay matrix	hematite rich	hematite rich	hematite rich	hematite rich	hematite rich	patchily hematitic	non-hematitic	non-hematitic	hematite rich (27a)	hematite rich	hematite rich	hematite rich	hematite rich

Table 2: Thin-section Petrographic Microscope Analyses (cont'd)

Notes and Explanations

R = rare; S = sporadic; C = common; A = abundant

1: a = angular; sa = subangular; f = frosted; r = rounded; sr = subrounded; wr = well rounded

2: p = plagioclase; o = orthoclase; m = microcline; t = perthite

3: biotite 'fresh' = still pleochroic and birefringent

4: muscovite single-crystal flakes

5: muscovite coarse-crystal polycrystalline aggregates, + **qtz** = with quartz-**crystalline** enclaves

6: sericite re-placed feldspar

7: included oxidised ?glauconite

8: t = tourmaline; z = zircon; u = unidentified

9: q = ± quartz-grain inclusions

10: p/i = phosphatized/phosphate-infilled; g/gi = glauconitized/glauconite -infilled; ci = carbonate-infilled; o = ?opalised; ech = echinoid; hpf = hyaline pelagic foram; hbf = hyaline benthonic foram; ost = ostracod; m = mollusc

11: ch = cherty; carbonate inclusions; qs = quartz sand/silt inclusions; he = hematitic

12: b = bone; t = teeth; ds = diamond-shaped fish scales

13: qz = quartz silt inclusions

14: bright red, typically semiequant/irregular-shaped; qz = quartz silt inclusions

15: non-hematitic, mostly tabular-shaped; p = ?phosphatic

16: he = hematitic enclaves; p = phosphatic enclaves; qz = quartz silt inclusions; cc = collophane rims; [16a = (overlaps in nature with carbonate-phosphate rock fragments)]

17: limestone and single-crystal clasts thereof; + ortho = orthospar chamber-infills in microfossils; [17a = ?+ ortho (present also as remnant cores in annular hole-artefacts)

18: including replaced marine micro-fossils

19: + hc = plus hematite cement; + dpm/c = plus some quartz sandstone with diagenetic phosphatic matrix/cement

20: + hc = plus hematite cement; + dpc = plus diagenetic phosphate cement

21: chl/qm = chlorite/quartz-mica schist

22a = large opaque clastic grains/clasts

22b = sandstone clasts of mixed quartz, phosphate-pellets and degraded biotite

22c = ?chlorite grain; red-brown commonly semi-cavenous, hematitic nodules/"clots"

22d = clasts of sandstone made up of ?degraded biotite, ?phosphatic pellets and quartz silt and sand

22e = sporadic clasts of quartz, feldspar etc. have thin phosphatic circumcrusts; some problematic grains appear to be clear ?phosphate with relatively large prismatic crystall-mosaics within; crystals have moderately high birefringence.

23: annular 'nodules'; phosphate/carbonate rock-fragments and hole-artefacts thereof

23a = no carbonate seen; some grains have hematitic circumcrusts

23b = no carbonate cores observed

23c = no carbonate cores observed

23d = confined? to periphery of sherd; no carbonate cores seen, **microcrystalline** linings are colourless and length-fast

23e = very finely crystalline carbonate cores nostly plucked during thin-section making

23f = carbonate cores absent in the main

23g = cores of both granular and caliche-like very finely grained carbonate

23h = primarily phosphatic; some contain hematite cores; most have silty hematitic clay circumcrusts

24: crystal-lined occluded subspherical and irregular-shaped cavities/enclaves; qz = quartz-silt grain-inclusions; 24a = pale to olive green, low? birefringence; tremolite- actinolite

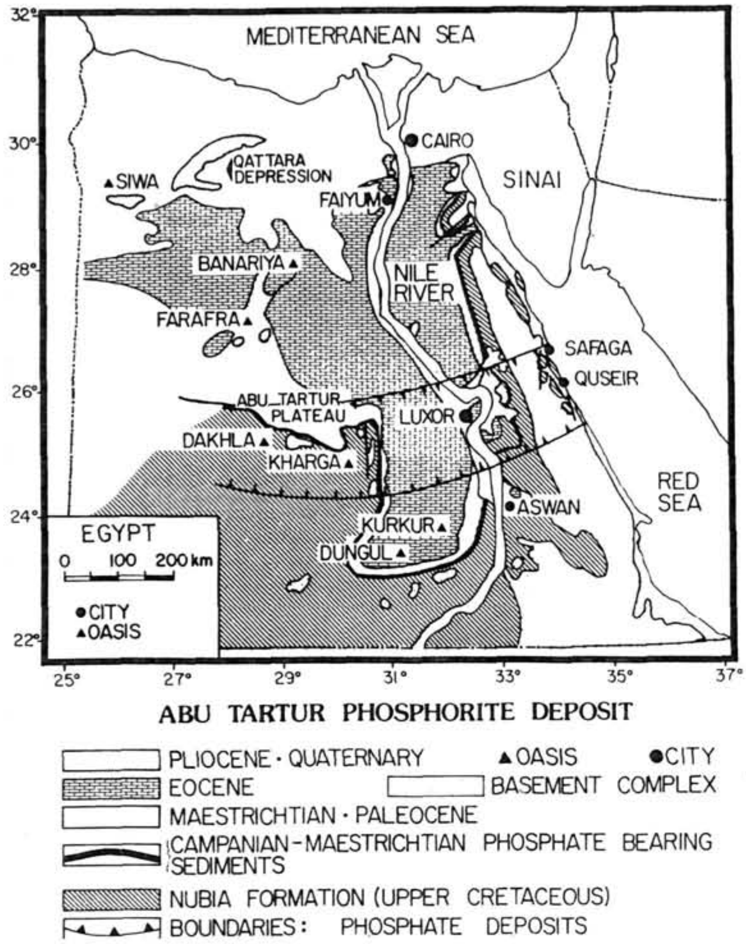
25: thermal-metamorphic euhedral hematite crystal-growths disseminated within shrinkage cavities throughout clay matrix

26a = mainly in outer zone (convex side)

26b = includes grain-margin pull-away and fissility gaps in fissile grains

26c = confined to fissility gaps in tabular grains

27a = some patches hematite poor



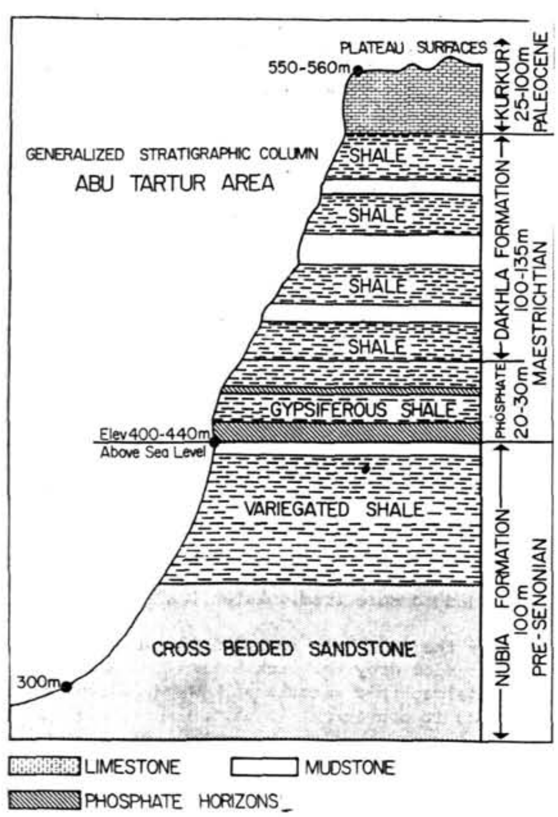


Fig. A–1. Abu Tartar phosphorite deposit.

Fig. A–2. Generalised stratigraphic section in the Abu Tartar area. (Figs A–1 and 2 from Garisson et al. 1979.)

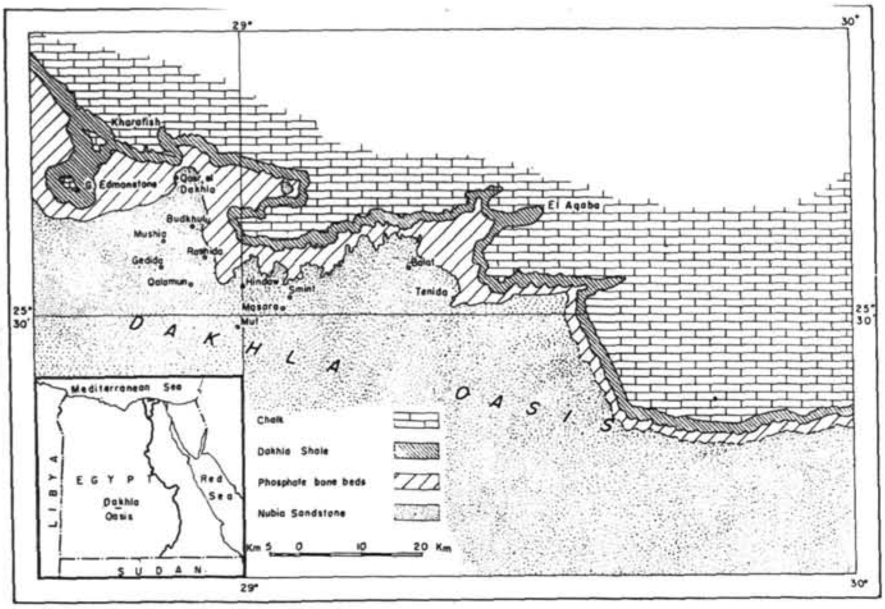


Fig. A–3. Geological map of Dakhla Oasis. (From Said 1962, fig. 10.)

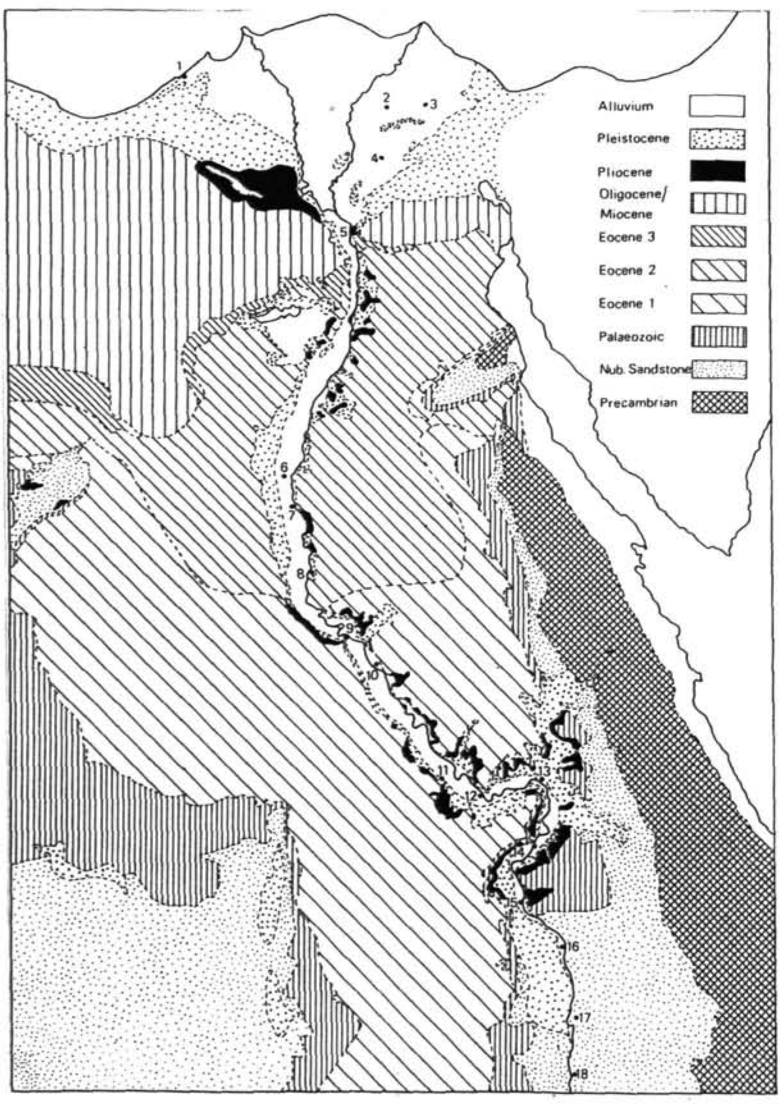


Fig. A–4. Map showing the geology of the Nile valley. (From Arnold and Bourriau 1993.)