THE PETROGRAPHIC ANALYSIS OF BEACH SAND FROM SIDON TO DETERMINE ITS UTILITY FOR CERAMIC PROVENANCE STUDIES

ARCHAEOLOGY & HISTORY IN THE LEBANON ISSUE TWENTY NINE: SPRING 2009, PP. 56-67.

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Introduction

Recent excavations at the site of Sidon in what is now the Lebanon have revealed evidence for the importation of Egyptian ceramics during the Middle Bronze Age [1]. The discovery of a faience jar with the cartouche of Tawosret (c. 1190 BC) indicates contact with Egypt probably continued throughout the Late Bronze Age [2]. To date, however, evidence for the materials Egypt presumably received in return has been lacking. The discovery in Egypt of transport amphorae, so-called Canaanite jars, signifies that Egypt acquired goods such as wine, oil, and resin from the Near East [3]. Petrographic analyses of Middle Bronze Age (MBA) Canaanite jars from the sites of Tell el-Dab'a and Memphis in Egypt have confirmed that some of these transport vessels derived from the coast of Lebanon [4]. Similarly, some of the Late Bronze Age (LBA) Canaanite jars from Memphis were also found to originate from coastal Lebanon [5]. Identification of the provenance of the Canaanite jars was based on the presence of inclusions typical of the geological outcrops along the Lebanese coast and fragments of the remains of marine species indicative of a coastal region. However, the exact location along the coast of Lebanon could not be precisely determined.

The examination of modern beach sand could provide a possible means to identify narrower areas for the production of Canaanite jars. In order to infer the possible provenance of clay-based ceramics from analysis of modern beach sand, it is necessary to understand the general origin of beach sand and its variability from place to place. The extent to which the composition of beach sand may be reflected in the inclusions within clay-based ceramics made near the coast also needs to be determined. To address these questions, a preliminary study was undertaken to examine thin sections of sand samples from the modern beaches near Sidon and a sand sample from the Middle Bronze IIA levels (2000-1750 BC) at Sidon. These samples were compared with thin sections of some MBA ceramics from Sidon [6], and some MBA and LBA Canaanite jars from Memphis, Egypt. This comparison was undertaken to ascertain the utility of modern beach sand for determining if Egypt received transport vessels from Sidon.

Concepts and techniques employed in this study

Most beach sand receives its components from two main sources: material derived from the geological composition of the coast and the hinterland, and material derived from the sea. It is often the case (and this applies to much of the Lebanese coast) that beach sand is predominantly composed of the calcitic remains of marine species, called bioclasts, and quartz grains derived from rivers that drain into the sea [7]. Additional minerals and rock fragments may be derived from geological deposits through which the rivers pass. The size and shape of the grains will depend on their history and should also vary based on where the beach sand was deposited . Marine currents moving along the shore may also contribute components from other regions. Nevertheless, the resulting beach sand is likely to be characteristic of its location and is likely to carry a signature from the geological deposits along the river beds inland of the beach.

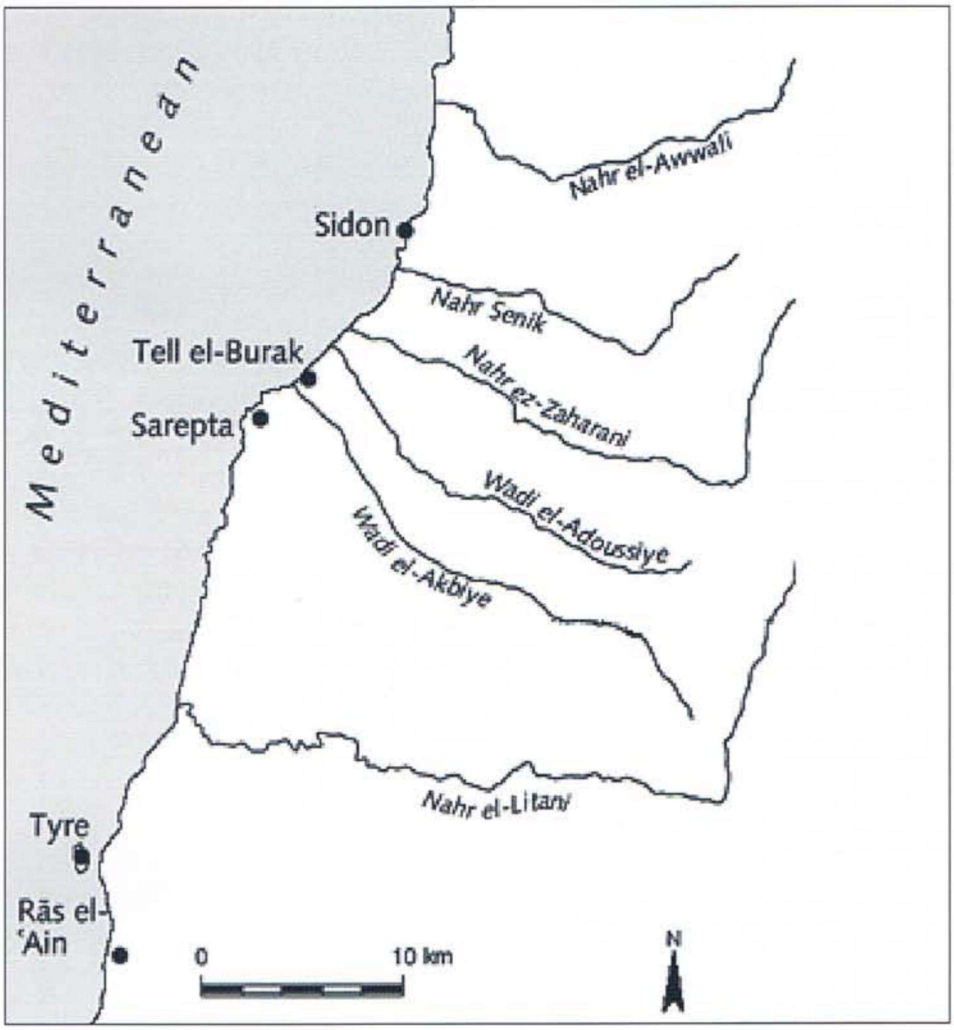
The processes occurring within the beach can result in considerable differences in the composition of sand within distances of a few metres. This highlights the importance of thorough sampling strategies in beach sand characterization studies, albeit it has not been possible to apply these in this preliminary study. In addition to local variations in beach sand composition, however, there may also be variations which occur over kilometre to hundred kilometre scales that may be useful in characterizing the beach sand from a particular region of the coastline. Thus, the suggestion made here is that the variations that occur in the composition of modern beach sand along a coastline might be useful in indicating the region of manufacture of ancient ceramics made near the coast.

Ceramics can be made quite satisfactorily out of a natural clay deposit mixed with water or out of a blend of one or more natural clay deposits. In other cases, the properties of a natural clay-water mix may exhibit shortcomings, such as lack of sufficient stiffness to allow the object to retain its form while drying, or excessive shrinkage while drying leading to cracking during drying and firing. Some of these issues may be overcome by the deliberate addition by the potter of non-plastic inclusions (such as sand) to the clay water paste. The potter is then considered to have "tempered" the properties of the clay-water paste, and the deliberately added inclusions may be termed "temper". If beach sand is employed as a temper, the characteristics of the temper may reflect the location of production. The origin of the ceramic may be inferred by comparing petrographic thin sections of the ceramic to thin sections from the beach sand. However, even where beach sand is deliberately added to ceramic pastes, the directness of the comparison may be influenced by processes used in the manufacture of the ceramic. For example, the beach sand might be processed by washing or sieving so that only a certain fraction of the beach sand is incorporated into the ceramic.

Where ceramics are not tempered by beach sand but are made from clay deposits inland (with or without deliberate addition of inclusions), studies of beach sand may still be useful in narrowing down the likely region of origin of the ceramic. This is the case because beach sand is typically derived in part at least from geological deposits along inland rivers. In many cases, these same inland geological deposits are likely to contribute to the natural clay and potential temper sources. Superficial clay and potential temper deposits may occur along river valleys for example, formed from the suspended burden which will also contribute to the beach sand when the river reaches the shore. The process of water transport in itself skews the directness of comparison between an inland deposit and the corresponding beach. Grains suspended in the river become more rounded during the transport process and coarser grains tend to be deposited before finer ones. Nevertheless sufficient common components may be present for the provenance of a ceramic made some way from the coast still to be identifiable by studying the composition of the corresponding beach sand. The presence of nummulite fossils in the beach sand (derived from a nummulitic limestone deposit) and found in an ancient ceramic from a Middle Bronze Age deposit at Sidon (see below) provides a good example of the value of studying modern beach sand as an aid to determining the provenance of ancient ceramics.

A complication that challenges the applicability of sampling *modern* beach sand to investigating the provenance of *ancient* ceramics is uncertainty over the extent to which the composition of the beach sand may have changed over the period separating the manufacture of the archaeologically recovered pottery from the present day. The duration of time between ceramic manufacture and the present is of course very brief in geological terms. Barring significant geological events such as volcanic eruptions or landslides that may alter river courses, the contribution to beach sand from inland may remain relatively constant over archaeological time. Nevertheless, alterations in river systems and climatic changes may significantly influence both the inland and marine contributions to beach sand over archaeological time. A more significant contribution to changes in beach sand composition, particularly over recent centuries, may be the influence of human activity. Inland and marine contributions to beach sand may be influenced considerably by engineering works such as the building of dams and canals. A possible approach to ascertaining the extent of difference between modern beach sand and the beach sand present at the time the ancient ceramics were manufactured is to examine ancient beach sand from sediment cores. Although sound in principle, the sediment core represents a very small area sample which, as noted above, might be far from being representative of the whole. Other archaeological sources of sand, such as intentionally placed layers of clean sand, may provide better samples to assess the changes beach sand has undergone during the course of archaeological time.

The Lebanese coast and the samples studied



1 Map of coast of Lebanon in the Sidon region.

In the case of the coast of Lebanon, the Quaternary beach sand is composed mostly of bioclastic material and minerals deriving from the nearby rivers that empty into the Mediterranean (fig. 1)[9]. The dominant geology on the coastal side of the Lebanese mountains is sedimentary outcrops of limestone, chalk, chert, and chalcedony[10]. Therefore, the beach sand features grains from some of these deposits and a variable amount of quartz, much of which may be brought in by currents along the coast.

For this study, thin sections were prepared of a sample of modern beach sand from Sidon. Further samples of modern beach sand from 1 km north and 9 km south of Sidon were also examined to gain a first impression of some of the aspects of regional variation in the beach sand composition in the Sidon area. In addition, a sample of the very large sand deposit found in the MB IIA levels of the current College site excavation just north of the land castle was examined. This deposit is of beach sand and simply in view of its enormous bulk it seems very likely to be derived from the local beach sand. In principle the deposit could simply be the beach sand found at Sidon in the MB IIA period transported to the location of the site. The deposit is, however, so remarkably clean and homogeneous throughout its considerable thickness that one is inclined to suspect that, while the archaeological deposit is very likely to be derived from the local beach sand, it is also likely to have been processed before deposition. The archaeological deposit is certainly far more uniform in its appearance than the modern beach sand at Sidon (ignoring modern contaminants).

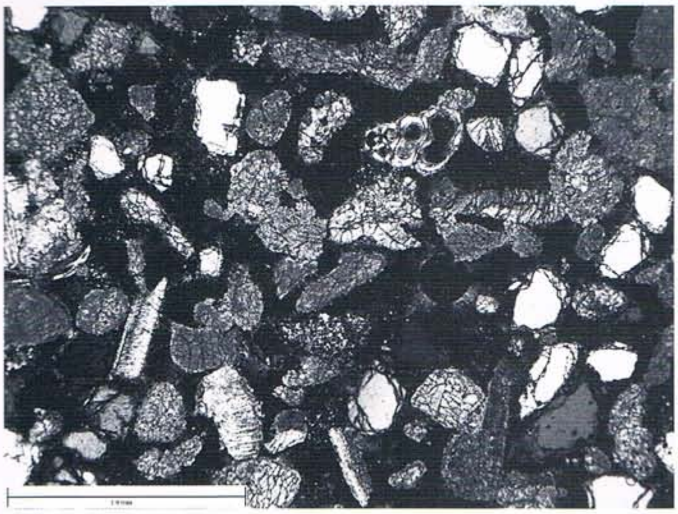
To ascertain the presence of inclusions suggestive of the beach sand in ceramics, the sand samples were compared to petrographic thin sections of MBA ceramics from the College site at Sidon. For further comparison with the sand samples, sherds of Middle Bronze Age (1750-1550 BC) and Late Bronze Age (1550-1000 BC) Canaanite jars from Memphis were selected. Previous petrographic analysis had confirmed the presence of inclusions consistent with Levantine coastal sand in a group of these vessels [11]. The inclusions comprised mostly bioclasts with a lesser amount of quartz. Additional inclusions comprised limestone, chert, and chalcedony. These components are present in the sedimentary outcrops of Santonian-Campanian or Eocene and Cenomanian-Turonian age, which are found predominantly along the Lebanese coastal plain [12]. Within the bioclasts, the presence of fossils of coralline algae, particularly the *Amphiroa* genus, indicated the beach sand derived from deposits of the Pleistocene and younger age [13]. Finally, the clay was identified as rendzina, a soil that develops on the limestone outcrops along the Mediterranean coast, particularly along the central coast of the Levant [14]. The combination of all of these features clearly indicated the provenance of these Canaanite jars was along the coast of Lebanon.

However, coastal sand of this type can be found from Akko to Sidon, and the beaches near Beirut and Tripoli [15]. Furthermore, within the Canaanite jars assigned to this region there was significant variability in the presence of the inclusions, their size, and amount, suggesting several areas along the Lebanese coast were producing the vessels. There is a lack of excavated Bronze Age kilns from this region that could supply ceramic material for comparison. The uncertainty over the exact origin of these ceramics excavated in Egypt was part of the stimulus for the present pilot study which has been initiated to start to investigate how useful modern beach sand might be as a source of data to assist research on the provenance of ancient ceramics in this region.

Results

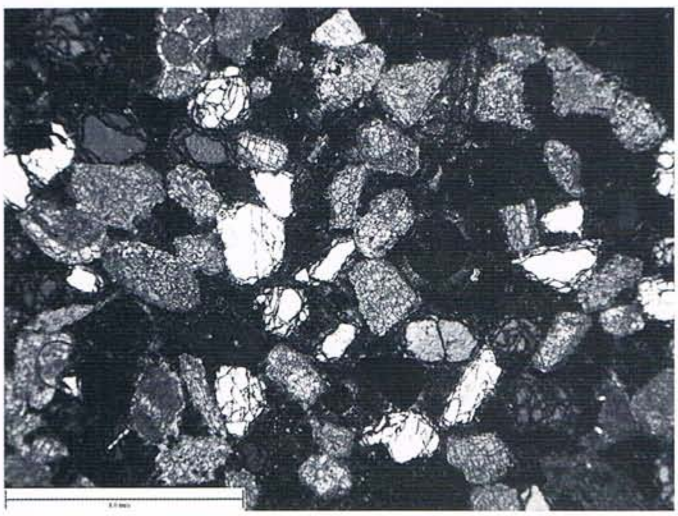
The beach sand from the MB IIA levels at Sidon (fig. 2) consisted primarily of bioclastic material (70%) ranging in size from very fine to coarse [16]. A fair number of these bioclasts were from the *Amphiroa* genus of algae. The bioclasts ranged in shape from angular to rounded. Quartz was present as roughly 20% of the inclusions and ranged from very fine to coarse in size. Most quartz grains were angular to subrounded. Subangular to subrounded chert was present (5%) in sizes fine to coarse. Notable were a few iron-oxide inclusions and green fragments, possibly glauconite, making up 5% of the inclusions. The angularity of the bioclasts, quartz, and chert indicate the materials were not transported geologically over a large distance, suggesting they reflect the immediate geology and

Mediterranean fauna surrounding the area of deposition, in this case the beach at Sidon. The Nahar Senik just south of Sidon is the likely source for the mineral inclusions as the Mediterranean currents move from south to north along the coast of the Levant.



2 Cross polarized image of MBA Sidon sand sample, white and grey inclusions are quartz, brown inclusions are bioclasts and limestone fragments. The scale bar is 1 mm long.

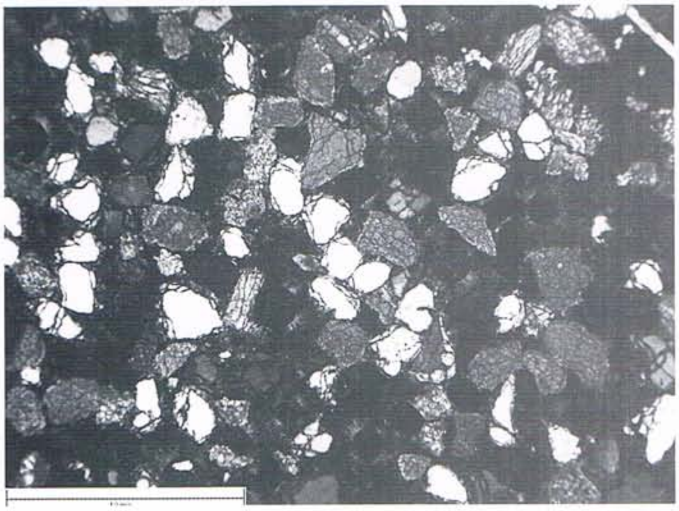
The modern Sidon beach sand had some slight differences from the MBA sand (fig. 3). The proportion of bioclasts to quartz grains was roughly 60% and 30% respectively. The bioclasts ranged in size from very fine to coarse, and were typically angular to rounded. The angular to subrounded quartz grains were found in sizes very fine to medium. Chert and *Amphiroa* clasts were very rare (1%), while there was a slight increase (8%) in the amount of iron oxides and green glauconite (?) inclusions. In addition to the iron oxides, fragments of manganese-rich inclusions and angular pieces of spinel were also noted among the opaques (inclusions that do not allow much light to pass through them). A few heavy minerals such as pyroxenes and amphiboles were present (1%) in this sample, which were not seen in the MBA Sidon sand. These slight differences do suggest some changes have occurred within the river systems near Sidon and in the Mediterranean Sea. The increased scarcity of the *Amphiroa* genus is known, however, so a lack of these inclusions is not surprising [17]. Finally, the lack of feldspar grains seems to distinguish this sample from the modern sand occurring along the coast of Israel.



3 Cross polarized image of modern Sidon sand sample, dark brown and black inclusions are opaques. The scale bar is 1 mm long.

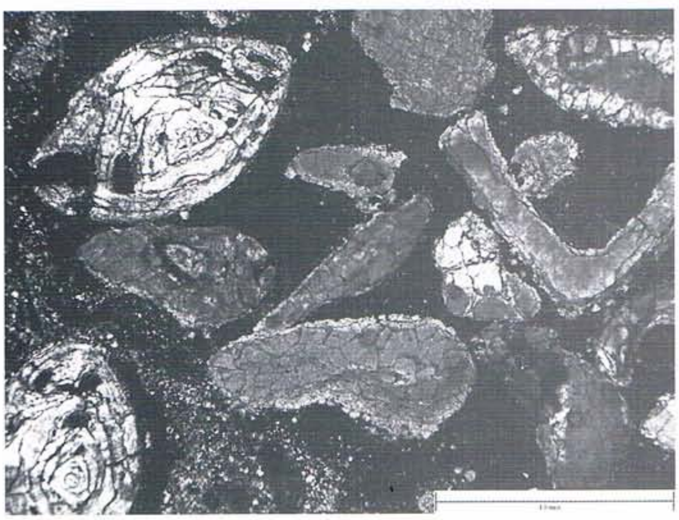
The modern beach sand collected from 1 km north of Sidon appears quite similar to the modern beach sand acquired at Sidon (fig. 4). The bioclasts make up approximately 55% of the inclusions, with quartz grains accounting for 30%. The bioclasts ranged in size from very fine to coarse, and were angular to subrounded. The quartz grains were present as very fine to medium sized pieces that were angular to subrounded. Once again, there were only one or two fragments of *Amphiroa* algae clast and chert (1%), while pieces of iron-oxide, manganese-rich inclusions, spinel and glauconite (?) comprised 10% of the inclusions. In addition to the pyroxene and amphibole minerals, tourmaline and epidote were also noted (4%). Overall, with the exception of the increase in types of heavy minerals and amount of iron-oxides, the two modern beach samples were virtually identical. Heavy mineral concentrations are not suitable for distinguishing between sands since their presence relates more to current and tidal action that will often deposit strips of heavy minerals on a beach [18]. The shapes of the inclusions also confirm that the materials from both modern samples were derived from the local Mediterranean fauna and rivers nearby.

4 Cross polarized image of modern sand north of Sidon sample, green inclusion in the centre is glauconite? The scale bar is 1 mm long.



The final sand sample came from a modern beach at Tell el-Burak, 9 km south of Sidon (fig. 5). This sand was quite different from the previously examined samples due to the increase in bioclasts (90%) and the reduction in the amount of quartz (5%). The bioclasts were subrounded to rounded and found in sizes very fine to very coarse, while the subangular to subrounded quartz grains were in fine to medium sizes. The sand is characterized by many nummulite fragments, the calcareous skeleton of a protozoa species, which is unsurprising as the geology in this area features nummulitic limestone. Fragments of the limestone were probably carried to the Mediterranean Sea by the nearby Wadi el-Akbiye and reworked to create a beach sand with numerous nummulite pieces (fig. 1). The presence of a number of *Amphiroa* algae clasts was notable. Angular, medium sized chert fragments were also present (5%). There were no heavy minerals or iron oxide and opaque inclusions within the sand. The difference between this sample and the other samples suggests within a 10 km range the sand can vary significantly. This is due to changes in the geological outcrops drained by the river systems and indicates the coastal sand can be characteristic of a narrow area.

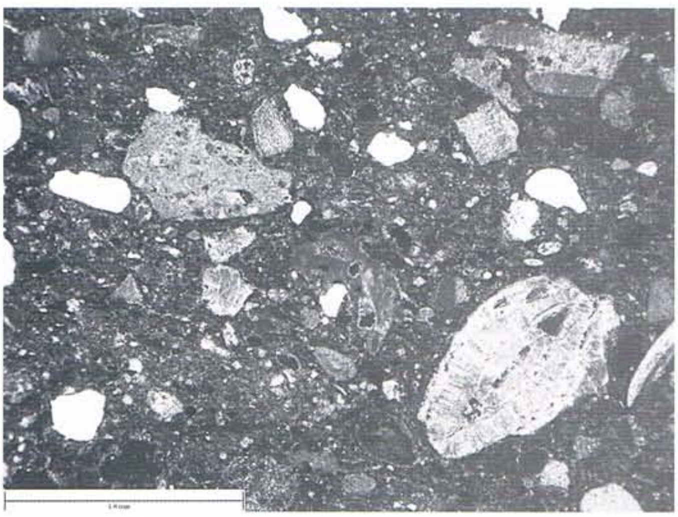
5 Cross polarized image of modern sand 9 km south of Sidon, oval inclusion at the top left is a nummulite. The scale bar is 1 mm long.



The examination of thin sections of MBA ceramics from Sidon was undertaken in order to determine if beach sand was a component in pottery at Sidon. This was necessary to establish before presuming beach sand would be present in transport amphorae exported to Egypt. Since a limited number of thin sections of the Sidon material were studied, the results are very preliminary. Several thin sections contained bioclasts and quartz inclusions similar to the Sidon MBA beach sand, suggesting that either beach sand was added in small amounts or a rendzina soil naturally containing beach sand inclusions was utilized to produce pottery (fig. 6). Several of the burial jars analyzed petrographically by Griffiths [19] contained such bioclastic material; however Burial Jar 14 and 15a contained more quartz than the Sidon MBA beach sand, while Burial Jar 15b had fewer bioclasts and larger quartz grains. Two samples (one was Burial Jar 18a [20]) featured inclusions of nummulites, bioclasts, and quartz grains (fig. 7). There is the possibility these samples were produced further south, closer to Tell el-

6 Cross polarized image of Sidon MBA ceramic sample (S/1029), note large limestone fragment at bottom right. The scale bar is 1 mm long.

7 Cross polarized image of MBA Sidon ceramic sample (S/15332), note oval nummulite fragment in lower right. The scale bar is 1 mm long.

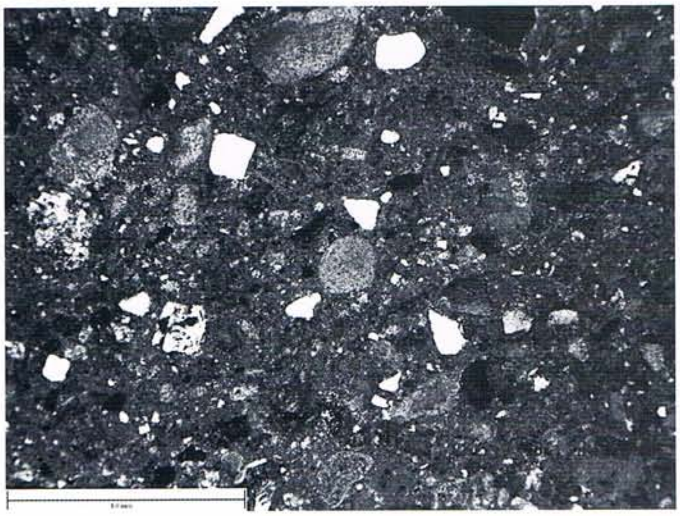


Burak and the nummulitic limestone outcropping in this region.

At this point it is difficult to determine how the Sidon potters were relating to their materials, although the variability in the samples suggests the technology of manufacture had not been standardized. Of the coarse wares examined, a good number of examples seemed to have utilized an unrefined clay with large inclusions and little tempering material. In fact, as was noted by Griffiths [21], the samples consist of a continuum with some examples being produced predominantly of clay and others showing an increased amount of quartz grains. The additional quartz grains in some instances were fairly angular and could have derived from the Nahr Senik or been present in a secondary deposit of clay. Even the clay material varied, suggesting production was based on localities with available material and the choices made by individual potters, rather than a consistent use of a single clay source and selection of specific tempering materials. These conclusions are preliminary and further study of the entire corpus of thin sections from Sidon should clarify the range of materials employed and techniques of manufacturing ceramics during the MBA.

The examination of late MBA Canaanite jars from Memphis revealed only a few samples with inclusions consistent with the composition of Sidon beach sand (fig. 8). However, there were difficulties in making the comparison due to the prevalence of large chalk and chert inclusions originating in the rendzina soil utilized to produce the vessels. This made it difficult to determine the proportions of bioclasts and quartz grains originating from what might have been beach sand temper. Additionally, the inclusions often consisted of grain sizes that were smaller than would be expected, and the presence of feldspars raised doubts about the connection to the MBA Sidon sand. Finally, the variability in the inclusions and clay components in the late MBA Canaanite jars from the coast of Lebanon is significant and inevitably comparisons between vessel inclusions and sand are complicated by the potters choice and utilization of materials. In particular, for this period it appears the potters selected a coarse clay with naturally large inclusions and a small amount of beach sand material that they employed directly without further refinements. Interestingly, these features of ceramic production resemble the attitude to manufacturing some of the MBA pottery at Sidon.
The comparison of the LBA Canaanite jars from Memphis with the MBA

archaeological sand deposit from Sidon gave a closer correlation. One sample contained inclusions that appeared quite similar to the MBA Sidon sand (fig. 9), while four others seemed likely possibilities for including Sidon sand material. Furthermore, the fabric of the LBA Canaanite jars appears to consist of a finer clay with discreet coastal sand inclusions suggestive of temper, as opposed to the materials utilized to produce the MBA Canaanite jars. The difference in Canaanite jar production may explain why it appears easier to relate the LBA jars to the Sidon sand than for the MBA examples.



8 Cross polarized image of Memphite MBA Canaanite jar sample (OW/23), note subangular quartz grains and bioclasts. The scale bar is 1 mm long.

Discussion

The examination of sand samples from Sidon, pottery excavated from Sidon and Canaanite jars found at Memphis has revealed important information regarding the usefulness of analysing sand samples for refining the provenances of ancient pottery. The opportunity to evaluate the similarities between modern beach sand and coastal sand from the Middle Bronze IIA levels at Sidon was invaluable for suggesting that in certain cases the modern sand may resemble the ancient materials, although slight differences can appear. These differences, particularly the markedly lower proportion of opaque fragments found in the archaeologically deposited sand, could be due either to changes over time in the systems producing the sand or to processing in antiquity of the sand deposited in the archaeological levels. Since this sand was deliberately brought from the beach and deposited on the site before a new level of building commenced, there is the possibility that the inhabitants cleaned the sand of dark inclusions to produce a white layer. Since the opaque pieces are heavier than the bioclasts or quartz, washing the sand in water in the manner of gold panning would separate the denser darker grains from the lighter less dense sand found in the archaeological deposit. Experimental washing of modern beach sand might provide further insight into the likelihood that the MBA inhabitants of Sidon had washed and cleaned the sand before depositing it in such great quantity.

9 Cross polarized image of Memphite LBA Canaanite jar sample (225/B), note *Amphiroa* algae clasts in centre and centre left. The scale bar is 1 mm long.

The petrographic analysis of modern beach sand from Sidon, north of Sidon and south of Sidon revealed little difference within 1 km, but noticeable variability within 10 km. In order to derive the maximum benefit to provenance studies of ancient ceramics from studies of modern sand, it is highly desirable to have a thorough understanding of the local geology that contributed to the deposition of the sand. Other sources of sand such as riverine or lacustrine sand should also be examined. In some cases, alternative sources of sand may prove more appropriate. If the mudbricks manufactured at a site were produced from clay and sand, then they may provide a better correlate for ancient materials as they are very likely to have been produced of local sand and clay. Nevertheless, modern sand may at a larger scale assist in characterizing the geological factors producing coastal sand. This is revealed by comparing the Sidon sand to samples of sand along the coast of modern Israel, which do show obvious differences. Further research on sand samples and their comparison to ancient pottery may assist in determining the suitability of this type of research for provenancing purposes.

The results of the study of the Sidon sand and MBA pottery from Sidon suggest that while components consistent with beach sand are present, the intentional use of beach sand for pottery production will require further research to confirm. Moreover, the variability seen in the petrographic sections of the Sidon MBA ceramic samples indicated that the technology of pottery manufacture for some ceramics during the MBA was quite variable and lacked standardization. This observation also applied to the MBA Canaanite jars found at Memphis, which show beach sand inclusions similar to the Sidon sand but coarse components that make certain determination difficult. Finally, the association of the Sidon MBA sand to several of the LBA Canaanite jars from Memphis indicates the possibility of using sand samples to narrow provenance assignments. Additional samples of sand from Byblos, Beirut, and Tripoli should clarify the differences in Lebanese coastal sand and may indicate if Canaanite jars were produced at these sites. The potential benefits of studies of modern beach sand in determining the provenance of ancient ceramics are well illustrated by the similarity between some of the Sidon MBA ceramics and the modern sand from Tell el-Burak; both contains distinctive nummulite fragments. The results of the current study suggest that inferences from direct comparisons can be made, but should be done cautiously. The continued petrographic examination of Canaanite jars found in Egypt and pottery produced at Sidon may confirm if Egypt received exports from Sidon.

Acknowledgements

This study would not have been possible without the provision of sand samples from Dr. Claude Doumet-Serhal, Dr. Karin Kopetzky, and Mr. Matt Williams from Sidon, and Dr. Hermann Genz from Tell el-Burak. The analysis of the MBA Canaanite jars from Memphis is part of M. Ownby's PhD research at the University of Cambridge, UK. I am grateful for the support provided by Dr. Charles French and Ms. Janine Bourriau. The LBA Canaanite jars from Memphis were examined through the kind permission and assistance of Dr. Laurence Smith. The samples studied were exported by permission of the Supreme Council of Antiquities, Egypt. Dr. Judith Bunbury provided valuable assistance with the mineralogy. This pilot study is a part of a much larger research project to utilize sand to assist in identifying the provenance of Canaanite jars.

NOTES

1 B. Bader, 2003; I. Forstner-Müller *et al.*, 2006; I. Forstner-Müller and Kopetzky, 2006; D. Griffiths and M. Ownby, 2006.

2 M. Marée, 2006.

3 M. Serpico *et al.*, 2003.

4 A. Cohen-Weinberger and Y. Goren, 2004; M. Ownby and J. Bourriau, forthcoming.

5 J. D. Bourriau *et al.*, 2001; L. M. V. Smith *et al.*, 2004.

6 D. Griffiths, 2003.

7 R. G. Dean and R.A. Dalrymple, 2002, p. 12-22.

8 R. G. Dean and R.A. Dalrymple, 2002, p. 29.

9 Z. R. Beydoun, 1977, Map from the Tell Burak Archaeological Project, http://wwwlb.aub.edu.lb/webhist/burak.htm.

10 L. Dubertret, 1949

11 M. Ownby and J. D. Bourriau, forthcoming; J. D. Bourriau *et al.*, 2001; L. M. V. Smith *et al.*, 2004.

12 Z. R. Beydoun, 1977.

13 B. Buchbinder, 1975; D. Sivan, 1996.

14 M. Wieder and D. Adan-Bayewitz, 2002, p. 397-398.

15 L. Dubertret, 1945; L. Dubertret, 1949; L. Dubertret and R. Weztel, 1945.

16 These size ranges are based on the Wentworth scale, very fine=0.06-0.125 mm, fine=0.125-0.25 mm, medium=0.25-0.5 mm, coarse=0.5-1 mm, very coarse=1-2 mm. The percentage of inclusions was estimated visually.

17 L. Piazzi and D. Balata, 2008.

18 R. G. Dean and R.A. Dalrymple, 2002, p. 22.

19 D. Griffiths, 2003, p. 19-20.

20 D. Griffiths, 2003, p. 21.

21 D. Griffiths, 2003.

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