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The Fabric of a Ceramic Jar from Sidon Decorated with Fish or Dolphins

The decoration and archaeological context of the jar in question are described in this volume by Claude Doumet-Serhal (p. 106). The jar (S/1785) was excavated from burial 7 on the College site just outside and to the east of the mediaeval wall of the port city of Sidon. This burial is a pit containing the skeletal remains of at least two human adults and a child as well as animal bones and Middle Bronze Age pottery.

The decoration of this vessel, although crude, is remarkable for its iconographic parallels with Minoan jars and with the Dolphin Vase excavated at Lisht in Egypt (Doumet-Serhal, p. 106). The Lisht Dolphin Vase was studied by McGovern *et al.* (1994) using neutron activation analysis to determine its chemical composition. They concluded that the Lisht Dolphin Vase (a pottery jug dated *ca.*1750-1700 BC) originated in the Gaza region of southern Palestine.

The unusual decoration and iconographic associations of the Sidon jar make its exact provenance a matter of considerable interest. This warrants detailed study of the fabric of the jar so that associations with other ceramic artefacts of similar fabric may be identified. It may also be possible in the future to correlate the fabric of the Sidon jar to that of ceramics of known origin or to particular geological clay deposits. The fabric has a number of similarities with the fabrics of other ceramics found at Sidon and the jar may well have been made quite locally. More precise determination of provenance will, however, have to await further study.

This study presents two complementary but independent approaches to the study of the fabric of the Sidon jar. The first is examination of thin sections of the fabric using polarized transmitted light microscopy (Bousfield, 1992; Gribble & Hall, 1985; Jones, 1987; Tucker, 1988). This allows identification of some of the larger inclusions in the fabric in terms of their mineral, rock or microfossil identity. It also allows study of the texture of the fabric in terms of the frequency of occurrence of particular inclusions and their size and shape distributions.

The second approach adopted in this study is the examination of a polished cross-section of the fabric using scanning electron microscopy (SEM) in conjunction with energy-dispersive X-ray spectrometry (EDS) (Potts, 1987; Jones, 1987; Tucker, 1988; Watt, 1985). This technique permits elemental analysis of any chosen area of the fabric such as analysis of areas of fine-grained matrix that appear free of inclusions, analysis of particular inclusions while avoiding contribution from the fine-grained matrix or a bulk analysis of a large area of matrix together with inclusions. This capacity to achieve spatial resolution and to analyse chosen areas, particular grains and small features down to a minimum diameter of a few micrometers (thousandths of a millimetre) in diameter is a considerable advantage in the analysis of inhomogeneous ceramic fabrics and forms a good complement to the information on texture and mineral composition obtained from the optical microscope. Although spatial resolution in analysis is a very significant advantage, particularly in the study of coarse fabrics, most analytical equipment has limitations as well as strengths. In the present study, the X-ray spectrometer used is limited to detection of the elements sodium and above in the periodic table and to detection of elements present at levels above about 0.1%. The detector used in this study does not detect light elements such as carbon and oxygen, nor does it detect elements that are only present at low levels (trace elements).

Optical petrology

Examination of a cross-section of the wall of the Sidon fish or dolpin jar with the naked eye or a hand lens shows a coarse fabric with inclusions up to about 3mm diameter and elongate pores running roughly parallel to the vessel walls. Some of the elongate pores appear to contain charred organic matter and may originally have derived from a fine organic temper that has charred and in some cases burned away. Near the outer edge of the sherd the carbon derived from charring of microscopic organic matter in the clay has been burned a way to reveal the orange-red colour of the fired clay. The same is true on the inner surface of the sherd, though here the depth of burning away of carbon is less reflecting a lesser availability of free oxygen inside the jar during firing. Away from the inner and outer surfaces of the sherd, the fabric is coloured pale grey probably due to remaining carbon. (See plate 1.)

Plates 2 to 6 give views of the fabric seen down the polarizing microscope in thin section. The dominant inclusions are light grey to light brownish mottled limestone fragments that are present in all sizes from about 3mm diameter down to very fine fragments dispersed throughout the fine-grained matrix of the fabric. Part of a limestone inclusion is seen in the upper right corner of plate 2.

A number of carbonate microfossils are also present. Those seen in plates 3 and 4 are the most common in the sections examined. They are probably crinoids (Adams *et al.*, 1984, 44). Other more fragmentary and as yet unidentified microfossils occur less commonly in the fabric.

The fabric also contains angular and sub-angular monocrystalline quartz grains (see plate 2). Some quartz grains are more rounded, and some show signs of having been strained. The two partially extinguished (dark) quartz inclusions in the lower right quadrant of plate 3 show strain. The inclusion on the right shows a sutured grain boundary. These quartz inclusions are probably of metamorphic origin.

Iron-rich clay pellets are also common in the fabric. In the top and bottom centre of plate 2 fairly large opaque iron-rich argillaceous inclusions are seen. Smaller iron-rich argillaceous inclusions are dispersed throughout the fabric, some with distinct boundaries suggestive of their being well cemented but others with more diffuse outlines suggesting more the consistency of plastic clay when the vessel was being formed.

Chert is also a fairly common component in the fabric. Most fragments are small but a few fragments are up 0.5mm in diameter. (See plate 5.) Far rarer (one fragment in about 7 square centimetres of thin section examined) is the fibrous chalcedonic chert seen in plate 6.

Optical petrology plate captions

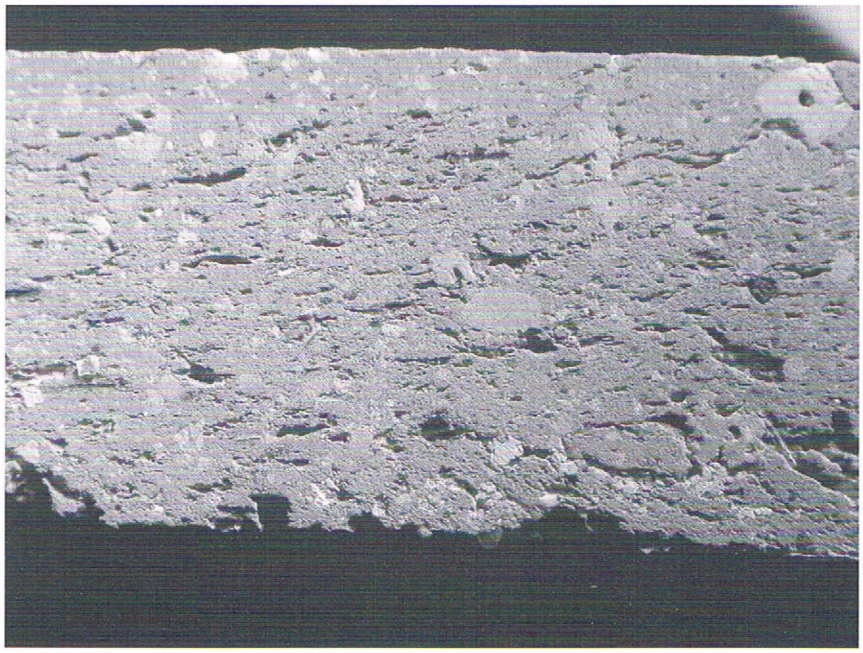


Plate 1.

Macrophotograph of a cross-section through the wall of the jar S/1785 from Sidon burial 7. The wall of the vessel is 10.5mm thick in the sample shown.

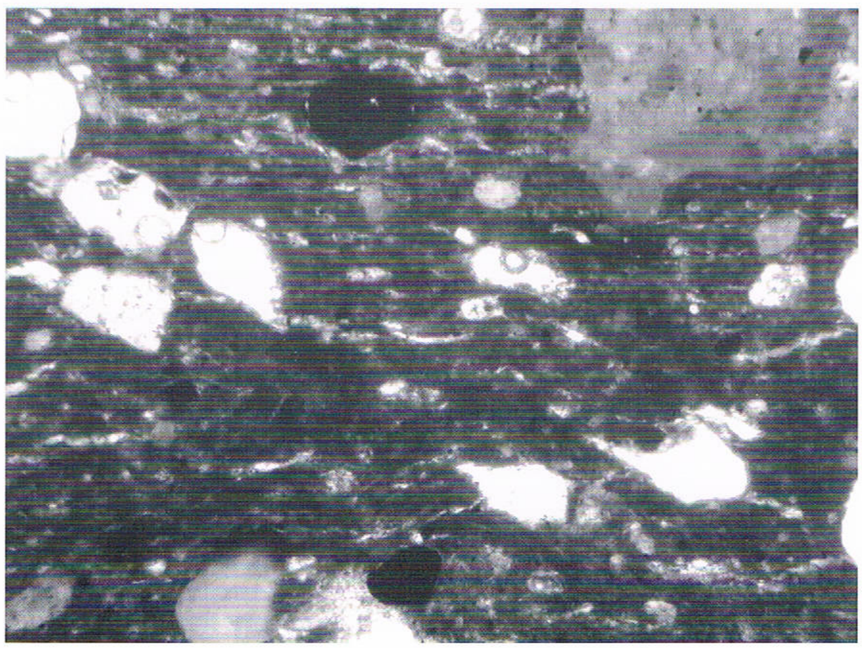


Plate 2.

This photograph shows a fairly typical view of the fabric in thin section under plane polarized light. The field of view is 1.8 mm across. Elongate voids are apparent. In the upper right corner is part of a mottled light grey-brown limestone inclusion. Smaller limestone inclusions are dispersed throughout the fabric. In the top and bottom centre of the photograph are fairly large iron-rich argillaceous inclusions. Smaller iron-rich argillaceous inclusions are dispersed throughout the fabric. The clear grains are quartz.

Plate 3.

The field of view is 1.8mm across and the photograph is taken with cross-polarized light. The two large carbonate fossils are probably crinoids (Adams *et al.*, 1984, 44).The two grains in partial extinction (dark) in the lower right quadrant of plate 4 are quartz inclusions showing strain. The inclusion on the right shows a sutured grain boundary. These inclusions are probably of metamorphic origin.

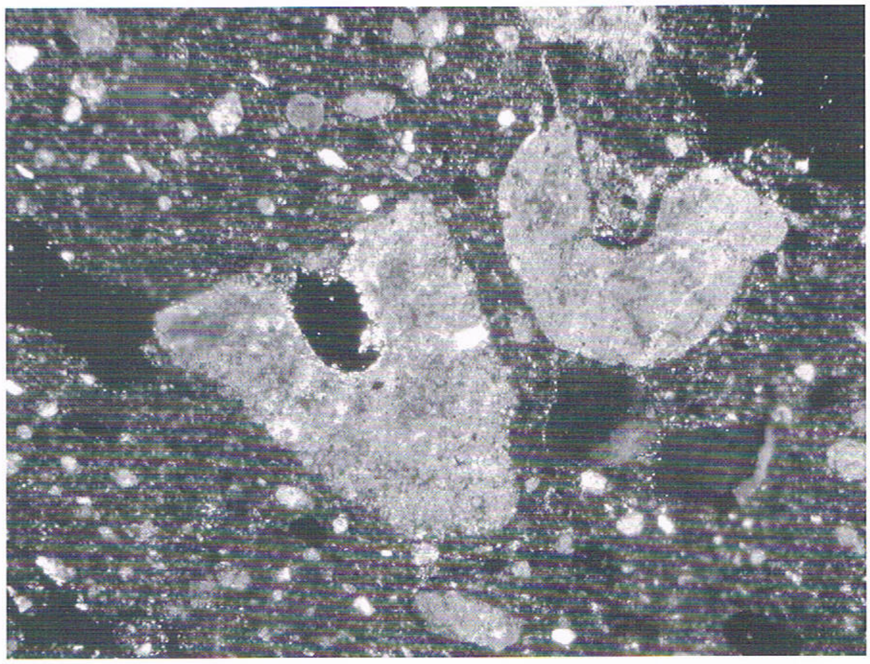


Plate 4.

The field of view is 1.8mm across and the photograph is taken with cross-polarized light. The large carbonate fossil is probably a crinoid (Adams *et al.*, 1984, 44).

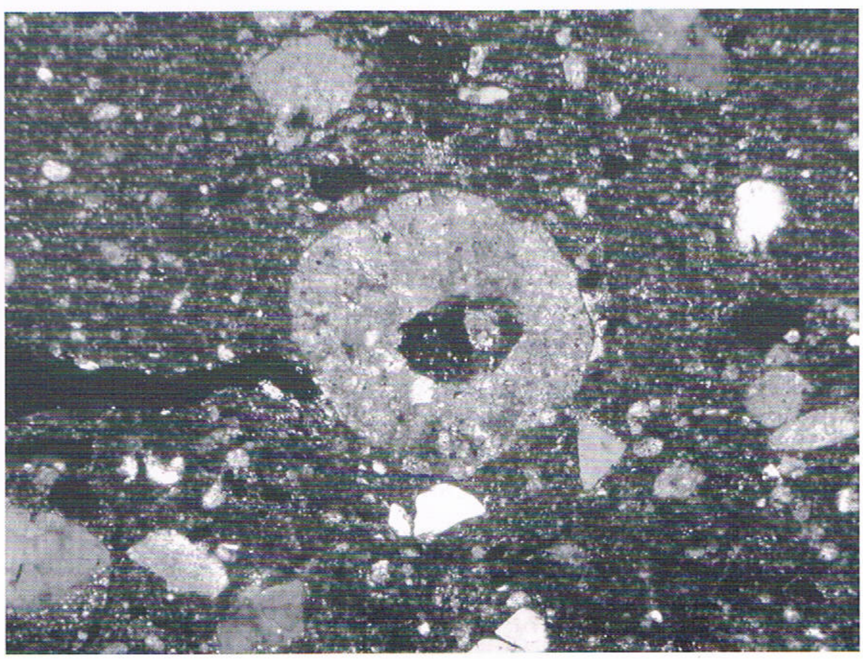


Plate 5.

The field of view is 0.74 mm across and the photograph is taken in cross-polarized light. The specked grain in the lower right which is about 0.35mm along its long axis is chert. The clear grain in the upper left is a quartz grain with some iron staining on the surface.

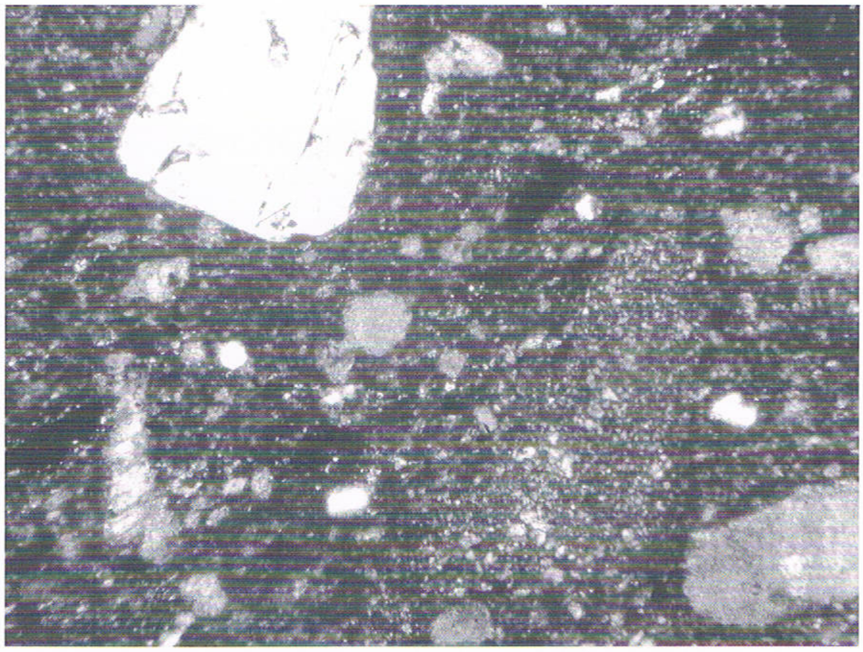
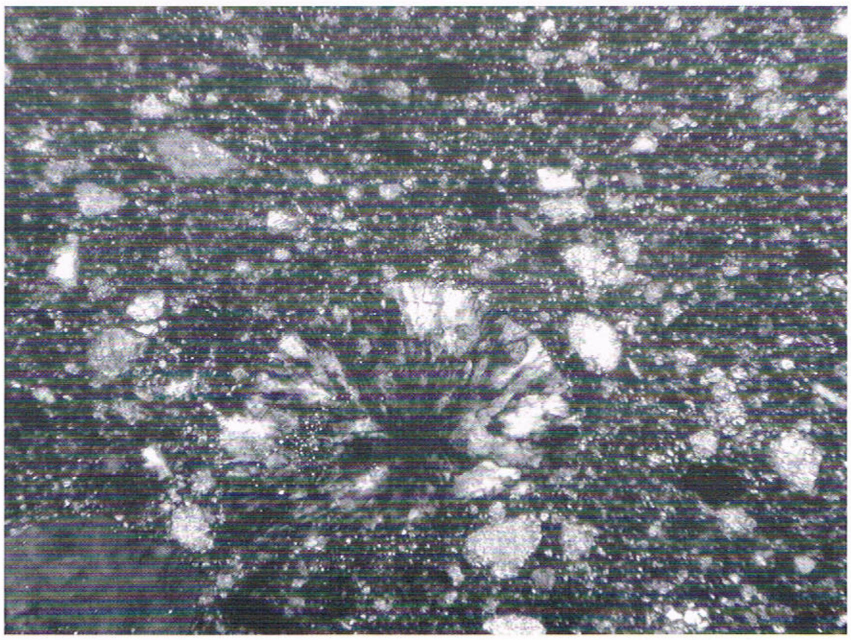


Plate 6.

The field of view is 0.74 mm across and the photograph is taken in cross-polarized light. The semicircular inclusion below the centre is a rare fragment of fibrous chalcedonic chert.



Scanning electron microscopy (SEM)

A small sherd from the Sidon jar was embedded in epoxy resin, ground and then polished to give a plane section through the vessel wall (Bousfield, 1992). The sample was coated with a thin evaporated coating of carbon to prevent electrostatic charging of the sample during examination under the SEM (Potts, 1987, 347-348). The choice of areas to analyse was guided by using backscattered electrons (BSE) to provide an image of the surface of the sample. BSE imaging (as opposed to the more commonly employed secondary electron imaging) helps to highlight areas of different chemical composition because the intensity of the backscattered radiation signal increases steeply with increasing average atomic number of the area being observed. In backscattered imaging, areas of the same composition appear to have the same shade of grey. Areas of higher average atomic number appear brighter and areas of lower atomic number darker (Watt, 1985, 66-69; Potts, 1987, 340-343).

The sample was analysed using an electron beam accelerated by a potential of 20kV. Following common convention the results are presented as oxides (Potts, 1987, 27-28). The results were normalized to a total of 100% to facilitate comparison between one analysis and another.

A typical BSE image of the ceramic fabric is shown in plate 8. Several of the areas and grains in this field of view (and others) were analysed.

A typical X-ray spectrum of counts per second plotted against energy is shown in plate 7. This spectrum is the result of analysing an area of the fine-grained ceramic matrix in an area apparently free of notable inclusions.

The raw data plotted in the spectrum are transformed by computer into numerical results, a few of which are listed in the table below. The results from spectrum 198 (the fine grained matrix) are fairly representative of other similar areas analysed. The uniformly high level of calcium found in even small areas of matrix is consistent with the optical appearance of the fabric as containing tiny grains of limestone throughout. Some calcium is also likely to be present as compensating cations associated with the clay minerals. Column 204 in the table is derived from analysis of another area of fine-grained matrix.

The large lighter coloured grain at the top left of plate 8 has a distinctly raised level of iron compared to the matrix. This grain is probably an iron-rich argillaceous inclusion. The inclusion is not homogeneous and within it can be found bright white grains. Analysis of one of these white grains gave the result shown in column 206 of the table. This grain is primarily iron oxide.

	198	204	206
MgO	0.8	0.5	0
Al_2O_3	13	12	3.0
SiO_2	57	60	2.1
K_2O	1.8	1.6	0
CaO	16	15	0.2
TiO_2	1.6	1.5	4.2
Cr_2O_3	0	0	0.4
MnO	0.4	0	0
FeO	8.9	9.1	90

In plate 8, the grain *ca.*300 micrometers wide below the large light grain gave a spectrum with only the calcium peaks visible. This would be consistent with it being a fairly pure limestone, the carbon and oxygen X-rays being absorbed the window of the detector before reaching the detector crystal.

The elongate grain at the bottom centre of plate 8 gave a spectrum that showed only silicon, consistent with that grain being one of the many quartz grains seen during the optical examination of the thin sections of the fabric.

Scanning electron microscopy plate captions

Plate 7.

This shows the X-ray spectrum from an area of fine-grained matrix from the Sidon fish or dolphin jar. X-ray counts per second are plotted against the energies of the X-rays. The spectrum comprises of an underlying continuum X-ray emission *(brehmsstrahlung)* upon which are superimposed characteristic X-ray peaks that indicate the elements present in the sample (by their position) and the amounts of the different elements that are present by the numbers of X-rays emitted by each element.

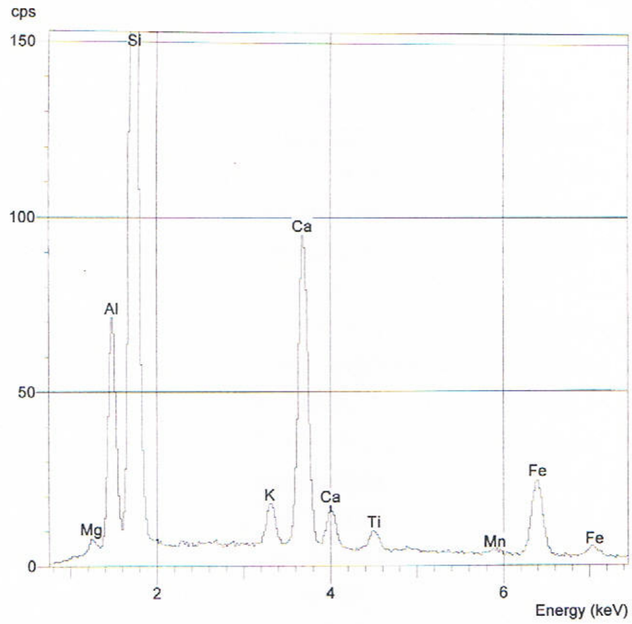


Plate 8.

A backscattered electron image of a part of the ceramic fabric of the Sidon dolphin or fish jar S/1785.

Conclusions

The fabric is consistent with the jar being of local manufacture although further research including sampling of geological clay deposits will be necessary to define possible areas of origin more closely.

The fabric of the Sidon fish or dolphin jar shares many of the characteristics of a fabric found throughout the Early Bronze Age layers at Sidon and labelled Fabric Group 2. The common characteristics include the fairly iron-rich calcareous fabric with rounded limestone inclusions, elongate voids, predominantly monocrystalline quartz inclusions, fossil fragments, chert and some chalcedony (Griffiths, 1999a; Griffiths, in press). There are also similarities with the fabrics of some of the other Middle Bronze Age Jars from Sidon (Griffiths, 2003).

From a methodological point of view, this study has illustrated the potential of SEM-EDS as a technique to be used in parallel with transmitted polarized light microscopy to provide complementary information that transmitted light optical microscopy alone cannot provide, including the elemental compositions of the fine-grained matrix, limestone inclusions, argillaceous inclusions, opaque inclusions and grains too small to identify with the optical microscope. With other samples, SEM-EDS could also be used to study slips and glazes (Griffiths, 1999b).

This is the first of the Sidon fabrics that has been studied by SEM-EDS as well as by optical petrology. In future it is hoped that it will be possible to apply the technique more widely to other ceramics and to samples of geological raw materials. The additional independent data the technique provides should be a valuable addition to the study of the provenance of ceramic (and other) objects, and a valuable tool in the search for a better understanding of cultural, technological and economic interaction in the Mediterranean region during the Bronze Age.

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