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The technological development of stonepaste ceramics from the Islamic Middle East

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ABSTRACT

The microstructures and chemical compositions of stonepaste bodies from the Islamic Middle East, typically produced from a mixture of ten parts crushed quartz, one part crushed glass and one part white clay, are investigated using analytical scanning electron microscopy. For comparison, replicate stonepaste bodies are produced in the laboratory at firing temperatures in the range 900–1200 °C, and are similarly examined. The stonepaste bodies are divided into four primary microstructural groups that reflect the increasing reaction during firing of the glass fragments with the clay and quartz particles. The observed microstructures are then used to assess the geographical and chronological variations in the production technology of stonepaste ceramics from Egypt, Syria, Iran, Uzbekistan and Turkey, spanning the period from 11th to 17th centuries AD.

1. Introduction

Stonepaste ceramics (also referred to as quartz-frit, fritware, and faience), which consist of a crushed quartz body bonded together by a glassy phase, were first produced in Egypt during the 11th century AD (Mason and Tite, 1994), and were subsequently extensively produced throughout the Islamic Near East, particularly for finewares (Kleinmann, 1987; Henderson, 1989; Agosti and Schweizer, 2002; Freestone et al., 2009). Abu'l-Qasim's treatise on the production of tiles and other ceramic objects in Iran, dating to about 1300 AD, describes stonepaste bodies as being made from some ten parts crushed quartz, one part crushed glass and one part fine white clay (Allan, 1973). In the production of ceramics from this mixture, the clay provided the plasticity necessary for forming the quartz-rich body, and then, during firing, reacted with the glass fragments and, to a limited extent, with the crushed quartz to produce interparticle glass that bonded together the quartz body. The result is a hard white body.

Mason and Tite (1994), in a study of the beginnings of Islamic stonepaste ceramic production, suggest that the first step in its evolution was the addition of glass fragments into the pottery clay bodies being produced at Baghdad in Abbasid Iraq during the 8th – 9th centuries AD. Next, after the move of potters from Abbasid Iraq to Fatimid Egypt during the later 10th century AD, proto-stonepaste ceramics, consisting of some two parts crushed quartz, three parts glass and five parts clay, were produced. Then, during the 11th century AD, true stonepaste ceramics, in which crushed quartz replaced clay as the major constituent and the proportion of glass was reduced, were produced. Subsequently, with the move of potters from Egypt towards the end of the 11th century AD, the stonepaste technology reached Iran and Syria, after which the great majority of fineware ceramics from the Islamic Middle East were stonepaste.

It is generally argued that the introduction of stonepaste bodies was inspired by a desire of the Islamic potters to imitate imported Chinese porcelains without the necessity of access to an abundance of white firing clays and to a high temperature firing technology

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(Mason and Tite, 1994; Tite and Wood, 2005). The fact that the monochrome incised wares produced in Fatimid Egypt in the 11th century AD are clearly imitations of *qingbai* porcelains supports this hypothesis. However, in the production of lustre ware in Egypt at this period, stonepaste bodies were used in combination with tin-opacified glazes which themselves provided a white background for the lustre decoration. Therefore, the predominance of stonepaste over clay bodies in the production of fineware ceramics from the Islamic Middle East probably also, in part, reflects the fact that quartz, as the major component of stonepaste bodies, was the same as far as the potter was concerned wherever it was found. Thus, when potters were moving from one area to another, quartz was a more "predictable" material than the local clays whose properties would have had to have been carefully assessed before use if they were to form the bulk of the body. In contrast, when clay made up only some 10 wt% of the body, there would have been greater flexibility in what were acceptable properties.

The aim of the present paper is to build on the earlier study of the beginnings of stonepaste production in Fatimid Egypt (Mason and Tite, 1994). The development of the microstructures of replicate stonepaste bodies with increasing firing temperature is first investigated by the examination of polished sections in a scanning electron microscope (SEM). On the basis of these results, the different microstructures observed in a range of stonepaste ceramics from across the Islamic Middle East, spanning the period from 11th to 17th centuries AD, are classified in terms of the surviving evidence of the original glass fragments and the extent of interparticle glass. These microstructures are then used to assess chronological and geographical variations in the production technology of stonepaste ceramics across the Islamic Middle East.

2. Experimental procedures

2.1. Samples

A group of 43 stonepaste ceramics from Fatimid and Mamluk Egypt and Syria; from Seljuk, Timurid, Turcoman and Safavid Iran; and from Ottoman Turkey were studied (Table 1). The sherds mainly either came from archaeological excavations or were surface finds. They were selected to be typologically diagnostic, and had previously been included in a comprehensive multidisciplinary study involving standard archaeological methods of typological analysis and ceramic petrography to investigate provenance (Mason, 1996, 2003; Mason and Golombek, 2003; Mason, 2004).

2.2. Determination of microstructures and chemical compositions

The ceramics were examined in polished cross-sections through the glazes and into the bodies in an analytical SEM (Cameca SU30) using the backscatter detector mode with which the different phases present can be distinguished on the basis of their atomic number contrast (e.g., quartz particles appear dark compared to the higher atomic number glass fragments and interparticle glass).

The bulk compositions of the ceramic bodies were determined by analysing areas up to about 0.3 mm × 0.3 mm using an energy dispersive spectrometer (EDS) attached to the SEM (Table 1). Bulk compositions of representative selections of surviving glass fragments and/or extended areas of interparticle glass in each of the ceramics were similarly determined. The compositions of the reaction zones surrounding surviving glass fragments and extended areas of interparticle glass, together with interparticle glass binding together adjacent quartz particles, were determined by point analysis (Table 2). The SEM was run at 20 kV and 10 nA with overall count times of 100 s. The relative errors for the analysis of the comparatively inhomogeneous stonepaste bodies were 5–10% for major and minor elements, and up to 15% for elements present at the 1% or less level. Comparison of the composition of the Corning A glass standard as published with that determined by EDS analysis (Table 3) indicates that the relative errors for a homogeneous sample are well within the ranges for the estimated errors for the stonepaste bodies. The detection limits were about 0.1 wt% for the elements sought.

2.3. Laboratory replication of stonepaste bodies

Replicate stonepaste bodies were produced from a mixture of (a) ten parts crushed quartz with grain sizes in the range from less than 63 μm–125 μm; (b) one part white bentonite clay; and (c) one part crushed glass with grain sizes in the range 100–300 μm. Three types of glass were prepared. The first was a high lead glass produced by firing lead bisilicate ($PbSi_2O_5$) to about 800 °C for some 30 min, its approximate chemical composition being 33 wt% silica, 62 wt% lead oxide and 5 wt% alumina. The second was a lead-alkali glass produced by firing a quartz-lead bisilicate-sodium carbonate-calcium carbonate-talc mixture to about 1050 °C for some 60 min, its approximate chemical composition being 67 wt% silica, 13 wt% lead oxide, 10 wt% soda, 9 wt% lime-plus-magnesia and 1 wt% alumina. The third was an alkali glass produced by firing a quartz-sodium carbonate mixture to about 1000 °C for 60 min. The approximate composition of this third glass was 49 wt% silica and 51 wt% soda, and thus was comparable in composition to the mixture of 105 parts of *shukar-i sang* (i.e., quartz) and 100 parts of *shakhar* (i.e., plant ash) described in Abu'l-Qasim's treatise (Allan, 1973).

As a result of restrictions in available time, stonepaste body mixtures were prepared using only the high lead and the lead-alkali glasses. These two mixtures were moistened and moulded into small tablets (approx. 0.5 cm thick). After drying, the test pieces were fired in a gradient furnace to temperatures in the range 900–1200 °C with a heating rate of 10 °C/min above 600 °C, and a dwell time at maximum temperature of 60 min. The microstructures of the stonepaste bodies thus produced were examined in polished cross-section in the SEM.

3. Results and discussion

3.1. Replicate stonepaste microstructures

In the stonepaste bodies produced using high lead glass fragments, the fragments, which were originally homogeneous with no crystalline phases (Fig. 1(a)), have developed central pores, and the glass has started to react with the quartz and adhering clay to form interparticle glass after firing to 900 °C (Fig. 1(b)). Subsequently, the extent of the interparticle glass was sufficient for the quartz particles to form an interconnecting network throughout the body after firing to 1000 °C, by which time glass fragments only survive as extended areas of interparticle glass (Fig. 1 (c) and 1 (d)).

In contrast, in the stonepaste bodies produced using lead-alkali glass fragments, the reaction of the glass fragments, which originally contained extensive crystalline phases (Fig. 2(a)), with the quartz and adhering clay appear to be minimal after firing to 900 °C, although central pores have started to develop within the fragments (Fig. 2(b)). After firing to 1000 °C, reaction between the glass fragments and the quartz-plus-clay has definitely started, the central pores have increased in size, and the fragments have begun to lose their original shape. However, the extent of the interparticle glass was still limited (Fig. 2(c)). As the firing temperature was further increased, the glass fragments progressively lose their original shape and only survive as extended areas of interparticle glass (Fig. 2 (d) and 2 (e)). After firing to 1200 °C, the extent of the interparticle glass has increased sufficiently to form an interconnecting quartz-glass