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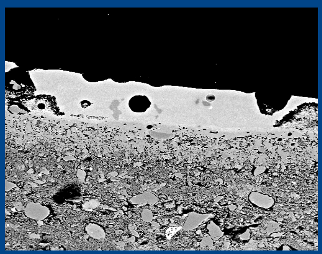

A Technological Examination of Some Chinese Ceramics

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Four sherds from the Belitung wreck were examined for this study. Much of the ship's cargo came from China, probably from the great trading city of Yangzhou in Jiangsu province, where ceramics were collected for export from both north and south China, via the Grand Canal and the Yangzi River. The cargo appears to have been destined for the Middle East, either through direct sailing or through transhipment. The wreck dates from a time when imported Chinese wares transformed the course of Middle Eastern ceramic history. White porcelains from north China in particular were imitated by Mesopotamian potters using pale calcareous earthenware bodies, and glazes opacified by tin oxide. Green- and white-glazed Chinese stonewares from both north and south China were also copied in the Middle East during this period, again using the newly developed tin-glazed earthenware technology.[1] Chinese forms and ornament also influenced Islamic ceramics at this time, most notably the northern white ware bowl-form with a *bi*-disc foot, and the broad and abstract styles of glaze decoration used on polychrome stonewares from such sites as Changsha in south China. Stonewares from the Changsha kilns made up the bulk of the ceramic cargo of the ninth-century wreck, although not all these Changsha wares may have been destined for the Middle East.[2,3]

Analytical techniques

All four sherds were examined using a Cameca SU30 scanning electron microscope (SEM) fitted with both Energy Dispersive and Wavelength Dispersive X-ray analysers (EDA and WDA). Slips and bodies were examined using quantitative EDA, using a de-focussed beam, whilst WDA was employed for point-analysis of the glazes. Typical operating conditions were 13Kv and 10na, with 200 seconds count time for EDA, 10 seconds for WDA.

Whilst EDA analysis of the bodies provided a general major element characterisation, full characterisation of 29 major and trace elements was employed on bulk body samples using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP–AES). Samples were prepared by dissolution in HF, and were analysed at the NERC facility at Royal Holloway College, University of London.

1 Mason and Tite 1994; Mason and Tite 1997.

2 Fleming et al. 1992; Ho Chuimei and Bronson 1987.

3 Allan 1991, 6–9; cf. also in this volume p. 356, 469.

The sherds

Three of the sherds sent for study were white wares, while the fourth was clear-glazed with a green glaze over its rim and a green-glaze splash on its inner surface. The glazes on the green-and-white sherd were found to be of the earthenware type and rich in lead oxide, although the body material was stoneware. The three white ware glazes proved to be high-temperature compositions, had dull surfaces and were somewhat etched by seawater. Although relatively high-fired, two of the four bodies examined appeared to be very porous, suggesting that the original body materials were rather refractory. A third showed greater firing maturity, while the fourth was thoroughly vitrified.

General body composition

On the broadest compositional level, all four sherds submitted for analysis appear to be from north China. Three were stonewares, while the fourth was a large piece of a slightly translucent porcelain cup. The main evidence for the northern origins of these samples lay in their high alumina levels (> 29% wt. Al_2O_3), a feature that has been accepted as characteristic of north Chinese ceramics since the pioneering work of Sundius and Steger in 1963.[4] These authors demonstrated that high-fired north Chinese ceramics are rich in clay (and consequently high in alumina) while their southern counterparts were rich in silt-grade quartz, and therefore siliceous, with correspondingly low clay and alumina levels. This trend has since been confirmed by hundreds of analyses of Chinese high-fired wares, carried out in both China and in the West.[5] Some essential differences between these two types of high-fired body can be seen in tables 1–3.

It has been suggested that the profound and consistent compositional disparity that is so evident between northern and southern high-fired ceramics in China may be the result of the two

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO
Sherd A	65	30.65	1.65	1.01	0.37	0.31	0.73	0.22	0.04	0.01
Sherd B	64	30.43	1.12	0.92	0.34	0.62	1.76	0.35	0.04	0.01
Sherd C	61	29.38	2.01	1.10	2.45	1.00	2.18	0.86	0.05	0.02
Sherd D	64	30.76	0.48	0.26	1.37	1.36	0.52	1.21	0.03	0.01

Table 1 ICP body analyses of the four Chinese sherds from the Belitung wreck (silica by difference).

4 Sundius and Steger 1963, 433; Guo Yanyi 1987, 13.

5 Two of the largest studies of Chinese ceramic bodies are Luo Hongjie 1996 and those made at the RLAHA Oxford (unpublished).

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Kiln Site & Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	Province
Xing body, Tang	69.9	25.1	0.2	0.6	0.9	1.6	0.9	0.9	Hebei
Xing body, Tang	68.0	27.0	0.3	0.6	0.8	1.5	0.9	0.9	Hebei
Xing body, Tang	67.6	28.5	0.4	0.75	0.6	0.7	0.75	0.2	Hebei
Ding body, Tang [6]	59.8	34.5	0.7	0.4	1.1	0.9	1.25	0.7	Hebei
Ding body, Tang [7]	59.8	29.9	0.9	0.4	4.8	0.9	1.7	1.1	Hebei
Gongxian body, Tang [8]	63.1	30.3	1.3	1.2	0.5	0.5	2.0	0.5	Henan
Gongxian *sancai* body [9]	63.8	29.8	1.4	0.9	1.6	0.6	0.7	1.2	Henan
Yaozhou *sancai* body [10]	65.9	27.85	1.15	1.2	1.5	0.5	1.3	0.5	Shaanxi

Table 2 Typical Tang dynasty stoneware, porcelain and *sancai* ware bodies from north China.

Kiln Site & Date	SiO_2	Al_2O_3	Fe_2O_3+ FeO	TiO_2	CaO	MgO	K_2O	Na_2O	Province
Changsha, Tang [11]	74.2	19.5	2.1	1.0	0.2	0.5	2.4	0.1	Hunan
Qionglai, Tang [12]	75.4	16.1	3.2	1.0	0.25	0.9	2.1	0.4	Sichuan
Ningbo, Tang [13]	76.9	15.8	3.2	1.0	0.3	0.6	2.65	1.0	Zhejiang
Yixing, Tang [14]	71.9	20.1	3.3	1.0	0.5	0.7	2.2	0.6	Jiangsu
Jingdezhen, 5 Dynasties [15]	75.2	16.9	3.6	1.2	0.4	0.6	2.4	0.1	Jiangxi

Table 3 Typical Tang and Five Dynasties stoneware bodies from south China.

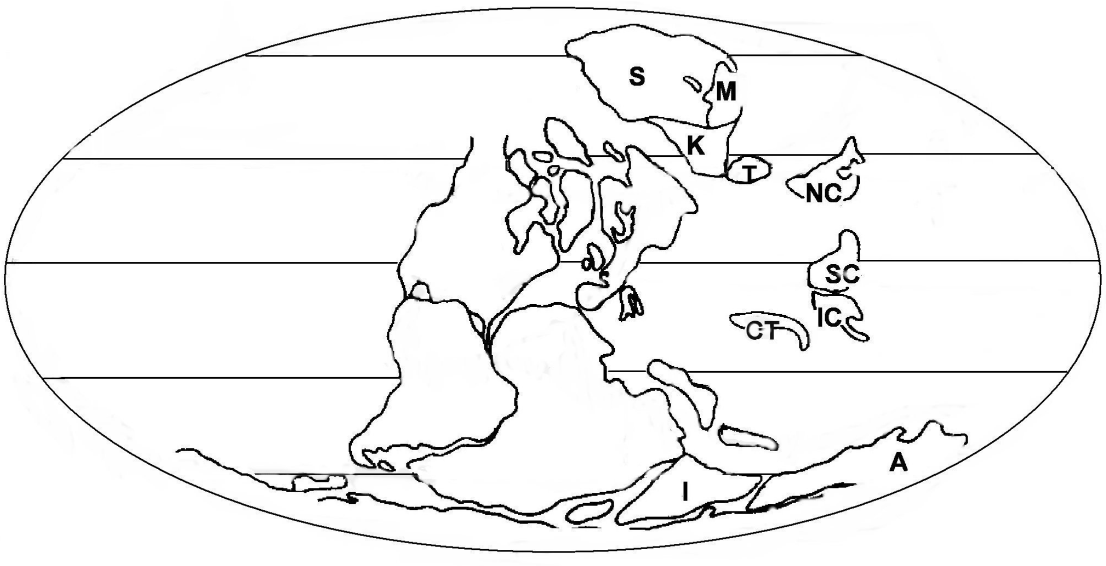

Fig. 1 North China (NC), South China (SC), Indochina (IC), and Central Tibet (CT) during the Permian Period (290–248 MYA) before the fusion of East Asia in the Triassic Period (248–209 MYA). Developed from Xu Guirong and Yang Weiping 1994, 163, fig. 8.1 (S is Siberia, M, Mongolia, K, Kazakhstan, T, Tarim, A, Australia and I, India).

6 Li Guozhen and Guo Yanyi 1986, 136, table 1.

7 Ibid.

8 Li Jiazhi et al. 1986, 130, table 1.

9 Li Guozhen et al. 1986, 77, table 1.

10 Ibid.

11 Chen Xianqiu et al. 1989, 314, table 2.

12 Zhang Fukang 1989, 63, table 1.

13 Guo Yanyi et al. 1980, 235–236, table 2.

14 Ibid.

15 Ibid.

areas' once having been separate tectonic blocks, with very different geological histories.[16] These merged during the Triassic period, 248–209 million years ago, to form China's present landmass (figs 1, 2).[17] When high-fired clay compositions are plotted on the present tectonic domains of north and south China their aluminous/siliceous distributions conform closely to the outlines of these ancient mini-continents (fig. 2).

16 Wood 2000, 15–16.

17 Xu Guirong and Yang Weiping 1994, 163, fig. 8.1.

Fig. 2 Map of China showing its main provinces, Tang kiln sites, the city of Yangzhou, and lines representing the fusion of its ancient tectonic blocks (heavy lines). All stoneware and porcelain bodies of Tang dynasty date, from the kiln sites identified on the map above the main division, contain more than 25% alumina, while those below the line contain less than 22% alumina.

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The four sherds in detail

Having established that all four sherds were typical of north Chinese kiln sites, the glaze, slip and body analyses were used to investigate the technologies that had been used to make them. The sherds, as received, were labelled A, B, C and D, so discussion of the results will take this order.

Sherd A

This is a large sherd (about 170 mm long, 55 mm wide, and about 6mm thick), probably from a bowl or dish with a diameter of about 230 mm. The body material is very white and rather porous, with some small pale grey areas where the body is thickest. These cloudy grey patches appear to be residual carbonaceous material, probably present in the clay when mined. A white slip is present between body and glaze. The glaze has flaked from the rim, and there is evidence of ancient spiral cracking in the body, with one long crack apparently recently repaired with glue. Further fine cracks in the glaze radiate from this fracture. However another body crack of the same type is simply discoloured, has not been broken or repaired, and the body still just holds together.

GLAZE A: The glaze is pale, straw-coloured and transparent, with cracking on the margins of the body fractures, and also where the glaze has flaked from the rim. Its very low titania level shows that little or no body or slip-clay was used in its original recipe. This distinguishes the glaze

SHERD A	SiO_2	Al_2O_3	FeO	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	PbO	CuO	SO_2	Total
Sherd A Glaze (WD)	65.3	14.7	0.75	0.09	11.3	0.8	2.3	1.4	0.5	-.-	0.03	0.04	0.02	97.32
Sherd A Slip (ED)	41.8	30.3	0.6	0.7	0.2	1.8	-.-	-.-	-.-	-.-				
Sherd A Body (ICP)	65.0	30.65	1.65	1.01	0.37	0.31	0.73	0.22	0.04	0.01				

Table 4: Glaze slip and body analyses of Sherd A.

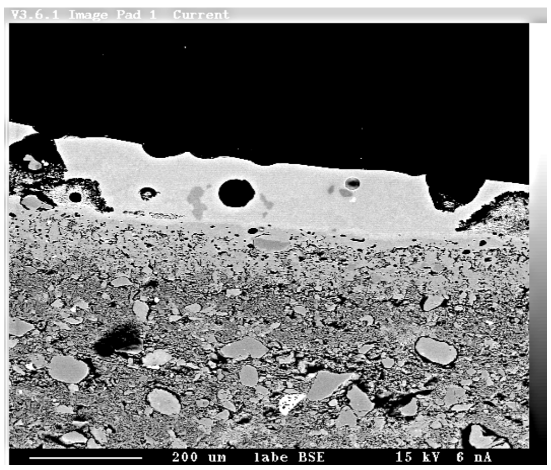

Fig. 3 Sherd A – The glaze is weathered and part of the outermost layer has detached. A 200 micron thick slip is seen, the outer part of which has reacted with the glaze and shows a corresponding higher (lighter grey) backscatter response.

quite clearly from Tang glaze-making practices in southern China, where the body clay, or a closely related material, was usually the main glaze ingredient (*c.* 60–65% of the glaze's weight). The use of a quite separate material from the body as the basis for the glaze is an advanced feature of glaze construction pioneered in the north.

From the composition of the glaze, and from its apparent maturity, the original firing of this vessel can be assessed as about Orton Cone 9.[18] At a finishing rate of some 15°C an hour this represents about 1224°C. At a finishing rate of 150°C an hour its final firing temperature would have about 1290°C. From what we know of the slow firing natures of northern *mantou* kilns, *c.* 1224°C may be the more realistic figure (fig. 4).[19]

Glaze colour suggests oxidized firing, with the colour deriving largely from Fe^{3+} ions. The glaze composition is essentially of the lime to lime-alkali type, typical of the late Tang period in north China. Phosphorus oxide levels suggest the use of botanic ash in the glaze recipe, and most of the calcia in Glaze A probably came from this source. Analysis therefore suggests that the glaze may have been made largely from a ground acid rock of high purity with additions of wood or plant ash, and a minor amount of clay. This use of a low-titania raw material as the basis for glaze-making seems to have been pioneered at white ware kiln sites in north China in the Tang dynasty. The technology later became an essential technique for the creation of such celebrated northern reduction-fired glazes as those used on Yaozhou Five Dynasties green wares, and the Ru

18 Wood 1999, 263. Glaze 2 (ibid.) has a very similar composition to Glaze A, and fires to between Orton Cone 8 and 9.

19 Shui Jisheng 1989. Shui's report refers to coal-fired *mantou* kilns. Wood-fired *mantou* kilns (as used in north China in the Tang dynasty) would have fired slightly faster, but still no faster than the rate suggested above.

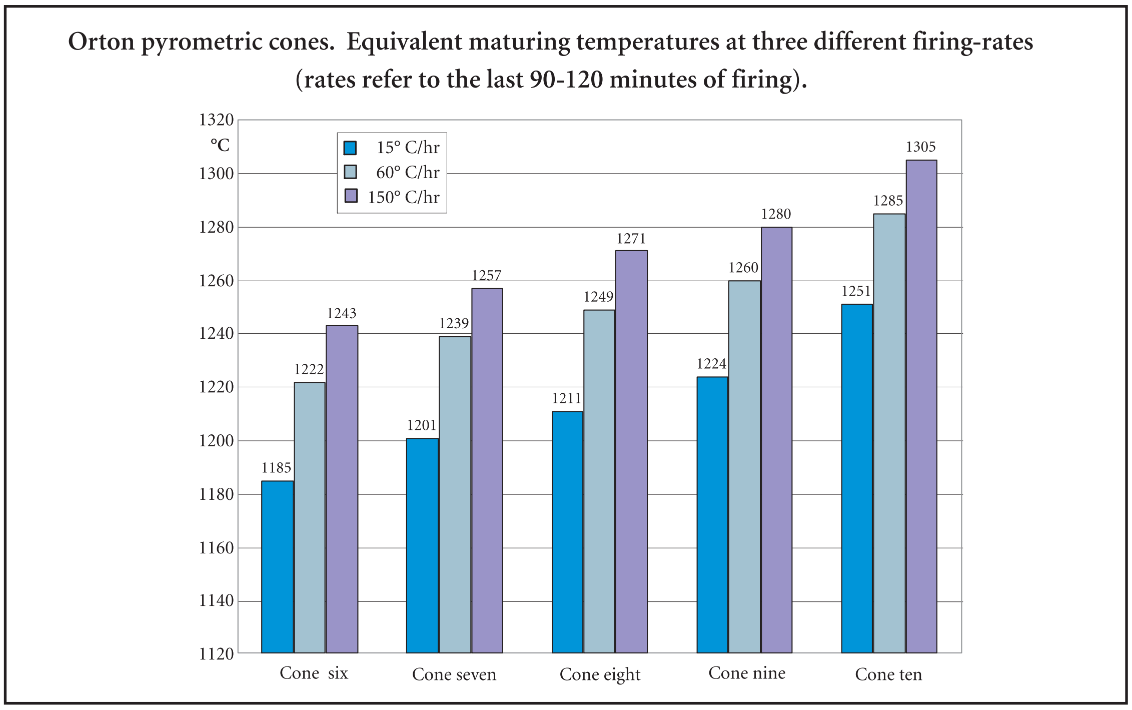

Fig. 4 The effects of firing-rates on ceramic maturity, represented by Orton pyrometric cones.

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and Jun wares of the Northern Song dynasty.[20] With thicker glaze application and reduction firing, the glaze on Sherd A would have produced a high-quality celadon. However, it was some time before these possibilities were fully explored in north China and, in the present case, the analysed composition simply gave a clear, slightly yellowish glaze.

SLIP A: ED analysis (table 4) suggests a very high-clay material, low in alkalis and low in colouring oxides (Fe_2O_3+TiO_2). However, the moderate titania level in the slip suggests the use of a secondary rather than a primary kaolin. The slip contains half the amount of iron oxide found in the body, hence its employment as a white ground for the glaze.

BODY A: The iron (1.65%) and titanium (1.0%) oxide levels in the body of Sherd A show the material to be a white stoneware rather than a true porcelain. Its relative immaturity after firing is due to two effects: First, the material's having been fired towards the lower stoneware range (see glaze notes above), and second, the high refractoriness of the body material, with a total flux-level (RO+R_2O) of only 1.63%. This refractoriness shows up clearly in the SEM, where little body glass is evident and much of the fired material retains its original morphology (fig. 5). This bowl seems to have suffered from the ceramic faults known as 'shivering' and 'spiral cracking', usually caused by the body's shrinking appreciably more than the glaze through the last stages of cooling.[21] Thus the cracks in the glaze may not be caused by tension (i.e. conventional crazing) but by compression. These compressive effects may take days or weeks to develop, so the vessel may well have been sound when it left the kiln. Although excess cristobolite is the usual cause of shattering no cristobolite was evident in the SEM studies of the body. However the lack of any

20 Wood et al. (forthcoming).

21 Hamer and Hamer 1997, 301–302.

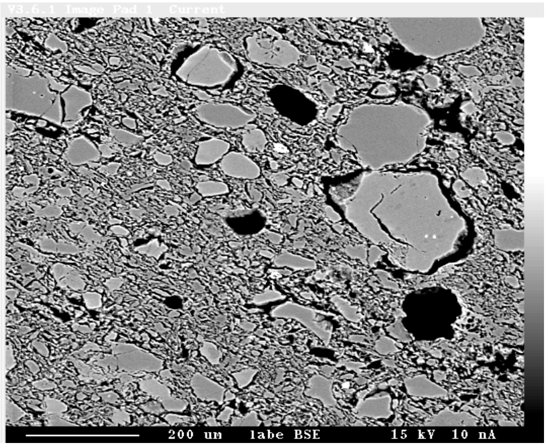
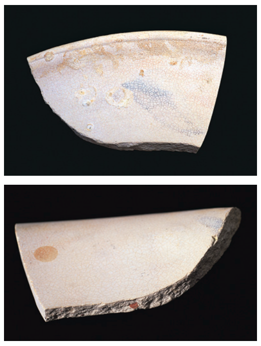


Fig. 5 Sherd A – showing good preservation of original constituent grains, quartz (dark grey) and clay (lighter grey). There is only a minimal development of a glass phase, restricted to grain edges. Note the retained angular morphology of much of the fine grains. Bright grains are zircon and rutile.

glassy phase in the body made any visual identification of cristobolite difficult.

Sherd B

This is also a sherd from a white ware bowl bearing a white slip beneath its glaze. The sample is about 100 x 45 mm maximum and about 6–8 mm thick. It may be from a bigger bowl than Sherd A, but as its rim is slightly distorted it is hard to assess its original size. The glaze is very white, but has also become very etched, with an eggshell surface and fine-scale crazing. There is some minor flaking from the rim, but no cracking of the body. There appears to be a fairly thick layer of slip (0.3–0.5 mm). The colour of the slip layer is the same as the body, but finer in texture. There are occasional reddish granular inclusions in the main body that are absent from the slip, and also some cloudy grey areas where the body is thickest. These cloudy areas again appear to be the result of carbonaceous material in the clay that has not been burned out in firing. Because of its highly weathered nature the glaze could not be analysed quantitatively, but was shown to be free from lead.



SHERD B	SiO_2	Al_2O_3	FeO	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	PbO	CuO
Glaze B -- too weathered to analyse												
Sherd B slip, scan 1 ED	60.7	36.3	0.5	0.9	0.1	-.-	1.4	0.2	0.1		-.-	
Sherd B slip, scan 2 ED	64.2	31.0	0.1	0.0	0.2	-.-	3.6	0.6				
Sherd B body, scan 1 ED	61.2	32.0	1.0	0.9	2.5	-.-	1.5	1.2	-.-		-.-	
Sherd B body, scan 2 ED	65.6	31.5	0.03	0.7	0.06	-.-	2.7	0.4	-.-		-.-	
Sherd B Body ICP	64.0	30.4	1.1	0.9	0.3	0.6	1.8	0.35	0.04	0.01		
(Sherd A Body ICP)	(65.0)	(30.65)	(1.65)	(1.01)	(0.37)	(0.31)	(0.73)	(0.22)	(0.04)	(0.01)		

Table 5 Slip and body analyses of Sherd B.

SLIP B: The material seems similar to the body, but with lower iron oxide levels. With enough heat this white slip would have made a porcelain material.

BODY B: Compositionally, Body B is superficially similar to Body A, with its lack of fired-maturity due mainly to unusual low levels of body-flux. The reddish inclusions suggest either inferior preparation or an altogether different raw material. Differences in the trace element compositions of Body A and Body B may suggest the latter (table 6).

	Ba	Co	Cr	Cu	Li	Ni	Sc	Sr	V	Y	Zn	Zr	La	Ce	Nd	Sm	Eu	Dy	Yb	Pb
Sherd A	151	2	107	19	76	23	19	112	107	38	18	309	58	115	62	10.3	1.6	7.5	4.4	36
Sherd B	354	3	65	37	167	21	15	115	89	18	51	133	127	220	124	12.9	1.4	5.2	2.1	22

Table 6 Trace element concentrations in bodies A and B.

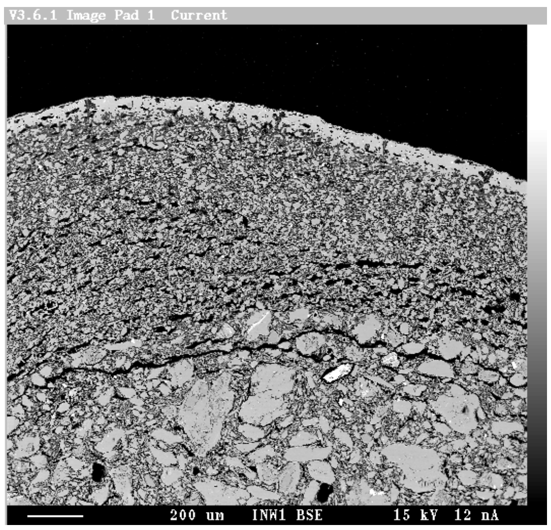
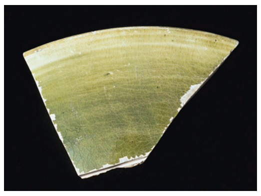


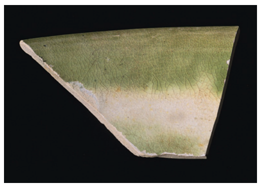
Fig. 6 Sherd B – The body contains angular clay clasts, indicating minimal glass formation. The body–slip contact is very well defined. The glaze has been lost except for part of the interaction layer. The majority of clasts in the body are of unfused clay.

Sherd C

Sherd C also appears to be a high-fired sherd with a pale body, although it is marginally less white than Sherds A and B. At its maxima it measures 100 mm by 500 mm, and the body averages 5 mm thick. The rim of the sherd curves slightly more than Sherds A & B, suggesting an original diameter for the bowl of about 160 mm. Its glaze is shiny, well preserved and crazed, although not so minutely as the glaze on Sherd B. The most obvious feature of the sherd is the yellowish-green glaze. This covers the outside of the sherd, half the inside, and with a further splash towards the bowl's centre. The green glaze appears to have been applied over a clear glaze of a similar type. There is a very thin white slip under the glazes, inside and out, and this is most obvious where the glazes have flaked from the body. The body contains occasional reddish inclusions, but these are much smaller than those in Sherd B. The body also contains numerous round pores. No cloudy grey areas are present.

GLAZE C: Glaze C is a low-firing lead glaze coloured with Cu^{2+} ions. It represents the kind of lead glaze used on wares of the late Tang dynasty excavated in Samarra in Iraq, and analysed and discussed by Rawson, Tite and Hughes in 1987–88.[22] Rawson et al. found that glazes, essentially similar to those used earlier in the Tang dynasty (late seventh–eighth centuries) for burial wares, at sites such as Chang'an and Luoyang, were later applied to stoneware bodies for export to the Middle East in the late ninth or early tenth century. They suggested Gongxian in Henan province as one source, but also mention the Xing kilns in Hebei province as another possible manufacturing centre.[23] The lead glazes examined by Rawson et al. had been applied to bodies already fired to low stoneware temperatures (*c.* 1200°C). The glaze on sherd C is slightly





22 Rawson et al. 1987–88, 44, table 1; see also the discussion in this volume pp. 239–240.

23 Ibid., 49–51.

SHERD C	SiO_2	Al_2O_3	FeO	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	PbO	CuO	SO_2
Sherd C Green glaze WD	40.3	9.6	0.35	0.4	0.9	0.5	0.7	0.3	0.05	-.-	42.9	1.4	1.4
Sherd C Slip ED	51.2	43.3	0.9	0.8	1.2	3.1	0.5	-.-					
Sherd C BODY ICP	61.0	29.4	2.0	1.1	2.45	1.00	2.2	0.9	0.05	0.02			
Sherd C Body ED	64.6	30.3	1.0	0.3	2.3	-.-	1.4	0.6					

Table 7 Glaze, slip and body analyses of Sherd C.

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lower in lead oxide than those reported in the 1989 paper, but copper-coloured lead glazes are rather prone to heavy-metal leaching so the original lead oxide content of this glaze may once have been higher.[24] The sulphur level in the glaze may represent some kind of environmental attack, or it may reflect the source of the lead ore, i.e. galena (PbS).

The idea for using green lead glazes on overall transparent lead-glaze coatings can be traced to burial wares of the Northern Qi period in north China,[25] before the style became a mainstay of the High Tang *sancai* tradition.[26] In the later Tang dynasty white wares with green stripes or splashes were made by stoneware potters in both north and south China, and this in turn became one of the ceramic styles borrowed by potters in Iraq in the ninth century (cf. below pp. 230–240).

Three separate techniques for achieving this green-and-white effect can be seen in Chinese wares exported to the Middle East during this period. The two northern methods were transparent green lead glazes over transparent straw-coloured lead glazes (as in the present sample) and transparent green stoneware glazes over transparent stoneware glazes. In the south it was more usual to use opaque green stoneware glazes over opaque white or yellowish stoneware glazes, and the Changsha kilns in Hunan province and the Qionglai kilns in Sichuan province both used this 'opaque glaze' method.

SLIP C. The slip is obviously purer than the body it covers, but less pure than that used on Sherds A and B. The magnesia content of the slip seems unusual but may simple be due to the single point-scan's taking in a magnesia-rich mineral grain. The slip is obviously very high in true clay minerals of the kaolinite type, with little free quartz.

BODY C. The body is the least pure and the highest in body-fluxes of the four examined, which must account for its more developed maturity. Its high RO level (CaO 2.45% and MgO 1.0%) may represent the presence of dolomite ($CaMg(CO_3)_2$) in the original body mixture.

24 See Wood et al. 1992, 133, for an account of heavy metal depletion and sulphur enhancement in Chinese Han dynasty lead glazes.

25 Yang Gen et al. 1985, 85, plate 82.

26 Zhang Fukang 1987; Zhang Fukang 1989; Li Guozhen et al. 1986.

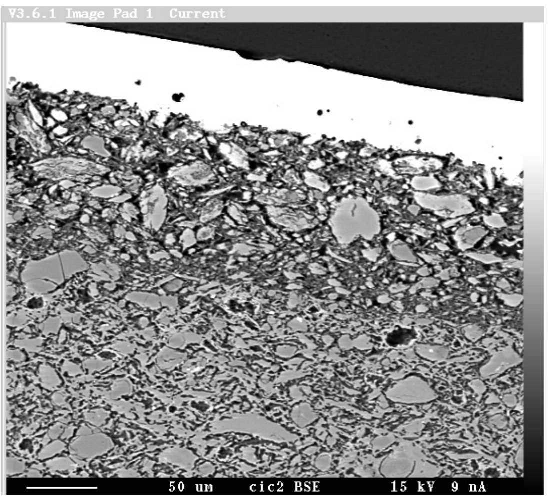


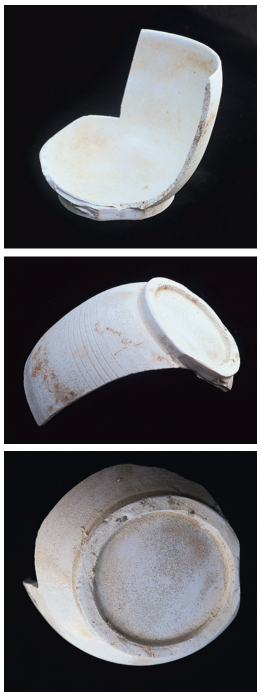
Fig. 7 Sherd C – The high backscatter response (white) of the glaze is due to its being a lead glaze. Interaction with the slip has not resulted in penetration of the glaze, and the lack of any extensive glass phase has meant that slip has been mechanically weak during polishing. By comparison, the body shows more advanced vitrification and has not deteriorated during polishing. The body of the sherd has a texture characterised by numerous elongate pores. Whilst this indicates significant vitrification, the glass phase is still minimal, being restricted to contacts between adjacent clay and quartz grains.

Sherd D

Sherds A, B and C are from reasonably large bowls and are relatively thick in section. By contrast, Sherd D is from a finely-made handle-less U-shaped cup of a form that had been used in China from the sixth century onwards, and which also occurs in Chinese silver, bronze and jade.[27] The cup is 65 mm tall and 89 mm in diameter at the top. Its turned foot is 52 mm in diameter outside and 42 mm inside (i.e. the foot ring is 5 mm across). The glaze is applied overall, and also within the foot ring. The extreme base of the foot is unglazed. The body is very thin (2–3 mm) and in strong sunlight the cup shows a slightly orange translucency in its thinner regions. The body is white, finely sugary, but bears no white slip, inside or out. The glaze is badly degraded on the outside, but a few outside areas show some glossiness where the glaze was originally thicker. The glaze inside is better preserved and is of a pale straw colour, very thin, and with numerous, fine, trapped bubbles. The bubbles have acted as weathering centres, dulling the glaze's originally gloss. This large cup-fragment appears to be the highest quality object in the group.

GLAZE D: The glaze on the porcelain cup is a lime glaze of exceptional purity, as shown by the very low levels established for Fe_2O_3 and TiO_2. This is very much a feature of north Chinese porcelain technology. Although this glaze composition is similar to that on Sherd A, Sherd D's body shows signs of far more advanced vitrification. This is evident in the high percentage of glass, spherical bloating, pores, and spherical expansion fractures centred on residual quartz cores, in the fired material (fig. 8). Sherd D contains nearly three times as much body-flux as Sherd A, and this high level of glass-forming material has encouraged a slight translucency in the material.

As with Glaze A, the P_2O_5 figure suggests the use of wood or plant ash in the original glaze recipe. The high calcium oxide figure in this glaze may suggest that the cup came from the Xing kilns rather than the Ding kilns, as calcia levels in Ding glazes rarely exceed 6% CaO, even at this early



27 See Vainker 1991, 62 and fig. 44.

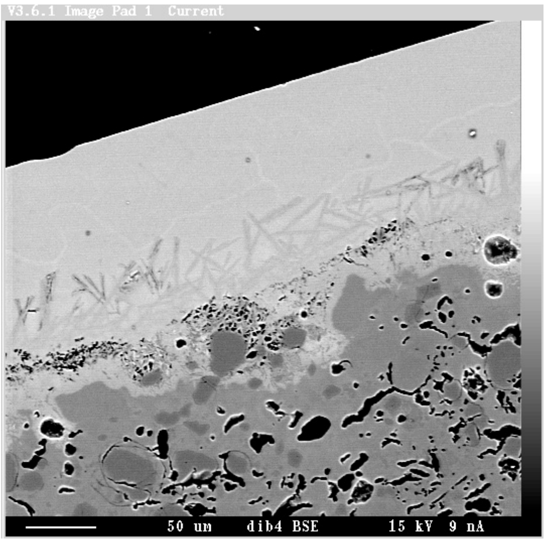


Fig. 8 Sherd D – There is no slip between glaze and body. Interaction has produced a fringe of acicular anorthite crystal extending into the glaze and lobate intrusion of glaze into the body.

period. Long firing is indicated by the presence of lime feldspar at the body/glaze interface (fig. 8).[28]

BODY D: No slip was used on this vessel, presumably because of the high purity of the raw material. As with all the examples studied, this is an aluminous (high clay) body, fluxed with about equal percentages of calcium, magnesium and sodium oxides. It is an example of the earliest type of Chinese porcelain – the world's first. It anticipates by nearly nine hundred years European porcelain bodies, such as those used at the Vienna factory in Austria in the early eighteenth century (table 8).

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	PbO	CuO	SO_2	Total
Sherd D glaze WD	63.5	14.2	0.3	0.06	14.7	3.6	0.30	1.0	0.4		0.05	0.02	0.01	98.3
Sherd D body ED	64.9	31.9	0.3	--.--	1.1	0.3	0.3	1.4						
Sherd D body ICP	64.0	30.8	0.5	0.26	1.4	1.4	0.5	1.2	0.03	0.01	(RO – flux -- total 4.5%)			
Sherd A Glaze WD	65.3	14.7	0.75	0.09	11.3	0.8	2.3	1.4	0.5	-.-	0.03	0.04	0.02	97.32
Sherd A	65.0	30.65	1.65	1.01	0.37	0.31	0.73	0.22	0.04	0.01	(RO – flux – total 1.63%)			
Vienna porcelain [29]	61.5	31.6	0.8		1.8	1.4	2.3							

Table 8 Glaze and body analysis of Sherd D and glaze and body of Sherd A for comparison.

28 For early Ding and Xing glaze analyses see Chen Yaocheng et al. 1989, 222–225; Li Guozhen and Guo Yanyi 1986, 136, table 1.

29 Brongniard 1844, tome 2, 386.

Summary

All of the four sherds examined had high-fired bodies. Three bore high temperature glazes, while the fourth was covered with low-firing lead glazes. However this lead-glazed sherd had already been fired, unglazed, to stoneware temperatures. All four examples examined were made from aluminous clay materials, two of which were extremely refractory and consequently still very porous, even after their stoneware firings. These clay bodies were all typical of Chinese ceramics made within the ancient tectonic domain of the North China block. The two high-temperature glazes that we examined were unusually low in the colouring oxides of iron and titanium. This is also a feature characteristic of Tang ceramics in north China, and is due to little or no use being made of the vessels' body materials in their original glaze recipes – a very different approach to that practised in the south. Another typical northern feature appears in the use of white slips, often on bodies that were already relatively white-firing. However, in the case of the porcelain sherd the purity of the material made a white slip unnecessary. At the time that the Belitung ship sank (mid-ninth century) the only porcelain produced in China was made in the north, and this is a very interesting example from this period.

These four high-fired wares from north China were part of a very mixed cargo of Chinese ceramics recovered from the Belitung wreck. Other styles of Chinese wares found on the wreck included a few rare examples of northern white wares decorated with underglaze cobalt blue (nos 107–109), many early southern celadon wares (see below pp. 352ff.), and huge quantities of decorated Changsha wares (see below pp. 466ff.). Examples of these latter three ceramic styles were not available for study. Nonetheless, the four sherds examined here represent some of the most advanced and sophisticated ceramics manufactured in the world in the ninth century – and are the kind of materials that provided models for the developing tin-glazed earthenware tradition in Iraq during the Abbasid period.[30] The porcelain sherd in particular represents a material of such advanced constitution and manufacture that its ceramic properties were not matched in the West until the second decade of the eighteenth century.

30 Mason and Tite 1997, 48–52.