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Source: *Muqarnas*, Vol. 9 (1992), pp. 67-71

Published by: BRILL

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LEAD-ISOTOPE ANALYSIS OF ISLAMIC GLAZES: AN EXPLORATORY STUDY

A significant number of Islamic ceramic types contain lead in the glaze. Lead is used as a flux to lower the melting temperature of quartz, thus enabling it to flow and so form a glaze. Glazes opacified with tin also contain lead.¹ Although it is technically feasible to have a tin-opacified alkali glaze, the technique of the medieval Islamic potters dictates that such glazes are never found.² Lead-isotope analysis is a technique that is often applied to leads, ores, and metal artifacts, but has only rarely been applied to lead-rich glazes. Use of this technique enables the origin of the lead to be identified, providing there are data from the original lead mine and the material in the artifact has not been mixed with leads of other sources.³

This study was initiated as part of a program of study of Islamic ceramics at the Royal Ontario Museum's West Asian Department, as it was hoped that the isotopic data might give some indication of the provenance of the ceramics. Other techniques, specifically petrographic analysis, have proved to be far more effective for this purpose.⁴ The lead-isotope study has, however, produced some interesting results and has methodological pertinence which should be of interest to others.

Lead-isotope analysis. An atom is constructed of a dense nucleus composed of protons and neutrons, surrounded by a cloud of orbiting electrons. Electrons carry a negative charge, protons carry a positive charge, and neutrons are neutral. Protons and electrons, having opposite charges, are mutually attractive, and the forces between these particles bind them together in an atom and also bind atoms together into solid matter. Many elements have atoms with different numbers of neutrons in their nuclei. These nuclei have different atomic weights but very similar chemical properties; they are called isotopes. Some isotopes are unstable and decay at measurable rates. This kind of decay provides the basis of carbon-14 dating, in which the unstable ¹⁴C isotope changes to the stable ¹⁴N (Nitrogen-14) thus reducing in proportion to ¹²C. Lead isotopes are derived from a very slow decay of Uranium and Thorium isotopes (²³⁸U, ²³⁵U and

²³²Th to ²⁰⁶Pb, ²⁰⁷Pb and ²⁰⁸Pb respectively). Theoretically the isotopic ratio is related to the date of emplacement of the lead ore. Essentially the nature of the lead isotope "fingerprint" of a particular sample is carried by the ratios between the different isotopes within the sample. This is shown on a graph with values for ²⁰⁸Pb divided by those for ²⁰⁶Pb, plotted against ²⁰⁷Pb divided by ²⁰⁶Pb, as shown in figure 1.

Lead sources. To determine the origins of the lead, it is necessary to obtain isotopic data from deposits of galena (lead-sulphide, the most common ore of lead) for comparison with the ratios in the ceramic glazes. Some mines utilized in the Islamic periods were referred to in contemporary documents, but other mines may have escaped mention. Some deposits known as workable in the present day may have been worked in the past, but we may have no evidence of this. Furthermore we do not as yet have isotopic data from every possible lead source. So although we can plot several mines on the graph, some may not have been utilized in our period, whereas some of those that were in use are poorly represented, or not represented at all. Nevertheless sufficient information exists to show that lead sources were quite common across the Middle East, particularly in Iran,⁵ and so it would be quite easy to find a local source of lead for glazing purposes. Abu'l-Qasim writes in about 1300 that lead is found in many places, particularly Kirman and Yazd in central Iran; "Rum" (Rome or Byzantium, presumably from Anatolia); and from "the land of the Bulgars" which was then in the Volga area.⁶ Quite often "sources" of materials in these medieval texts simply refer to the last stage in the journey from the true source, before entering the political sphere of the writer. In about 1154 al-Idrisi refers to lead from Yazd being "traded far and wide."⁷ Coupled with trade in lead, the raw glaze in crushed form was also widely traded.⁸

Sample preparation. Of the eight samples of glazes processed so far in this study, most are from Royal Ontario Museum fieldwork in the Yemen. Table 1 lists the sam-

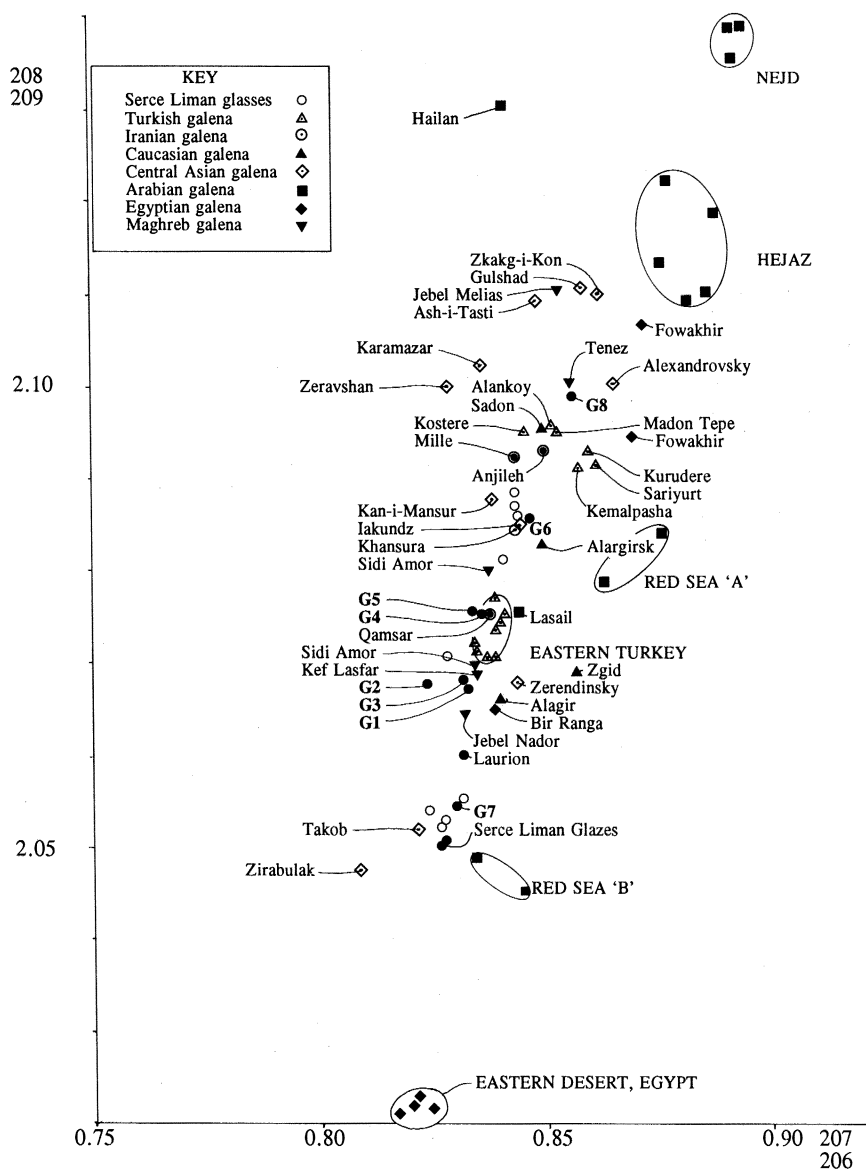


Fig. 1. Lead sources in the Middle East.

ples; they are mostly of widely recognized types and have all been published previously with their petrographic data.⁹ Dates are suggested more for the information of those not familiar with the types than for a contribution to the debate on Islamic ceramic chronology. The molded relief sample is of typical "Samarra" type as defined previously by Lane,¹⁰ is of good Basra petrofabric, and was recovered at al-Husseiniya in the Yemen. The sgraffiato, also of "Samarra" style as influenced by imports of Chinese "Sancai" ceramics, is of an unpro-

nanced Iraqi petrofabric, and is from Samarra, Iraq.¹¹ The Abbasid luster is an abraded bichrome sherd, but of good Basra petrofabric, and was recovered at Zabid, Yemen. Hatched sgraffiato is identical to Whitehouse's late or Style III sgraffiato,¹² as excavated at Siraf, which is shown by petrography as well as by stylistic analysis. The two Tihama wares were found at Zabid, the Zabid-produced pseudo-celadon being an imitation of Yuan forms, and the Hays Cup is associated with the introduction of small bowls for the consumption of coffee. The

Table 1. Samples tested

Sample	Date	Produced	Recovered
G1: Moulded Relief Ware	8– 9th cent.	Basra, Iraq	Yemen
G2: Splashed Sgraffiato	9–10th cent.	Iraq	Samarra, Iraq
G3: Abbasid Luster Ware	9–10th cent.	Basra, Iraq	Yemen
G4: Hatched Sgraffiato	11–12th cent.	Southern Iran	Yemen
G5: Tihama Pseudo-Celadon	13–14th cent.	Zabid, Yemen	Yemen
G6: Tihama Fine Hays Cup	15–16th cent.	Hays, Yemen	Yemen
G7: Fatimid Luster Ware	11th cent.	Fustat, Egypt	Fustat, Egypt
G8: Seljuq Luster Ware	13th cent.	Kashan, Iran	Ghubeyra, Iran

Fatimid luster is of “buff-bodied” petrofabric, and is a sample from Fustat itself. The Seljuq luster is of Kashan style,¹³ and is from the Ghubeyra excavations.¹⁴

Small, well-preserved glaze grains, 0.1 to 0.7 mg, in weight, were selected for analysis and dissolved in ultra-pure hydrofluoric acid. The samples were then dried, dissolved again in hydrobromic acid, and loaded onto ion-exchange columns to separate the lead from other elements in the glaze. The lead was extracted from the columns with 10N hydrochloric acid. A small fraction of the sample was then mounted onto a silica-gel substrate on a rhenium filament, and dried at 600° to 700°C. The sample was loaded into the ion-source of a 90° magnetic deflection solid source mass spectrometer (standardized using U.S. Bureau of Standards S.R.M. 981). The results with 2 sigma variation are given in table 2.

Discussion. The results of this study, plotted together with data for a number of lead sources in the Middle East derived from the literature, are shown in figure 1.¹⁵ Isotopic data from glazes and glass from the early-eleventh-century wreck site at Serçe Limanı are also shown.¹⁶ Here it can be seen that the Abbasid luster ware (G3) and molded relief ware (G1) sherds, both produced in Basra, have practically identical isotopic ratios, whereas the splashed sgraffiato sherd (G2) considered to be from

elsewhere in Iraq has a slightly different ratio, but may have the same source. One glass vessel from the Serçe Limanı wreck may also be in this group. Isotopic ratios from a number of deposits lie in this region of the graph. These include North African mineral occurrences, as well as an important group of mines in eastern Turkey.

The ratios for the Iranian hatched sgraffiato sherd (G4) and the Yemeni pseudo-celadon sherd (G5) are also close together, although they are from widely separate provenances. These sherds have ratios which are very close to those values for Qamsar, which was a very important center for the production and processing of various raw materials utilized in ceramic production, at least in the thirteenth and fourteenth centuries.¹⁷

The isotopic composition of the Fine Hays Cup (G6) forms a tight group with three glasses from Serçe Limanı, with possible sources in Iran and Central Asia. It could here be noted that none of the Yemen glazes are near the only published ratio for the important lead source of Hailan in Yemen. As Yemen has a similar tectonic setting as the Saudi Arabian Shield, it is possible that further analyses of Yemeni galena would form a mixing line of isotopic ratios similar to that of data for galena from this area. Here Precambrian galena (Nejd group on figure 1) become isotopically modified by contamination from, and proximity to, younger tectonism

Table 2. Results of testing

Sample	208–206	207–206
G1 Relief Ware	2.0693 ± 0.0025	0.8335 ± 0.0004
G2 Splashed Sgraffiato	2.0678 ± 0.0029	0.8242 ± 0.0004
G3 Abbasid Luster	2.0685 ± 0.0025	0.8323 ± 0.0005
G4 Iranian Hatched Sgraffiato	2.0748 ± 0.0025	0.8362 ± 0.0004
G5 Yemeni Pseudo-Celadon	2.0756 ± 0.0025	0.8342 ± 0.0005
G6 Yemeni Hays Cup	2.0852 ± 0.0025	0.8474 ± 0.0015
G7 Fatimid Luster	2.0544 ± 0.0025	0.8300 ± 0.0009
G8 Seljuq Luster	2.0988 ± 0.0025	0.8538 ± 0.0004

associated with the opening of the Red Sea (Hijaz group and Red Sea groups A and B). If this is the case then the locally produced Yemen glazes may conceivably be utilizing Yemen lead.

The Fatimid luster (G7) data are not near those for any Egyptian lead sources, but they are close to ratios for the lead glazes of two bowls, and of four glasses and some lead weights from the Serçe Limanı wreck, which date to within the period of production of Fatimid luster. In this case it may be that the source of lead for the Serçe Limanı pottery and the Fatimid luster are the same, although this may not mean that they were made at the same place. This group has been attributed to Takht-i Sulaiman, Iran, by the researchers analyzing the Serçe Limanı finds, but they have not published any isotopic ratios for this mine.¹⁸ The published data for Takob in Turkestan are within this group. Recent petrographic analysis by Mason of some of the glazed wares from Serçe Limanı was aimed at determining the origin of this material.¹⁹ The petrofabric of this pottery consists of rounded grains of quartz and carbonate (possibly limestone fragments), with traces of chert, and has a thin slip of white clay with quartz and chert inclusions.²⁰ Similar pottery with an identical petrofabric and slip has been recovered in excavations at Caesarea,²¹ and similar pottery is also known from Jerusalem.²² None of these sites has produced kiln evidence for this material. The closest parallel for which we are certain of the provenance is in fact Fatimid luster produced at Fustat, although of the "red-body" luster petrofabric.²³ The parallel is not exact, however, and it is possible that the bulk of material from Palestine would indicate a source there. From a geological perspective a source on the southern littoral of the Mediterranean, along North Africa to Palestine, is favored over a source elsewhere in the Mediterranean and the Middle East.

The data point for the Kashani Seljuq Luster piece (G8) is not particularly near any given mine data, but may relate to adjacent data points for lead mines from Iran (including Anjileh near Yazd), eastern Turkey, and the Caucasus.

Conclusion. Although giving some tantalizing preliminary results, the study requires further analysis of pottery and lead sources. An important consequence would seem to be evidence for major trade in lead or lead-frit, perhaps specifically for the use of potters. In almost all cases the most likely sources candidates are very distant from the site of production of the pottery. Given that more accessible sources of lead were available, this

would seem to indicate trade in and use of pre-mixed lead-frit, which would go some way to explaining the uniformity of technology in Islamic ceramics.

The lead-isotope study of glazes would appear to be a very fruitful field for future study. Lead-isotope analysis of such materials as bronze, other metals, and glass, is beset with problems created by the melting, mixing and recycling of objects. Glazes can only be tampered with before being applied to the pot and are inviolate afterwards. They are certainly never recycled. By analyzing glazes of pottery with known dates of manufacture, and their provenance securely determined by petrographic analysis, it should be possible to develop a data bank linking specific isotopic ratios to lead utilization in time and space. This would serve as a much more useful reference for other materials, such as bronzes and glass, than the range of values for known mines and other lead deposits, since the latter may not have been exploited as lead sources in Islamic times.

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NOTES

1. B. Kleinmann, "History and Development of Early Islamic Pottery Glazes" in J. A. Olin and M. J. Blackman, ed., *Proceedings of the 24th International Archaeometry Symposium* (Washington, D.C., 1986), pp. 73–84; M. S. Tite, "Inter-Relationship Between Chinese and Islamic Ceramics from 9th to 16th Century A.D." in R. M. Farquhar, R. Hancock, and L. Pavlish, eds., *Proceedings of the 26th International Archaeometry Symposium* (Toronto, 1988), pp. 30–34.
2. J. W. Allan, "Abu'l-Qasim's Treatise on Ceramics," *Iran* 11 (1973): 111–20.
3. R. H. Brill, "Lead and Oxygen Isotopes in Ancient Objects," *Philosophical Transactions of the Royal Society of London, Series A* 269 (1970): 143–64.
4. Relevant publications not otherwise referred to are: R. B. Mason "Defining Syrian Stonepaste Ceramics: Petrography of Pottery from Ma'arrat al-Nu'man," in James W. Allan, ed., *Islamic Art in the Ashmolean Museum*, Oxford Studies in Islamic Art (in press); R. B. Mason, "Petrography of Islamic Ceramics," in I. Freestone and A. Middleton, eds., *Recent Developments in Ceramic Petrology*, British Museum Occasional Papers (in press); R. B. Mason and L. B. Golombek, "Differentiating Early Chinese-Influenced Blue and White Ceramics of Egypt, Syria and Iran," in E. Pernicke and G. A. Wagner, eds., *Archaeometry '90: Proceedings of the 27th International Archaeometry Symposium* (Basel: Birkhauser Verlag, 1990), pp. 165–74; R. B. Mason, J. R. Hallett, and E. J. Keall, "Provenance Studies of Islamic Pottery from Yemen: INAA and Petrographic Analysis," in Y. Maniatis, ed., *Archaeometry: Proceedings of the 25th International Symposium* (Amsterdam: Elsevier, 1988), pp. 543–50; R. B.

- Mason and E.J. Keall, "Islamic Ceramics: Petrography and Provenance," *Proceedings of the 26th International Archaeometry Symposium* (Toronto, 1988), pp. 184–87.
5. J.W. Allan, *Persian Metal Technology*, Oxford Oriental Monographs 2 (Oxford, 1979).
 6. Allan, "Abu'l Qasim's Treatise."
 7. Ibid.
 8. A.Y. Hassan and D.R. Hill, *Islamic Technology* (Cambridge: Cambridge University Press, 1986).
 9. Analysis published in R.B. Mason and E.J. Keall, "Provenance of Local Ceramic Industry and the Characterization of Imports: Petrography of Pottery from Medieval Yemen," *Antiquity* 62 (1988): 452–63. Further work on Basra in R.B. Mason and E.J. Keall, "The 'Abbasid Glazed Wares of Siraf and the Basra Connection: Petrographic Analysis," *Iran* 29 (1991). Further work on Fustat in idem, "Petrography of Islamic Pottery from Fustat," *Journal of the American Research Center in Egypt* 27 (1990): 165–84.
 10. A. Lane, "Glazed Relief Ware of the Ninth Century A.D.," *Arts Islamica* 6 (1939): 56–65.
 11. This is of "Abbasid fabric B" of Mason and Keall, "Yemen," which is considered to be Iraqi due to its similarities with other known Iraqi petrofabrics. It has so far only been found in pottery from Samarra.
 12. David Whitehouse, "Maritime Trade in the Gulf: The 11th and 12th Centuries," *World Archaeology* 14 (1983): 328–34.
 13. Oliver Watson, *Persian Lustre Ware* (London: Faber, 1985).
 14. A.D.H. Bivar and G. Fehérvári, "Excavations at Ghubayra, 1971: First Interim Report," *Journal of the Royal Asiatic Society*, (1974): 107–41.
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 17. Allan, "Abu'l Qasim's Treatise."
 18. Barnes et al., "Lead Isotopes."
 19. R.B. Mason, "Petrography of Glazed Pottery from Serçe Liman," in G. F. Bass and F. H. van Doornick Jr., eds., *Serçe Liman: An 11th-Century Shipwreck* (Texas A & M University Press for American Institute of Nautical Archaeology, in press).
 20. Islamic pottery of the very general type of the Serçe Liman pieces, that is with a white slip under a lead glaze, and with sgraffiato or champlévé incision and/or an oxide pigment-splashed glaze, are more commonly found with a stonepaste slip (see Mason and Keall, "Yemen"; "Fustat"; "Siraf").
 21. Denys Pringle, "Medieval Pottery from Caesarea: The Crusader Period," *Levant* 17 (1985): 171–202.
 22. A.D. Tushingham, *Excavations in Jerusalem 1961–1967* (Toronto: Royal Ontario Museum 1985), for example fig. 35 no. 22, fig. 39 no. 21.
 23. Mason and Keall "Yemen," "Fustat."