# Indian Glass in The Middle East? Medieval and Ottoman Glass Bangles from Central Jordan

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THIS ARTICLE deals with two groups of glass bangles dating from the Mamluk (1171–1517) and Ottoman (1517–19th century) periods. They were discovered during archeological excavations at Tell Abu Sarbut and Khirbat Faris in central Jordan. Our focus is on the interrelated aspects of typology, textual references to glass production, scientific analysis, and some suggested sources for the glass and bangles.[1] As part of this consideration, on a local scale, we have investigated the hypothesis that two different "cultures" existed at the two sites.

Four hundred bangle fragments, about 100 fragments of glass vessels, and a considerable quantity of pottery were found during excavations at Tell Abu Sarbut, directed by Hendricus Edouard Lagro and Margreet Steiner of Leiden University, between 1992 and 1998. This site was abandoned at the end of the Mamluk period. It is located in the Jordan Valley, about one and a half kilometers northeast of Tell Deir 'Alla, an area that specialized in the production of cane sugar and indigo.[2] Khirbat Faris was excavated between 1988 and 1994 under the direction of Jeremy Johns of Oxford University and Alison McQuitty, then of the Council for British Research in Levant. Two phases of settlement were identified: (1) from the ninth to 12th centuries and (2) from the 12th century to the end of the Ottoman period.[3] Sixty-seven colored bangles (most of them dating to the Ottoman period), a large group of jewelry (including 42 rings and bangles), and about 180 fragments of glass

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1. The bangles discussed are included in Stéphanie Boulogne, "Reflections of Popular Art: Coloured Glass Bangles from Medieval and Ottoman Bilad al-Sham," Ph.D. diss., Université Paris–Sorbonne (Paris IV), 2007; and *idem*, "Les Bracelets de verre coloré polychromes des sites de Damas, Masyaf, Tell Abu Sarbut et Khirbat Faris . . . : Essai de synthèse," *Bulletin d'Etudes Orientales* (Institut Français du Proche-Orient), v. 57, 2006–2007, pp. 127–153.

2. Margreet L. Steiner, "An Analysis of the Islamic Glass Bracelets Found at Tell Abu Sarbut," in *Sacred and Sweet: Studies on the Material Culture of Tell Deir 'Alla and Tell Abu Sarbut*, ed. M. L. Steiner and E. J. van der Steen, Ancient Near Eastern Studies Supplement Series, no. 24, Leuven: Uitgeverij Peeters, 2008, pp. 231–240; Margreet L. Steiner and Eveline J. van der Steen, "The Glass Bracelets of Tell Abu Sarbut," *Studies in the History and Archaeology of Jordan*, v. 5, 1995, pp. 537–540.

3. M. Khoury, "The Glass Archaeology from Khirbet Faris (Jordan): The Mamluk Evidence," *Aram* (Journal of the Aram Society of Syro-Mesopotamian Studies), v. 9, Leuven: Peeters, 1997, pp. 190–193; A. McQuitty, "Bangles," in *Report on Excavations at Khirbat Faris* (in preparation).

vessels dating from the 15th to 19th centuries (including some enameled examples) were found.[4]

Tell Abu Sarbut is one of several medieval villages in the Jordan Valley dating to the Umayyad, Abbasid, Ayyubid, and Mamluk periods. Four of these villages—Tell Deir ‘Alla, Tell Abu Gurdan, Tell Qudsiya, and Tell Sahl el-Sarabet—were occupied during the Ottoman period.[5] Khirbat Faris is on the Kerak Plateau, an area of about 875 square kilometers, located between Wadi Mujib and Wadi al-Hasa. A survey published in 1991 identified 151 Ayyubid–Mamluk settlements and 21 Ottoman villages. Some of them, such as Khirbat Shihan, were permanently occupied from Abbasid times.[6]

## BANGLES AND SITES

### TELL ABU SARBUT (see Table 1)

One hundred eighty-two bangles of the most representative patterns were selected for study. Most of them (91 multicolored and 78 monochrome) were surface finds and date, according to typological parallels, to the Mamluk–Ottoman periods. Three multicolored bangles were assigned to the Ayyubid period, and 10 to the Mamluk period.[7]

#### *Multicolored Glass Bangles*

One hundred one multicolored glass bangles were assigned to three typological groups: (1) decorated with prunts (10 examples), (2) spirally twisted (87), and (3) decorated with a glass strip (1); the decoration of the other three bangles was unclassified. The glass is generally translucent, sometimes lightly tinted, but mostly of darker hues, either green or apparently "black" (mainly brown). The bangles are often decorated with a "surface coating."[8]

Parallels for these bangles vary according to the types, and the same combination of decoration is rarely found. Parallels for bangles with a flat section and decorated with crumbs or specks come from Mamluk levels at Hubras,[9] from two separate levels at Khirbat Minyeh (Palestine),[10] and from Shihr (Yemen; medieval and later levels).[11] Another example, with a triangular section, found at Kawd am-Saila (Yemen), is dated to a later period.[12] Spirally twisted bangles with round sections, a dark glass core with surface coating, and several colored cables, such as yellow, red, and blue, are known from Tell Erani (Mamluk).[13] The type has also been identified among material from other sites on the Arabian Peninsula, such as in Abbasid levels at Sharma (Yemen).[14]

Examples of bangles decorated with a thick glass strip on the surface have been found at Qusayr al-Qadim (Mamluk), and the same general type has been uncovered in present-day Nepal.[15]

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4. Some of the glass was published in J. Johns and A. McQuitty, "The Faris Project: Supplementary Report on the 1986 and 1988 Seasons: The Coins and the Glass," *Annual of the Department of Antiquities of Jordan*, v. 33, 1989, pp. 245–258; Khoury [note 3].

5. Jum'a Mahmoud H. Kareem, *The Settlement Patterns in the Jordan Valley in the Mid- to Late Islamic Period*, BAR International Series, no. 877, 2000, Oxford: Hadrian Books Ltd., pp. 8–63 and 66–81.

6. J. Maxell Miller, ed., *An Archaeological Survey of the Kerac Plateau*, American School of Oriental Research, Atlanta: Scholars Press, 1991, pp. 23–167 and 307–319.

7. Steiner [note 2]; Steiner and van der Steen [note 2].

8. Maud Spaer, "Islamic Glass Bracelets of Palestine: Preliminary Findings," *Journal of Glass Studies*, v. 34, 1992, pp. 44–62.

9. Stéphanie Boulogne, "Glass Bangles from Hubras and Malka Excavations," in Bethany J. Walker and others, "The Northern Jordan Project 2006: Village Life in Mamluk and Ottoman Hubras and Sahm: A Preliminary Report," *Annual of the Department of Antiquities of Jordan*, v. 52, 2007, pp. 429–470.

10. Spaer [note 8], pp. 59–60.

11. This unpublished material was studied during the 2007 Shihr mission, directed by C. Hardy-Guilbert (Centre National de la Recherche Scientifique, Unité Mixte de Recherche 8167 Orient et Méditerranée [hereafter, UMR]). We are grateful for permission to refer to it.

12. T. Monod, "Sur un site à bracelets de verre des environs d'Aden," *Rayden* (Journal of Ancient Yemeni Antiquities and Epigraphy), v. 1, 1978, pp. 111–125.

13. Spaer [note 8].

14. Sharma was investigated by A. Rougeulle, and the material is being processed by the Centre National de la Recherche Scientifique, UMR. We thank her for giving us permission to refer to it.

15. M. Gaborieau, "Bracelets et grosses perles de verre: Fabrication et vente en Inde et au Népal," *Objets et mondes* (Paris), v. 17, no. 3, 1977, pp. 111–130, esp. pp. 112–117.

TABLE 1

Chemically Analyzed Samples from Tell Abu Sarbut and Khirbat Faris (by Date)

| *Sample Number* | *Site* | *Type** | *Inventory Number* | *Dating* | *Comparative Data* |
|---|---|---|---|---|---|
| *High-Alumina Glass* | | | | | |
| AB34 | Tell Abu Sarbut | PPrunts | [205] | Mamluk | No parallel for this combination of colors |
| AB30 | Tell Abu Sarbut | MSmooth | [314] | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB17 | Tell Abu Sarbut | MSmooth | [315] | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB26 | Tell Abu Sarbut | MSmooth | [315] | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB21 | Tell Abu Sarbut | MSmooth | [317] | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB22 | Tell Abu Sarbut | MSmooth | [327] | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB1 | Tell Abu Sarbut | MTwisted | [382] | Mamluk–Ottoman | Pre-Islamic and Islamic: Rahba-Mayadine, Qasr al-Hayr, Hubras |
| AB36 | Khirbat Faris | MSmooth | [423] | Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB32 | Khirbat Faris | MSmooth | [422] | Ottoman–Modern | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| *Mineral Glass* | | | | | |
| AB2 | Tell Abu Sarbut | PPrunts | **[207]** | Mamluk | No parallel for this combination of colors |
| AB3 | Tell Abu Sarbut | PPrunts | [220] | Mamluk–Ottoman | Flower type found on antique jewels from eastern Europe |
| AB4 | Tell Abu Sarbut | PPrunts | [219] | Mamluk–Ottoman | No parallel for this combination of colors |
| AB13 | Khirbat Faris | Combined | [398] | Mamluk–Ottoman | Tell el-Hesi |
| AB15 | Khirbat Faris | PTrails | [394] | Ottoman | Tell Erani, Hebron |
| *Plant-Ash Glass* | | | | | |
| AB6 | Tell Abu Sarbut | PPrunts | [202] 935 | Ayyubid | Qusayr al-Qadim |
| AB11 | Tell Abu Sarbut | PTwisted | [203] | Ayyubid | No parallel for this combination of colors |
| AB35 | Tell Abu Sarbut | PPrunts | **[207]** | Mamluk | No parallel for this combination of colors |
| AB7 | Tell Abu Sarbut | PCrumbs | [222] | Mamluk–Ottoman | Hubras, Khirbat Minyeh, Kawd am-Saila, Shihr |
| AB25 | Tell Abu Sarbut | PCrumbs | [223] | Mamluk–Ottoman | Hubras, Khirbat Minyeh, Kawd am-Saila, Shihr |
| AB37 | Tell Abu Sarbut | PCrumbs | [223] | Mamluk–Ottoman | Hubras, Khirbat Minyeh, Kawd am-Saila, Shihr |
| AB38 | Tell Abu Sarbut | PCrumbs | [223] | Mamluk–Ottoman | Hubras, Khirbat Minyeh, Kawd am-Saila, Shihr |
| AB20 | Tell Abu Sarbut | PStrips | [227] | Mamluk–Ottoman | No parallel for this combination of colors |
| AB8 | Tell Abu Sarbut | PTwisted | [239] | Mamluk–Ottoman | Tell Erani, Sharma, Shihr |
| AB9 | Tell Abu Sarbut | PTwisted | **[239]** | Mamluk–Ottoman | Tell Erani, Sharma, Shihr |
| AB23 | Tell Abu Sarbut | PTwisted | TR22 02 | Mamluk–Ottoman | Tell Erani, Sharma, Shihr |
| AB28 | Tell Abu Sarbut | PTwisted | S1122 | Mamluk–Ottoman | Tell Erani, Sharma, Shihr |
| AB29 | Tell Abu Sarbut | PTwisted | S1122 | Mamluk–Ottoman | Tell Erani, Sharma, Shihr |
| AB18 | Tell Abu Sarbut | MSmooth | [311] | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB19 | Tell Abu Sarbut | MSmooth | [329] | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB12 | Tell Abu Sarbut | MSmooth | **S1104** | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB5 | Tell Abu Sarbut | MSmooth | **S1104** | Mamluk–Ottoman | Pre-Islamic and Islamic: Saladin's Castle, Raqqa, Beyrouth, Hubras, Shihr |
| AB24 | Tell Abu Sarbut | MTwisted | [377] | Mamluk–Ottoman | Pre-Islamic and Islamic: Rahba-Mayadine, Qasr al-Hayr, Hubras |
| AB10 | Tell Abu Sarbut | MTwisted | S1242 | Mamluk–Ottoman | Pre-Islamic and Islamic: Rahba-Mayadine, Qasr al-Hayr, Hubras |
| AB16 | Khirbat Faris | PPrunts | [389] | Mamluk | Hama |
| AB31 | Khirbat Faris | MTwisted | [443] | Ottoman–Modern | Pre-Islamic and Islamic: Rahba-Mayadine, Qasr al-Hayr, Hubras |
| AB33 | Khirbat Faris | MTwisted | [434] | Ottoman–Modern | Pre-Islamic and Islamic: Rahba-Mayadine, Qasr al-Hayr, Hubras |
| AB27 | Khirbat Faris | MTwisted | [440] | Ottoman–Modern | Pre-Islamic and Islamic: Rahba-Mayadine, Qasr al-Hayr, Hubras |
| AB14 | Khirbat Faris | PPrunts | [38oo] KHf | Not identified | No parallel for this combination of colors |

*P=polychrome; M=monochrome

*Monochrome Glass Bangles*

The 76 monochrome bangles were assigned to three types: (1) smooth (30 examples have flat and triangular sections), (2) spirally twisted (45 examples have rounded sections), and (3) with vertical ribbing (one example has a half-rounded section). All of these have parallels from late antiquity.[16] The glass is generally of translucent dark colors (brown, green, or blue) and has a surface coating.

Examples of smooth cobalt blue bangles have been found in Ayyubid contexts at Saladin's Castle (Damascus), Raqqa,[17] Beirut and Hubras (in Ottoman–modern contexts), and Shihr (Yemen, medieval contexts). In India, some darkly tinted or smooth blue examples are known from medieval levels at Nevasa, Baroda, and Brahmapuri.[18]

Spirally twisted bangles, especially those with narrow, thick twists, were widespread during pre-Islamic times and in Ayyubid levels (cobalt blue) at Rahba-Mayadine (many examples)[19] and Raqqa; others have been found in Qasr al-Hayr al-Sharqi (Mamluk) and Hubras.[20] One fragment, decorated with vertical ribbing, is a well-known type in late antique contexts in the Middle East; parallels have also been found in Umayyad levels at Khirbat Minyeh.[21]

## KHIRBAT FARIS (see Table 1)

At Khirbat Faris, most of the bangles (18 multicolored and 41 monochrome examples) came from Ottoman and Ottoman–modern periods.

Three multicolored fragments were dated to the Ayyubid–Mamluk periods. Of the monochrome examples, five came from Abbasid–Mamluk contexts and five were found in layers dating to the Ayyubid–Ottoman periods.

*Multicolored Bangles*

A typological study of polychrome glass bangles highlighted six decorative groups: (1) decorated with prunts (5 examples), (2) twisted (2), (3) marvered (1), (4) decorated with trails (3), (5) decorated with colored patches (4), (5) twisted (2), and (6) decorated with crumbs (1).

Most of these bangles have a deep translucent color. Those decorated with prunts often also have a surface coating of glass. A parallel can be cited from medieval Hama, Syria.[22] Bangles with diagonal lines surrounding the main decoration of prunts have been found in medieval and late contexts at al-Tur, Sinai, and in late contexts at Shihr.[23] No parallels have been found for the marvered example with a semicircular cross section. One trail-decorated translucent blue bangle with a triangular section was found in medieval and later levels at Tell Erani (Bilad al-Sham), and another was excavated in a late context at Hebron.[24] The patch-decorated bangles have parallels from Hubras (Mamluk–Ottoman levels), the Damascus citadel (Ottoman period), Khalil

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16. Spaer [note 8].

17. Julian Henderson, "Archaeological and Scientific Evidence for the Production of Early Islamic Glass in al-Raqqa, Syria," *Levant*, v. 31, 1999, pp. 225–240.

18. H. D. Sankalia, S. B. Deo, and Z. D. Ansari, *From History to Prehistory at Nevasa, 1954–1956*, Poona, Pune: Deccan College Postgraduate and Research Institute, 1960, p. 446; H. D. Sankalia, "The Antiquity of Glass Bangles in India," *Bulletin of the Deccan College Research Institute* (Poona), 1947, pp. 252–259; H. D. Sankalia and M. G. Dikshit, "Excavations and Stratigraphy," *Excavations at Brahmapuri (Kolhapur) 1945–46*, Poona: Deccan College, 1952, pp. 111–121.

19. Excavations by M. O. Rousset (Centre National de la Recherche Scientifique, UMR Orient-Méditerranée), unpublished.

20. Excavations of Qasr al-Hayr al-Sharqi were directed by D. Genequand (Council for British Research in the Levant, Amman, and Service Cantonnal d'Archéologie, Geneva, Switzerland). We thank Bethany Walker (director of the Hubras mission, Missouri State University, Springfield, Missouri) for permission to mention this material.

21. Spaer [note 8].

22. J. Riis and V. Poulsen, "Les Verreries et poteries médiévales," in *Hama: Fouilles et recherches, 1931–1938,* v. 4, no. 2, Copenhagen: Nationalmuseet, 1957, pp. 30–130.

23. Y. Shindo, "Islamic Glass Bracelets Found in the Red Sea Region," *Annales de l'Association Internationale pour l'Histoire du Verre*, v. 13, Pays Bas, 1995 (Lochem, 1996), pp. 269–276; *idem*, "The Classification and Chronology of the Islamic Glass Bracelets from al-Tūr, Sinaï," *Cultural Change in the Arab World,* Senri Ethnological Studies, v. 55, Osaka: National Museum of Ethnology, 2001, pp. 73–100. The material from the Shihr excavations is being prepared for publication.

24. M. Spaer and others, *Ancient Glass in The Israel Museum: Beads and Other Small Objects*, Jerusalem: The Israel Museum, 2001, pp. 193–205.

(late Ottoman), and Upper Egypt (Mamluk period).[25] A subtype with both marvered and patch decorations, of late Ottoman date, was found at Tell el-Hesi, Palestine.[26] A blue fragment with a triangular section decorated with patches, mixed with a thick white central band, has a parallel close to those from Khirbat Minyeh, dating to medieval and later times.[27]

Twisted bangles with fragmentary orange inner twisted cables are well known from the medieval and later levels at Masyaf Castle, Beirut,[28] and from collections of glass bangles bought in Vienna in 1873.[29] This type was also found among the material excavated from al-Tur, Fustat, and Kawd am-Saila. T. Monod described this kind as "corps transparents et ornaments internes" (translucent body with inner ornament).[30]

### *Monochrome Bangles*

Four types have been identified among the 41 monochrome bangles: (1) smooth (22 examples), (2) spirally twisted (16), (3) with vertical ribbing (2), and (4) with horizontal ribbing (1). The types and colors are generally similar to those described for examples from Tell Abu Sarbut. The glass core is frequently of a translucent dark color, with a surface coating that is generally of the same color. Four of the smooth fragments are dated to the Abbasid–Mamluk periods, and two to the Ottoman period. One twisted bangle is pale yellow-ocher, and it is dated to the Abbasid–Mamluk periods. Most of the other examples, from the same periods, are dark in color. Two examples are dated to the Ayyubid–Ottoman periods and seven to the Ottoman–modern periods.

Dark glass bangles with a flat section and decorated with horizontal ribbing can be dated to the Ottoman period. The same type is also found in fifth- and sixth-century contexts in the Middle East. One example with diagonal ribbing was found at Masyaf Castle, Beirut (Ottoman), and another came from Nevasa, Pravara, in western India, but it has not been dated.

## DISCUSSION

The heterogeneity of the collections of polychrome bangles from Tell Abu Sarbut and Khirbat Faris is remarkable. They share only two typological groups: those with prunts, and those with strips. Variations are nevertheless dissimilar, even though they may be made from translucent deep "black" or green glass.

At Tell Abu Sarbut, bangles with crumb decoration and those with multicolored twisted cables have interesting parallels from Khirbat Minyeh, Tell Erani in Bilad al-Sham, Kawd am-Saila, and Shihr in Yemen.

Parallels for the bangles found at Khirbat Faris have been found at Hubras (decorated with patches); at Hebron and Tell Erani (decorated with strips on the side); and at Beirut, Hebron, and Kawd am-Saila (decorated with an inner cable). It is apparent that Kawd am-Saila must be considered as a point of reference for the numerous parallels.

In contrast, there is some typological and technical homogeneity among the monochrome bangles from both sites. Those that are smooth, twisted, and decorated with horizontal ribs in dark colors also show a surface coating. It was difficult to find parallels for this material from Middle Eastern medieval and late Islamic sites

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25. Stefano Carboni, "Glass Bracelets from the Mamluk Period in The Metropolitan Museum of Art," *Journal of Glass Studies*, v. 36, 1994, pp. 126–129; Stéphanie Boulogne, *Les Bijoux de la Citadelle de Damas* (in preparation). We thank Dr. Sophie Bertier for permission to refer to these bracelets.

26. L. E. Toombs, "Modern Military Trending and Muslim Cemetery in Field I Strata III," *Tell el-Hesi: The Joint Archaeological Expedition to Tell el-Hesi,* v. 2, 1985, Waterloo, Ontario: Wilfred Laurier University, 1985, p. 200.

27. Spaer [note 8].

28. Boulogne, "Reflections" [note 1].

29. In the Österreichisches Museum für Angewandte Kunst, Vienna.

30. Monod [note 12], no. 20, fig. 85.

where mainly turquoise blue fragments (such as those from Damascus, Masyaf, Beirut, and Qasr al-Hayr) have been found.[31] Based on typological parallels, the bangles are thought to have been made in various locations. Some may be of "local" origin, while others may have come from farther afield, perhaps from Yemen and India.[32] The heterogeneity of the polychrome examples from each site could also suggest a range of provenances.

## WORKSHOPS

### WORKSHOPS IN BILAD AL-SHAM

Secondary glass workshops are well represented by textual sources and archeological remains, particularly in Bilad al-Sham. Moreover, in the case of Tyre and Hebron, there is mention of sand sources, one of which is noted by Manfred Korfmann: "le sable provenait du village de Beni Naïm, à quelques kilometres à l'est de Hébron."[33]

#### *Glass Vessel Workshops*

There is historical and archeological evidence of urban workshops in Beirut, Damascus, Aleppo, and Raqqa. In the 12th century, Ibn 'Asakir noted that a glass workshop in Damascus ("masbak az-Zubak") is located to "l'est du Dar al-Bittih au nord du quartier de Kenchk."[34] In Beirut, archeological evidence of vessel production during the Mamluk period was found next to the Ribbat Ibn 'Iraq. In Aleppo, the cosmographer al-Qazwīnī (d. 1283) mentions the *sūq al-marzuqīn* (market of enamelers); purple glass is said to have come from Jerusalem.[35] In Raqqa, extensive evidence for the production of glass vessels—including moils for glassblowing—has been found.[36] The large quantity of glass dated to the Ayyubid and Mamluk periods found in Hama, and the glass slag discovered on the Citadel Mound there, suggests local production, especially of vessels decorated with vertical ribs, filets or prunts, and cutting and painting. There is also conclusive evidence of primary glass production at Tyre, as well as historical evidence for a workshop at Somelaria next to the city of Acre (12th and 13th centuries).[37]

#### *Glass Vessels and Jewelry Workshops*

Glass bangles and beads dated to late antiquity were among the material excavated from the necropolis at Tyre.[38] Al-Maqdisi believes that glass bead production was common during the 10th century.[39] Twisted bangles decorated with patches or with an inner colored cable have been identified among the collections of bracelets discovered in the late Ottoman workshops at Hebron in 1873 and stored in the Österreichisches

31. Boulogne, unpublished material.
32. Sankalia [note 18].
33. Manfred Korfmann, "Zur Herstellung nahtloser Glasringe," *Bonner Jahrbücher*, v. 166, 1966, pp. 48–61.
34. Nikita Elisseeff, *La Description de Damas d'Ibn 'Asakir,* Damascus: Institut Français de Damas, 1959, p. 102.
35. J. M. Abdallah, "The AUB Beirut Souks Excavations, 1994–1996: The Closed Glass Vessels," M.A. thesis, American University, Beirut, Lebanon, 1999, pp. 128–136, 141, and 317; Shulamit Hadad, "Marvered Glass Vessels from the Umayyad through Mamluk Periods at Bet Shean, Israel," *Levant*, v. 34, 2002, pp. 151–158; Rachel Hasson, "Islamic Glass from Excavations in Jerusalem," *Journal of Glass Studies*, v. 25, 1983, pp. 109–113; R. Irwin, "A Note on Textual Sources for the History of Glass," in *Gilded and Enamelled Glass from the Middle East*, ed. Rachel Ward, London: British Museum, 1998, pp. 24–26.
36. Henderson [note 17].
37. Fred Aldsworth and others, "Medieval Glassmaking at Tyre, Lebanon," *Journal of Glass Studies*, v. 44, 2002, pp. 49–66; S. D. Goitein, "The Main Industries of the Mediterranean Area as Reflected in the Records of the Cairo Geniza," *Journal of the Economic and Social History of the Orient*, v. 4, no. 2, 1961, pp. 168–197; Gladys Davidson Weinberg, "A Glass Factory of Crusader Times in Northern Israel (Preliminary Report)," *Annales de l'Association Internationale pour l'Histoire du Verre*, v. 10, Madrid–Segovia, 1985 (Amsterdam, 1987), pp. 305–316.
38. M. Chehab, "Fouille de Tyr. La Nécropole IV: Description des fouilles," *Bulletin du Musée de Beyrouth* (Paris), v. 36, 1986, pp. 97–157; S. Boulogne, "La Production de bijoux de verre dans l'espace islamique médiéval et tardif: Un artisanat spécialisé," *Annales de l'Association Internationale pour l'Histoire du Verre*, v. 18, Antwerp, 2006 (in press).
39. Personal communication from Dr. Michel al-Maqdisi, director general of antiquities, Damascus, Syria.

Museum für Angewandte Kunst in Vienna.[40] The glass production area is called the "Harat Ksassy."[41]

The well-known traveler Frescobaldi explained that, in Hebron, "ils font le premier modèle de verre . . . et plus qu'il n'ait jamais vu."[42] During the 15th century, Anselmo Adorno reported that "sont faits tous les objets de verre trouvés en Syrie et au Caire."[43] Between 1783 and 1787, Volney described Hebron as "une verrerie fort ancienne, la seule qui existe en Syrie. Il en sort une grande quantité d'anneaux colorés, de bracelets pour les poignets, pour les jambes, pour le bras au-dessus du coude, et diverses autres bagatelles que l'on envoie jusqu'à Constantinople. Au moyen de ces branches d'industrie, Habroun est le plus puissant village de ces canton."[44]

In 1851, Ch. de Pardieu stated that al-Khalil is "renommée maintenant pour ses verreries. On y fabrique beaucoup de vases, d'ornements pour la toilette des femmes arabes, de bracelets en verroterie qu'on expédie assez loin."[45]

## "FOREIGN" WORKSHOPS

We will focus on workshops in Yemen and India, since parallels have been found there for the Jordanian bangles.

### *Yemen*

In Yemen, bangles have been found with single prunts surrounded by diagonal lines (lozenges), and with crumbs and speckled decoration. Several examples with spirally twisted cables were discovered among the bangles from Shihr and among those found at Kawd am-Saila, but the latter had only inner cables. At Shihr, excavations produced more than 550 bangle fragments together with glassy slags of a color similar to that of most of the fragments and numerous crucibles, suggesting local production of at least part of this material. Local workshops were identified by Monod in 1978 and described by Gaborieau as follows: "J'ai eu l'occasion cette année de visiter un atelier ancien de verriers proche d'Aden, où l'on fabriquait des bracelets souvent très semblables à ceux que j'avais recueillis en Erythrée."[46]

### *India, Asia, and Southeastern Asia*

Chemical analyses of glass bangles (see below) show that a component of the glass with elevated alumina levels probably derived from these areas, especially where it is present in smooth, translucent deeply colored bangles found at both Tell Abu Sarbut and Khirbat Faris. Parallels for bangles from these two locations can be found among Indian material: multicolored bangles decorated with patches, some decorated with prunts, and some monochrome examples with horizontal ribbing, as discussed above. Such bangles have been discovered at the western Indian sites of Brahmapuri, Baroda, and Nevasa.

In Brahmapuri, traces of kilns suggest local production during the medieval period.[47] Recycled material and imported ingots may have been employed to produce bangles there. Some of the bangles may have been imported from southeastern Asia. Monochrome examples were discovered near Brunei, and others were found

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40. Korfmann [note 33].

41. Ulrich Jasper Seetzen, *Reisen durch Syrien, Palästina, Phönicien, die Transjordan Länder Arabia Petrae und Unter-Aegypten,* Berlin: Georg Friedrich Hermann Müller, v. 2, 1854–1859, p. 48.

42. Frescobaldi, "From Gaza to Hebron," in Leonardo Frescobaldi, Giorgio Gucci, and Simone Sigoli, *Visit to the Holy Places of Egypt, Sinai, Palestine, and Syria in 1384*, trans. from Italian by Fr. Theophilus Bellorini, Jerusalem: Franciscan Press, 1948, pp. 67–68.

43. A. Adorno, *Itinéraire d'Anselme Adorno en Terre Sainte (1470–1471)*, ed. Jacques Heers and Georgette de Groer, Paris: Editions du Centre National de la Recherche Scientifique, 1948, p. 251.

44. M. C.-F. Volney, *Voyages en Syrie et en Egypte pendant les années 1783, 1784 et 1785*, v. 2, Paris: Volland, Desenne, 1787, p. 300; Dawson Borrer, *A Journey from Naples to Jerusalem . . .* , London: J. Madden, 1845, pp. 453–454.

45. Ch. de Pardieu, *Excursion en Orient: L'Egypte, le Mont Sinaï, l'Arabie, la Palestine, la Syrie, le Liban*, Paris: Garnier Frères, 1851, pp. 224–225.

46. Unpublished letter from M. Gaborieau to T. Monod.

47. Sankalia and Dikshit [note 18].

at Kuala Lumpur and Sungaï Lumut.[48] Several trade routes may have been involved, with ships leaving Red Sea ports and stopping in India or southern Asia before returning to China or the Red Sea.[49]

### DISCUSSION

It is very probable that the al-Khalil bangles were locally produced. Adorno explained that, in Hebron, these objects could have been sent to Cairo.[50] Work by al-Ju'beh proposes the existence of some "comptoirs" at Fustat and Kerak.[51] Hawking may have been another mode of distribution, using trade routes of the "Bahri Mamluks," between the 12th and 14th centuries.[52] However, a tribute group from Hebron named the Majali or Banu Tamim (or Tamiyya), which arrived at Khirbat Faris in the 16th century, may have brought the bangles to that location. Another possible mode of distribution was pilgrimages to Hebron.[53]

The ethnographic study by Manfred Korfmann at Hebron revealed that crafts and craftsmen, as well as their ovens, were mobile.[54] As noted above, workshops must have existed in Yemen and in India; connections may also have been stimulated by trade. During Ayyubid times, letters from Jewish merchants living in Aden, which quote exchanges with eastern India and Ceylon, are well-known.[55] Under the Mamluks, trade controlled by the Karimis, who were Jewish or Christian merchants, occurred in Syria, Egypt, Yemen, and the Sudan.[56]

Aden and Shihr were commercial ports on the Indian Ocean. Shihr apparently traded with the Far East, while Aden was the main harbor linking the Indian Ocean, the Red Sea, and the Sinai under the Ayyubid period, and then under the Rasulids and Ottomans.[57]

## SCIENTIFIC ANALYSIS

### EXPERIMENTAL METHODS

Thirty-six microsamples of bangles, selected on the basis of color and type (see Table 2), were chemically analyzed by electron probe microanalysis. The technique and the potential sources of error are described in detail elsewhere.[58] The system used was a Cameca SX50, located at the British Geological Survey, Keyworth, U.K. The microprobe was calibrated using geological and National Institute of Standards and Technology glass standards. A combination of systematic and analytical error (the gross error) of the analytical system, by element, is shown by a comparison between the cited chemical composition of the Corning B standard and that obtained by an average of three chemical analyses of Corning B following calibration using the other standards (see Table 2). Examples of bangles of each of the three main compositional types described below are shown in Figures 1–3.

48. N. Huet, "Eléments de parure, bracelets et perles," in *La Mémoire engloutie de Brunei: Une aventure archéologique sous-marine*, Paris: Précis Scientifique, 2001, pp. 129–137.

49. *Ibid*.

50. Adorno [note 43].

51. N. al-Ju'beh, "La Route de pèlerinage entre Jérusalem et Hébron: La Production du verre," in *L'Art Islamique en Méditerranée, Pèlerinages, Sciences et Soufisme: L'Art Islamique en Cisjordanie et à Gaza*, Edisud: Musée Sans Frontières, 2004, pp. 187–211 and 214–215.

52. Jean Sauvaget, *La Poste aux Chevaux dans l'empire des Mamelouks,* Paris: Librairie d'Amérique et d'Orient, Adrien Maisonneuve, 1941, pp. 1–41.

53. Shindo, "The Classification" [note 23], p. 93.

54. Korfmann [note 33].

55. S. D. Goitein, *Letters of Medieval Jewish Traders*, Princeton, New Jersey: Princeton University Press, 1973, pp. 181 and 183.

56. E. Ashtor, "The Karimi Merchants," *Journal of the Royal Asiatic Society*, April 1965, pp. 45–56.

57. Michel Tuchscherer, "Des épices au café[: L]e Yémen dans le commerce international (XVI^e^–XVII^e^ si[è]cle)," in *Chroniques Yéménites* (Cefas, Sanaa): http://cy.revues.org/document103.html; Claire Hardy-Guilbert: "Shihr, porte du Hadramaout sur l'océan Indien, à la période islamique," *Les Dossiers d'Archéologie* (Dijon), no. 263, 2001, pp. 82–86.

58. Julian Henderson, "Electron Probe Microanalysis of Mixed-Alkali Glasses," *Archaeometry*, v. 30, no. 1, February 1988, pp. 77–91.


FIG. 1. *Plant-ash glasses:*

*202 (AB6). Tell Abu Sarbut. Polychrome bangle of dark translucent glass, decorated with yellow prunts, flat section. Ayyubid period. L. 3.9 cm, D. 0.6 cm.*

*203 (AB11). Tell Abu Sarbut. Polychrome twisted bangle of translucent light blue glass, rounded section. Ayyubid period. L. 2 cm, D. 0.5 cm.*

*222 (AB7). Tell Abu Sarbut. Polychrome bangle of dark translucent glass with crumb decoration, flat section. Mamluk–Ottoman periods. L. 5.1 cm, W. 0.6 cm.*

*223 (AB25). Tell Abu Sarbut. Polychrome bangle of dark translucent glass with crumb decoration, flat section. Mamluk–Ottoman periods. L. 2.4 cm, W. 0.5 cm.*

*239 (AB8). Tell Abu Sarbut. Polychrome dark translucent bangle with twisted yellow cable, rounded section. Mamluk–Ottoman periods. L. 7.7 cm, W. 0.5 cm.*

*377 (AB24). Tell Abu Sarbut. Monochrome twisted translucent green bangle with rounded section. Mamluk–Ottoman periods. L. 6.4 cm, W. 0.5 cm.*

*389 (AB16). Khirbat Faris. Polychrome bangle of dark translucent glass, decorated with yellow prunts, half-rounded section. Mamluk period. L. 5.3 cm, D. 0.5 cm.*

*443 (AB31). Khirbat Faris. Monochrome twisted bangle of dark translucent blue glass. Ottoman–Modern periods. L. 2.9 cm, W. 0.8 cm.*


FIG. 2. *Mineral glasses:*
*207 (AB2). Tell Abu Sarbut. Polychrome bangle of dark translucent glass with surface coating. Mamluk period. L. 1.9 cm, W. 0.6 cm.*
*219 (AB4). Tell Abu Sarbut. Polychrome bangle with light blue core and surface coating, flat yellow prunt with orange tip, triangular section. Mamluk–Ottoman periods. L. 2.4 cm, W. 0.4 cm.*
*220 (AB3). Tell Abu Sarbut. Polychrome bangle decorated with prunts, surface coating, flat section. Mamluk–Ottoman periods. L. 2.6 cm, W. 0.6 cm.*
*394 (AB15). Khirbat Faris. Polychrome bangle of blue glass with twisted white and dark translucent cables on sides, triangular section. Ottoman period. L. 5.9 cm, W. 1 cm.*
*398 (AB13). Khirbat Faris. Polychrome bangle of translucent green glass, with polychrome cable marvered on one side and decorated with plain band on other sides, triangular section. Mamluk–Ottoman periods. L. 2.8 cm, W. 0.7 cm.*

## RESULTS

The chemical analyses of the 36 samples are given in Table 2. They reveal an unexpectedly wide range of compositions that fall into three main types: (1) plant-ash glass, (2) high-alumina glass, and (3) mineral glass, made with an alkali-rich mineral other than natron. There is also a single example of a glass made using the mineral natron (AB35). Two samples of plant-ash glass that have compositions somewhat different from those of the main plant-ash group have been designated "plant-ash 1 glass." The compositional characteristics that led to the classification into three main types can be seen in the biplots of pairs of components.

The relative levels of alkalis in the glass types are shown in Figure 4. Most of the plant-ash glasses contain the lowest total alkali (about 11%–16%). There is one unusual plant-ash glass (AB27) that contains 5.98% potassium oxide and 8.79% sodium oxide. However, its other


FIG. 3. *High-alumina glasses:*
*205 (AB34). Tell Abu Sarbut. Fragment of translucent blue glass with two brown prunts, half-rounded flat section. Mamluk period. L. 2.6 cm, W. 0.5 cm.*
*314 (AB30). Tell Abu Sarbut. Smooth, dark fragment with triangular section. Mamluk–Ottoman periods. L. 4.3 cm, W. 0.7 cm.*
*423 (AB36). Khirbat Faris. Smooth, dark fragment with half-rounded section. Ottoman period. L. 3 cm, W. 0.7 cm.*

components fall well within the plant-ash group. The total alkali contents of the mineral glasses range from about 14% to 19%, those of the two plant-ash 1 glass samples are 22.79% and 24.21%, and the high-alumina glasses have some of the highest levels—21% to 28% (Figs. 4–8).

The plant-ash glasses are further characterized by typically elevated magnesia and potassium oxide contents,[59] as shown in Figure 5. (This figure clearly shows that each compositional type is distinct in the relative levels of these two oxides.) Other compositional characteristics indicating that the glasses were made from an organic (plant-ash) flux are elevated phosphorus pentoxide and sulfur trioxide (Figs. 6 and 7). They contain the highest calcium oxide levels of the glasses analyzed (7.17%–10.47%). Apart from one sample (AB15, a mineral glass), the glasses contain calcium oxide levels below 5.57% (Fig. 6). The alumina levels in the plant-ash glasses are variable, with a mean of 1.21% (Fig. 8). These levels suggest that an impure quartz sand was used to make the glasses. Only in the case of the two plant-ash 1 glass samples, with alumina levels of 2.23% and 2.3%, can it be suggested that a beach sand, with alkali feldspar impurities introducing these levels of alumina, was employed.

The high-alumina glasses are compositionally very distinct from the other types. Their alumina levels range from 5.95% to 10.25%

59. Edward V. Sayre and R. W. Smith, "Compositional Categories of Ancient Glass," *Science*, v. 133, no. 3467, 1961, pp. 1824–1826.

TABLE 2

Chemical Analyses, by Electron Probe Microanalysis, of Glass Bangles from Tell Abu Sarbut and Khirbat Faris

| *Sample Number* | *Color* | *$Na_2O$* | *MgO* | *$Al_2O_3$* | *$SiO_2$* | *$P_2O_5$* | *$SO_3$* | *Cl* | *$K_2O$* | *CaO* | *$TiO_2$* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *High-Alumina Glass* | | | | | | | | | | | |
| AB1 | dtr br | 18.08 | 2.04 | 8.97 | 52.37 | 0.52 | 1.03 | 0.59 | 6.21 | 4.77 | 1.24 |
| AB17 | dtr br/pu | 18.31 | 1.85 | 8.00 | 52.59 | 0.66 | 1.01 | 0.65 | 7.39 | 4.28 | 1.10 |
| AB21 | dtr emgr | 18.83 | 1.94 | 8.80 | 48.50 | 0.52 | 1.42 | 0.40 | 9.32 | 4.63 | 1.16 |
| AB22 | dtr emgr | 14.71 | 2.42 | 9.32 | 51.29 | 0.51 | 0.99 | 0.34 | 8.32 | 5.57 | 1.29 |
| AB26 | tr bl | 18.20 | 1.84 | 8.18 | 52.67 | 0.80 | 1.10 | 0.61 | 7.79 | 4.44 | 0.98 |
| AB30 | tr br | 21.38 | 1.79 | 6.83 | 55.25 | 0.62 | 0.96 | 0.79 | 4.59 | 5.47 | 0.80 |
| AB32 | tr br | 16.88 | 1.52 | 5.95 | 60.73 | 0.50 | 0.74 | 0.72 | 5.61 | 5.05 | 0.76 |
| AB34 | tr br | 18.39 | 2.62 | 10.25 | 47.40 | 0.52 | 1.29 | 0.26 | 9.17 | 5.06 | 1.15 |
| AB36 | tr br | 17.98 | 1.98 | 8.11 | 54.83 | 0.46 | 0.95 | 0.64 | 6.32 | 5.24 | 0.98 |
| | mean | 18.08 | 2.00 | 8.27 | 52.85 | 0.57 | 1.06 | 0.55 | 7.19 | 4.95 | 1.05 |
| | s.d. | 1.746 | 0.333 | 1.292 | 3.923 | 0.106 | 0.198 | 0.182 | 1.624 | 0.447 | 0.187 |
| *Mineral Glass* | | | | | | | | | | | |
| AB2 | tr cobl | 12.90 | 0.66 | 0.91 | 71.84 | 0.19 | 0.10 | 0.79 | 2.37 | 5.54 | 0.09 |
| AB3 | ogr | 13.48 | 0.37 | 0.65 | 66.71 | 0.08 | 0.29 | 0.60 | 4.05 | 2.80 | 0.08 |
| AB4 | ogr | 11.64 | 0.39 | 0.75 | 67.68 | 0.16 | 0.14 | 0.79 | 3.19 | 3.08 | 0.11 |
| AB13 | tr gr | 15.48 | 0.74 | 1.07 | 71.81 | 0.19 | 0.12 | 0.80 | 3.68 | 4.49 | 0.14 |
| AB15 | tr tu | 14.10 | 0.13 | 0.23 | 71.58 | 0.18 | 0.22 | 0.29 | 2.35 | 7.61 | 0.04 |
| | mean | 13.52 | 0.46 | 0.72 | 69.92 | 0.16 | 0.17 | 0.65 | 3.13 | 4.70 | 0.09 |
| | s.d. | 1.423 | 0.246 | 0.319 | 2.517 | 0.045 | 0.080 | 0.219 | 0.767 | 1.965 | 0.035 |
| *Plant-Ash Glass* | | | | | | | | | | | |
| AB6 | tr pu | 12.39 | 2.84 | 1.61 | 68.36 | 0.47 | 0.28 | 0.59 | 2.15 | 8.51 | 0.15 |
| AB7 | tr bl | 11.30 | 3.24 | 1.36 | 69.07 | 0.43 | 0.24 | 0.66 | 2.31 | 8.92 | 0.20 |
| AB8 | tr gr | 11.87 | 3.73 | 1.36 | 66.32 | 0.54 | 0.28 | 0.53 | 2.84 | 10.47 | 0.25 |
| AB9 | or | 11.08 | 3.30 | 1.22 | 61.93 | 0.53 | 0.16 | 0.51 | 2.78 | 9.40 | 0.13 |
| AB10 | tr pu | 9.79 | 3.39 | 1.37 | 65.88 | 0.43 | 0.28 | 0.52 | 2.52 | 9.60 | 0.18 |
| AB11 | tr gr | 11.20 | 4.07 | 0.94 | 66.86 | 0.46 | 0.21 | 0.64 | 3.32 | 10.40 | 0.12 |
| AB12 | tr pu | 11.24 | 2.71 | 1.19 | 70.29 | 0.36 | 0.13 | 0.73 | 1.52 | 7.17 | 0.18 |
| AB16 | tr bl | 10.62 | 3.95 | 1.12 | 64.63 | 0.55 | 0.12 | 0.59 | 2.80 | 9.64 | 0.17 |
| AB18 | tr pu | 10.54 | 2.73 | 1.69 | 67.89 | 0.38 | 0.44 | 0.33 | 2.28 | 9.14 | 0.15 |
| AB19 | tr pu | 11.51 | 3.81 | 0.81 | 66.28 | 0.42 | 0.20 | 0.54 | 3.46 | 8.65 | 0.18 |
| AB23 | col/v pgr | 11.35 | 3.93 | 0.91 | 66.38 | 0.50 | 0.14 | 0.62 | 3.35 | 10.23 | 0.18 |
| AB24 | tr pgr | 12.68 | 2.99 | 1.09 | 68.49 | 0.46 | 0.22 | 0.63 | 2.39 | 9.24 | 0.13 |
| AB25 | tr pbl | 11.20 | 3.20 | 1.25 | 68.44 | 0.48 | 0.20 | 0.55 | 2.49 | 8.48 | 0.15 |
| AB27 | dtr gr | 8.79 | 3.55 | 1.30 | 68.16 | 0.43 | 0.15 | 0.70 | 5.98 | 9.52 | 0.14 |
| AB28 | col | 15.33 | 2.97 | 0.78 | 67.99 | 0.31 | 0.18 | 0.75 | 2.22 | 9.11 | 0.15 |
| AB29 | ow | 8.60 | 2.43 | 1.07 | 57.48 | 0.28 | 0.17 | 0.47 | 2.56 | 7.79 | 0.14 |
| AB33 | tr pu | 11.26 | 2.78 | 1.64 | 67.87 | 0.55 | 0.28 | 0.50 | 2.45 | 8.63 | 0.16 |
| AB37 | emgr | 10.89 | 3.21 | 1.20 | 68.24 | 0.47 | 0.27 | 0.64 | 2.63 | 8.62 | 0.12 |
| AB38 | emgr | 11.03 | 3.19 | 1.18 | 68.36 | 0.51 | 0.21 | 0.59 | 2.59 | 8.79 | 0.20 |
| | mean | 11.19 | 3.26 | 1.21 | 66.9 | 0.45 | 0.22 | 0.58 | 2.77 | 9.07 | 0.16 |
| | s.d. | 1.43 | 0.474 | 0.26 | 2.91 | 0.075 | 0.077 | 0.100 | 0.902 | 0.836 | 0.03 |
| *Plant-Ash 1 Glass* | | | | | | | | | | | |
| AB14 | dtr br | 20.71 | 4.76 | 2.30 | 62.19 | 0.41 | 0.64 | 0.84 | 2.08 | 3.68 | 0.26 |
| AB31 | dtr gr | 19.52 | 4.69 | 2.23 | 59.19 | 0.29 | 0.47 | 0.49 | 2.47 | 9.88 | 0.08 |
| *Natron Glass* | | | | | | | | | | | |
| AB35 | dbr | 14.25 | 0.72 | 2.25 | 61.03 | 0.20 | 0.16 | 0.55 | 0.65 | 7.65 | 0.10 |
| Corning B standard (recommended) | | 17.26 | 1.19 | 4.22 | 61.55 | 0.84 | 0.54 | 0.2 | 1.1 | 6.71 | 0.1 |
| Corning B standard (average of 3) | | 17.06 | 1.02 | 3.99 | 60.75 | 0.84 | 0.47 | 0.13 | 1.09 | 8.56 | 0.09 |

Key: 0.00 = not detected, s.d. = standard deviation, tr = translucent, dtr = dark translucent, pu = purple, bl = blue, pbl = pale blue, cobl = cobalt blue, tu = turquoise, gr = green, pgr = pale green, v pgr = very pale green, emgr = emerald green, ogr = opaque green, or = opaque red, br = brown, dbr = dark brown, col = colorless, ow = opaque white

| $Cr_2O_3$ | MnO | $Fe_2O_3$ | CoO | NiO | CuO | ZnO | BaO | $As_2O_3$ | $Sb_2O_5$ | SnO | PbO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.20 | 14.93 | 0.01 | 0.09 | 0.01 | 0.01 | 0.05 | 0.00 | 0.16 | 0.03 | 0.00 | 101.33 |
| 0.00 | 0.06 | 2.93 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.04 | 0.01 | 99.07 |
| 0.00 | 0.16 | 4.05 | 0.06 | 0.00 | 0.10 | 0.13 | 0.00 | 0.00 | 0.14 | 0.05 | 0.12 | 100.33 |
| 0.03 | 0.20 | 4.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.22 | 0.00 | 0.02 | 99.38 |
| 0.07 | 0.08 | 2.97 | 0.06 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 99.95 |
| 0.00 | 0.12 | 2.58 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 101.19 |
| 0.03 | 0.16 | 1.40 | 0.06 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.04 | 0.03 | 0.08 | 100.27 |
| 0.00 | 0.11 | 3.95 | 0.00 | 0.09 | 0.00 | 0.00 | 0.06 | 0.00 | 0.20 | 0.00 | 0.12 | 100.64 |
| 0.00 | 0.10 | 2.60 | 0.05 | 0.03 | 0.00 | 0.00 | 0.03 | 0.00 | 0.15 | 0.00 | 0.01 | 100.46 |
| | 0.13 | 4.38 | | | | | | | 0.13 | | | |
| | 0.051 | 4.05 | | | | | | | 0.070 | | | |
| | | | | | | | | | | | | |
| 0.00 | 0.00 | 0.51 | 0.06 | 0.00 | 0.00 | 0.02 | 0.06 | 0.00 | 0.05 | 0.00 | 0.00 | 96.09 |
| 0.00 | 0.75 | 0.34 | 0.00 | 0.00 | 4.19 | 0.05 | 0.04 | 0.00 | 0.03 | 1.63 | 3.62 | 99.75 |
| 0.03 | 0.07 | 0.59 | 0.09 | 0.00 | 0.75 | 0.03 | 0.00 | 0.00 | 0.15 | 0.57 | 7.14 | 97.33 |
| 0.00 | 0.04 | 0.48 | 0.02 | 0.04 | 0.02 | 0.12 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 99.33 |
| 0.00 | 0.10 | 0.16 | 0.00 | 0.00 | 1.29 | 0.00 | 0.03 | 0.17 | 0.00 | 0.00 | 0.32 | 98.78 |
| | | 0.42 | | | | | | | 0.07 | | | |
| | | 0.171 | | | | | | | 0.064 | | | |
| | | | | | | | | | | | | |
| 0.00 | 3.62 | 0.75 | 0.02 | 0.07 | 0.00 | 0.07 | 0.08 | 0.00 | 0.04 | 0.00 | 0.00 | 99.90 |
| 0.00 | 1.09 | 0.96 | 0.02 | 0.00 | 0.09 | 0.17 | 0.03 | 0.00 | 0.10 | 0.00 | 0.03 | 100.20 |
| 0.02 | 0.70 | 0.73 | 0.00 | 0.03 | 0.00 | 0.04 | 0.04 | 0.00 | 0.00 | 0.00 | 0.03 | 99.78 |
| 0.04 | 2.18 | 3.11 | 0.05 | 0.00 | 3.16 | 0.00 | 0.03 | 0.00 | 0.10 | 0.07 | 0.45 | 100.22 |
| 0.00 | 3.99 | 0.94 | 0.00 | 0.09 | 0.02 | 0.08 | 0.01 | 0.00 | 0.04 | 0.00 | 0.00 | 99.11 |
| 0.00 | 0.12 | 0.46 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.01 | 0.16 | 99.13 |
| 0.01 | 2.48 | 0.80 | 0.06 | 0.03 | 0.00 | 0.13 | 0.01 | 0.00 | 0.02 | 0.02 | 0.00 | 99.07 |
| 0.00 | 1.07 | 0.93 | 0.10 | 0.12 | 0.26 | 0.09 | 0.00 | 0.00 | 0.18 | 0.18 | 1.18 | 98.28 |
| 0.00 | 2.68 | 0.86 | 0.04 | 0.03 | 0.12 | 0.00 | 0.11 | 0.00 | 0.00 | 0.01 | 0.05 | 99.46 |
| 0.02 | 2.03 | 0.49 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.12 | 0.11 | 0.00 | 98.65 |
| 0.00 | 0.01 | 0.42 | 0.00 | 0.00 | 0.06 | 0.01 | 0.00 | 0.00 | 0.10 | 0.02 | 0.06 | 98.26 |
| 0.00 | 0.00 | 0.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 99.08 |
| 0.00 | 1.45 | 0.99 | 0.08 | 0.07 | 0.10 | 0.10 | 0.11 | 0.00 | 0.00 | 0.00 | 0.03 | 99.34 |
| 0.00 | 0.29 | 0.61 | 0.00 | 0.00 | 0.25 | 0.00 | 0.01 | 0.00 | 0.04 | 0.05 | 0.03 | 100.00 |
| 0.00 | 0.04 | 0.41 | 0.00 | 0.04 | 0.03 | 0.00 | 0.02 | 0.00 | 0.16 | 0.00 | 0.03 | 100.53 |
| 0.00 | 0.33 | 0.50 | 0.04 | 0.03 | 0.00 | 0.01 | 0.00 | 0.00 | 0.15 | 3.80 | 12.23 | 98.08 |
| 0.00 | 3.12 | 0.79 | 0.08 | 0.05 | 0.14 | 0.00 | 0.08 | 0.00 | 0.01 | 0.00 | 0.03 | 100.41 |
| 0.00 | 1.04 | 0.56 | 0.00 | 0.02 | 1.54 | 0.13 | 0.03 | 0.00 | 0.06 | 0.00 | 0.00 | 99.65 |
| 0.01 | 1.08 | 0.63 | 0.01 | 0.01 | 1.49 | 0.03 | 0.11 | 0.00 | 0.14 | 0.00 | 0.00 | 100.15 |
| | 1.44 | 0.82 | | | | | 0.03 | | 0.08 | | | |
| | 1.271 | 0.586 | | | | | 0.040 | | 0.060 | | | |
| | | | | | | | | | | | | |
| 0.04 | 0.04 | 1.24 | 0.00 | 0.04 | 0.00 | 0.01 | 0.00 | 0.00 | 0.06 | 0.00 | 0.02 | 99.31 |
| 0.00 | 0.05 | 1.06 | 0.02 | 0.06 | 0.02 | 0.02 | 0.05 | 0.00 | 0.07 | 0.01 | 0.00 | 100.66 |
| | | | | | | | | | | | | |
| 0.00 | 0.91 | 11.51 | 0.00 | 0.01 | 0.00 | 0.11 | 0.07 | 0.00 | 0.08 | 0.01 | 0.00 | 100.23 |
| 0.01 | 0.28 | 0.35 | 0.04 | 0.09 | 2.7 | 0.2 | 0.14 | 0.00 | 0.46 | 0.04 | 0.40 | 100.41 |
| | | | | | | | | | | | | |
| 0.00 | 0.28 | 0.33 | 0.05 | 0.12 | 2.93 | 0.26 | 0.05 | 0.00 | 0.54 | 0.02 | 0.51 | 99.10 |

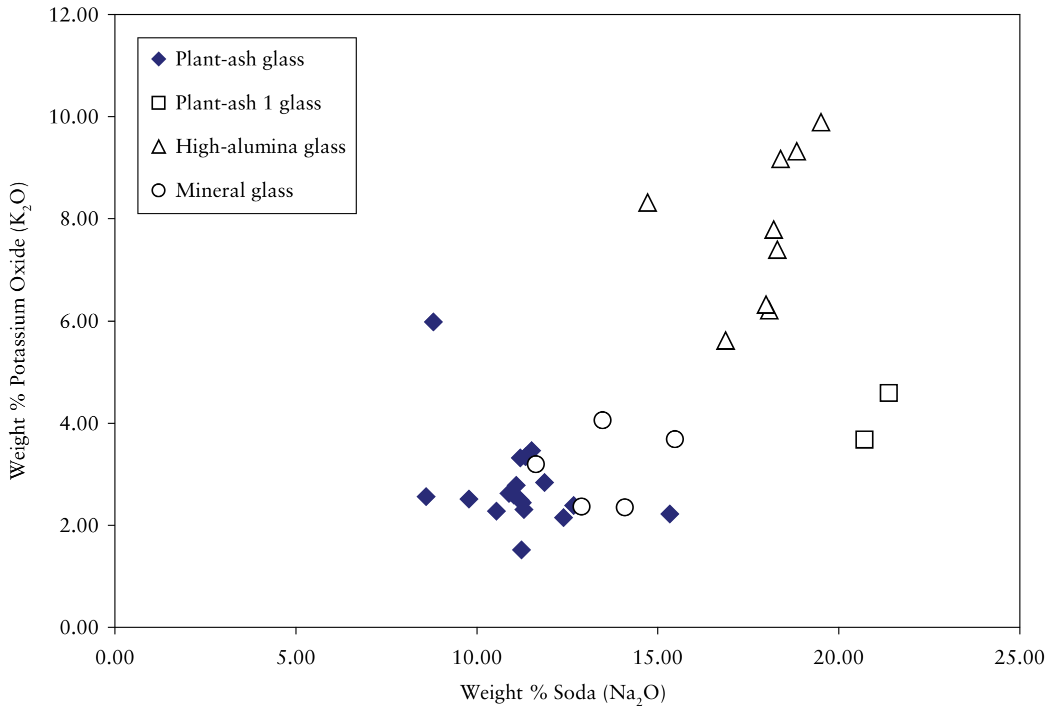


FIG. 4. *Relative levels of soda ($Na_2O$) and potassium oxide ($K_2O$) in bangles from Tell Abu Sarbut and Khirbat Faris.*

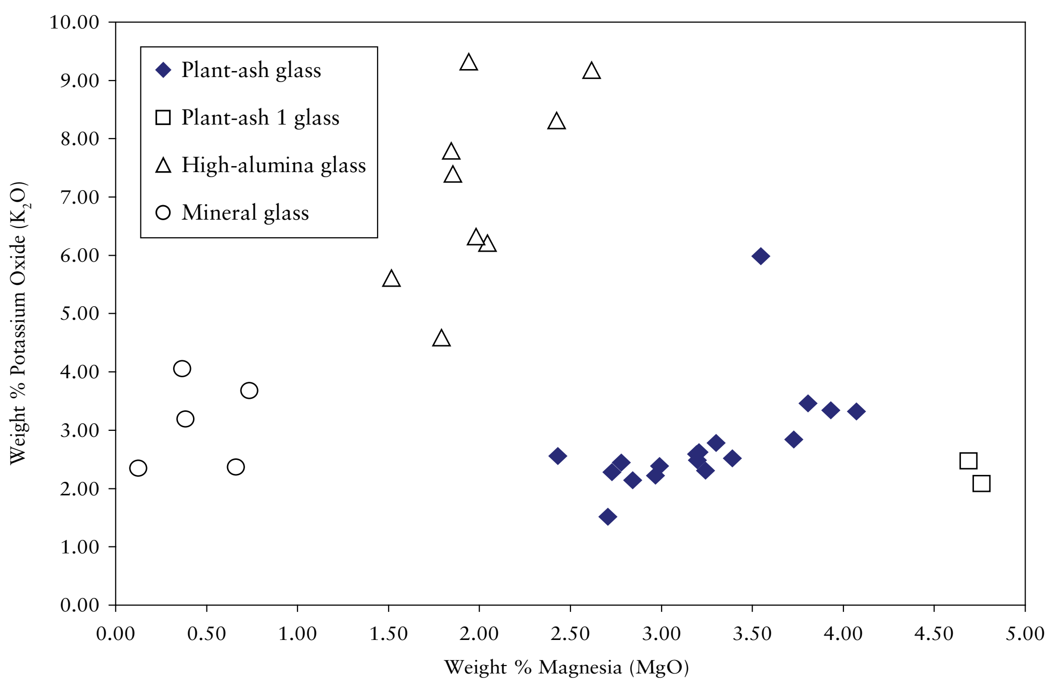


FIG. 5. *Relative levels of magnesia (MgO) and potassium oxide ($K_2O$) in bangles from Tell Abu Sarbut and Khirbat Faris.*

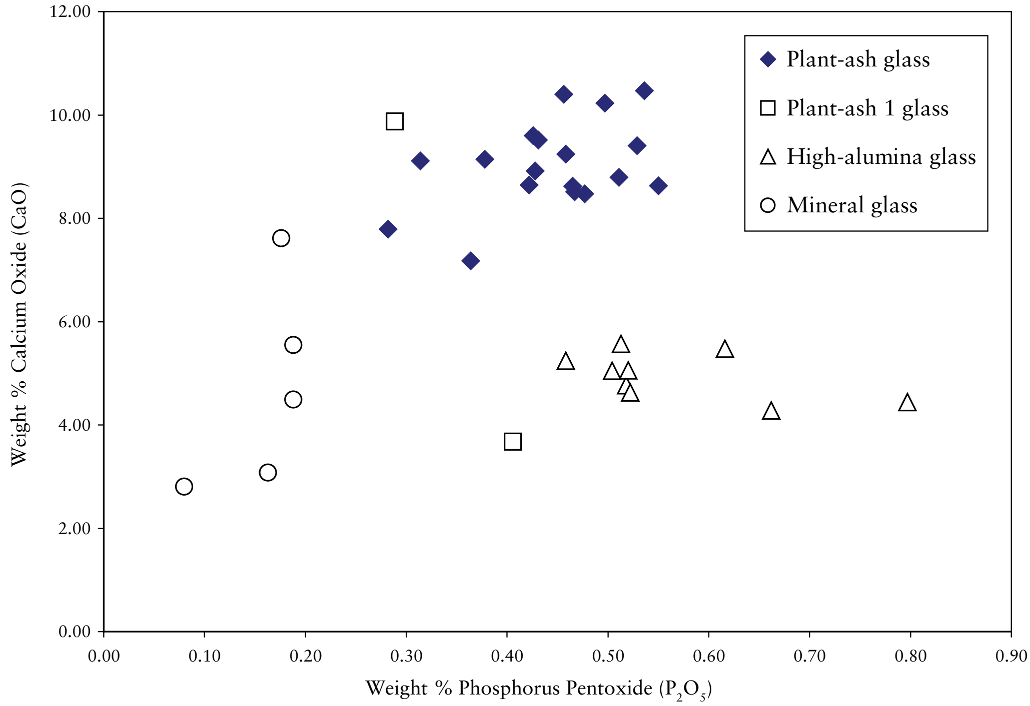


FIG. 6. *Relative levels of phosphorus pentoxide ($P_2O_5$) and calcium oxide (CaO) in bangles from Tell Abu Sarbut and Khirbat Faris.*

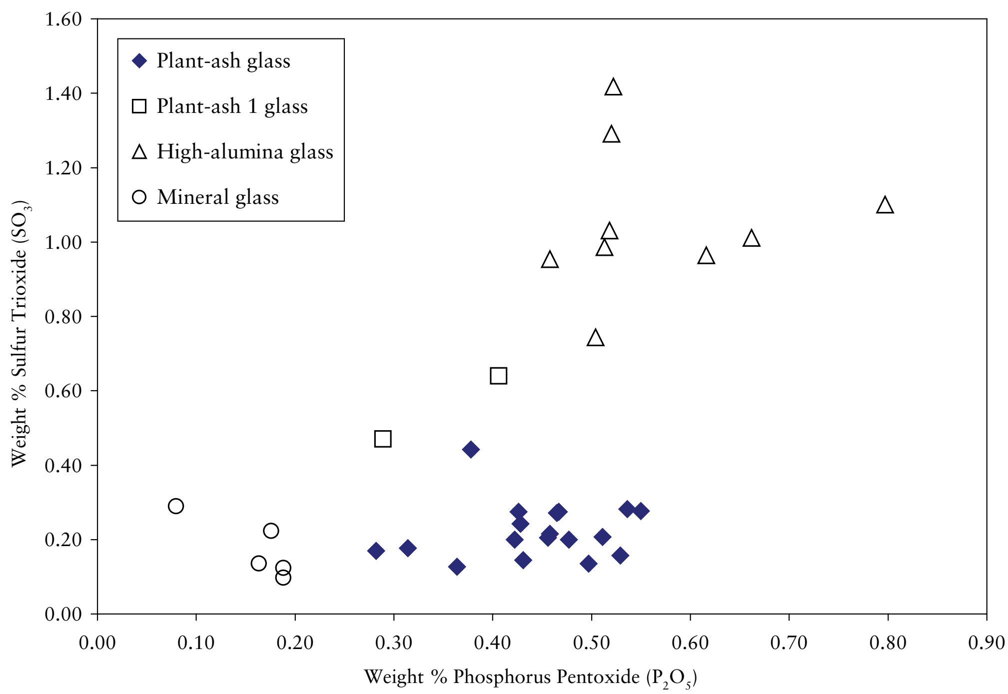


FIG. 7. *Relative levels of phosphorus pentoxide ($P_2O_5$) and sulfur trioxide ($SO_3$) in bangles from Tell Abu Sarbut and Khirbat Faris.*

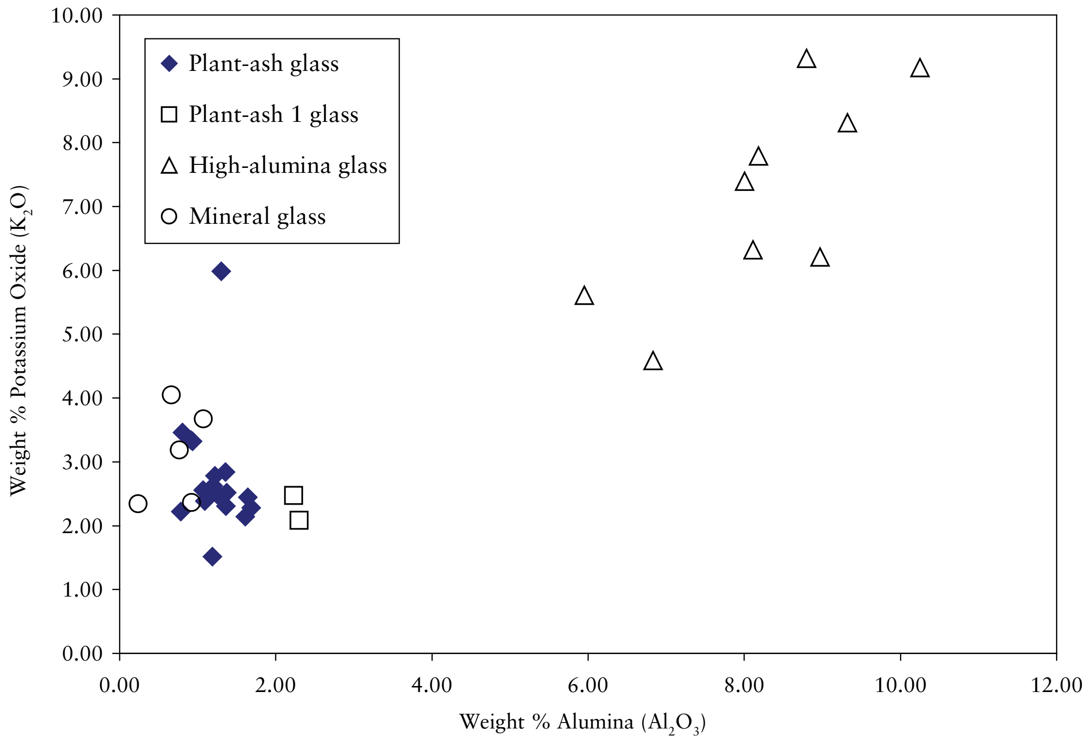


FIG. 8. *Relative levels of alumina ($Al_2O_3$) and potassium oxide ($K_2O$) in bangles from Tell Abu Sarbut and Khirbat Faris.*

(Fig. 8), considerably higher than the maximum levels of 1.69% and 1.07% found in the other two principal types. They also contain higher levels of potassium oxide than the other samples analyzed (4.59%–9.32%; Fig. 4), and consistently high phosphorus pentoxide levels, with a maximum of 0.8% (Fig. 6). These high-alumina glasses contain relatively low calcium oxide levels (Fig. 6). All of them contain high titania (0.76%–1.29%) and iron oxide (1.4%–12.93%) levels.

The mineral glasses are characterized by elevated potassium but low magnesium oxide levels (Fig. 5) and by lower phosphorus pentoxide levels than are found in the other two types, with a maximum value of 0.19% (Figs. 6 and 7).

A single example of a bangle made from natron glass (AB35) was found at Khirbat Faris. It has low levels of magnesia and potassium oxide. It also contains levels of calcium oxide (7.65%) and alumina (2.25%) indicating that beach sand containing shell fragments was used to make it.

## *Composition and Color*

The high-alumina glasses are translucent dark brown, translucent blue, or emerald green (Fig. 3), and most of the dark brown bangles have this composition. The only three exceptions are dark brown (AB14) and dark green (AB31) plant-ash 1 glass samples and a dark green plant-ash glass with an unusually high level of potassium oxide (AB27). The mineral glasses (Fig. 2) are blue, green, or turquoise. Two examples (AB3 and AB4) are opaque green, and they were opacified by lead-tin oxide. The plant-ash glasses are colorless or pale purple, blue, green, or emerald green (see Table 1), with one exception (AB27; see above). The only opaque sample with a plant-ash composition is red (AB9).

The colorants involved are the normal range of transition metals and opacifiers found in Islamic glasses.[60] The variety of parameters that can affect the final color of the glass produced is quite extensive, and this is discussed elsewhere.[61] Manganese oxide produces purple glass; iron and manganese oxides usually produce brown or green colors, but also pale blue, depending on the furnace atmosphere when the glass was melted; and cobalt normally results in a blue color. The last of these can be affected by the concentrations and relative absorption strength of other colorant ions. For example, $Co^{2+}$ is dominated by high concentrations of $Fe^{2+}$ in AB21, AB26, AB32, and AB36, producing dark brown colors in high-alumina glasses. Moreover, the chemical environment in which the colorant operates within the silicate network can affect the color. In these high-alumina glasses, the relatively high levels of potassium would help to produce darker glass tints than for the equivalent amount of sodium.[62] The only opacifying compounds that were used in these glasses were tin oxide in opaque green glass and cuprous oxide in opaque red glass. Both of these opacifiers were employed in the making of Islamic vessel glasses and enamels.[63]

## DISCUSSION

The range of compositional types is unexpectedly wide. If, for example, this compositional range is compared with the 284 glass compositions determined for the ninth- to 12th-century factory site at al-Raqqa, Syria, including some for glass bangles,[64] only one (ninth-century) high-alumina glass and no examples of mineral glass were detected in the Raqqa data. This indicates that (1) a correspondingly wider range of primary raw materials was used to make the bangles, and (2) in all probability, they had a wider range of geographical origins. Apart from three examples—two of plant-ash 1 glass compositions and another with a high potassium oxide level (AB27)—the bangles made with plant-ash glass are of a relatively consistent composition, with, for example, a relatively constrained range of magnesium and aluminum oxide levels, compared with al-Raqqa data (Fig. 9 and mean and standard values in Table 2). A comparison with the Raqqa data indicates that, according to the relative levels of magnesia and alumina, most of the plant-ash bangles are consistent with glass types 1, 2, and 4 found at Raqqa (Fig. 9). (The only exception is AB27, which contains 5.98% potassium oxide but not an unusually high magnesia level (3.55%).) The calcium oxide levels are similar to those detected in Raqqa type 1; the soda levels fall at the low end of the compositional range for Raqqa type 1.[65]

In the ninth century, there was a high compositional variation in the glass made at al-Raqqa because of experimentation that occurred during the shift from a glass technology dominated

60. Robert H. Brill, "Some Thoughts on the Chemistry and Technology of Islamic Glass," in *Glass of the Sultans*, New York: The Metropolitan Museum of Art in association with The Corning Museum of Glass, Benaki Museum, and Yale University Press, 2001, pp. 28–29 and 34–35; J. Henderson, S. D. McLoughlin, and D. S. McPhail, "Radical Changes in Islamic Glass Technology: Evidence for Conservatism and Experimentation with New Glass Recipes from Early and Middle Islamic Raqqa, Syria," *Archaeometry*, v. 46, no. 3, August 2004, pp. 439–468, esp. pp. 460–463.

61. Julian Henderson, *The Science and Archaeology of Materials: An Investigation of Inorganic Materials*, London and New York: Routledge, 2000, pp. 29–38.

62. C. R. Bamford, *Colour Generation and Control in Glass*, Amsterdam: Elsevier Scientific Publishing Co., 1977, p. 42.

63. Julian Henderson and James Allan, "Enamels on Ayyubid and Mamluk Glass Fragments," *Archeomaterials*, v. 4, no. 2, Summer 1990, pp. 167–183; Ian C. Freestone and Colleen P. Stapleton, "Composition and Technology of Islamic Enamelled Glass of the Thirteenth and Fourteenth Centuries," in *Gilded and Enamelled Glass from the Middle East*, ed. Rachel Ward, London: British Museum, 1998, pp. 117–122; Marco Verità, "Analytical Investigation of European Enameled Beakers of the 13th and 14th Centuries," *Journal of Glass Studies*, v. 37, 1995, pp. 83–98.

64. Henderson, McLoughlin, and McPhail [note 60], table 1, analyses 189 and 263–271; A. S. Meek, "Tracing Continuity: The Scientific Investigation of Glass Compositions from al-Raqqa, Syria, by EPMA/WDX and LA-ICP-MS," M.Sc. thesis, University of Nottingham, 2005.

65. Henderson, McLoughlin, and McPhail [note 60], p. 455, table 2, fig. 5.

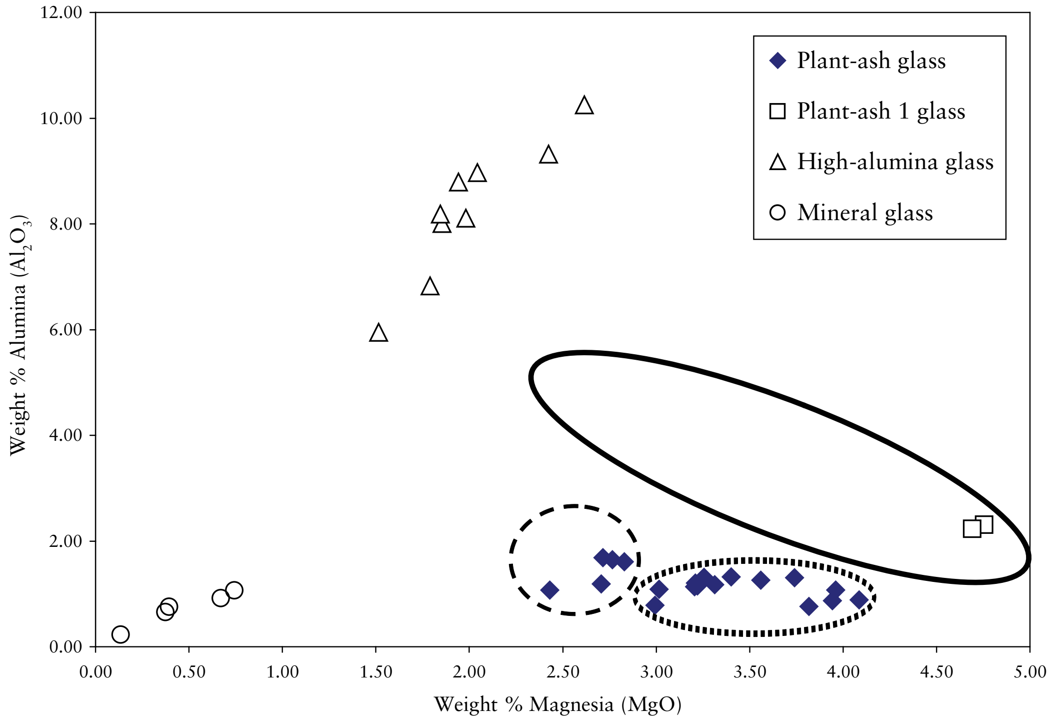


FIG. 9. *Relative levels of magnesia (MgO) and alumina ($Al_2O_3$) in bangles from Tell Abu Sarbut and Khirbat Faris, compared with compositional ranges for al-Raqqa plant-ash types 1 (dotted line), 2 (broken line), and 4 (solid line).*

by the use of a mineral source of alkali (natron) to one that employed an organic (plant-ash) source.[66] A lower compositional variation is found in plant-ash glasses made in Syria and Lebanon between the 10th and 12th centuries.[67] This relatively restricted compositional variation is evident in most of the bangle plant-ash data, as reflected in their standard deviations (see Table 2). Furthermore, it is notable that these Jordanian plant-ash glasses have consistently high titania and relatively high iron oxide levels, indicating that a rather impure silica source was used to make them.

Early 11th-century raw glass, probably manufactured in the Levant, was traded westward,[68] and it was of a mixed plant ash and natron composition.[69] This indicates either that a source of relic natron glass was recycled or, less likely, that

66. Ian C. Freestone, Yael Gorin-Rosen, and Michael J. Hughes, "Primary Glass from Israel and the Production of Glass in Late Antiquity and the Early Islamic Period," in *La Route du verre: Ateliers primaires et secondaires du second millénaire av. J.-C. au Moyen Age*, ed. Marie-Dominique Nenna, Lyons: Maison de l'Orient Méditerranéen, 2000, pp. 65–84; Julian Henderson, "Tradition and Experiment in First Millennium A.D. Glass Production: The Emergence of Early Islamic Glass Technology in Late Antiquity," *Accounts of Chemical Research*, v. 35, no. 8, 2002, pp. 594–602; Henderson, McLoughlin, and McPhail [note 60], p. 457.

67. Henderson, McLoughlin, and McPhail [note 60], p. 465; Ian C. Freestone, "Composition and Affinities of Glass from the Furnaces on the Island Site, Tyre," *Journal of Glass Studies*, v. 44, 2002, pp. 67–77.

68. George F. Bass, "The Nature of the Serçe Limanı Glass," *Journal of Glass Studies*, v. 26, 1984, pp. 64–69; Frederick H. van Doorninck, 'The Serçe Limanı Shipwreck: An 11th-Century Cargo of Fatimid Glassware Cullet for Byzantine Glassmakers," in *1. Uluslararasi Anadolu cam Sanati Sempozyumu=1st International Anatolian Glass Symposium*, Istanbul: Türkiye Şişe ve Cam Fabrikalari A.Ş. 1990, pp. 58–63.

69. Henderson [note 66].

natron glass, fused from primary raw materials at the time, was employed.[70] Five bangles, all from Tell Abu Sarbut, have plant-ash compositions with elevated alumina and/or lower magnesia levels (Fig. 9), have the Raqqa type 2 composition, and are compositionally similar to (raw) glass found on the Serçe Limanı shipwreck.[71] The main "experimental" type of plant-ash glass found at Raqqa, type 4, was still used to make most of the translucent dark glass bangles found in 11th-century contexts at Tell Fukhkhar, Raqqa.[72] This compositional type has its closest match in the two plant-ash 1 glass compositions, both from Tell Abu Sarbut. One Raqqa bangle, of a translucent dark brown color and securely dated to the 11th century, even contains the high soda level[73] that is characteristic of the two Tell Abu Sarbut samples (Fig. 4).

The production of plant-ash glass on an enormous scale in tank furnaces at Tyre dates to sometime between the 10th and 12th centuries.[74] The chemical composition of this glass is similar to Raqqa type 2 plant-ash glass in terms of relative magnesia, potassium oxide, and alumina, for example, but some is distinguishable from Raqqa type 2 by its higher calcium oxide levels (11.1%–14.3%).[75] The chemical compositions of the Tyre glasses are similar, but not identical, to those of the Serçe Limanı glasses.[76] Another compositional group of Islamic plant-ash glass with a characteristic chemical composition is a 10th-century colorless group from Nishapur, Iran,[77] with high soda and low calcium oxide levels. None of the bangles, including the colorless ones, have this composition.

Until now, high-alumina glass has been identified as originating mainly in India, Sri Lanka, southeastern Asia, and Africa.[78] Its presence in Jordan at both Tell Abu Sarbut and Khirbat Faris is therefore surprising and constitutes its westernmost known occurrence. However, the high potassium oxide and phosphorus pentoxide levels, combined with elevated magnesium oxide and sulfur trioxide levels, strongly suggest that these glasses were made not only from a mineral source of soda but also from an organic source. Lankton and Dussubieux[79] have noted the occurrence of a mineral high-soda and high-alumina glass in southeastern Asia, which, because only a mineral alkali source was used, has several compositional differences from the data set considered here. These researchers have also noted the presence of a plant-ash, high-alumina and high–calcium oxide glass in southeastern Asia. However, most of the potassium, aluminum, and iron oxide levels are below those present in these Jordanian high-alumina bangles, and the magnesium oxide levels reported by Lankton and Dussubieux are higher than those found in the bangles. The high-alumina mixed-alkali glasses that they discuss contain significantly lower soda levels, comparable iron oxide levels, and much higher silica levels. Therefore, none of the compositions reported by Lankton

70. Irina Andreescu-Treadgold and Julian Henderson with Martin Roe, "Glass from the Mosaics on the West Wall of Torcello's Basilica," *Arte Medievale*, v. 5, no. 2, 2006, pp. 87–140, esp. p. 135.

71. Robert H. Brill, *Chemical Analyses of Early Glasses*, v. 1, *Catalogue of Samples*, and v. 2, *Tables of Analyses*, Corning: The Corning Museum of Glass, 1999, v. 1, p. 90, nos. 3553 and 3554, and p. 92, nos. 3733–3744, and v. 2, pp. 180–181 and 185–186; Henderson [note 66].

72. Henderson, McLoughlin, and McPhail [note 60], p. 450, table 1, analyses 263–271.

73. *Ibid*., p. 450, table 1, analysis 265.

74. Aldsworth and others [note 37].

75. Freestone [note 67], table 1.

76. *Ibid*., p. 76.

77. Robert H. Brill, "Appendix 3: Chemical Analyses of Some Glass Fragments from Nishapur in The Corning Museum of Glass," in *Nishapur: Glass of the Early Islamic Period*, New York: The Metropolitan Museum of Art, 1995, pp. 211–233; Brill [note 60]; Henderson [note 66], fig. 8.

78. Robert H. Brill, "Chemical Analyses of Some Early Indian Glasses," in *Archaeometry of Glass, Proceedings of the Archaeometry Session of the XIV International Congress on Glass*, Calcutta: Indian Ceramic Society, 1987, pp. 1–25; James W. Lankton and Laure Dussubieux, "Early Glass in Asian Maritime Trade: A Review and an Interpretation of Compositional Analyses," *Journal of Glass Studies*, v. 48, 2006, pp. 121–144; L. Dussubieux and others, "The Trading of Ancient Glass Beads: New Analytical Data from South Asian and East African Soda-Alumina Glass Beads," *Archaeometry*, v. 50, no. 5, October 2008, pp. 797–821.

79. Lankton and Dussubieux [note 78].

and Dussubieux match those of the glass bangles. Moreover, none of the high-alumina glasses from Africa and southeastern Asia published by Dussubieux and others[80] contain such high potassium oxide levels as are found here.

As noted above, the total alkali levels detected in the high-alumina bangle glasses (21%–28%) are quite exceptional. Islamic plant-ash Raqqa type 1 glasses dating from the ninth to 15th centuries, and perhaps later, normally contain total alkali (soda + potassium oxide) of about 11% to 16%.[81] With one exception, the Jordanian bangles have a deep translucent color because of high iron levels (correlated with both alumina and titania). None of the other *translucent* glasses analyzed contain high levels of all three oxides. This suggests that a granitic sand of variable composition was used to make them. Moreover, by using such an impure silica source, a deep, almost opaque translucent color was guaranteed. If this very dark glass was mixed with glass cullet or raw glass of a different color, the dark hue would be dominant. Four of the high-alumina glasses contain sufficient cobalt oxide levels (0.05% or 0.06%) to color a plant-ash glass blue, but here the cobalt colorant is dominated by the high iron levels. This is evidence that the unusual glass composition probably resulted from the mixing of two compositional types (see below), one sometimes containing cobalt oxide.

Although the high iron and aluminum oxide levels in these dark-colored glasses could produce a glass with a short working period, the very high levels of total alkali and the low levels of calcium and silicon oxides would counteract this to some extent. These glasses would be much easier to work, for longer periods and at lower temperatures than, for example, the mineral high-alumina glasses discussed by Lankton and Dussubieux.[82] Moreover, the occurrence of such unusually high total alkali levels also suggests that two sources of alkali were involved, probably produced by mixing raw glass of two different chemical compositions. One of these was probably made from a high-alumina raw material, such as *reh*,[83] perhaps combined with granitic sands containing high alumina levels, and the other was likely to have been a plant ash associated with high magnesia. It has been suggested that the use of ancient sources of *reh* introduced low levels of magnesia (about 1%) and higher levels of potassium oxide (3%–6%) in the glasses.[84] Nevertheless, Brill's analysis of extracted *reh* then formed into a glass gave only a level of 2.28% potassium oxide,[85] so an additional potassium source would have been necessary to form our high-alumina bangle glasses with such high potassium oxide levels. Such a mixture of glass, one made from *reh* and the other from plant ash, could account for the high levels of soda, potassium oxide, alumina, and magnesia. An alternative or additional way of producing high alumina levels from alumina derived from sands would be from aluminosilicate impurities in the alkali source used.[86] In Figures 4, 5, and 8, it can be seen that, in these high-alumina glasses, alumina, magnesia, phosphorus pentoxide, sulfur trioxide, soda, and potassium oxide fall on mixing lines for alkalis and impurities associated with them. Therefore aluminum, magnesium, phosphorus, and sulfur, all of which can be associated with alkalis and fall on mixing lines, were probably mixed, occurring at various levels in the two glass types that were mixed.

The high-potassium plant-ash glass (AB27) is a single example of an unusual plant-ash glass (see Figure 8), with a possible Afghan origin (see below). If mixed with the high-alumina glass, it could produce potassium oxide levels of about 9% in those glasses. Brill has published results for Islamic glasses found in Afghanistan, and on the basis of these, he has suggested that Islamic

80. Dussubieux and others [note 78], table 3.
81. Henderson [note 66], table 3.
82. Lankton and Dussubieux [note 78], p. 127, table 2.
83. Brill [note 71], v. 2, p. 481.
84. P. Robertshaw and others, "Chemical Analysis of Glass Beads from Madagascar," *Journal of African Archaeology*, v. 4, no. 1, 2006, p. 98, fig. 2; Dussubieux and others [note 78].
85. Brill [note 71], v. 1, p. 212, and v. 2, p. 481.
86. Robertshaw and others [note 84], pp. 102 and 104.

glasses containing more than 4% potassium oxide were probably made there.[87] For example, five of the 12 compositional analyses of vessel fragments from Shahr-i-Banu, north of Tashkurghan, dated between the seventh and 13th centuries, contain more than 5% potassium oxide.[88] This is an unusual compositional characteristic and could have provided some of the high potassium levels found in the high-alumina Jordanian bangles. Only three samples of plant-ash glasses out of 234 ninth–11th-century glass samples from al-Raqqa, Syria, were found to contain more than 4% potassium oxide.[89] This underlines the rarity of such glasses in the Middle East.

The chemical composition of the "mineral glass" is quite difficult to interpret. It could be suggested that these glasses were made from a natron alkali source with elevated potassium levels based on a potassium-rich feldspar in the silica used. However, their low alumina levels (0.23%–1.07%) are significantly lower than that of about 2%–3% found in most natron glass, normally attributed to the presence of feldspars in the sands employed;[90] the low levels of magnesium, phosphorus, and sulfur oxides confirm the use of a relatively pure alkali source and therefore a mineral one. However, it appears that a silica source other than that normally used to make natron glass was employed to make the compositional type. Although only five analyses are involved, part of the evidence for suggesting this is that the source of the potassium in the glass is not correlated with magnesium, as it clearly is in both plant-ash and high-alumina glasses (Fig. 5), a correlation that is well known in ancient natron glasses.[91] Instead, the magnesium is positively correlated with alumina (Fig. 9). This also suggests that the glass was made from a silica source unlike that normally employed to make natron glass. Moreover, the mineral alkali used was purer than natron. It is of particular significance that none of the contexts in which bangles of this composition were found were securely "ancient." The best compositional parallels are 19th-century Italian tesserae glasses with the same low impurity levels, some of which have the same characteristic ratios of potassium oxide:magnesia and potassium oxide: alumina.[92]

Moreover, it may be significant that AB15, a translucent turquoise bangle from Khirbat Faris (Fig. 2), is the only bangle analyzed that contains 0.17% arsenous oxide. Apart from its association with the use of cobalt ores in ancient glasses, it is found only in glasses dating to the 17th century and later, and it is increasingly found as an impurity in 19th-century glasses. The only major difference between the bangles made with this mineral glass and analyzed 19th-century glass tesserae is the significantly higher silica levels in the bangles. This may simply be the result of a slightly different, possibly contemporaneous, batch composition. We do not know how early this compositional type was produced, and without any securely dated examples earlier than the 19th century, we cannot even be sure whether it was made in the 18th century.

## CONCLUSIONS

The glass bangles analyzed here display a wide compositional range. This could suggest that the bangle makers simply used any raw glass or cullet that was available to them. However, there is no evidence that the compositional types defined here were mixed. The high-alumina glasses are the most westerly examples known to the authors. The chemical compositions of examples

87. R. H. Brill, "Thoughts on the Glass of Central Asia with Analyses of Some Glasses from Afghanistan," in *Proceedings of the XV International Congress on Glass, Leningrad, 1989, Archaeometry*, Moscow: Rotoprint VNIIZSM, 1989, pp. 19–24; Brill [note 60], p. 28, fig. 17, table 2.

88. Brill [note 71], v. 1, p. 145, and v. 2, pp. 342–343.

89. Henderson, McLoughlin, and McPhail [note 60], pp. 443, 445 and 448, table 1, analyses 18, 104, and 188.

90. R. H. Brill, "Scientific Investigations of the Jalame Glass and Related Finds," in *Excavations at Jalame, Site of a Glass Factory in Late Roman Palestine*, ed. Gladys Davidson Weinberg, Columbia: University of Missouri Press, 1988, p. 259.

91. Sayre and Smith [note 59]; Henderson [note 61], fig. 3.28.

92. Andreescu-Treadgold and Henderson with Roe [note 70], p. 121, table 1.

from East Africa, India, and Sri Lanka published by Dussubieux and others are dated between the fourth century B.C. and the fifth century A.D.; those from Africa are as late as the 19th century.[93] However, none of these has the same high levels of potassium oxide found in the Jordanian bangles, making the bangle glasses highly distinctive. The chemical compositions of the high-alumina glass bangles from Tell Abu Sarbut and Khirbat Faris nevertheless suggest that part of the glass used came from central Asia or perhaps the Far East. If the bangles were made in the Levant, the glass would have reached the area along the Silk Road or by sea.

Most of the high-alumina bangles have a deep translucent green or brown color because of high iron levels, correlated with both alumina and titania. This suggests that a granitic sand of variable composition was used to make them. Moreover, by using such an impure silica source, a deep, almost impenetrable translucent color was guaranteed. If this very dark glass was mixed with glass cullet or raw glass of a different color, the dark color would dominate. Four of the brown high-alumina glasses contain easily enough cobalt oxide (0.5% or 0.6%) to color a plant-ash glass blue, but here the cobalt colorant is dominated by the coloring effect of the high iron levels. This is further evidence that this unusual glass composition resulted from the mixing of two compositional types, a plant-ash glass, perhaps with high potassium oxide, and a high-alumina glass, one originally colored with cobalt.

Most of the plant-ash glass compositions are similar to others reported for the Middle East. However, an attempt to determine the provenance of plant-ash glass (and other compositional types) using chemical analysis alone is not straightforward,[94] even with the discovery of production sites where the glass was being made.[95] The determination of radiogenic isotope ratios in these glasses (and potential raw materials used to make them) could contribute to the study by (1) relating the isotopic signatures of the glasses to the signatures of raw materials used[96] and (2) showing that raw glasses made from raw materials of different geological ages and types had been mixed.[97] Such work would therefore have a strong potential for providing a *geological provenance* for the glasses. This approach would have its best chances of success if conducted in conjunction with the scientific analysis of glass from newly discovered bangle-making sites. One outcome would be to prove unambiguously that (raw) glasses made from different raw materials had been mixed (as suggested here for the high-alumina Jordanian bangles).

In connection with the study of glass provenance at a local level, we have investigated the hypothesis that two different "cultures" existed in central Jordan, the first in the Jordan Valley, where Tell Abu Sarbut is located, and the second in the Kerak area, where Khirbat Faris is situated, as reflected in the presence of glass bangles and in their chemical compositions. The same three basic compositional types have been found at Tell Abu Sarbut and Khirbat Faris, showing that the bangles were probably made from the same types of raw materials. This is hardly surprising because the primary manufacture of raw glass is likely to have occurred in urban contexts, as was the case (based on archeological

93. See note 78.

94. Th. Rehren, "A Review of Factors Affecting the Composition of Early Egyptian Glasses and Faience: Alkali and Alkali Earth Oxides," *Journal of Archaeological Science*, v. 35, no. 5, May 2008, pp. 1345–1354, esp. p. 1353.

95. See Henderson, McLoughlin, and McPhail [note 60].

96. J. Henderson and others, "The Use of Oxygen, Strontium and Lead Isotopes to Provenance Ancient Glasses in the Middle East," *Journal of Archaeological Science*, v. 32, no. 5, May 2005, pp. 665–673; J. Henderson, J. Evans, and Y. Barkoudah, "The Roots of Provenance: Glass, Plants and Isotopes in the Islamic Middle East," *Antiquity,* v. 38, 2009, in press; P. Degryse and J. Schneider, "Pliny the Elder and Sr–Nd Isotopes: Tracing the Provenance of Raw Materials for Roman Glass Production," *Journal of Archaeological Science*, v. 35, no. 7, July 2008, pp. 1993–2000; Henderson and others [note 60].

97. Ian C. Freestone, Sophie Wolf, and Matthew Thirlwall, "The Production of HIMT Glass: Elemental and Isotopic Evidence," in *Annales de l'Association Internationale pour l'Histoire du Verre*, v. 16, London, 2003 (Nottingham, 2005), pp. 153–157; P. Degryse and others, "Evidence for Glass 'Recycling' Using Pb and Sr Isotopic Ratios and Sr-Mixing Lines: The Case for Early Byzantine Sagalassos," *Journal of Archaeological Science*, v. 33, no. 4, April 2006, pp. 494–501.

evidence) in the slightly earlier contexts of Raqqa and Tyre.

The bangles could have been made in or near these primary production centers, or in separate, secondary production centers. The second possibility would have relied on the mobility of artisans and/or middlemen. Although a separation of primary and secondary glass production centers has been suggested as an abiding model for ancient glass production, it would make little sense to export raw glass from an urban center such as Cairo, Damascus, or Raqqa in order to form bangles (or glass vessels) in a different urban center, when there would have been an existing demand for them among the populations of these cities. Whether or not this separation existed would have depended, in part, on where bangle- or vessel-making specialists were located.

The trail-decorated type of bangle from Khirbat Faris, which is also found at Hebron and Erani, was made from the very unusual soda-lime glass referred to here as "mineral" glass. It is notable that two bangles of this compositional type have no ancient "Islamic" parallels and that one bangle with *ove* or flower-type decoration (Fig. 2, no. 220) has a parallel in jewelry of the third and second centuries B.C. found in eastern Europe.[98] The only possible example for which a medieval date can be suggested is from Tell Abu Sarbut (Table 1, AB2), but even this was a surface find, so it cannot be securely dated. Because the only securely dated parallels for this compositional type are from the 19th century,[99] such a production date would explain the use of raw materials that are purer than those used to make ancient glasses.

Until examples of this compositional type are found in secure "ancient" (e.g., Mamluk) contexts, it is difficult to be certain whether the type is indeed the result of ancient production. At the moment, it does not seem likely. Further archeological and scientific work may eventually shed light on the origins of some of the glass found at the Hebron workshop referred to above.[100] Some examples are highly colored and/or opaque (Fig. 2), and the use of tin oxide, a typical ancient Islamic opacifying raw material, is somewhat unexpected if the glass was made in the 19th century. It is therefore important to establish when this glass was first manufactured.

Chemical analysis supports the idea of the diffusion of raw glass and bangles. Hawking is one mechanism that can be suggested for this. It is also possible that the same ethnic groups present at the two sites used bangles of similar origins. There are several possible interpretations for the presence of a group of dark monochrome bangles that contain high alumina levels. The first is that the bangles themselves were imported from India, Africa, or Southeast Asia, the second is that the bangles moved as a result of a population movement, and the third is that raw glass was imported from these areas and made into bangles in the Middle East. Their chemical analyses suggest that different glass types were mixed, and this could have occurred in the Middle East. The lack of compositional parallels for the high–potassium oxide, high-alumina glasses among published examples of African, Indian, and Southeast Asian high-alumina glasses increases the possibility that the mixing of glass occurred in the Middle East.

The question remains as to whether the characteristics of the material culture at Khirbat Faris and Tell Abu Sarbut, with the occurrence of dark, smooth bangles, is exceptional. In the future, perhaps it will be possible to create parallels with symbolic aspects of color, of great importance in the Islamic world, so that we will be able to suggest that they formed part of a special cultural/belief tradition. Ongoing research by S.B. at Tell Hesban (central Jordan) and at Hubras and Malka (both in northern Jordan) will shed further light on this first set of data, especially in relation to regional and cultural aspects of glass study.[101]

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98. Paul-Marie Duval, *Les Celtes,* L'Univers des formes, v. 25, Paris: Gallimard, 1977, p. 266, nos. 357–360.

99. See note 70.

100. See note 42.

101. In 2009, S.B. plans to study material from these sites.