

Studies in Early Egyptian Glass

C. Lilyquist and R.H. Brill



The Metropolitan Museum of Art

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with M. T. Wypyski

**and contributions by
H. Shirahata, R. J. Koestler, and R. D. Vocke, Jr.**

**The Metropolitan Museum of Art
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Preface

These studies were undertaken to form a historical and technological context for the large amount of vitreous material, most of which is now in The Metropolitan Museum of Art, believed to come from the tomb of three foreign wives of Tuthmosis III (ca. 1479–1425 B.C.). The tomb yielded a glass vessel and a large number of beads and inlays, as well as two more unusual vitreous vessels; and, as the reign of Tuthmosis III is commonly understood as the beginning of intentional glassmaking in Egypt, the study became an opportunity to consider the larger question of its origin: did glassmaking grow out of experimentation in other vitreous materials, or did it arrive with artisans or objects from nearby Western Asia? This survey of the archaeological and analytical literature, many compositional analyses of glass and additional vitreous materials, and lead-isotope studies are offered here as an integrated effort to move that discussion forward. Concluding statements at the end of each study suggest interpretations and indicate limitations.

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Part 1. Glassy Materials

C. Lilyquist, R. H. Brill, and M. T. Wypyski

Introduction

During the Predynastic period of Egyptian history prior to ca. 3000 B.C., artisans of the Nile Valley glazed stone and manufactured faience, a powdered quartz with alkali glaze. By Dynasty 4, ca. 2400 B.C., they had manufactured Egyptian Blue, a synthetic crystalline material that, like faience, could be shaped and fired into small objects. But it was not until almost a thousand years later that Nile Valley inhabitants produced glass, the fourth major vitreous technology of ancient Egypt (Part 2). Prior to that moment, however, and contemporary with it (i.e., ca. 1800–1400 B.C.), there were other vitreous materials being made which may or may not have had a relation to intentionally made glass (hereafter glass). It is the intention of this essay to describe some of those materials in The Metropolitan Museum of Art (see Fig. 1).

Survey of the Literature and Major Collections

A survey of the literature and of major collections by the primary author reveals that glass can only surely be said to appear at the end of the Second Intermediate period (Dynasties 15/17) or beginning of Dynasty 18, ca. 1550 B.C. (see Chronology and Part 2).¹ J. Harris's 1962 edition of A. Lucas's classic text listed some earlier instances² but several objects were deleted by D. Barag³ and E. Peltenburg,⁴ and a few others should also be deleted: the Sedment 1680 *wḏjt*-amulets are faience;⁵ the blue leonine spacer has been termed Egyptian Blue by J. Cooney;⁶ the nonvitreous

1. Glass vessels in general have received more attention than small objects: see P. Newberry ("A glass chalice of Tuthmosis III," *JEA* 6 [1920], pp. 155–60), D. Barag ("Mesopotamian glass vessels of the second millennium B.C.," *JGS* 4 [1962], pp. 23–25; Barag 1970, pp. 181–84; Barag, *Catalogue of Western Asiatic glass in the British Museum*, 1 [London, 1985], pp. 37f., and Nolte 1968, pp. 46–65. For small objects see Beck 1934, pp. 7–21; Lucas/Harris 1962, pp. 179–83; C. Aldred, *Jewels of the pharaohs* (London, 1971), pp. 36, 48, 126–29; and Wilkinson 1971, *passim*.

2. Lucas/Harris 1962, pp. 46–65.

3. Barag, "Mesopotamian glass vessels," p. 23 n. 84; Barag 1970, p. 181 n. 152. The pitted and weathered glass foot from Sedment 1300 (UC 16070) appears to be a late find that made its way deep into what is otherwise a grouping of Second Intermediate period objects; the smooth surface on the bottom of the foot is probably the result of modern grinding.

4. Peltenburg 1987. Without annotated references, it is difficult to be sure of the author's citations, but it appears that the frog found by E. M. Ayrton at Abydos was eliminated (it is surely of New Kingdom date; the excavator labeled it 18th dynasty).

5. Petrie/Brunton 1924, p. 6: UC 31661 is broken and allows one to see alternating strips of porous sandy material (cream and brownish purple) with glaze on top; and UC 22085 is intact but spots of glaze have flaked off the surface, allowing one to see the matte porous fabric below. These amulets have the effect of glazed composition spiraled beads (UC 31575 from Hu cemetery W, UC 20672 from Qau 5303, UC 20865 from Qau 5010), and a marbleizing pendant (also UC 20672 from Qau 5303), although the paste in the Sedment 1680 *wḏjt*'s is bicolored. The "strange piece of inlay, apparently of green glass, partly decomposed, with a dark strip let into it" reported by Petrie from tomb 523, Dynasty 1 at Abydos (*The royal tombs of the earliest dynasties, 1901; Part II*, EEF Memoir, 21 [London, 1901], p. 38) could be similarly misidentified but cannot presently be found at University College.

6. Cooney 1976, no. 362, contra Beck 1934. The surface is somewhat grimy and it is difficult to judge the fabric. This appears to be what Peltenburg lists as "Thebes, 1600" on p. 17 (= Beck 1934, no. 17). J. Bourriau

nature of the Qau 3712 kohl jar in Cairo that Lucas examined is here confirmed.⁷ The mosaic rod naming Amenemhat III cannot be confirmed (it was lost during World War II), but there is some support for Bissing's belief that the object was most likely Roman.⁸

Generally, Lucas/Harris's citations of "imperfect glass" ("a glass matrix in which a considerable proportion of uncombined quartz is embedded") in the pre-New Kingdom period refer to black, blue, and green objects (such as the beads published by C. Andrews, 1981⁹). Some of the references to objects of other colors do not seem to be correct.¹⁰ And it could be significant that Kaczmarczyk/Hedges did not come across true reds or yellows in the faience they studied; therefore, they did not believe that lead antimonate was used before Dynasty 18.¹¹ However tomb cards from Sedment 1680 mention red and yellow faience disk beads, today to be found in University College;¹² and Brunton 1930 noted yellow and red glass ring beads (along with other colors) in Qau 5505, a burial he assigned to the Second Intermediate period.¹³ These references need further investigation.

"Middle Kingdom" jewels of unknown provenance which are said to contain glass inlay were introduced by H. W. Müller¹⁴ and Andrews.¹⁵ The inlays are small, but red in the Munich description would be important if it could be confirmed. At present there is no way to date these jewels to Dynasty 12 as opposed to a subsequent period.¹⁶ G. Martin has proposed two scarabs in the British Museum, while we termed similar-looking items "glassy faience" (nos. 4, 5). A toggle pin in our group, which has inlay we believe is glass (Part 2, no. A), would also belong to this

has assigned a typologically similar example to the post-New Kingdom era ("Egyptian antiquities acquired in 1984 by museums in the United Kingdom," *JEA* 72 [1986], p. 182, no. 219).

7. As discussed in Barag 1970, p. 181. Note, however, Brunton's reference to a "glass" scaraboid and "glass paste" scarab from this tomb (1930, pl. 19); Lilyquist did not examine these in the Cairo group JdE 48238-65.

8. Berlin 18439: Beck 1934, no. 21; information kindly supplied by K.-H. Priese. A cult of Amenemhat III in the Fayum is documented in the Ptolemaic period, see Kemp/Merrillees 1981, p. 41.

9. Cited by Peltenburg 1987. These should be nos. 213, 216, 268, 303, 317, 329, 581, 630; cf. no. 471. Andrews's 1981 dating seems to be that of the excavators; these dates are uncertain, see Lilyquist, *Ancient Egyptian mirrors*, MÄS, 27 (Munich/Berlin, 1979), pp. 2f. and Appendix. The earliest historically dated glass beads appear to be from the burial of Mentuhotep II's concubine Mayet, MMA 22.3.323 (= Beck 1934, no. 18).

10. In "First Intermediate period" Qau 1521 Brunton found a "red glass bead" but ruled it out as an accidental intrusion even though he considered the grave undisturbed (G. Brunton, *Qau and Badari II*, BSA and ERA 29th year, 1923 (London 1928), p. 21; Beck 1934, no. 14). In Qau 4512 he found a "red paste" bead and stated it "need not be contemporary, as the grave was badly plundered and not well dated," although he reported red paste in 3908 and 4504 (Brunton, *Qau and Badari II*, p. 11). The "four red glass beads" found at Armant (R. Mond and O. Myers, *Cemeteries of Armant* [London, 1937], p. 72) are actually described by the excavator as "pink clear glass" with their date open to doubt. For the report of yellow beads in a predynastic burial, see Beck 1934, no. 3.

11. Cf. Lucas/Harris's three "Dynasty 12" beads, opaque green with one yellow end.

12. UC 31647; R. Janssen kindly provided help with the records.

13. Brunton 1930, pl. 6. The burial had only an anhydrite kohl pot for dating purposes; there are several instances of such vessels in Dynasty 18 burials.

14. Munich ÄS 5381, gold shell with inlaid butterfly and lotuses, no provenance; light blue, dark blue, red inlays; height of ornament 2.9 cm. Müller stated that it was "presumably Dynasty 12," (*Staatliche Sammlung ägyptischer Kunst* [Munich, 1970], room 2, vitrine 68); see also S. Schoske and D. Wildung, *Ägyptische Kunst München* (Munich, 1985), pp. 44f.

15. Andrews 1981, no. 414: BM 3077, light and dark blue glass, width of ornament 2.3 cm. Her dating includes Dynasty 12 and all but the last ca. 25 years of Dynasty 13; Bourriau wrote that the date should be extended to the New Kingdom because of the glass, *Pharaohs and mortals; Egyptian art in the Middle Kingdom* (Cambridge, 1988), no. 154.

16. Lilyquist, "On [late] Middle Kingdom style, with reference to hard stone scarabs, inlaid jewels, and Beni Hasan," *Discussions in Egyptology* 27, in press.

intermediate period. A purchased object, it probably comes with a group from or near the Hyksos capital of Avaris (Lilyquist 1993).

Since the Lucas/Harris survey, several additions have been made to alleged pre-New Kingdom glass, both from excavations and from the art market. Some of these can also be deleted, while others await further investigation. A. Wilkinson reintroduced turquoise-colored inlays in several jewels from the pyramid precincts at Dashur¹⁷ and Lahun,¹⁸ though generally not the same ones E. Vernier had mentioned.¹⁹ None of the Dahshur/Lahun jewels examined by Lilyquist recently in Cairo²⁰ seemed to be glass;²¹ more importantly, Wypyski analyzed two of the Dashur pendants with turquoise-colored inlay in New York and showed that they were turquoise.²² Wilkinson also proposed the turquoise and blue inlays in the Antef diadem (presumably Dynasty 17)²³ as glass;²⁴ and M. Raven has looked at the inlay and reports that the dark blue, but not the light blue, may be glass.²⁵

Much more problematic is P. Lacovara's dating of the Lafayette/Boston jewel to late Dynasty 13–Dynasty 17.²⁶ This object varies considerably from known pre-Empire objects; its dating is complicated and its provenance is the art market. It is therefore discussed elsewhere; it should probably not be dated earlier than Dynasty 18.²⁷

17. In Khnemet's jewels: parts of the bodies in the vultures' pendant (Wilkinson 1971, p. 58, CG 52913); the cheeks of the two small falcon terminals (CG 52920/1) and some of the amulets strung with them (ibid., pp. 65f., CG 52926/29–31/59–61/63–74); the large falcon terminals' dots and crescents (CG 52861/2), and inlays of the *ḥh*, *ḏd*, and *w3s* amulets strung with them; and in petal pendants (CG 53019). See Vernier 1925.

18. In Sithathoryunet's pectoral: Vernier 1907–09, CG 52712, again the buff-colored inlay, cf. Wilkinson 1971, pp. 83, 88.

19. Vernier, "Le Verre, l'Émail," *Bulletin de l'Institut français d'Archéologie orientale* 12 (1916), pp. 36–38; Vernier 1907–09, CG 52001/2/3. She did not follow Vernier on CG 52001 (Wilkinson 1971, p. 85), although apparently did on the buff-colored inlay of Meret's CG 52003.

20. The turquoise material (probably also in the eight-part scarab, Vernier 1907–09, CG 52257; seemingly also in CG 52260, Wilkinson 1971, p. 77) is indeed exceptionally free of impurities, but bubbles or conchoidal fractures were not apparent, and there seemed to be no difference between the inlays cited by Vernier and Wilkinson and the ball beads from the same treasure.

21. Wilkinson also proposed glass as the turquoise (Vernier 1907–09, CG 52257/9) and white (CG 52247, 52250/1/2) substance of several Dashur scarabs; unfortunately it was not possible to examine these items in Cairo.

22. MMA 26.7.1302 and .1304, by EDS; see H. Winlock, "Elements from the Dahshur jewelry," *ASAE* 33 (1933), pp. 135–39. Wypyski's finding would mean that Beck's barrel bead no. 22 was not necessarily Dynasty 12. Having handled the Dashur jewels in Cairo on several occasions, Lilyquist believes that the MMA pendant is altogether consistent with them.

23. Cf. M. Raven, "The Antef diadem reconsidered," *Oudheidkundige Mededelingen, Rijksmuseum van oudheden* 68 (1988), pp. 83–85 and Kitchen 1987, p. 50.

24. Wilkinson 1971, p. 113.

25. Leiden AO 11a: ten dark blue inlays in two separate lotuses; width of each lotus ca. 3.5 cm. Raven and J. Sloos observed that the light blue inlays of the diadem were probably faience on the basis of gritty edges, but that the dark blue inlay could possibly be glass because of minute air bubbles and apparent lack of inner sandy core: on the date, Raven in "The Antef diadem," pp. 80, 83–85.

26. BMFA 1981.159; "An ancient Egyptian royal pectoral," *Journal of the Museum of Fine Arts, Boston* 2 (1990), pp. 18–29; see also, R. Newman, "Technical examination of an Ancient Egyptian royal pectoral," ibid., pp. 31–37.

27. "The Boston/Lafayette jewel and other inlaid ornaments," *Varia Aegyptia* 9, nos. 1–2, in press.

Current Study

The description of vitreous materials other than glass, assigned to the period late Dynasty 12—reign of Amenhotep II and today in The Metropolitan Museum of Art, is the substance of this essay.

By "vitreous materials" we mean materials which contain a significant glassy phase, even though it may be only minor and serving as a glaze or a connective phase. We include a schematic drawing to illustrate the materials and clarify what we mean by the terms used here (Fig. 2).

The first three objects in our study are from the MMA's excavations at Lisht. Although still unpublished, this site offers a range of vitreous materials of the later 12th and 13th dynasties (ca. 1800–1650 B.C., see Chronology) that have potential for further investigation.

Two manganese-colored cylinder beads from the "Glaze Factory" at Lisht were examined; we determined them to be glassy faience (nos. 1, 2; Fig. 3), by which we mean a material intermediate between glass (essentially a single homogeneous phase) and faience (essentially an aggregate of crystalline grains held together by a "connective tissue" of glass).²⁸ Faience usually has a large proportion of interstitial air space, but glassy faience contains a continuous glassy phase filled with a large proportion (perhaps half) of incompletely fused mineral grains (usually quartz). The air space in glassy faience exists as isolated, rounded bubbles.

A second material from Lisht was more difficult to define. It appears to have a composition intermediate between glassy faience and Egyptian Blue; we studied it in a crocodile from a toilet basket (no. 3; Figs. 1, 4) and recognized it in a small vessel from an adjacent basket (Fig. 5, left).²⁹

A third vitreous material used at late Middle Kingdom Lisht was Egyptian Blue: it was used to form small sculptures³⁰ as well as vessels (Fig. 5, the three on the right).³¹ We did not analyze Egyptian Blue objects, but we observed that the shape and size of a small unprovenanced glass vessel in the MMA (Fig. 6, left)³² was similar to late Middle Kingdom vessels from Lisht of Egyptian Blue and stone (cf. Fig. 5 and Fig. 6, center and right):³³ it would appear that intentional glassmaking followed soon after these late Middle Kingdom objects were produced at Lisht.

Our study then considered two unprovenanced scarabs of the late Middle Kingdom (late Dynasty 12 and Dynasty 13) or Second Intermediate period (Dynasties 15/17). As mentioned above, G. Martin identified glass as the material of "Dynasty 12" (ca. 1963–1786 B.C.)³⁴ and "Dynasty 13" (ca. 1786–1648 B.C.)³⁵ opaque turquoise scarabs in the British Museum some years

28. Kaczmarczyk/Hedges 1983, p. 20, relates glassy faience to glass; M. S. Tite to frit with reference to faience ("Characterization of early vitreous materials," *Archaeometry* 29, no. 1 [1987], p. 23).

29. MMA 44.4.1 from toilet basket 1.

30. MMA 22.1.66 from LNP 379.

31. MMA 22.1.64 from LNP 378 (Dynasty 13), 15.3.119 from LNP 444 (late Dynasty 12), and 22.1.112 from LNP 884 (late Dynasty 12–early Dynasty 13). Dates supplied by J. Bourriau, communication 1992.

32. MMA 26.7.1179; from the Hood collection, reportedly found at Qurna, ca. 1860. Height 3.5 cm.

33. MMA 11.151.755 and 44.4.3 from toilet basket I (late Dynasty 12–Dynasty 13, Bourriau date 1992).

34. BM 66738, ca. 2.4 cm long: *Egyptian administrative and private-name seals, principally of the Middle Kingdom and Second Intermediate period* (Oxford, 1971), no. 1199, back type 3d (one of five examples, 202); Cooney 1976, p. xv. This scarab, a dense opaque turquoise, has bubbles in the surface and seems similar to our no. 4. For Martin's dating see Lilyquist, "On [late] Middle Kingdom style." A close look at the dating of the scarabs by which the two glass examples Martin publishes were dated indicates the second half of Dynasty 12 to the first half of Dynasty 13 for this scarab.

35. BM 67737, fragmentary, ca. 2.0 cm long: Martin no. 441, back type 6s (worn; one of 58 examples), *Private-name seals*, p. 202. This scarab is quite weathered today, most of a thick whitish crust having flaked off the back to reveal a bright opaque turquoise core, with only the delineated tips of the elytra preserved in the weathered crust.

ago. Although the dating of scarabs varies among specialists,³⁶ and much of the back of Martin's Dynasty 13 example is missing, both of those scarabs are surely earlier than Dynasty 18, as are other glassy scarabs in the British Museum³⁷ and MMA.³⁸ Furthermore, Martin's Dynasty 13 example looks particularly glassy.

The two scarabs in the MMA, which appeared glassy and fell within the pre-New Kingdom period, are nos. 4 and 5 here (Figs. 1, 7, 9). No. 4 is visually similar to the British Museum's "Dynasty 12" scarab, although the details of the MMA's example look "carved." No. 5, assigned to Dynasties 15/17 (ca. 1648–1540 B.C.), has a fused appearance but its fabric nevertheless has a few cracks. Energy-dispersive X-ray spectrometry (EDS) analysis of the surface showed less calcium than copper, a feature that would be atypical of ancient glasses. Unfortunately, this scarab had no interior surface exposed to examine. We termed both New York scarabs "glassy faience," without ruling out the possibility that minor amounts of Egyptian Blue are present in both.

In the MMA's early Dynasty 18 collection, we examined several additional seals: a cowroid with engraved inscription from the time of Hatshepsut (ca. 1479–1457 B.C.) that "looked like" glass but had 18.9% CaO and 4.8% CuO (no. 6; Fig. 9, center); a scarab naming Tuthmosis III (ca. 1479–1425 B.C.) with "stamped" details and very glassy breaks (no. 7; Figs. 1, 9); and a scarab naming Amenhotep II (ca. 1427–1401 B.C.) with bubbles on the surface but a granular interior and "carved" details (no. 14; Figs. 1, 8, 9). We also termed these glassy faience.

Our final focus was aimed at two gold-trimmed vessels from the tomb of three foreign wives of Tuthmosis III in the Wady Qirud. Much of the jewelry in this tomb was inlaid with copper- and cobalt-colored glass (Part 2, nos. F, 8–10), and a turquoise opaque glass vessel was recovered from the tomb as well (Part 2, no. 11). But two other vessels from the tomb were more difficult to classify.³⁹

The first vessel, an inscribed krateriskos with lid (no. 8; Cover and Fig. 10, left), is so weathered that, despite sampling, it is difficult to be sure of its fabric. Separating layers on the inside of the vessel and bubble holes in several places speak for glass. The magnesium level is low for a glass, but a similar level is recorded for a water-damaged glass from the same tomb (Part 2, no. F). Furthermore, gold trim was used on the turquoise-glass chalice from this tomb (Cover; Part 2, no. 11), and on a glass kohl jar in the British Museum stylistically dated to the period.⁴⁰ However, while severe weathering of the vessel in question may have affected the alkali level, we note that the copper level is higher than in most ancient glasses and that the bottom of the foot is only slightly concave, its edge more precise than one would expect in a fabric which had flowed.

The second vessel from the Wady Qirud tomb is much more unusual (nos. 9–13; Cover and Fig. 10, right). Its shape⁴¹ and decorative pattern had previously prompted Barag to relate it to marbled vessel fragments from Nuzi level II, even before a modern trumpet-shaped foot was

36. Not addressed in Martin's system of dating, for instance, is how late a "scribe of nomes Kheperka" might have existed (note the high-quality scarab with back type 3 but also the splayed style of the beetle sign), since Martin states that the examples from Byblos, which go into Dynasty 13, were particularly fine; whether a glass scarab of back type 6 for the "overseer of granaries, Udjaren," follows the same chronology as scarabs made in steatite; and the extent of overlap of back types (the god's father Montuhotep has back type 6 scarabs [nos. 568–70, 572] as well as back type 9c [no. 571]).

37. BM 66732, 67738; 26981, 67697, 4266, 37698, 51102, 65104 are less glassy.

38. MMA 22.1.521.

39. For detailed discussion of the reasons all three vessels are assigned to this tomb, see Lilyquist, *The tomb of three foreign wives of Tuthmosis III*, The Metropolitan Museum of Art, in preparation.

40. Cooney 1976, no. 1760.

41. For parallels to the button-base chalice shape see the larger pottery examples in R. Starr, *Nuzi; report on the excavations at Yorgan Tepe . . . 1927–1931* (Cambridge, Mass., 1939), pl. 77. Barag 1970 states that the goblet form with globular body, knob base, and flaring rim was also found at Assur (p. 142 n. 56, no. 20083); the piece, as drawn in the records of the German expedition and kindly supplied by E. Klengel, was drawn as a lid. It could likewise be considered an open cup; whether the edge was finished or not is not specified.

removed from this vessel in 1983.⁴² Indeed the palette as well as the marbled pattern are not representative of classic Egyptian taste. Swirling black and turquoise glazes are found on Egyptian faience from time to time,⁴³ but colored pastes swirled together have otherwise not been noted in Egypt. Such fabrics are known in the Near East however: in addition to the vessel fragments at Nuzi in Barag 1970, at least two red-and-cream marbled beads were found there,⁴⁴ and two marbled beads were found at Tell Brak (J. Oates, personal communication 9/90). Farther to the east, at Susa, three "bricks" of brown, cream, and yellow pastes were found in Achaemenid levels.⁴⁵ In China, marbling lacquer can be dated from the 3rd century A.D., vitreous pastes swirled or rolled as jelly rolls from 700 A.D., and marbling paper from the 10th century.⁴⁶ Of more interest here is what appears to be a beaker fragment from Susa with coloration and pattern very similar to those of the Nuzi fragments (cf. Figs. 11–14).

Indeed, microscopic examination, compositional analysis, and lead-isotope ratios (see Part 3) combine with evidence of shape, fabric, and color to show that the Wady Qirud goblet originated in the Near East and not in Egypt. As this discovery is unique as far as we know, a detailed discussion of it is necessary.

The large Nuzi fragment illustrated in Barag 1970 (here Fig. 11) is one of four marbled vessel sherds from Nuzi level II now in the collections of the Harvard Semitic Museum.⁴⁷ H. Beck and H. Jackson had originally called the largest fragment "faience," but Barag felt this was an inappropriate term for a colorful mixture which lacked glaze and had at least some spots of dark blue glass. Brill was given two of the four Semitic Museum sherds to study in 1968 (Fig. 12), one of which yielded Corning Museum of Glass samples 1200 [white], 1201 [beige], and 1202 [red]. Sample 1200 proved to be crushed quartz with a little lime; 1201 was that same base material with flakes of the familiar lead antimonate yellow pigment; and 1202, the base ingredient with the addition of some finely divided, orange-red ferric oxide.⁴⁸ X-ray diffraction confirmed that the three materials are all highly crystalline and that they must be considered faience or glassy faience rather than glass. The preserved interiors are quite porous, like ordinary faience, but the original surfaces could have had a fire-polished appearance.

42. Barag 1970, p. 182. See also Nolte 1968, pp. 49f. no. 11, and idem 1985, p. 12, for a good color photo. A wider foot was added by the earl of Carnarvon, the first owner of the object, presumably for stability.

43. Ashmolean E 35, Archaic cylinder vase from Abydos M 69; UC 20672, "Middle Kingdom" pendant from Qau 5303.

44. P. Vandiver, "Mid-second millennium B.C. soda-lime-silicate technology at Nuzi (Iraq)," in T. A. and S. F. Wertime, eds., *Early pyrotechnology; The evolution of the first fire-using industries* (Washington, D.C., 1982), p. 79-t; lower bead is HSM 930.62.15 (28-12-291).

45. Louvre, Département des Antiquités orientales, Sb 3382: R. de Mecquenem, "Contributions à l'Étude du Palais achéménide de Suse," *Mémoires de la Mission archéologique en Iran, Mission de Susiane* 30 (1947), p. 35, fig. 15. Dr. Caubet suggests they may have been dados or window sills rather than pavement blocks (communication 1992).

46. James C. Y. Watt, communication, Oct. 1991; see his "Marbled clay, 'marbled glaze,' and marbled paper," *Shanghai Museum Bulletin* 4 (1987), pp. 252–55 and "Marbled ware of the Tang and Song periods," *Festschrift for Tsugio Mikami on his 77th birthday* (Tokyo, 1985), pp. 69–78.

47. Barag 1970, p. 140, no. 15, states that the large fragment [HSM 930.82.1] is from the "Palace, Court M 100" and has the [field] number M 100/3; it has the number 2[8]-11-11 written on it, followed secondarily by a "D." Barag states that there are two more fragments of the material recorded, one from G 91 and another from A 33; neither location appears on the expedition's plans. These are probably the two sherds currently in Corning with Brill (Fig. 12): a ridged fragment in a tin Brill labeled "22-11-11D M 100/3"; and a triangular sherd in a tin he labeled "27-28 A-33 Dec. 14." It is the ridged fragment that yielded the CMG samples 1200, 1201, and 1202. In September 1992 at the Semitic Museum, Lilyquist examined a rectangular marbled sherd in a box labeled 27-28 A-33 (26); this sherd has the HSM number 930.82.3. C. Gavin and G. Pritico kindly allowed examination and illustration.

48. Chemical analyses, X-ray diffraction patterns, and microscopic examination by Brill of some 20 other Nuzi objects have not yet been published.

Wypyski's EDS surface analysis of the MMA goblet scanned its four colors (white, yellow [now beige], brick red, and turquoise) as well as an especially glassy turquoise spot. Visually, the four Nuzi marbled fragments belonging to the Semitic Museum are pale and chalky compared to the MMA goblet; but the former have suffered from weathering, while the latter probably exhibits some of the fire-polished glossy sheen it had in antiquity. The glassy greenish blue spots that Barag noted on the largest Nuzi fragment, which also occur on the MMA vessel, are of interest in this respect.⁴⁹

Brill suggests that the Wady Qirud and Nuzi marbled goblets were made by first pressing together doughlike layers or wads of different colored, unfired faience mixes so as to form multilayered sandwiches. These could then have been flattened, sliced, or rolled into swirling or spiraling patterns, assembled on a core, and then fired to consolidate them into a vessel. Depending upon the firing conditions (and whether or not some glazing agent was applied) the surface of the vessel could have become fire-polished. As in the regular core-forming technique, the friable core would have been scraped out. By incorporating bits of colored glass, or by using powdered glass in some of the starting mixes, glassy zones having the chemical composition of glass would have become part of the finished vessels. Such a procedure, resembling the normal core-forming technique, can also be seen as a precursor of both the ribbon glass and millefiori techniques that were to come into use centuries later throughout the ancient world.

The turquoise glassy spot analyzed in our study (no. 13) had a composition that Brill thought typical of early Mesopotamian glasses. But the lead-isotope analysis from the red of the Wady Qirud vessel was more precise evidence of its having been imported from Mesopotamia (as explained in Part 3, Pb-2168). As we have no ores to match it, we do not know where this type of isotopic lead originated, but we believe it must have been in the Near East, and may well have been the source of lead used for the strikingly similar Susa fragment referred to above (Figs. 13, 14; Pb-2166 in Part 3). The latter fragment has the chalky appearance of the Nuzi sherds and has the banded arrangement of colors that is seen on the three smallest fragments from Nuzi. C. J. Lamm originally published the unstratified Susa piece with Islamic glass from that site, but with a query as to whether it might not be more ancient;⁵⁰ Brill and Lilyquist think that the fragment is a product of the same technology as the Nuzi pieces and possibly the same workshop. It is most likely the bottom of a beaker, a shape known at that period.⁵¹ However, as the lead source of the Nuzi fragment (Part 3, Pb-1095) was used for more than a thousand years, a matching lead source for the Susa piece—if one were found—would not date the object.

In sum, the Wady Qirud vessel's shape, palette, and marbled pattern are not Egyptian; and isotope ratios as well as microscopic examination and compositional analyses corroborate this information to yield highly unusual—and possibly unique—evidence of a well-preserved, luxury object of foreign manufacture found in Egypt. Egyptian texts mention manufactured foreign

49. Vandiver 1983 terms several marbled beads from Nuzi frit, and refers to premelted ground glass used as a raw material in blue frit bodies.

50. Musée du Louvre, Département des Antiquités orientales, Section Islamique MAO S 1241; C. J. Lamm, "Les Verres trouvés à Suse," *Syria* 12 (1931), pp. 366f., pl. 79-10. We thank A. Caubet with G. Joel for kindness in allowing examination, sampling, and reproduction of this object. Lamm cites three marbled glass sherds from Samarra, an Islamic site of the 9th century A.D.; two of these (nos. 295-96) are in the Museum für Islamische Kunst in Berlin. According to kind information from J. Kröger, these are yellowish brown translucent glass with streaks of white and turquoise on the top surface. They are thus somewhat different from the Susa object. Although he has not examined the Susa fragment, Dr. Kröger states that millefiori glass is known in the late Sasanian and early Islamic periods, and therefore he sees no reason to exclude consideration of an Islamic date for the Susa fragment.

51. For mid-2nd-millennium straight-walled glass beakers see examples from Nuzi (Barag 1970, p. 139, no. 13) and Emar (Louvre AO 27812 and 27813). Against this interpretation could be the polished, convex surface of what would be the bottom of the vessel.

goods arriving in the Nile valley from an early period. Because of shape, pattern, composition, and source of lead, we believe this object to be one.

This button-based vessel—no matter where made—was an exotic object when buried in the Theban tomb of three royal wives, and was much more complicated than any extant glass from the tomb of Tuthmosis III (Part 2). Tuthmosis' son Amenhotep II had glasses with swirled surface patterns in his tomb (Part 2, nos. 12–17); the MMA goblet could have been a source of inspiration for them.

In a historical sense, the MMA vessel is also important as it appears to link Tuthmosis III glass with that of Nuzi level II. We do not know where in the Near East the MMA goblet was made; it has the swirled pattern of the large Nuzi sherd (as two barrel beads from Nuzi), but the shape is not precisely the same, and there is no raised cord where neck meets bowl. However, the three smaller Nuzi sherds, with their more banded pattern, show that even at Nuzi there was some variety in marbling; further, we know that the MMA goblet was produced *somewhere* outside Egypt during the time of Tuthmosis III. With similar items at Nuzi, as well as thousands of other sophisticated glass and glassy-faience objects found there, we may at least suggest that the Nuzi industry was operating during the time of Tuthmosis III, however long it continued into the 14th century.⁵²

Description of Scanned and Sampled Objects

No. 1 Small cylinder bead from MMA Lisht North Pyramid "glaze factory," excavated in 1920/21 (Fig. 3, right; Table 1; Appendix), MMA 22.1.1656b. Diam. ~3 mm; dark purple. Innermost part of body contains many black mineral grains, outer part contains many angular quartz grains; held together by continuous, purple glassy phase; well melted glaze on surface. Wypyski's analysis is for the glassy phase that makes up most of the material; some areas containing lead, higher sodium, and a trace of zinc were also found.

No. 2 Larger cylinder bead with provenance as above (Fig. 3, left; Table 1; Appendix), MMA 22.1.1656c. Diam. ~7 mm. Similar to no. 1, but less vitrified; quartz crystals predominate. Contains some traces of lead and higher amounts of sodium with the glassy particles.

No. 3 Crocodile from MMA Lisht North Pyramid cemetery, toilet basket 2 (Figs. 1, 4; Table 1), MMA 07.227.19. Length 8.8 cm; light turquoise opaque fabric. Body modeled in the round except for the bottom, which is flat and pierced with two holes, probably for dowels; crack between left rear leg and body appears to be from the shrinking of the fabric in drying.

Brill thought the smooth outer surface resembled glassy faience but found the interior fabric very porous with large grains; air pockets in the interior were very rounded, being evidence of interior melting.

Wypyski's X-ray diffraction of a sample drilled from the interior showed the presence of wollastonite, a small amount of Egyptian Blue, and possibly some silica. He suggests that the fabric includes these components as well as some interstitial glassy phase, as is often found in objects formed of Egyptian Blue with a relatively high alkali content. Wollastonite is a common devitrification product of glasses containing high calcium, but, more importantly, it is often found in Egyptian Blue made with excess calcium carbonate (lime) and silica.⁵³

In a pocket of the light turquoise fabric, which is sample no. 3 in Table 1, several dark blue crystals were noted and analyzed by Wypyski using EDS. An approximate 4:1:1 atomic ratio of Si, Ca, and Cu was found, with about 5% by weight Na, and traces of Al, K, S, Cl, and Fe. These crystals were subsequently identified as Egyptian Blue by D. Schorsch of the MMA, using

52. Lilyquist 1993.

53. Tite/Bimson/Cowell 1984.

X-ray diffraction. It was suggested that the crystals could have been an accidental inclusion of Egyptian Blue, or that Egyptian Blue was one of the ingredients from which the object was made.

No. 4 Scarab dated late Dynasty 12/early Dynasty 13 by J. Weinstein in 1979 and G. Martin, H. Hornung and E. Staehlin in 1990 (MMA records); from the Sinadino collection, Alexandria (Figs. 1, 7, 9; Table 1), MMA 26.7.665 (purchase, Edward S. Harkness Gift, 1926). Turquoise opaque; 2.3 cm long. The base is decorated with intertwined spirals surrounded by a rope. Tool marks are clearly visible in the formation of the serrated clypeus and legs; there are cracks in the fabric along many of the incised lines. Microscopic examination of the surface revealed a continuous glassy phase surrounding many quartz crystals; identified as glassy faience.

No. 5 Scarab with pseudo-Hyksos royal name (Figs. 1, 7, 9; Table 1), MMA 17.190.1979 (gift of J. Pierpont Morgan). Turquoise opaque; hieroglyphs *nfr* and *R^c* appear as if made by a tool drawn through soft dough. Brill noted that the material appeared to be mostly unreacted very fine quartz particles surrounded by a continuous glassy matrix; no appearance of devitrification or crystal growth around silica particles; identified as glassy faience.

No. 6 Cowroid naming the mother of Senenmut (official of Hatshepsut) set into a gold bezel, from MMA excavations at Thebes (Fig. 9, center; Table 1), MMA 36.3.16. Turquoise opaque, length of bezel 1.6 cm. The legend, apparently engraved, is an *nh*-sign "protected" by an upright falcon facing left with one wing up, the other down; below them is a *nb*-sign. Termed glassy faience.

No. 7 Scarab with prenomen of Tuthmosis III (Figs. 1, 9; Table 1), MMA 30.8.547 (bequest of Theodore M. Davis). Turquoise opaque, length 1.30 cm. Surface examination indicates manufacture by molding and wire abrasion; bottom surface of hieroglyphs shiny and patterned. Breaks in fabric revealed a continuous glassy phase with many bubbles and quartz grains; termed glassy faience.

No. 8 Gold-trimmed lid of a krateriskos, believed to come from the Wady Qirud tomb of three foreign wives of Tuthmosis III (Cover and Fig. 10, left; Table 1), MMA 26.8.34b (Fletcher Fund, 1920). Lid and vessel engraved with name of Tuthmosis III. Diameter of lid, 6.8 cm. Pale turquoise opaque fabric with some beige discoloration; pigment is fine-grained and well distributed. Exterior has sheen and some fine cracks; underside of lid and point where foot joins bowl has small round holes in surface.

The edge of the lid and the neck of the vessel are completely covered by gold foil. There is a crack encircling the lower part of bowl, below which the surface is discolored beige; the interior of the vessel has fallen away, and no crack can be detected in the inner core; thus it cannot be determined absolutely that the bottom part was once separated from the rest of the vessel. There may be a small fill around the foot, but the vessel is essentially complete.

Microscopic examination of both lid and vessel shows white material (44.4% Ca in prepared sample via EDS) intermixed with light turquoise: this material has collected or been deposited between layers of the vitreous matrix and fills inscribed lines. The analysis corresponds approximately to calcium carbonate.

Nos. 9–13 Button-based goblet with gold foil trim, same provenance as no. 8 (Cover and Fig. 10, right; Table 2), MMA 26.7.1175 (purchase, Edward S. Harkness Gift, 1926). Height 10.2 cm. Matrix is variegated sections of brick red, beige, white, and turquoise, with occasional glassy spots of the latter. Small round pits in surface; exterior polished except for foot; interior smoothed. A. von Saldern noted that the largest Nuzi fragment seemed to be built up of preformed elements around a core and then subjected to heat for fusing;⁵⁴ this also agrees with our

54. von Saldern in Oppenheim et al. 1970, p. 207. Oppenheim notes (*loc. cit.*, p. 65) that a passage in a Middle Babylonian text may mention variegated glass.

thoughts as to how the MMA goblet could have been made. Lead isotope sample Pb-2168 (Part 3) is from a region of no. 10.

No. 14 Scarab with prenomen of Amenhotep II purchased in Cairo (Figs. 1, 8, 9; Table 1), MMA 26.7.189 (purchase, Edward S. Harkness Gift, 1926). Medium green opaque, length 2.1 cm. Deep undercutting of the legs and wing case; tool marks very clear. Fabric has a dull, brownish cast, but chips show the interior to be a granular light turquoise. Brill noted continuous glassy phase with many large, angular quartz grains; crystals appear somewhat opaque, possibly from weathering or devitrification of the glassy phase around the quartz particles; identified as glassy faience.

Table 1

EDS Analyses of Vitreous Materials

	1 ¹	2 ¹	3 ¹	4 ²	5 ²	6 ²	7 ²	8 ¹	14 ²
Weight %	small bead	large bead	croc-odile	scroll scarab	Hyksos scarab	cowroid	T. III scarab	krater-iskos	A. II scarab
SiO ₂	89.2	83.0	66.9	76.0	80.9	68.8	85.9	82.4	74.0
Na ₂ O	3.3	3.3	5.3	2.1	0.7	3.1	0.1	2.3	1.9
CaO	0.3	1.6	20.1	7.8	4.6	18.9	6.1	4.0	11.3
K ₂ O	1.2	2.6	2.3	2.0	2.5	1.2	0.9	2.2	2.0
MgO	-	-	0.3	1.3	0.8	0.2	0.2	0.9	1.3
Al ₂ O ₃	0.8	3.5	0.7	2.0	1.4	1.4	1.0	1.0	2.6
Fe ₂ O ₃	0.5	0.8	1.9	0.7	0.7	0.6	0.5	0.8	1.2
TiO ₂	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.3
Sb ₂ O ₃	-	-	-	-	-	-	-	-	-
MnO	3.9	2.3	-	-	-	-	-	-	-
CuO	0.4	1.6	1.9	5.7	5.8	4.8	2.2	5.3	3.1
CoO	-	-	-	-	-	-	-	-	-
PbO	-	-	-	-	-	-	-	-	-
SO ₃	-	-	0.6	1.1	1.6	0.3	1.2	0.3	0.5
Cl	0.2	0.2	0.4	1.2	0.9	0.9	1.8	0.6	1.1
P ₂ O ₅	-	-	-	-	-	-	-	-	0.8

The elemental compositions were determined by MTW using energy-dispersive X-ray spectrometry (EDS). Analyses were obtained by using a Kevex model Delta IV EDS with an AMRAY modified model 1100T (1600) scanning electron microscope, operated at an accelerating voltage of 30 KV. Results were quantified with Kevex Quantex software, using MAGIC V ZAF corrections. Oxide weight percentages were calculated stoichiometrically from the detected elements, as this model EDS does not detect elements below the atomic weight of sodium.

1. Analyses of polished, cross-sectioned examples.
2. Surface scans.

Table 2**EDS Analyses of MMA Marbleized Goblet**

Weight %	9 white	10 red	11 beige	12 turquoise	13 glassy turquoise
SiO ₂	87.8–89.5	76.0–82.3	76.0–77.8	83.6–86.4	60.2
Na ₂ O	0.9–2.3	2.6–4.3	1.5–3.6	0.8–1.9	9.3
CaO	0.9–1.3	2.3–2.6	3.6–3.8	2.4–4.4	4.1
K ₂ O	1.2–2.0	1.4–2.4	2.0–2.8	1.9–2.3	5.3
MgO	1.4–2.7	2.3–5.6	3.2–4.7	1.3–1.9	5.1
Al ₂ O ₃	0.3–1.0	1.0–1.5	1.1–1.3	0.7–1.4	5.7
Fe ₂ O ₃	0.8–1.5	3.3–5.3	5.8–8.0	1.0–1.9	2.3
TiO ₂	0.2–0.3	0.2–0.3	0.2–0.3	0.2–0.3	0.6
Sb ₂ O ₃	-	-	-	-	-
MnO	-	-	-	-	-
CuO	0.4–0.9	0.7–1.2	0.3–0.5	1.3–2.2	4.8
CoO	-	-	-	-	-
PbO	-	-	-	-	-
NiO	-	-	-	0.3–0.4	0.1
ZnO	0.2–0.3	0.2–0.6	0.2–0.3	0.2–0.3	0.1
SO ₃	0.7–0.9	1.0–1.4	0.5–1.0	0.8–1.3	1.5
Cl	0.7–0.9	0.8–1.2	0.5–0.9	0.7–0.9	0.9
P ₂ O ₅	-	-	-	-	-

For basic procedure by MTW, see Table 1.

Each color was analyzed in three different places on the surface of the goblet. The variations seen are from a combination of uneven weathering of the surface and heterogeneity of the materials. All colors were found to contain many fine silica particles, mostly on the order of 2–10 microns in size with occasional larger particles, in a glassy matrix; they appear by composition and visual appearance to be glassy faience. Nos. 9–12 were scanned at a magnification of 500X and are overall compositions for both the silica particles and surrounding matrix; no. 13, a particularly glassy area of turquoise, was analyzed at 20,000X. Results show the minimum and maximum values detected.

Conclusion

In summary, the cylinder beads, the scarabs, and the cowroid of our study are all best described as glassy faience; the crocodile and pale turquoise krateriskos are difficult to categorize; and the Nuzi goblet is an import, a composite type of glassy faience.

Further definition by curators⁵⁵ and archaeologists,⁵⁶ and technological studies of glassy materials by vitreous specialists⁵⁷ will no doubt expand the database begun here. However, the exact role that the above objects played in the beginning of glassmaking in Egypt may never be proved. Furthermore, many of the more subtle distinctions we see today (often only on a microscopic scale) may be the results of accidental occurrences: a little extra alkali in the mix, inclusion of a crushed waster, a somewhat higher temperature, a little longer time in the kiln—or a dozen other day-to-day variations in working conditions—could very well have caused some of the distinctions we observe. Continued refinements of classification may, indeed, prove useful; but it remains to be seen how much they tell us about the artisans and technologists of the ancient world.

Part 1, Appendix

Notes on the Two Beads from Lisht

The cylindrical beads from the Lisht "glaze factory" (nos. 1 and 2 of this section) were selected for closer examination at Corning, New York.

J. F. Wosinski of Corning, Incorporated, examined thin sections of the beads with one of the authors (RHB). The smaller of the two beads (no. 1, CMG 4736) has a very dark purple body which is highly vitreous. The larger bead (no. 2, CMG 4737) has a pink or pale purple body and is less vitrified. Both still preserve a dark, unweathered surface glaze that is black to the eye. In thin sections, both bodies have a continuous glassy phase with an abundance of angular quartz grains and black mineral inclusions. Microscopically the thin sections show the surface vitreous glazes on both beads to have a gray-blue color: neither the blue of a typical copper glaze nor the purple of a manganese glaze. The predominating body colorants are the black mineral grains and purple glassy phases of the body.

Scanning electron micrographs of the samples were taken by E. Sanford, also of Corning, Incorporated. The micrographs provided elemental analyses of about two dozen selected points. The major phases, as expected, analyzed as silica, SiO₂. In no. 4737 (the larger bead) several of the inclusions were found to contain iron, manganese, and titanium. They appear to be grains of the primary mineral ingredient used as a colorant. (See Figs. 15, 16). In no. 4736 (the smaller bead), the black grains were generally rich in manganese, but one was found which contains only nickel and silica. (See Figs. 17, 18). This apparently is a grain of a nickel compound, presumably a minor mineral phase accompanying the major manganese-containing mineral phase used by the faience-makers as a purple colorant.

55. An interesting Middle Kingdom "faience" fragment with black spots set into a fine, hard blue fabric was found in Middle Kingdom MMA tomb 604 at Thebes. Unfortunately this fragment (MMA 26.3.332), deaccessioned to the University of Miami at Coral Gables, Florida, in 1957, cannot be found today (B. A. Dursum, communication, June 1990). The inlaid spots were "as thick as one cm in places."

56. Regarding field conditions see J. Reade, "Field observations of glass and glazed materials" in *EVM*, pp. 31–38.

57. See Tite/Bimson/Cowell 1984; B. McCarthy and P. Vandiver, "Ancient high-strength ceramics; Faience manufacture at Harappa (Pakistan), ca. 2300–1800 B.C.," in *Materials issues in art and archaeology* 2, Materials Research Society Proceedings, 185 (Pittsburgh, 1991), pp. 495–509; and Vandiver/Swann/Cranmer 1991.



Fig.1 Glassy objects; MMA; nos. 3 (center), 4 (upper left), 5 (lower left), 7 (lower right), 14 (upper right)

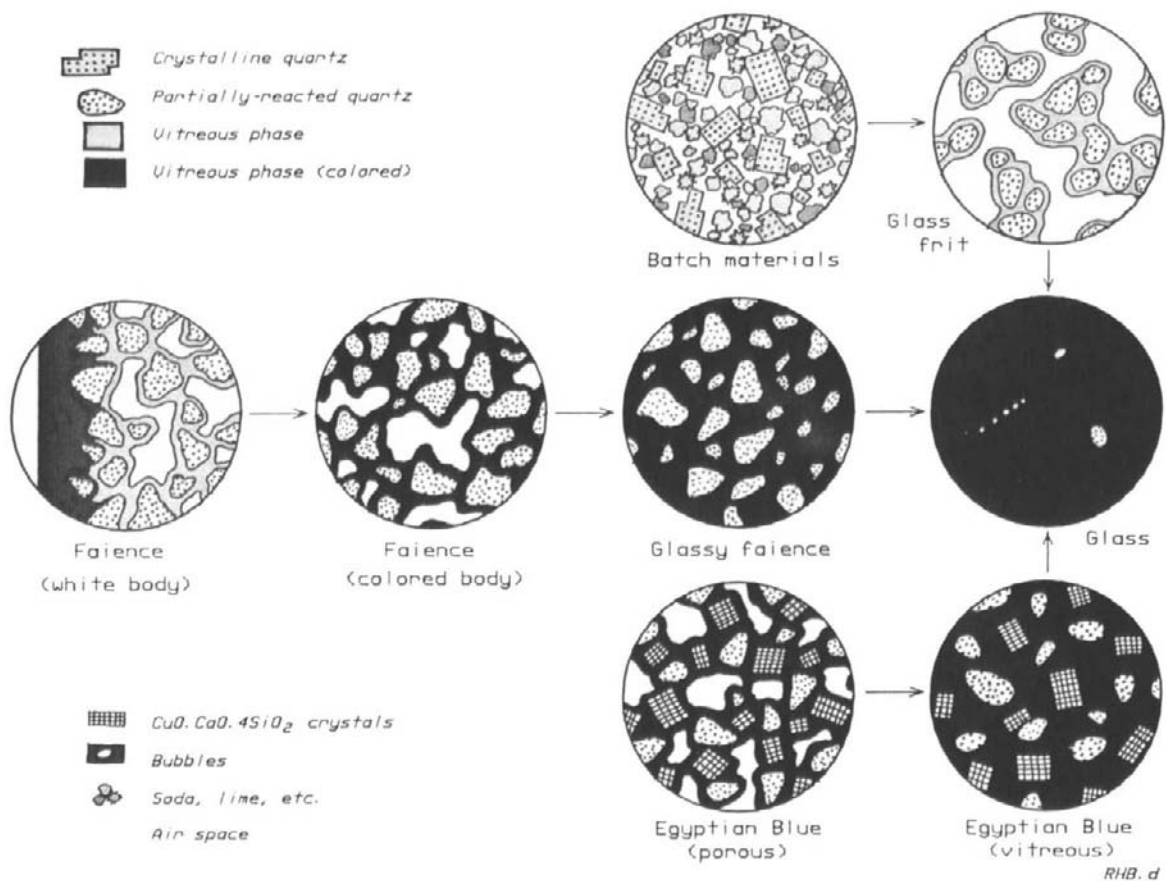


Fig.2 Chemical and structural progressions of some ancient vitreous materials. Among other ways, the changes could have been brought about by increasing firing temperatures or heating times, or by introducing additional alkali or crushed wasters in the starting mixes. The "discovery" of glass could have resulted from processes paralleling some of these steps. It is important to realize that not all ancient vitreous materials fall unambiguously into one of these categories. Materials intermediate between them are not uncommon, and composites of different categories are frequently found. The preparation of a glass from batch materials in ancient times is believed to have utilized (at least sometimes) a preliminary heating at about red heat to expel moisture and evolve gases. The intermediate frit thus formed would then have been crushed and reheated at higher temperatures to complete the chemical reactions and form a glass melt without excessive frothing.

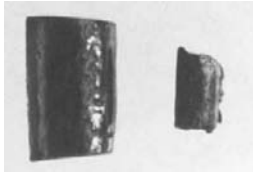


Fig.3 Manganese-colored cylinder beads; Lisht, MMA Glaze Factory; MMA; nos. 1 (right) and 2 (left)

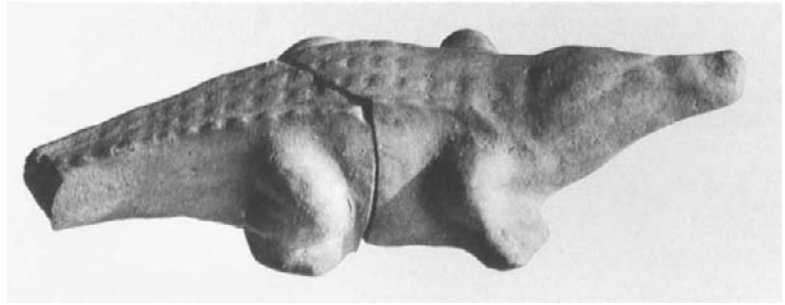


Fig.4 Crocodile; Lisht, MMA toilet basket 2; MMA; no. 3

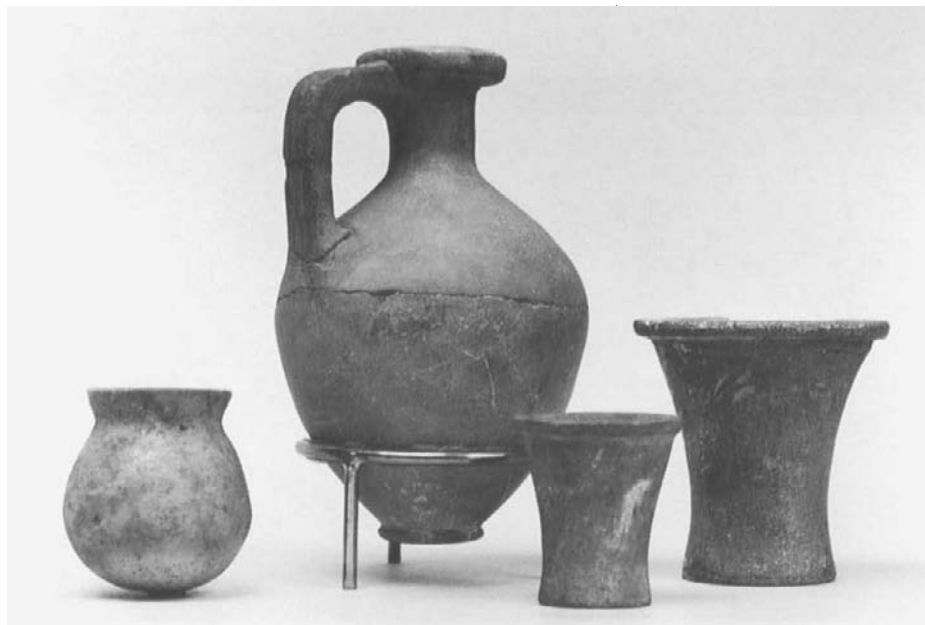


Fig.5 Vessels of materials similar to crocodile (left) and of Egyptian Blue (others); Lisht, MMA; MMA



Fig.6 Two stone vessels from Lisht (center and right) compared with glass vessel; MMA



Fig.7 Scarabs; MMA; nos. 4 (top) and 5 (bottom)

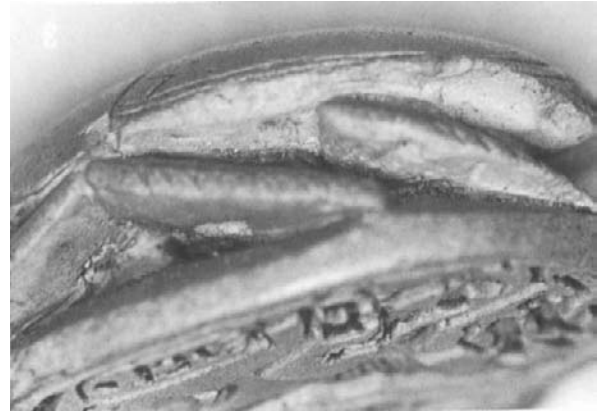


Fig.8 Scarab showing "carved" details; MMA; no. 14



Fig.9 Scarabs; MMA; nos. 4, 5, 6, 7, 14 (left to right)



Fig.10 Vessels; Wady Qirud; MMA; no. 8 (left), nos. 9-13 (right)

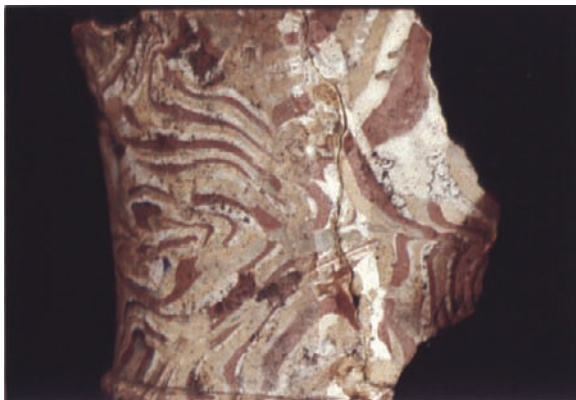


Fig.11 Goblet wall, detail; Nuzi II; HSM 930.82.1



Fig.12 Two vessel fragments; Nuzi II; HSM 27-28 A-33 (left) and 22-11-11D M 100/3 (right)



Figs.13 and 14 Beaker base, interior and exterior; Susa; Louvre MAO S 1241

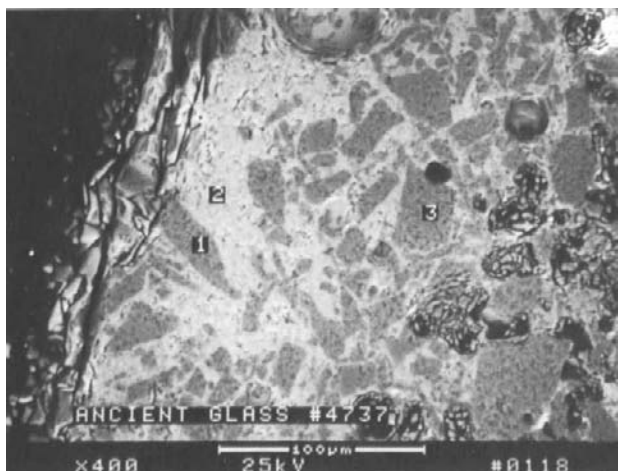


Fig.15 Scanning electron micrograph of a polished thin section of the Lisht bead no. 2 (CMG 4737), showing the edge and glazed surface of the bead. Points 1 and 3 identify partially reacted grains of quartz. Point 2 indicates the continuous glassy phase that contains Si with minor concentrations of K, Ca, Na, Cu, and Mn. The glassy phase shows up lighter in this micrograph. The Cu and Mn are apparently responsible for the color.

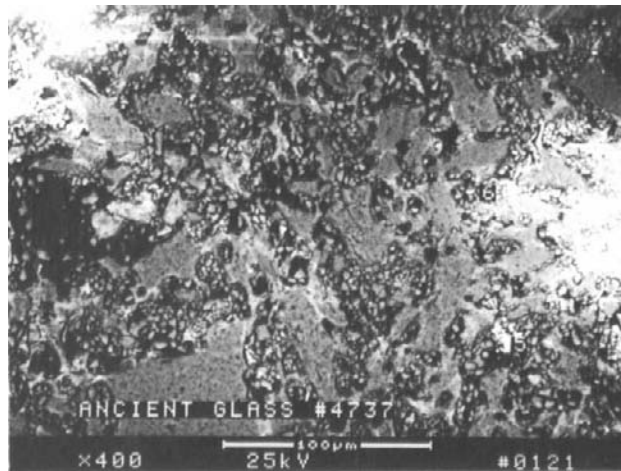


Fig.16 Scanning electron micrograph of the same polished thin section of bead no. 2, showing the body material. Black regions are air spaces accounting for the porosity. The small bright grains marked 5 are minute inclusions rich in Ti, Mn, and Fe, which are believed to be remnants of a mineral phase introduced with the colorant. Point 6 marks an area containing primarily Fe and Si, with minor concentrations of Cr and Ni. Similar bright grains, in denser concentration than appear here, can be found throughout the entire thin section of the body material.

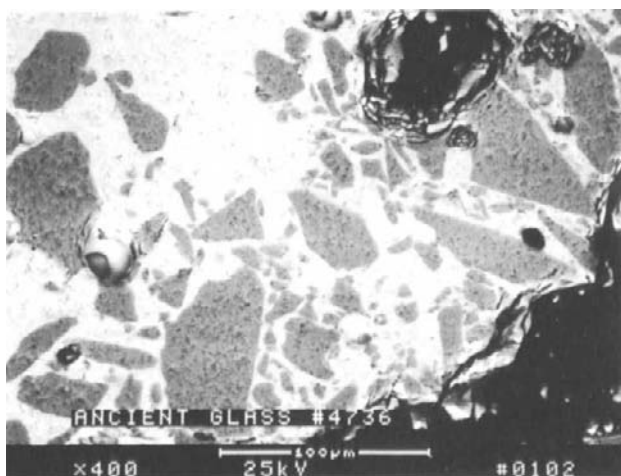


Fig.17 Scanning electron micrograph of a polished thin section of the Lisht bead no. 1 (CMG 4736), showing the glazed surface of the bead. The darker, angular patches are partially reacted grains of quartz. The light field is the continuous glassy phase that contains Si with minor concentrations of Ca, K, Na, Mn, and Cu. The Cu and Mn are apparently responsible for the color.

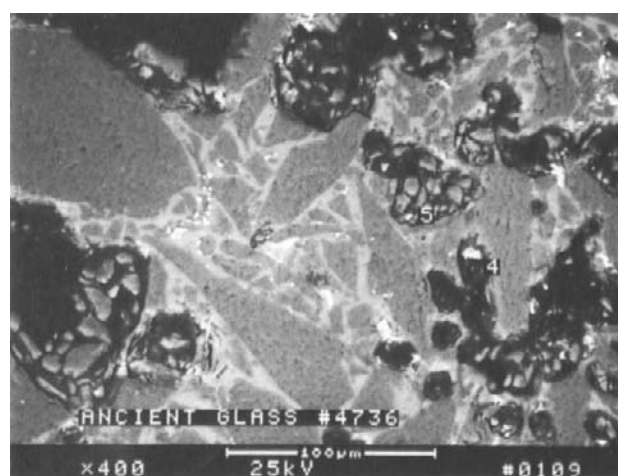


Fig.18 Scanning electron micrograph of the same polished thin section of bead no. 1, showing the body material. Black regions are air spaces. Large, angular grains of quartz are connected by the lighter colored continuous glassy phase, as in the previous micrograph. The small bright grain marked 4 contains a major concentration of Mn with little Si and almost no other metals. It is probably a grain of MnO_2 . The bright grain marked 5 contains Ni and Si. It is probably a remnant of a Ni compound introduced as a mineral contaminant with the original colorant.

Part 2. Glass

C. Lilyquist, R. H. Brill, M. T. Wypyski,
and R. J. Koestler

Review of Early Egyptian Glasses, Including Those Analyzed Here

The earliest datable examples of glass at present are translucent beads from Qau 3757 in the Petrie Museum at University College London and from Qau 902 in the Ashmolean Museum; they are sizable and were wound on armatures (Fig. 25; the glass appears copper-green).¹ The locally made Bichrome jar in Qau 902 indicates that the period is very close to, if not in, Dynasty 18 (J. Bourriau communication, 1991; see Chronology), ca. 1550 B.C.² A glass inlay from the eastern Nile Delta is of less certain date and is very small (no. A, Fig. 20).

The Qau beads³ can be complemented by two types of glass inlay in the Ahhotep treasure. The names of Kamose⁴—expeller of the Hyksos—and of Ahmose⁵—first king of Dynasty 18—both appear on objects in this group. The most interesting type is the bicolored hemispherical "eye" set in round pendants (Fig. 21).⁶ Two examples of these pendants are in the Metropolitan Museum and were available for analysis (no. B, Fig. 22). The level of antimony suggested that the glass was opaque, and the level of aluminum indicated that the glass could have been cobalt-colored.⁷ As discussed elsewhere,⁸ the goldwork is of Canaanite type, and the inlay has parallels at Tell el-Ajjul and Megiddo. No. B is probably an import to Egypt.

More "Egyptian" is the Ahmose-inscribed pectoral with glass inlay from Ahhotep's burial (Fig. 23).⁹ (Several bits in the Kamose armlet, including the cartouche tie, may be dark blue glass,¹⁰ but

1. Ashmolean 1923.582; Brunton 1930.

2. R. Merrillees ("Evidence for the bichrome wheel-made ware in Egypt," *Australian Journal of Biblical Archaeology* 1, no. 3 [1970], p. 17) felt that none of the pottery with Bichrome affinities found in the Nile Valley required a date "later than the end of the Hyksos period." Seventeen ball beads were found in Qau 3757 (one translucent green): UC 26020, Brunton 1930, pl. 5. For Qau 902 see Merrillees, "Bichrome" pp. 14f.

3. Similar beads are reported in graves at Sedment, cemetery K (Mayana) 1262, 1265, as noted by Merrillees, "Bichrome," pp. 10f., 13.

4. On the fan and the gold boat.

5. On the ax, dagger, pectoral, sphinx armlet, two beaded bracelets, and inlaid bangle.

6. Vernier 1925, CG 52673; JdE 4725; according to Vernier and Bissing 1900, fourteen 0.09 cm in diameter, and twelve 0.07 cm in diameter. It should be understood that the "Ahhotep treasure" was not retrieved by archaeologists; for instance, the roundels here are given the provenance of Ahhotep's burial only in the JdE of the Cairo Museum. Bissing guessed the Ahhotep inlays to be pearls; J. Wolters also identified the material in Cairo as glass (*Die Granulation; Geschichte und Technik einer alten Goldschmiedekunst* [Munich, 1983], p. 94). M. Saleh, M. Mohssen, and G. Sharawy kindly permitted study and publication of all Cairo Museum objects discussed in this paper; A.-M. Mohammed kindly facilitated access.

7. Copper and lead were not detected. Unfortunately even the best preserved of the inlays in Cairo is discolored; the outer ring is beige, the inner dot a purplish brown (possibly staining from resin), seemingly covered by a transparent layer.

8. Lilyquist 1993.

9. Vernier 1907-09, CG 52004, 7.2 cm high; bubbles and conchoidal fractures are noticeable in cheek of Horus, reed-leaves at bottom, zigzag of water before king's face, body of bird behind Seth, triangular inlay below *di* at bottom. Probably all turquoise material is glass, as Vernier already guessed. Wilkinson 1971, p. 136, suggested that the water holding the boat may have been dark blue glass; Lilyquist does not agree.

this identification is not sure.) The turquoise opaque glass of the pectoral seems to be the same type as that used to form an unprovenanced plaque naming Ahmose in the Metropolitan Museum (no. C, Fig. 24); a plaque naming Ahmose and Amenhotep I in Boston;¹¹ and an amulet, in University College, naming Amenhotep I.¹²

To the Kamosa-to-Hatshepsut period probably belongs a hairpin of turquoise opaque glass, from a tomb which A. Lansing thought predated the temple of Hatshepsut (Fig. 26).¹³ Two amulets and a bead from Reisner's excavations at Ballas¹⁴ and "blue" and "green" items reported by Brunton/Engelbach at Gurob belong to this period as well;¹⁵ translucent and opaque turquoise fish amulets from Carter/Carnarvon burials in the Assasif could extend into the time of Tuthmosis III (nos. D, E; Fig. 28).

Surely of the time of Hatshepsut are beads inscribed for her official Senenmut: one of swirled turquoise and lapis-colored blue glass¹⁶ and one of green translucent glass¹⁷ according to reports, and three more which are translucent and colorless (no. 1, Fig. 27; Appendix 1).¹⁸

To the period of Hatshepsut could also belong the two "Tuthmosis I" vessel sherds from KV 38.¹⁹ The identification of Tuthmosis I's mummy²⁰ and tomb or tombs²¹ is still not sure; but in any event the Journal d'Entrée of the Cairo Museum²² states that the sherds were found near KV

10. Vernier 1925, CG 52642; Wilkinson 1971, pp. 101, 217 n. 11, believed she saw red and dark blue glass in the nemes headdresses and the same colors plus turquoise in the box's triangular inlays; also, possibly blue glass in the ties of the cartouche (see the color photograph in C. Andrews, *Ancient Egyptian jewellery* [London, 1990], p. 159). Vernier and M. Rosenberg looked at the turquoise inlay in the vulture armlet, CG 52068: *Zellenschmelz, I. Entstehung, II. Technik in Geschichte der Goldschmiedekunst, auf technischer Grundlage 4* (Frankfurt am Main, 1921), p. 7.

11. BMFA 1978.691; analyzed but not published, see Appendix 1; 1.3 cm square.

12. UC 11894: molded *wꜥꜣt* with name incised, length 1.2 cm: W. F. Petrie, *Scarabs and cylinders with names* (London, 1917), pl. 24-15, and idem, *Arts and crafts of Ancient Egypt* (Edinburgh, 1910), p. 120.

13. Cairo JdE 45640, slightly greenish opaque turquoise, length 14.8 cm. Shaft has long striations; tip broken off; two rings and a rosette incised at the head. Lansing, "Excavations in the Assasif at Thebes," p. 21, 5A pit 3, burial B 4: *The Egyptian Expedition, 1915-16, Metropolitan Museum of Art Bulletin 12, Supplement May 1917*; beginning of Dynasty 18 to Hatshepsut; reference from M. Hill.

14. Phoebe Apperson Hearst Museum of Anthropology 6-8787, from tomb 154.

15. G. Brunton and R. Engelbach, *Gurob* (London, 1927), pls. 21-15, 22-21.

16. Liverpool Merseyside 11568. Diameter 2 cm. M. Eaton-Krauss in *Egypt's golden age*, no. 193.

17. Now lost; said by S. Birch in Wilkinson to be bottle green (C. N. Reeves, "Two name-beads of Hatshepsut and Senenmut from the mortuary temple of Queen Hatshepsut at Deir el-Bahri," *Antiquaries Journal* 66 [1986], pp. 387f. n. 111 [iii]), and by A. Nesbitt to be "a dusky green glass, quite transparent" (*Glass*, [London, 1878], p. 11). See also Ashmolean 1892.684, an olive green translucent ball bead naming *Dsr-k3-r*; acquired at Qena by G. J. Chester.

18. BM 26290, whole, 2.1 cm diam.; a second smaller bead, BM 26289, is fragmentary and was the one analyzed. The smaller was drilled from one end; the "top" hole of the larger is rounded, but the "bottom" hole flattened. Reeves ("Two name beads") suggested that the beads should be dated early in the queen's reign.

19. Nolte 1968, p. 46; Barag 1970, p. 181.

20. E. Wente, "Royal mummies of the 18th dynasty: a biologic and Egyptological approach," in *After Tutankhamun; Abstracts of papers and presentations June 15-17* (Highclere Castle, 1990).

21. Reeves 1990 presents most of the arguments, but see also L. Gabolde, "La Chronologie du Règne de Thoutmosis II . . .," *Studien zur altägyptischen Kultur* 14 (1987), pp. 61-81. P. Der Manuelian is of the opinion that KV 38 was Tuthmosis I's original tomb ("The recarved sarcophagus of Queen Hatshepsut and King Thutmose I in the Museum of Fine Arts, Boston," paper delivered at the Annual Meeting of the American Research Center in Egypt, 22 Apr., 1993, Baltimore, Md.).

22. A report of Loret's excavations in 1899 has not been found; Daressy 1902 published the two fragments.

38, while other assorted nonvitreous items were found in it.²³ It is possible that Tuthmosis I was buried by his successor, Tuthmosis II,²⁴ and inscriptions on a vase in KV 38 as well as on vases and a sarcophagus in KV 20 suggest that Hatshepsut (Tuthmosis II's wife) took part in the burial too. Tuthmosis II's reign is estimated to have lasted between three and fourteen years;²⁵ Hatshepsut's subsequent one lasted twenty-two years. Of interest (in terms of this study) is the small size and tentative nature of one of the two sherds in the Cairo Museum that were found near KV 38²⁶ (Fig. 29): its very translucent turquoise matrix is filled with bubbles and its festoons of yellow and white are thin and feathery. A horizontal blue thread midway on the sherd seems to be translucent, occurs below the surface, and almost bleeds into the matrix; at the same time, the festoons and a yellow thread below them appear opaque. Each swag has an area of white, then extremely fine threads of yellow and white.

Items dated to Tuthmosis III's reign (the first half overlaps that of Hatshepsut) came from the king's own tomb, KV 34.²⁷ These glasses are simple, albeit a bit more proficient than the sherd just described. A kohl-jar lid is opaque blue, its color quite bright with a suggestion of purple (Fig. 30).²⁸ The color is heterogeneous, however—as if the ingredients didn't quite mix. Two polychrome sherds in Cairo are more sophisticated: they have an opaque turquoise matrix with highlights of yellow. One of them, from a pitcher, has translucent cobalt threads,²⁹ while the other has a twist of black and yellow.³⁰ It is likely that the latter sherd belongs with a fragment in The Brooklyn Museum (nos. 2–4,³¹ Figs. 19, 31; two lead samples from this fragment appear in Part 3 as Pb-2184 and -2185), which, judging by a reconstructed drawing, is from an amphora with segments of marvered twist around its shoulder. Since the Cairo (and Brooklyn) objects are from KV 34, they could be late in the king's reign, as the glass inlays in the king's much damaged and reworked coffin observed by Daressy.³² Other glass items assumed to date to Tuthmosis III

23. A canopic head which had borne a uraeus, two inscribed blocks, fragments of an inscribed canopic, an alabaster "furniture foot," and a wooden firedrill: see Lilyquist, "Stone ointment jars and cosmetic vessels with royal provenance or name, Auserre Apophy through Tuthmosis IV," forthcoming.

24. Some scholars have suggested, based on the KV 38's tomb type and the sarcophagus in it, that Tuthmosis III effected a reburial of Tuthmosis I (summarized in Reeves 1990, pp. 17f.), but no objects with Tuthmosis III's name were found in KV 38.

25. As reviewed by Gabolde, "La Chronologie . . . Thoutmosis II."

26. Daressy 1902, CG 24981; JdE 33869/SR 3067; wall sherd that curves toward bottom; 2.9 cm high, 2.0 wide, thickness 0.2 at bottom and 0.25 at top; deposit on inside is thin and white. Lilyquist was not able to locate the second sherd in Sept. 1990 although Nolte saw it around 1964.

27. In Feb. 1898 an inspector sent word to V. Loret of the discovery of the tomb, mentioning inscriptions naming Tuthmosis III that must have been those in the burial chamber. Loret subsequently came and "opened" the tomb (1899). The account does not mention glass vessels ("vases brisés" would probably have been stone or pottery). Loret mentions linen "aux couleurs douces, sur lesquels s'entrecroisent des bandelettes aux teintes plus vives" on two anephegraphic mummies which appear to be late (see Reeves 1990, p. 24); otherwise, nothing mentioned there or published later by Daressy seems anachronistic.

28. Daressy 1902, CG 24959; Nolte 1968, p. 47, no. 4. Cast; the upper surface convex and polished, the lower surface matte.

29. Daressy 1902, CG 24961; JdE 32259b/SR 3870; Nolte 1968, p. 46 no. 1, pl. 35-4. Height 4.2, th. 0.3 cm. Lustrous; hollow handle wound with flat dark blue and bright yellow threads; flat yellow petals on shoulder; one raised horizontal and one raised vertical [translucent] dark blue thread below.

30. Daressy 1902, CG 24960; JdE 32259a/SR 3871. Height 4.3, th. 0.3 cm; marvered yellow petals and horizontal threads; marvered twist of black and yellow. Nolte 1968, p. 46, no. 2, pl. 35-5.

31. Nolte 1968, p. 47, no. 3. R. A. Fazzini with J. Romano kindly made this fragment available for examination, sampling, and publication. The object was purchased in Luxor around 1932 and is said to have been found in the necropolis many years before.

32. CG 61014: Daressy 1902, p. 19.

were found in Tutankhamun's tomb: two model persea fruits of turquoise opaque glass, one inscribed *Mn-hpr-r* (Tuthmosis III; Fig. 32).³³

The second and larger group of glass associated with Tuthmosis III is from the Wady Qirud tomb of his three foreign wives. This tomb no doubt yielded a turquoise opaque lotiform cup incised with the king's name (no. 11; Cover, Fig. 34) and surely yielded the following: pieces of turquoise translucent glass of some thickness (no. 6; Fig. 38, right); bits of brown translucent glass (no. 7; Fig. 38, left); and about one thousand beads and inlaid elements (Figs. 36, 37, 39, 40). The beads of turquoise opaque glass occur in five different shapes; the sixth bead type is too deteriorated to guess its original color (Fig. 39, left). The inlays—of turquoise opaque (no. 8, Fig. 37, above left), blue opaque (nos. 9, 10; Fig. 37, below; Fig. 40, above left), and blue translucent glass (no. F; Fig. 40, left center)—occur in eleven different types of ornament.

In terms of quantity, this represents an extraordinary amount of early Egyptian glass. Most of the inlay is in the roughly 900 rosettes that formed a unique jewel or jewels (Fig. 40); on the basis of the types and fabrication of the rosettes and "head plate" with which they seem to belong, this jewel appears un-Egyptian.³⁴ But glass also occurs in Wady Qirud jewels of Egyptian design and high-quality workmanship, thus indicating that all glass-inlaid jewels were made in Egypt. At present the tomb seems best assigned to the later reign of Tuthmosis III, ca. 1425 B.C.

As for less-well-provenanced glasses associated with the reign of Tuthmosis III, some small items can be dated by means of inscription: opaque blue beads and plaques inscribed with the king's name (no. 5, Fig. 33).³⁵ For vessels, Petrie mentioned a "piece of a glass vase with an inlaid name of Tahutmes III," but it has disappeared.³⁶ A goblet in Munich has mannered festoons and an integral (rather than applied) foot; these features contrast sharply with the orientation of the inscription (on its side);³⁷ the vessel is from the art market.

A more instructive vessel is one in the British Museum; it is without recorded provenance but shares tentative decoration—as well as color and size—with sherds near or from the tombs of Tuthmosis I and III.³⁸ The decoration of this small pitcher, inscribed "*Mn-hpr-r* given life" (i.e., living), is best seen in a drawing (Fig. 43). A scale- or feather-pattern encircles the neck; a frieze of dots covers the juncture of neck and body; and a band of hieroglyphs framed by dotted swags encircles the shoulder. Three feathery forms (termed "conventionalized tamarisk trees" by Cooney) appear below; the handle is striped with threads of white, blue, and yellow. Cooney identified the vessel as a *nhnm*-vase, a container for one of the seven sacred oils of Egyptian tradition. However, the shape of this vessel is not so different from that of faience juglets in Middle Bronze Age Palestine; striped handles,³⁹ horizontal zones toward the top and around the base (rudimentary ring base), and feathery forms also appear there. The botanical forms sometimes

33. JdE 61870; H. Murray and M. Nuttall, compilers, *A handlist to Howard Carter's catalogue of objects in Tutankhamun's tomb* (Oxford, 1963), no. 585u; larger and lighter blue than the uninscribed example.

34. Lilyquist 1993.

35. BM 65662, a drop bead; UC 12027, a ball bead (Petrie 1891, pp. 19f., pl. 22-27, and A. Thomas, *Gurob; A New Kingdom town* [Warminster, 1981], no. 270).

36. Petrie, *Arts and crafts*, p. 120.

37. The broadly sweeping festoons, colors pulled into the foot and onto the top of the rim, and trailed-on inscriptions are found in glasses from KV 35 (Amenhotep II), but the orientation of the inscription may be unique, and seems incompatible with such a sophisticated vessel. This is aside from the question of lampblack, a suggestion made by S. Goldstein in *Egypt's golden age*, no. 173.

38. Cooney 1976, no. 764; reproduced with the kind cooperation of the Department of Egyptian Antiquities. For example, the handle of a turquoise pitcher from the tomb of Tuthmosis III was striped with blue and yellow, see n. 29 above.

39. The handle can also be understood as dotted; see also MB IIa painted juglets and Cypriote White-painted pendant-line style vessels.

appear as trees,⁴⁰ and sometimes as branches hanging downward, as on a faience pitcher of Middle Bronze type found in Egypt (Fig. 41).⁴¹ The tree/branch motif occurs on earlier Palestinian pottery⁴² and on Bichrome ware,⁴³ as well as a pottery example found in Egypt of unestablished origin (Fig. 44).⁴⁴ Dotting is a feature of Near Eastern art more than Egyptian;⁴⁵ it appears on yet another foreign but Egypt-found vessel somewhat earlier than the British Museum glass pitcher, a painted pottery juglet (Fig. 42).⁴⁶ As the decoration on the British Museum pitcher was made with powdered glass as well as trailed and marvered threads,⁴⁷ Cooney stated that "so sophisticated a technique . . . so well executed is [indicative of] considerable experience and tradition." Putting all this information together, foreign style—if not a foreign craftsman—is suggested for the small British Museum pitcher.

Several uninscribed vessels have been associated with the reign of Tuthmosis III on stylistic grounds: a kohl jar from Riqqeh⁴⁸ and one of unknown provenance.⁴⁹ It is also clear that a fragment of what seems to be a kohl tube in Cairo (Fig. 35, right),⁵⁰ currently labeled as from KV 34, would agree stylistically with glass from this reign; but this attribution must otherwise be

40. D. P. Williams, *The tombs of the Middle Bronze Age II period from the '500' cemetery at Tell Fara (south)*, University of London Institute of Archaeology, Occasional Publication, 1 (London, 1977), fig. 83.

41. Ashmolean 1921.1373 from Sedment 1270, Petrie/Brunton 1924, pl. 41; found with an imported Bichrome ware jug (J. Bourriau, *Umm el-Ga'ab; Pottery from the Nile valley before the Arab conquest*, Exh. cat. [Cambridge, 1981] no. 261) and a wooden dish of Middle Bronze type (cf. K. Kenyon, *Excavations at Jericho, volume one; The tombs excavated in 1952-4* [Jerusalem, 1960], pp. 385-89).

42. R. Amiran, *Ancient pottery from the Holy Land; From its beginning in the Neolithic period to the end of the Iron Age* (Jerusalem, 1969), pl. 28-11.

43. W. M. F. Petrie, *Ancient Gaza II, Tell el Ajjul*, BSAE (London, 1932), pl. 40-36; *Ancient Gaza III, Tell el Ajjul*, BSAE (London, 1933), pl. 41-7; *Ancient Gaza IV, Tell el Ajjul*, BSAE (London, 1934), pl. 54-57H5, cf. C. Epstein, *Palestinian Bichrome ware*, *Documenta et Monumenta orientis Antiqui*, 12 (Leiden, 1966), p. 53-14.

44. Ashmolean 1923.538 from Qau 619; reproduced with thanks to H. Whitehouse. Other examples, Brunton 1930: pls. 17-76p, 31-266.

45. Amiran relates the decoration on a Palestine-found jar she considers an Egyptian import to Canaanite pottery ("Ancient pottery," cf. pl. 58-5, p. 187). Dots occur in Megiddo XII (G. Loud, *Megiddo II; Seasons of 1935-39*, Oriental Institute Publications, 62 [Chicago, 1948], pl. 28-20), on Chocolate-on-white ware at Pella (A. W. McNicoll et al., *Pella in Jordan 2; The second interim report of the Joint University of Sydney and College of Wooster at Pella 1982-1985*, *Mediterranean Archaeology Supplement*, 2 [Sydney, 1992], pl. 29-2), and on Bichrome (Epstein, *Bichrome ware*, p. 53-6 to -8); White-slipped Cypriote milk bowls use similar bands (cf. *Ancient Gaza II*, pls. 37, 40-28 and -37).

46. By courtesy of the Petrie Museum, University College London: UC 13498, from Sedment 1300: Petrie/Brunton 1924, pl. 41-18. Foreign by shape, ware, and decoration but without parallel known to B. Gittlen, communications, Apr. 1993. A similar vessel was found in Aniba S 69 (base unspecified): G. Steindorff, *Aniba II, Service des Antiquités, Mission archéologique de Nubie 1929-1934* (Glückstadt, 1937) p. 190, pl. 83. See the MB Ila juglet with bands of punctate decoration on an oval body (but with small base), Amiran, *Ancient pottery*, p. 118, photo 116.

47. The raised opaque yellow threads on rim and foot contrast with the white, yellow, and blue diagonal threads on the handle; the latter are "buried" in the surface, the yellow is slightly translucent, and the blue definitely is. The white and yellow decoration on the body is all done by enameling; the yellow is thinner than the white; both colors penetrate into the turquoise, and rather deep bubbles are formed in the mixture. I. C. Freestone suggested (communication, Aug. 1990) that the thin, bubbly quality indicated that the melting period was short, with no time for bubbles to escape, and that the enameling had been done by reentering the vessel into a furnace. A good color photo also appears in B. Nolte, *Die Glasgefäße im alten Ägypten* (in Japanese, ed. by Takashi Taniichi [Kyoto, 1985], p. 10).

48. UC 19657, Nolte 1968, p. 48, no. 6; apparently no context (R. Engelbach, *Riqqeh and Memphis VI*, BSAE and ERA 19th Year, 1913 [London, 1915], pp. 9, 16, pl. 12-14). Incised line at constricted point of neck.

49. BM 24391, Cooney 1976, no. 1760; translucent turquoise with rich yellow (i.e., not a lemon yellow) trim; central hole drilled.

50. SR 3870, opaque turquoise; thickness 0.3 cm at midpoint.

regarded with reservation.⁵¹ The small lotiform vessel found at Gurob by L. Loat⁵² was published with objects that could be from the first half of Dynasty 18,⁵³ although other vessels from that site seem to be later (Appendix 1).

In the following reigns of Amenhotep II and his son Tuthmosis IV, the range of object-types manufactured in glass—amulets, beads, inlays, and vessels, possibly sculpture⁵⁴—continues from the reign of Tuthmosis III.

But the reign of Amenhotep II yielded a great deal more glass, of much more sophisticated technology, and it displays a high degree of variety and proficiency. B. Nolte has estimated that there were at least 76 vessels, in many techniques,⁵⁵ in the king's tomb.⁵⁶ One is reconstructed as a vessel more than 40 cm high, several have button bases and separate stands, and there is a very large carinated bowl (CG 24826). One cannot help asking whether some of the vessels are imports, in light of traditional Egyptian vessel shapes and two-dimensional patterns, the small simple glass objects from the previous reign(s), and the glass from subsequent reigns.⁵⁷ Hence the importance of our analyses nos. 12–30 (Figs. 19, 45–47),⁵⁸—chosen for comparison with the plainer, smaller, earlier glasses—and of their lead samples in Part 3 (Pb-2181, -2182). An estimated span of 24 to 32 years separates the tombs of Tuthmosis III and Amenhotep II.

Besides vessels, there were other interesting glass objects from Amenhotep II's tomb, KV 35. Daressy termed some items "colonnettes," describing them as light blue opaque tubes decorated by

51. Two other sherds, SR 3872 and 3873 (mentioned in Nolte 1968, p. 47, no. 3), rim and foot of perhaps the same vessel, have modern paint marks like those from the tomb of Amenhotep II. But a fourth sherd deserves illustration: SR 3869, rim of a translucent turquoise bowl with white and yellow festoons, and a twist of blue and yellow along the outside of the rim (Fig. 31, left). Thickness 0.5 cm at bottom; surface quite weathered. A similar sherd is known from Alalakh level II (Antakya 6089: L. Woolley, *Alalakh, an account of the excavations at Tell Atchana in the Hatay, 1937–1949* [Oxford, 1955], p. 298, fig. 74b-1, AT/46/22).

52. Ashmolean E 2451 from tomb 58: Loat 1905, pl. 4-43; Nolte 1968, p. 149, no. 10.

53. Pottery (Loat 1905, pls. 2-28, 3-44), a cowroid (pl. 4-30), shawabtys (pl. 5-9, -17, -18), and a stone vase (pl. 6-3, probably missing its neck).

54. E.g., the cobalt translucent royal head from a kneeling(?) statue: CMG 79.1.4, 4 cm high. Goldstein has dated it to Amenhotep II ("A unique royal Head," *JGS* 21 [1979], pp. 8–16) but it seems stylistically earlier; cast and engraved. Cobalt translucent glass is documented in the Wady Qirud tomb of Tuthmosis III's foreign wives (no. F).

55. Daressy 1902, CG 24753–832 (81 entries); for descriptions see Nolte 1968, pp. 53–62; there also seems to be a bilbil present, JdE 97663/SR 3083.

56. This tomb was also cleared by V. Loret, immediately after that of Tuthmosis III, and Loret published accounts of both in the same journal of 1899. Broken pieces of faience and of a stone shawabty with the names of Amenhotep II were found outside the door, and broken antiquities continued to be found on the other side of the door and down into the burial chamber, all in great disorder, "two or three thousand" total according to Loret, including shawabty and canopic fragments of prince "Oubkh-snou," presumed to be the king's son (see Lilyquist, "Some royal canopic jars of earlier Dynasty 18," *Journal of the American Research Center in Egypt* 30). The king's mummy was in the sarcophagus, and a great many objects had the king's name on them. It would appear that the only objects in the tomb postdating the burial of the king were nine coffins with the mummies of eight other kings, together in the second room on the right off the burial chamber (this was the "second" Dynasty 22 cache of royal mummies, buried in this tomb for protection). Glass fragments are mentioned in the burial chamber; Loret 1899 writes: "plusieurs centaines de débris de verre, dont quelques-uns portent la légende du roi. Il y a là, pour ceux qui s'intéressent à l'histoire de la verrerie, matière à une importante monographie. Toutes les espèces s'y trouvent réunies, depuis le verre opaque jusqu'au verre le plus transparent, depuis les verres monochromes, jusqu'aux verres striés en dents de scie, aux verres imitant le marbre, l'agate, la serpentine. Certain fragment de verre blanc opaque, tacheté de violet foncé et de bleu clair, est du plus joli effet. Quelques morceaux portent même des rosaces et des croix de goût asiatique et sont peut-être l'oeuvre des Phéniciens, qui passaient pour avoir inventé le verre" (pp. 18f.). Several mummies from the tomb examined by James E. Harris were of 18th dynasty type (personal communication, 25 April, 1993).

57. For relevant historical information from Amenhotep II's reign see P. der Manuelian, *Studies in the reign of Amenophis II*, Hildesheimer Ägyptologische Beiträge, 26 (Hildesheim, 1987), pp. 45–92.

58. Apparently no compositional analyses have been made of the Cairo Museum glasses.



Fig.19 Glass vessel sherds from the time of Tuthmosis III (upper left, nos. 2-4), Amenhotep II (upper right, nos. 12-14; center, nos. 15-17; lower left, nos. 18-30), and Tuthmosis IV (lower right, nos. 32-35)

yellow and white festoons with interior bronze rods⁵⁹ (possibly similar to those from Megiddo and Hazor);⁶⁰ two items with rather fine marbling surfaces were examined which seemed to belong to this group.⁶¹ There were also bangle fragments of green, white, yellow, and various blue glasses (including transparent); they were decorated by combed threads, twists, eyes, and stripes.⁶² More conventional were inlays shaped as hieroglyphs—for furniture according to Daressy—of light blue, dark blue, and red.⁶³ Our inscribed rim sherd of translucent purple may come from this tomb (no. 31, Fig. 48).

One of Amenhotep II's favored officials, Maiherpri,⁶⁴ owned—like the king—both unusual and plain glasses (the officials Kenamun⁶⁵ and Hekareshu⁶⁶ had only Egyptian-style glass objects, shawabtys). Maiherpri owned the vessel that Barag compared with vessels from Nuzi level II and Assur tomb 37,⁶⁷ as well as a colorful "eye" bead.⁶⁸ Maiherpri's more conventional glass items were beads,⁶⁹ opaque blue eyebrows on the gilded anthropoid coffin CG 24004, and inlay plaques of light and dark blue, one of a jackal.⁷⁰

The glass deposited in Tuthmosis IV's tomb, KV 43, was less extensive than the glass in his father's tomb ten years earlier. Furthermore, while the furniture inlays in KV 43 appear to be a bit

59. Daressy 1902, CG 24833. Diameter 1.2, length of largest piece 6.8 cm.

60. Lilyquist 1993.

61. JdE 97686/CG 24833?

62. CG 24834–43 (10 entries). Bangles flat, convex, or with tri-cord profiles; inner diameters 6.5 to 7.6; width 2.2 to 3.8 cm. Invariably the inner surfaces are ground but not polished, and the same is usually true for the edges. For the technique of making later bracelets, see M. Spaer, "The pre-Islamic glass bracelets of Palestine," *JGS* 30 (1988), pp. 52f.

63. CG 24845–46 (2 entries). Some 6 cm long according to Daressy 1902.

64. Manuelian, *Reign of Amenophis II*, pp. 168f., 154 n. 9. On Kenamun, *ibid.*, pp. 114–16 and 159f.; Hekareshu, p. 132. The bond between Maiherpri and the king was probably sport.

65. J. Cooney, "Glass sculpture in Ancient Egypt," *JGS* 2 (1960), p. 11; cast, turquoise opaque, 38 cm high, CG 46531; P. Newberry, *Funerary statuettes and model sarcophagi*, Catalogue général des Antiquités égyptiennes du Musée du Caire, nos. 46530–48575 (Cairo, 1930 and 1957).

66. Active in the reigns of both Amenophis II and Tuthmosis IV: C. Roehrig, "The Eighteenth Dynasty titles royal nurse (*mn't nswt*), royal tutor (*mn' nswt*), and foster brother/sister of the Lord of the Two Lands (*sn/snt mn' n nb t3wy*)" (Berkeley, University of California Ph.D. dissertation, 1990). Cast, turquoise opaque, height 17.5 cm, CG 48329, JdE 34405: Cooney, "Glass sculpture," pp. 12–14. M. Bimson analyzed a glass model coffin by X-ray diffraction (opaque yellow, white and turquoise; translucent dark blue), which A. F. Shore linked to the shawabtys of Hekareshu and Kenamun, but the British Museum example may not date so early: Cooney 1976, no. 1840; Bimson and Shore, "An Egyptian model coffin in glass," *British Museum Quarterly* 30 (1966), pp. 105–9. The core material is described in M. Bimson and A. E. Werner, "Two problems in ancient glass: opacifiers and Egyptian core material," in *Proceedings of the IV International Congress on Glass, Ravenne-Venise, 1967* (Liège, 1969), pp. 264–66. More similar is a calcite shawabty inlaid with red glass, Newberry, *Funerary statuettes*, CG 48331.

67. A flask of turquoise translucent with chartreuse, white, and rich yellow opaque trailed decoration (a richer opaque color than the usual lemon yellow). Daressy 1902, CG 24059; SR 4319; Nolte 1968, p. 51, right column. According to Nolte there is also a brown and white twist on the rim.

68. Turquoise translucent bead with rich yellow opaque spots within white opaque rings, Daressy 1902, CG 24068 bis E. Diameter 1.0 cm according to Daressy, who also reports that there are eight dots. JdE 35122/SR 4352.

69. Daressy describes beads from the right wrist, CG 24068 bis C: one barrel 1.2 long in dark blue with gold attachment; five ball beads, 0.5 to 0.8 cm diameter, two being dark blue, two light blue, two red—the blue ones are equipped with an inner tube of bronze. He also describes two long beads on the breast, CG 24068 bis D: dark blue, 1.4 cm long, with inner bronze tubes. On the basis of study from outside the vitrine, the following beads seem to be glass: of dark blue, two balls, one bell-shape, and four barrels with tubes (two medium and two large); of turquoise, one ball.

70. CG 24068 bis; Daressy 1902 suggests they formed part of a pectoral with carnelian and gypsum; no dimensions given.

more varied than before,⁷¹ and the gameboard inlay rather colorful,⁷² the bangles are plain⁷³ and the vessels small, their decoration more homogeneous: the vessels are completely in line with what one imagines of "Egyptian cored vessels," although the lead used in one of our samples was not identical to the Malkata/Amarna leads (Part 3, Pb-2183). Most vases are small krateriskoi with turquoise or violet-blue opaque matrix and combing that includes white and yellow opaque glass.⁷⁴ Part of one such vessel yielded analyses nos. 32–35 (Fig. 49).

Catalogue and Chemical Data

While scientists have explored the origin of glassmaking in Egypt and the Near East⁷⁵ with regard to the relation of glass to other vitreous materials⁷⁶ or metal technologies,⁷⁷ the source of cobalt,⁷⁸ or types of alkali used,⁷⁹ the dating of the objects sampled leaves much to be desired from an archaeologist's point of view (Appendix 1). Furthermore, data from the pre-Malkata period, the crucial period of development, is almost nonexistent.

Therefore the primary author selected a group of pre-Malkata period glasses in New York for compositional analyses (nos. A–F, 1, 5–35 from the Metropolitan Museum, and nos. 2–4 from The Brooklyn Museum). Procedures for EDS analysis at the MMA were developed by Koestler and Wypyski with M. Verità,⁸⁰ and the sampling and analyses were undertaken by Wypyski.

The glasses analyzed below (see Appendix 2 for methodology) have been dated by various means. They were excavated in a royal tomb (nos. 6–8; 32–35) or are associated with one on various grounds (9–11); match glasses in the Cairo Museum gathered in the tombs of Ahhotep (B), Tuthmosis III (2–4), the foreign wives of Tuthmosis III (F, 8), and Amenhotep II (12–30); are inscribed with the names of kings or their contemporaries (C, 1, 5, 31); or are from datable tombs (A, D, E).

71. Carter/Newberry 1904, CG 46133. According to the authors, "on one piece is the cartouche of Thoutmosis IV" [*blty (Mn-hpr-r)*]; on the three others, "the usual conventional feather pattern, executed in white and light blue glass, inlaid in plaster on the wood."

72. CG 46119: according to Newberry, top and bottom decorated with "squares composed of violet glass rods, divided by rods of yellow, blue, and yellow glass"; the sides decorated with "violet glass rods arranged horizontally."

73. CG 46520–22. Violet glass; one plain, one with white opaque threads, one with yellow opaque threads. Diameter 7–8, width 2.0–2.5 cm.

74. At least 35 vessels represented according to Nolte 1968, p. 63, CG 46488–519, 46523–25; a few bowls, amphoriskoi, beaker (according to Nolte); brown reported.

75. On this important technological step see R. H. Brill, "Ancient glass," *Scientific American* 209 (1963), pp. 120–30.

76. Kaczmarczyk/Hedges 1983, pp. 248f.; P. R. S. Moorey, *Materials and manufacture in Ancient Mesopotamia*, British Archaeological Reports International Series, 237 (Oxford, 1985), pp. 200ff.; P. Vandiver and D. Kingery, "Egyptian faience; The first high-tech ceramic," in W. D. Kingery, ed., *High technology ceramics; Past, present, and future* (Westerville Ohio, 1986), pp. 27, 29.

77. Peltenburg 1987; L. Biek and J. Bayley, "Glass and other vitreous materials," *World Archaeology* 11 (1979), p. 3; J. Henderson, "The scientific analysis of ancient glass and its archaeological interpretation," in *Scientific analysis in archaeology and its interpretation* (Exeter, 1989), p. 47.

78. R. H. Brill in G. F. Bass, "A Bronze Age shipwreck at Ulu Burun (Kas); 1984 Campaign," *American Journal of Archaeology* 90 (1986), p. 282; E. R. Segnit, "Evaporite minerals from the Dakhleh Oasis," pp. 97–102 in C. Hope et al., *Ceramics from the Dakhleh Oasis; Preliminary studies*, Victoria College Archaeology Research Unit, Occasional Paper, 1 (Burwood, Victoria, 1987) contra Kaczmarczyk 1986.

79. Sayre 1967; Freestone 1987, p. 185; J. Henderson, "The raw materials of early glass production," *Oxford Journal of Archaeology* 4 (1985), pp. 267–91. These are all studies that have appeared since E. R. Caley's *Analyses of ancient glasses, 1790–1957* (Corning, N.Y., 1962).

80. M. Verità et al., 1993.

None of the glasses yielding the 35 samples is from a known factory area (in contrast to the Malkata, Amarna, and Nuzi glasses with which we compare them in Table 3 and Figs. 50, 52–57). One might, however, suggest Thebes as the origin for nos. 32–35 in view of the homogeneity of glass from Tuthmosis IV's Theban tomb and in view of the fact that the Malkata glass came from the Theban palace of his son, Amenhotep III.

The very earliest glasses occur in small format and, as a result, their data in Table 1 are not as extensive or reliable as the data in Table 2 from glasses which could be sampled and prepared normally. Data from the earliest or especially weathered glasses are not included in Table 3 or Figs. 50, 52–57.

The samples in both Tables 1 and 2 are arranged chronologically. Colors are noted with the following abbreviations: CT = colorless translucent, BLKT = black translucent, TT = turquoise translucent, AT = amber translucent, BT = blue translucent, PT = purple translucent; TO = turquoise opaque, YO = yellow opaque, BO = blue opaque, WO = white opaque, RO = red opaque. "Turquoise" is used for glasses colored with copper, "blue" for those colored with cobalt. "Translucent," "transparent," and "opaque" are subjective terms.

Deteriorated Glasses and Glasses too Small to Sample (Table 1)

Hyksos Period:

No. A Inlay on head of a toggle pin, MMA 68.136.2 (Fig. 20); purchase, Lila Acheson Wallace Gift, 1968. Diameter of pin head 1.3 cm. Colorless transparent glass with spot of milky white in center. See Part 1, pp. 6f.; Lilyquist 1993.

Kamose–Ahmose:

No. B Inlay in round gold pendant (Fig. 22, left), MMA 40.9.4b (gift of Mrs. Edward S. Harkness, 1940). Diameter of pendant 0.75 cm. Two areas of severely weathered glass, the outer beige, the inner (sampled) glass whitish opaque with a spot of faint transparent blue. The original surface of one of the inlays is preserved around the edge; it is a medium brown (stained from resin, like Cairo examples?). This is one of two pendants in the MMA, the other is .085 cm in diameter. Bissing wrote about small Ahhotep items that never reached the Cairo Museum or were lost from it (1900, pp. 14, 16).

No. C Amulet formed as a cartouche, with name of Ahmose (Fig. 24), MMA 10.130.170 (gift of Helen Miller Gould, 1923; ex-Murch collection). Length 1.4, thickness 0.4 cm. Molded; the cartouches, hieroglyphic signs, and a line around the circumference of the object engraved.

Early Reigns of Dynasty 18:

No. D Fish-shaped amulet (Fig. 28, right), MMA 26.7.1375 (purchase, Edward S. Harkness Gift, 1926). From excavations of H. Carter for the earl of Carnarvon in the Assasif (*Five Years' Explorations at Thebes* [Oxford, 1912], pl. 73, no. 78; tomb 37, pit D, no. 53), no later than the time of Tuthmosis III. Length 1.1 cm. Dark turquoise translucent; one of three glass amulets from a necklace which also included the tin-alloy bead that yielded Pb-2169 discussed in Part 3 below. All three amulets flat and unpolished on back; hole bigger at one end of suspension loop than at the other.

No. E Fish-shaped amulet from same necklace (Fig. 28, left). Length 0.7 cm. Light turquoise opaque.

Foreign Wives of Tuthmosis III:

No. F Inlay from rosette (Fig. 40, left center), MMA 26.8.117 (purchase, Henry Walters and Edward S. Harkness Gifts, 1920). Believed to have same provenance as no. 8. Diameter of second rosette from bottom, 1.6 cm. Transparent blue-tinged fabric, very shattered.

Table 1

**Deteriorated Glasses
and Glasses too Small to Sample**

Weight %	A ¹ Hyksos	B ² Ahhotep	C ¹ Ahmose TO	D ¹ Tuthmoside TT	E ¹ Tuthmoside TO	F ² Foreign wives BT
SiO ₂	85-90	75.3	60-62	67-69	60-63	82.7
Na ₂ O	~1	0.8	15-17	14-16	15-17	2.2
CaO	3-6	1.9	8-9	6-7	6-7	1.7
K ₂ O	1-3	1.8	~3	~3	~2	0.8
MgO	<1	10.1	5-6	4-5	5-6	0.5
Al ₂ O ₃	1-3	1.7	~1	<1	~1	2.2
Fe ₂ O ₃	<1	0.4	<0.5	<0.5	<1	0.3
TiO ₂	-	-	-	-	-	-
Sb ₂ O ₃	-	3.2	-	-	-	-
MnO	-	-	-	-	0.1	-
CuO	~1	-	~0.5	~0.5	~0.5	0.6
CoO	-	-	-	-	-	0.07
PbO	-	-	-	-	-	-
NiO	-	-	-	-	-	-
ZnO	-	-	-	-	-	0.05
SO ₃	~1	0.4	0.5	0.5	0.5	1.0
Cl	<1	1.5	<1.0	<1.0	<1.0	2.9
P ₂ O ₅	-	-	-	-	-	-

1. Surface scans of polished but uncoated area.

2. Samples of weathered glass, prepared as normal glass samples.

Glasses Analyzed Quantitatively (Table 2)

Hatshepsut:

No. 1 Bead (Fig. 27), MMA 26.7.746 (purchase, Edward S. Harkness Gift, 1926. Diameter 2.1, height ca. 1.5 cm. Colorless translucent glass wrapped around armature. Asymmetric: angled circumference below midpoint of bead; glass pulled away from bottom of hole. Inscription naming Senenmut essentially same as BM 26290 (Appendix 1).

Tuthmosis III:

Nos. 2-4 Vessel shoulder sherd (Figs. 19, 31), Brooklyn 53.176.4 (anonymous gift). Height 4.8 cm. Nolte 1968, p. 47, no. 3. Probably belonging to CG 24960 from KV 34, tomb of Tuthmosis III; from an amphoriskos[?] Opaque turquoise matrix (2); opaque yellow (3) petals and two horizontal opaque yellow threads (this yellow yielded Pb-2184 and -2185 in Part 3); with translucent black (4) and opaque yellow twist between them. The dimensions, general design, and glossy colors of this fragment relate it closely to the Cairo fragment; there is more organic residue within the Brooklyn sherd, and three of the petals go in the opposite direction (one goes the direction of the Cairo fragment), but the sherds could be from the same vessel. Of interest is a bit of the neck on the Brooklyn sherd: the petals formed a yellow garland at its base. Of greater interest is the clumsy application of threads: the distance between the two horizontal yellow threads varies from .6 to .8 cm, and the join of the lower thread is obvious; furthermore, the black and yellow twist has been applied in at least two sections, the stripes being "slanted" to "vertical,"

and the segment in the center of the sherd being quite narrow. Judging by E. Simpson's drawing, this vessel was an amphoriskos.

No. 5 Plaque inscribed with Tuthmosis III's names (Fig. 33), MMA 30.8.566 (bequest of Theodore M. Davis, 1915). Height and width 1.3, thickness 0.5 cm; blue opaque, pierced through center. The legend "Menkheperre, chosen of Re" on one face, and "Menkheperre, gilder of Thebes" on the other; inscriptions and frame bordering them engraved. There is a pair of faint grooves radiating from each hole.

Foreign Wives of Tuthmosis III:

No. 6 Fragment excavated at the Wady Qirud tomb of three foreign wives of Tuthmosis III (Fig. 38, right), MMA. Dimensions 1.8 x 1.2 x 1.1 cm; translucent turquoise. Brill saw internal shattering (perhaps the result of low calcium, high sodium), thought the glass heterogeneous, and commented that it looked like the glass in Nuzi pendants he had analyzed. Considering the size and shape of the fragments found, the possibility exists that the fragments came from some object other than a vessel; an opaque turquoise disk pendant from Nuzi was analyzed by Vandiver (1983, p. 243, no. 30-2-7-1; 1982, p. 80, no. 1); she also analyzed translucent turquoise glasses.

No. 7 Fragment with same provenance as no. 6 (Fig. 38, left), MMA. Dimensions 1.1 x 0.6 x 0.4 cm; translucent amber.

No. 8 Trapezoidal inlay from a drop pendant (Fig. 37, top left), MMA. Provenance same as nos. 6, 7. Width 1.0, height 0.5, maximum thickness 0.15 cm. Opaque turquoise; upper surface convex and polished, sides ground, back flat.

No. 9 Triangular inlay from a "headdress" element (Fig. 40, top left), MMA. Believed to have provenance as nos. 6-8. Height 0.75, width 0.3, thickness 0.15 cm. Opaque blue; upper and lower surfaces flat, sides ground.

No. 10 Half-moon inlay from a drop pendant (Fig. 37, bottom left), MMA 1988.17 (purchase, Lila Acheson Wallace Gift, 1988). Provenance same as no. 9. Height 0.8, width 0.9, maximum thickness 0.2 cm. Opaque blue; upper surface flat and polished, sides ground, back flat and with fine surface striations running on greatest axis.

No. 11 Lotiform goblet inscribed *Mn-hpr-r* (Cover, center; Fig. 34), MMA 23.9 (bequest of Lord Carnarvon, 1923). Provenance same as no. 9. Nolte 1968, p. 48, no. 8. Height 7.5 cm; opaque turquoise cup, foot missing. Cast; outer surface fire-polished, inner smoothed vertically. Inner surface shows two cracks and a "crease," probably caused by protrusion on core. Lotus petals and inscription are engraved on exterior.

Amenhotep II:

Nos. 12-14 Body sherd similar to CG 24804 from KV 35, tomb of Amenhotep II (Figs. 19, 45), MMA 16.7.9 (gift of Bashford Dean, 1916). Width 5.9, height 3.4, thickness 0.8 to 0.7 cm. White opaque matrix (12) with swirls of brown translucent (13) and turquoise opaque (14) on surface. Thick white core material shows scrape marks. Nolte has cited other sherds outside Cairo (1968, p. 54, including MMA 26.7.1160; A. von Saldern et al., *Gläser der Antike, Sammlung Erwin Oppenländer*, [Mainz, 1974], no. 12). Similar sherds, some with yellow and some of less thickness, are also in Turin (*Reperti del Museo Egizio di Torino, ricerche ed analisi* [Turin 1991], no. 1371, pp. 29f., 89). A number of sherds must have gotten into the hands of dealers and collectors at the time of Loret's discovery of the tomb, contra M. Bell, "An armchair excavation of KV 55," *Journal of the American Research Center in Egypt* 27 (1990), pp. 108f., 136; cf. C. N. Reeves and J. H. Taylor, *Howard Carter before Tutankhamun* (London, 1992), pp. 61-63.

Nos. 15-17 Rim sherd similar to ware of CG 24804 from KV 35 (Figs. 19, 46), MMA 26.7.1150d (purchase, Edward S. Harkness Gift, 1926; ex-Wallis and Carnarvon collections). From amphoriskos or krateriskos; two fragments of this vessel are in the MMA; the analysis was made from the smaller. Original height perhaps 15 cm; larger fragment (a-c) ca. 4.9 high, inner

diameter of neck ca. 3.2, wall thickness 0.5 to 0.2 cm. White opaque matrix (15) with amber translucent swirled on surface (17); blue opaque thread on outer edge of rim (16).

Nos. 18–22 Bowl sherd similar to one in the group CG 24828 from KV 35 (Figs. 19; 47, bottom), MMA 26.7.1163 (purchase, Edward S. Harkness Gift, 1926; ex-Carnarvon collection, in lot said to be mostly from the Valley of the Kings). Width 3.2, height 4.1, thickness 0.45 to 0.25 cm. Bottom of rounded bowl in true mosaic technique uses opaque colors: center of vessel is red (22), beyond which are concentric rings of turquoise (19), yellow (21), dark blue (20), yellow, dark blue, and white (18); then radiating white spokes into which red and blue rectangles are set. Top and bottom surfaces polished. The red in this and the following sherds is a bright, intense hue. The Cairo (Nolte 1968, p. 56) and New York sherds may be from the same vessel, along with BMFA 65.1783a, and—according to notes of J. Cooney supplied by A. Kozloff—Ashmolean 1965.325 and Victoria and Albert C.12yy.1946 (the last from Newberry, who stated it was from Malkata). Turin has two fragments; a related piece is in a private collection (Nolte, "Gläserne Raritäten aus der Sammlung Kiseleff," *Studien zur altägyptischen Kultur* 6 [1978], pl. A-6).

Nos. 23–27 Bowl sherd (Figs. 19; 47, top) MMA 26.7.1164. Same provenance as nos. 18–22; possibly from same vessel as MMA 26.7.1163 (color and finish are similar but not the curvature and thickness). Wall fragment; 4.0 x 3.0 x 0.3 to 0.35 cm thick. Both sides polished; rectangle series is red (27), dark blue (25), turquoise (24), dark blue; then yellow (26) alternating with red. White radiating spokes (23) are wider on the inside of the bowl than on the outside. Yellow yielded Pb-2181 in Part 3.

Nos. 28–30 Bowl fragment similar to a different sherd in the group CG 24828 from KV 35 (Figs. 19; 47, middle right), MMA 26.7.1165. Same provenance as nos. 18–22. Belongs with BMFA 65.1783b, and possibly JdE 97670. Wall fragment; dimensions 1.35 x 1.8 x 0.3 cm thick. Turquoise (28) and yellow (30) rectangles, apparently set in blue (29) matrix. Yellow yielded Pb-2182 in Part 3.

No. 31 Rim sherd incised with king's name (Fig. 48), MMA 26.7.1169 (purchase, Edward S. Harkness Gift, 1926; ex-Amherst and Carnarvon collections). Height and width 2.7, thickness 0.5 to 0.3 cm. Translucent purple.

Tuthmosis IV:

Nos. 32–35 Bowl and foot of a jar from KV 43, tomb of Tuthmosis IV (Figs. 19, 49), MMA 30.8.44a (bequest of Theodore M. Davis, 1915). Height 6.0, wall thickness 0.5 to 0.3 cm; no traces of handles. Neck (b) formerly placed with body now separate since it does not seem to have come from the same vessel (it is lighter in color, thinner walled, has a more matte surface and a layer of thick white core material rather than stained thin core residue, and its neck diameter is too small for such a globular body). For an amphoriskos from the tomb see CG 46499–500 with handles, and for a krateriskos (but without trace of handles) see CG 46488. Nolte 1968, p. 63, no. 1. Turquoise opaque matrix (32) with zigzags of white (33) and yellow (35) bordered by blue (34) (termed violet by Carter/Newberry 1904), all opaque; yellow opaque thread around the circumference of the foot. Yellow yielded Pb-2183 of Part 3. The peaks of the zigzags correspond to bulges on the shoulder (see D. B. Harden, *Catalogue of Greek and Roman glass in the British Museum, Volume I, Core- and rod-formed vessels and pendants and Mycenaean cast objects* [London, 1981], p. 27 "combing"). Concavity in bottom of foot shows that the foot was separately made.

Table 2

Glasses Analyzed Quantitatively¹

Weight %	1 Hatshepsut CT	2 Tuthmosis III [TO	3 YO	4 BLKT] ²	5 <u>BO</u>	6 TT	7 AT	8 TO	9 <u>BO</u>	10 <u>BO</u>	11 TO
SiO ₂ a	64.6	61.3	62.9	55.3	64.1	68.4	66.1	61.6	61.1	61.5	62.7
Na ₂ O	20.5	17.3	17	16.5	17.2	18.3	19.4	15.3	18.4	17.8	16
CaO	3.98	7.24	5.65	6.91	7.44	3.22	4.98	8.68	8.1	7.76	8.82
K ₂ O	2.14	2.94	2.93	2.27	1.29	3.69	3.52	4.2	0.83	0.76	3.36
MgO	5.6	5.98	4.76	2.51	4.06	2.69	3.89	5.58	4.13	4.28	3.68
Al ₂ O ₃	1.63	1.27	0.71	2.61	2.42	0.74	0.6	1.18	3.65	3.98	0.77
Fe ₂ O ₃	0.32	0.45	0.46	3	0.38	0.48	0.36	0.41	0.66	0.68	0.4
TiO ₂	0	0	0	0.17	0.06	0	0	0.05	0.1	0.09	0
Sb ₂ O ₅	0	1.49	0.66	0	1.44	0	0	1.25	1.42	1.87	1.71
MnO	0	0.08	0	5.27	0.32	0	0	0.07	0.26	0.31	0
Cu ₂ O											
CuO	0	0.72	0.26	3.53	0.58	1.33	0	0.65	0	0.47	0.71
CoO	0	0	0	0.18	0.11	0	0	0	0.19	0.28	0
SnO ₂	0	0	0	0	0	0	0	0	0	0	0
PbO	0	0	3.5	0.82	0	0	0	0	0	0	0
NiO	0	0	0	0.06	0.08	0	0	0	0.12	0.23	0
ZnO	0	0	0	0.09	0.11	0	0	0	0.27	0.36	0
SO ₃	0.44	0.38	0	0	0.32	0.24	0.33	0.47	0.4	0.44	0.2
Cl	1.05	0.83	1.03	0.85	0.95	1.35	1.28	0.49	0.83	0.73	1.08
Total	100.26	99.98	99.86	100.07	100.86	100.44	100.46	99.93	100.46	101.54	99.43
100-T=d	-0.26	0.02	0.14	-0.07	-0.86	-0.44	-0.46	0.07	-0.46	-1.54	0.57
Sum	100.26	99.98	99.86	100.07	100.86	100.44	100.46	99.93	100.46	101.54	99.43
M	98.77	96.48	94.41	89.1	96.89	97.52	98.85	96.95	96.87	96.76	95.73
SiO ₂ *a	65.40	63.54	66.62	62.07	66.16	70.14	66.87	63.54	63.07	63.56	65.50
SiO ₂ *d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na ₂ O*	20.76	17.93	18.01	18.52	17.75	18.77	19.63	15.78	18.99	18.40	16.71
CaO*	4.03	7.50	5.98	7.76	7.68	3.30	5.04	8.95	8.36	8.02	9.21
K ₂ O*	2.17	3.05	3.10	2.55	1.33	3.78	3.56	4.33	0.86	0.79	3.51
MgO*	5.67	6.20	5.04	2.82	4.19	2.76	3.94	5.76	4.26	4.42	3.84
Al ₂ O ₃ *	1.65	1.32	0.75	2.93	2.50	0.76	0.61	1.22	3.77	4.11	0.80
Fe ₂ O ₃ *	0.32	0.47	0.49	3.37	0.39	0.49	0.36	0.42	0.68	0.70	0.42
T*	100.00	[100.00	100.00	100.00]	<u>100.00</u>	100.00	100.00	100.00	<u>100.00</u>	<u>100.00</u>	100.00

1. Quantitative chemical analyses in relative weight percentages, both overall compositions and reduced compositions. The reduced compositions are the numbers for the basic components of the glasses (Na, Mg, Al, Si, K, Ca, and Fe) normalized to 100%, calculated to facilitate study of the different base glasses without colorants, opacifiers, etc.

2. Brackets group samples that belong to the same sherd; horizontal lines highlight cobalt samples.

Weight %	12	13	14	15	16	17
	Amenhotep II					
	[WO	AT	TO]	[WO	\overline{BO}	AT]
SiO2 a	62.1	63.8	59.8	60.9	61.9	62.2
Na2O	17.7	19.6	19.1	17.3	21.6	16.9
CaO	7.69	6.55	7.52	9.31	6.44	9.31
K2O	2.22	2.54	1.74	2.3	0.72	2.77
MgO	5.13	5.07	4.08	3.47	3.14	4.47
Al2O3	0.83	0.58	0.53	0.59	3.01	0.67
Fe2O3	0.4	0.26	0.33	0.29	0.61	0.35
TiO2	0.08	0	0.06	0.09	0.09	0.08
Sb2O5	2.2	0	2.38	4.13	1.12	0
MnO	0	0	0	0	0.23	0.27
Cu2O						
CuO	0	0	2.75	0	0.09	0
CoO	0	0	0	0	0.15	0
SnO2	0	0	0	0	0	0
PbO	0	0	0	0	0	0
NiO	0	0	0	0	0.15	0
ZnO	0	0	0	0	0.33	0
SO3	0.3	0.35	0.43	0.44	0.45	0.34
Cl	1.03	1.12	1.02	1.02	1.27	1.06
Total	99.68	99.87	99.74	99.84	101.3	98.42
100-T=d	0.32	0.13	0.26	0.16	-1.3	1.58
Sum	99.68	99.87	99.74	99.84	101.3	98.42
M	96.07	98.4	93.1	94.16	97.42	96.67
SiO2*a	64.64	64.84	64.23	64.68	63.54	64.34
SiO2*d	0.00	0.00	0.00	0.00	0.00	0.00
Na2O*	18.42	19.92	20.52	18.37	22.17	17.48
CaO*	8.00	6.66	8.08	9.89	6.61	9.63
K2O*	2.31	2.58	1.87	2.44	0.74	2.87
MgO*	5.34	5.15	4.38	3.69	3.22	4.62
Al2O3*	0.86	0.59	0.57	0.63	3.09	0.69
Fe2O3*	0.42	0.26	0.35	0.31	0.63	0.36
T*	100.00	100.00	100.00	100.00	<u>100.00</u>	100.00

Weight %	18 Amenhotep II [WO	19 TO	20 BO	21 YO	22 RO]	23 [WO	24 TO	25 BO	26 YO	27 RO]
SiO2 a	62.3	61.5	62.3	57.1	55.5	62.8	62.1	62.5	57.7	55.3
Na2O	19.1	17.9	19.9	18.8	15.6	18.6	17.9	18.7	18.2	14.1
CaO	7.13	6.98	6.92	6.17	8.66	7.24	7.01	6.48	6.34	8.85
K2O	2.34	2.69	1.63	2.13	2.29	2.22	2.72	1.56	1.64	2.29
MgO	4.99	4.39	4.64	4.9	3.81	4.85	4.53	4.71	5.03	3.26
Al2O3	0.68	0.68	2.42	0.82	1.47	0.49	0.51	2.52	0.76	1.08
Fe2O3	0.3	0.29	0.36	0.46	0.56	0.32	0.33	0.37	0.4	0.6
TiO2	0	0	0	0.06	0.1	0.06	0	0	0	0.1
Sb2O5	1.93	1.77	1.4	0.6	2.08	2.1	2.16	1.5	0.74	2.2
MnO	0	0	0.22	0.09	0	0	0	0.23	0.1	0
Cu2O					9.43					10.7
CuO	0.16	1.77	0	0.09		0.27	1.74	0.1	0.06	
CoO	0	0	0.14	0	0	0	0	0.19	0	0
SnO2	0	0	0	0	0.57	0	0	0	0	0.67
PbO	0	0	0	7.8	0	0	0	0	7.8	0
NiO	0	0	0.09	0	0	0	0	0.19	0	0
ZnO	0	0	0.14	0.08	0.07	0	0	0.15	0.1	0.1
SO3	0.29	0.29	0.37	0	0.46	0.44	0.52	0.54	0	0.51
Cl	0.97	0.89	1.1	0.93	0.83	1.11	1.02	1.13	0.8	0.87
Total	100.19	99.15	101.63	100.03	101.43	100.5	100.54	100.87	99.67	100.63
100-T=d	-0.19	0.85	-1.63	-0.03	-1.43	-0.5	-0.54	-0.87	0.33	-0.63
Sum	100.19	99.15	101.63	100.03	101.43	100.5	100.54	100.87	99.67	100.63
M	96.84	94.43	98.17	90.38	87.89	96.52	95.1	96.84	90.07	85.48
SiO2*a	64.33	65.13	63.46	63.18	63.15	65.06	65.30	64.54	64.06	64.69
SiO2*d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na2O*	19.72	18.96	20.27	20.80	17.75	19.27	18.82	19.31	20.21	16.50
CaO*	7.36	7.39	7.05	6.83	9.85	7.50	7.37	6.69	7.04	10.35
K2O*	2.42	2.85	1.66	2.36	2.61	2.30	2.86	1.61	1.82	2.68
MgO*	5.15	4.65	4.73	5.42	4.33	5.02	4.76	4.86	5.58	3.81
Al2O3*	0.70	0.72	2.47	0.91	1.67	0.51	0.54	2.60	0.84	1.26
Fe2O3*	0.31	0.31	0.37	0.51	0.64	0.33	0.35	0.38	0.44	0.70
T*	[100.00	100.00	<u>100.00</u>	100.00	100.00]	[100.00	100.00	<u>100.00</u>	100.00	100.00]

Weight %	28 Amenhotep II [TO	29 BO	30 YO]	31 PT	32 Tuthmosis IV [TO	33 WO	34 BO	35 YO]
SiO2 a	62.6	62.1	60.4	68	62	58.9	58.6	58
Na2O	18.4	20.6	19	17.6	18.3	19.7	23.4	17.6
CaO	6.69	6.33	6.07	6.99	6.37	8.32	3.37	6.58
K2O	2.3	1.46	2.09	0.79	2.72	2.46	1.42	1.75
MgO	4.61	4.74	4.65	3.09	5.14	4.09	4.62	3.9
Al2O3	0.55	1.91	0.61	0.75	1.24	0.99	3.72	0.78
Fe2O3	0.31	0.36	0.33	0.44	0.49	0.33	0.42	0.39
TiO2	0.07	0.05	0	0.07	0	0	0.06	0.05
Sb2O5	1.89	1.58	0.6	0	1.03	2.62	1.41	1.32
MnO	0	0.19	0.13	0.65	0	0	0.38	0
Cu2O								
CuO	1.68	0.08	0	0	1.77	0.34	0.07	0.07
CoO	0	0.17	0	0	0	0	0.13	0
SnO2	0	0	0	0	0	0	0	0
PbO	0	0	5	0	0	0	0	8.6
NiO	0	0.15	0	0	0	0	0.07	0
ZnO	0	0.14	0.07	0	0.1	0.06	0.08	0.09
SO3	0.49	0.43	0	0.24	0.33	0.62	1.12	0
Cl	1.05	1.07	0.9	1.39	1.12	1.18	1.2	0.9
Total	100.64	101.36	99.85	100.01	100.61	99.61	100.07	100.03
100-T=d	-0.64	-1.36	0.15	-0.01	-0.61	0.39	-0.07	-0.03
Sum	100.64	101.36	99.85	100.01	100.61	99.61	100.07	100.03
M	95.46	97.5	93.15	97.66	96.26	94.79	95.55	89
SiO2*a	65.58	63.69	64.84	69.63	64.41	62.14	61.33	65.17
SiO2*d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na2O*	19.28	21.13	20.40	18.02	19.01	20.78	24.49	19.78
CaO*	7.01	6.49	6.52	7.16	6.62	8.78	3.53	7.39
K2O*	2.41	1.50	2.24	0.81	2.83	2.60	1.49	1.97
MgO*	4.83	4.86	4.99	3.16	5.34	4.31	4.84	4.38
Al2O3*	0.58	1.96	0.65	0.77	1.29	1.04	3.89	0.88
Fe2O3*	0.32	0.37	0.35	0.45	0.51	0.35	0.44	0.44
T*	[100.00	<u>100.00</u>	100.00	100.00]	[100.00	100.00	<u>100.00</u>	100.00]

Comments on Chemical Data

Wypyski's EDS analyses of pre-Malkata glasses were compared with Brill's unpublished atomic absorption analyses of Malkata,⁸¹ Amarna,⁸² and Nuzi⁸³ glasses for The Corning Museum of Glass.⁸⁴ The combined results are represented in Table 3 and Figs. 50–57 as follows:⁸⁵

Table 3: Mean values of normalized (= *) major components for pre-Malkata, Malkata, Amarna, and Nuzi glasses;⁸⁶

Figure 50: Na_2O^* and CaO^* contents for 34 pre-Malkata glasses analyzed quantitatively for this study (Table 2, excluding no. 4) as well as for 42 unpublished Malkata, Amarna, and Nuzi glasses analyzed by Brill;

Figure 51: K_2O^* and MgO^* contents in a graph prepared by Brill. The approximate ranges of these oxides in several hundred ancient soda-lime glasses of various sources and dates is indicated in shaded areas to show the differences between natron and plant-ash based glasses. Superimposed unshaded areas show K_2O^* and MgO^* limits for the 64 Egyptian glasses of Table 3 and Figure 50; two groups are defined, cobalt-colored and noncobalt-colored (= "all others");

Figure 52: K_2O^* vs MgO^* contents for all glasses of Figure 50;

Figure 53: K_2O^* vs MgO^* contents for cobalt-containing glasses of Figure 50. All Egyptian glasses contain less than 2.0% K_2O^* (the Nuzi glasses analyzed do not contain cobalt).

Figure 54: K_2O^* vs MgO^* contents for all glasses of Figure 50 in which cobalt was not found;

Figure 55: Al_2O_3^* vs SiO_2^* contents for all glasses of Figure 50;

Figure 56: Al_2O_3^* vs SiO_2^* contents for cobalt-containing glasses of Figure 50. All Egyptian glasses contain greater than 1.2% Al_2O_3^* (Nuzi glasses here do not contain cobalt);

Figure 57: Al_2O_3^* vs SiO_2^* contents for glasses of Figure 50 which do not contain cobalt.

81. CMG 3900–3905, 3908/10/11/13.

82. CMG 1515/21; 3350–63, 3365–67.

83. CMG 1209–1210/13–21.

84. With atomic absorption, SiO_2 is estimated by difference from 100%, while in EDS it is determined directly.

85. A probable natron glass from Nuzi is included in these plots.

86. Normalization of the major components is a way to compare the basic compositions of different glasses. The major and minor oxides are added together and then divided through to normalize the sum of the selected oxides to 100% (here SiO_2 , Na_2O , CaO , K_2O , MgO , Al_2O_3 , and Fe_2O_3). See R. H. Brill, "Chemical analyses of some early Indian glasses," *Archaeometry of glass; Proceedings of the archaeometry session of the XIV International Congress on Glass, New Delhi, 1986* (1987), pp. 1–25.

Table 3

Mean Values of normalized Major Components ¹								
	Pre-Malkata Glasses ²				Malkata Glasses ³			
	Cobalt glasses (8) ⁴		All others (26)		Cobalt glasses (4)		All others (6) ⁵	
	Mean	1σ	Mean	1σ	Mean	1σ	Mean	1σ
SiO ₂ *	63.67	1.27	65.04	1.72	63.28	1.14	64.28	3.75
Na ₂ O*	20.31	2.08	18.91	1.35	20.71	1.30	17.43	1.30
CaO*	6.88	1.49	7.44	1.67	7.69	0.59	10.41	1.55
K ₂ O*	1.25	0.36	2.63	0.69	1.57	0.39	2.20	0.58
MgO*	4.42	0.52	4.70	0.81	3.98	0.62	3.97	0.58
Al ₂ O ₃ *	3.05	0.74	0.88	0.32	1.86	0.25	0.85	0.10
Fe ₂ O ₃ *	0.50	0.14	0.41	0.10	0.92	0.09	0.84	0.18

	Amarna Glasses ³				Nuzi Glasses ³	
	Cobalt glasses (9)		All others (11)		All glasses (10) ⁶	
	Mean	1σ	Mean	1σ	Mean	1σ
SiO ₂ *	64.81	2.58	64.87	2.71	68.38	3.03
Na ₂ O*	18.58	1.20	19.02	1.59	15.53	1.96
CaO*	8.53	0.98	8.40	1.52	7.66	1.47
K ₂ O*	1.10	0.29	2.14	0.63	2.76	0.55
MgO*	4.08	0.42	3.84	0.55	4.46	0.69
Al ₂ O ₃ *	2.09	0.56	0.85	0.24	0.72	0.32
Fe ₂ O ₃ *	0.81	0.23	0.90	0.33	0.48	0.30

1. Calculations by MTW.
2. Glasses quantitatively analyzed by MTW (Table 2) and discussed in text.
3. Glasses analyzed by RHB (unpublished). SiO₂ values estimated by difference from 100%.
4. Excluding MMA no. 4, black translucent glass.
5. Excluding CMG 3910, probably weathered sample.
6. Excluding CMG 1218, appears to be natron glass.

Although similarities and differences between individual pre-Malkata glasses and glasses in the other groups were not pursued, some overall comparisons were made as follows.

The Egyptian glasses of the three groups are similar. All have high magnesium, while the potassium values vary considerably.

The Egyptian glasses are generally similar to the Nuzi glasses, the major difference being the lower soda levels in the Nuzi glasses and their higher silica contents.

The mean values of CaO, K₂O, MgO, and Fe₂O₃ in Nuzi glasses (none of which contained cobalt) are closest to those in pre-Malkata noncobalt glasses; the major difference is the low soda values of the Nuzi glasses (range 12–18.1% Nuzi vs 14.1–23.4% pre-Malkata). The difference in silica levels may be due in part to the different analytical methods used.

The pre-Malkata calcium values vary widely, covering a range of 3.22–9.31%. These glasses represent a period of time more than twice as long as that for the Malkata and Amarna glasses together, however, and—as pointed out—the number of pre-Malkata factories, and their locations, are not known.

The potassium level in the cobalt glasses from Egypt is noticeably lower than in the noncobalt glasses of Egypt and Nuzi; the magnesium levels are about the same.

The similarities of the Egyptian and Nuzi glasses listed in Table 3 could suggest that the Egyptian glasses, like those from Nuzi, were made with high-soda plant ash and siliceous pebbles in a

two-batch system as documented by Brill for Mesopotamian glass.⁸⁷ The high magnesium levels found argue for plant ash. However, the relatively low K_2O^* values for some of the Egyptian glasses might argue against this. There is as yet no experimental data to explain the wider variation in potassium levels, and there are no Egyptian texts comparable to those Brill used in his experiments for Mesopotamian glass or for Roman glass (with Belus river sand and natron)⁸⁸ to help elucidate the matter. Various proposals have been made to account for components in Egyptian glass;⁸⁹ and a mention of the possibility of plants with lower levels of magnesium and potassium than heretofore encountered⁹⁰ is something to keep in mind; but there are as yet no experimental data for 2nd-millennium Egyptian glasses.

Variability in the Egyptian cobalt glasses of the three different periods (cf. below as well as the findings of Segnit and McGovern et al.⁹¹) suggests that further study should be made of cobalt provenance. However, in reference to the work of Sayre, Kaczmarczyk, and Brill⁹² concerning the character of cobalt glasses, the following may be observed.

The cobalt ranges in pre-Malkata glasses are 0.07–0.28%; copper is not present in two samples.

Aluminum is elevated in all the cobalt glasses (see Figs. 55–57) but particularly in the pre-Malkata group, where the mean (3.05%) is nevertheless only half the percentage in a cobalt glass from Timna (6.17%).

Zinc exists in pre-Malkata cobalt glasses (range of 0.08–0.33%)⁹³ but also occasionally in light blues, yellows, reds, and white at the low end of this range.

One pre-Malkata purple with 0.65% manganese has low potassium, like the cobalts, but the aluminum is not elevated, and no nickel or zinc was detected.

The reason for the low potassium values in the cobalt glasses as opposed to other glasses is not known at this time. They could result from a different basic recipe, or—assuming the cobalt glasses to have been the product of a two-batch plant-ash recipe—the low potassium values could have resulted from the use of a plant with a different ratio of potassium to magnesium.⁹⁴ The

87. Brill, "The chemical interpretation of the texts," in Oppenheim et al. 1970, p. 122.

88. "9. Scientific investigations of the Jalame glass and related finds," in G. Weinberg, ed., *Excavations at Jalame; Site of a glass factory in late Roman Palestine* (Columbia, Mo., 1988), pp. 270f.

89. W. F. Petrie, *Tell el Amarna* (London, 1894), pp. 25–27; F. Matson, "The composition and working properties of ancient glasses," *Journal of Chemical Education* (Feb. 1951), pp. 84f.; E. V. Sayre and R. Smith, "Analytical studies of ancient Egyptian glass" in Bishay 1974, pp. 58f.; W. E. S. Turner, "Studies of ancient glasses and glass-making processes; Parts I, IV, V," *Journal of the Society of Glass Technology* 38 (1954), pp. 436–44; 40 (1956), pp. 162–86, 277–300.

90. Brill, "The chemical interpretation of the texts," p. 111.

91. Segnit, "Evaporite Minerals"; P. E. McGovern, S. J. Fleming, C. P. Swann, "The Late Bronze Egyptian garrison at Beth Shan: Glass and faience production in the late New Kingdom," *Bulletin of the American Schools of Oriental Research* 290–291 (1993); *The Late Bronze and Early Iron Ages of central Transjordan; The Baq'ah Valley project, 1977–1981* (Philadelphia, 1986), pp. 236–41.

92. Sayre 1964, p. 11; Sayre/Smith, "Analytical studies," p. 51; Kaczmarczyk 1986; Brill/Barnes 1988, p. 218.

93. The calculated detection limit for zinc-oxide at the MMA, with EDS, was determined to be approximately .06%; Verità et al., 1993.

94. Brill prefers to reserve final judgment on the matter of raw materials used for glassmaking in Egypt. He sees difficulties in each of the theories proposed and considers the matter somewhat more complicated than as usually presented. On the question of the low K_2O contents of the Egyptian cobalt-containing glasses, he points out that this could be consistent with the view that the glasses were plant-ash glasses colored by a cobalt-containing alum—the latter being a proposal of Kaczmarczyk. In order to obtain enough cobalt to give the glass a blue color, a considerable proportion of alum would have had to have been added; consequently the glassmakers might have used less plant-ash soda, thereby reducing the potassium level. A higher level of aluminum in the cobalt-containing glasses could also be explained in this way. But this particular argument is

differences in composition between cobalt and noncobalt glasses in any event implies that these glasses were produced separately, either in the same workshop or at different sites.

Conclusion

This study provides new archaeological and compositional data for early glass in Egypt and shows that the glasses from the tomb of the foreign wives of Tuthmosis III are comparable to glasses otherwise datable to his reign.

In a larger sense, the study shows that a consideration of small objects, as well as vessels, results in a pre-Amenhotep II corpus of glass colors and forms richer than generally recognized. Specific points have been made: glass can be dated ca. 1550 in the tomb of Ahhotep, and the sherd associated with a burial of Tuthmosis I appears more tentative than the glass vessels from the tombs of Tuthmosis III and his foreign wives. Various colors and compositional analyses have been documented in the pre-Malkata period, including black, amber, cobalt, and red.

For the question of whether Egyptian glass developed independently or in response to technology from Western Asia, it will be necessary for additional nonglass vitreous materials of Dynasties 13–17 to be identified and analyzed, as a supplement to the small corpus published in Part 1. However, the involvement of the Near Eastern industry with Egypt's cannot be minimized, as evidence for both imports and craftsmen accumulates. More glass is documented in the Near East than in Egypt in the 16th century,⁹⁵ and the earliest dated examples in Egypt—in the tomb of Ahhotep, ca. 1525 B.C.—are inlays in Palestinian- and Egyptian-style jewels. While the Palestinian jewels could have been imported, the copper- and cobalt-colored glasses from the Wady Qirud (ca. 1425 B.C.)—which occur in jewels of both Egyptian and Near Eastern style and workmanship—indicate that Asiatic craftsmen were present in Egypt. The same is suggested by the large button-based vessels from the tomb of Amenhotep II: a preliminary statistical evaluation of significant elements did not allow these glasses to be separated from other pre-Malkata glasses, and two of the yellow glasses are shown below to belong with other Egyptian glasses, although slightly separate from those of Malkata and Amarna (Part 3). Thus these unusual vessels must have been made in Egypt although their shapes and sizes indicate Asiatic craftsmen. There is also some slight indication of relationship between glass recipes of the two geographic areas: the statistical pattern of the 34 pre-Malkata glasses in Table 3 bears some relation to the Nuzi glasses, despite the much longer period of pre-Malkata—as compared to Malkata/Amarna—glass, and despite the many provenances that must be represented from the pre-Malkata period.

There has been previous discussion of the importation of raw glass into Egypt. Redford believes glass to be the material brought from an unknown land after Tuthmosis III's seventh campaign ("numerous stones-of-casting").⁹⁶ Certainly manufactured goods arrived: to the flask belonging to Amenhotep II's official Maiherpri—of Mesopotamian style—we have added a sure import, a glassy faience goblet (Part 1, nos. 9–13; Part 3, Pb-2168). It also seems that a lead ore or a yellow glass was imported: while the leads in the Amenhotep II, Tuthmosis IV, and Malkata yellow glasses studied in Part 3 are shown to belong with leads found in Amarna-Fayum area objects (and in kohls from Egypt of earlier periods), the earliest lead ores studied—no. 3, from a Tuthmosis III vessel of Egyptian style and coloration (Pb-2184, -2185), and from a tin bead (Pb-2169)—belong with Mesopotamian rather than Egyptian leads. The vessel is not the only object of Egyptian style found in Egypt with a Near Eastern lead; and the complexities of interchange are indicated further by a brick of Egyptian style found at Mycenae which used a Laurion-type lead.

While the question of technological invention is still in abeyance, there is rich new evidence through material culture of Egypt's contacts with her neighbors.

weakened by the fact that the magnesium levels of the blue glasses are about the same as those of the other colored glasses and there are similar if not higher levels of sodium. The matter could be further complicated by contamination introduced by refractory corrosion.

95. Lilyquist 1993.

96. D. Redford, *Egypt and Canaan in the New Kingdom*, ed. by Shmuel Ahituv (Beer Sheva, 1990), p. 46.

Part 2, Appendix 1

Compositionally Analyzed Glasses

Associated with Dynasty 18¹

Compositional analyses of New Kingdom glasses have been concerned with raw materials, opacifiers, and colorants (particularly cobalt and lead); provenance has been studied through oxygen isotopes. But while it might seem that such studies provide firm ground for discussions of the character and origin of Egyptian glass, even the Brookhaven project² does not seem to have been based on many specimens. Furthermore, most researchers have unwittingly used broadly dated specimens or samples connected to the ca. 60-year period in the second half of the 18th dynasty (the time of the palaces at Malkata³ and Amarna);⁴ the ca. 150-year period before Malkata has received almost no attention.

The best provenanced and most numerous compositional analyses of Egyptian glasses up to now come from Amarna. K. Kühne's nine samples came from the excavations of the Deutsche Orient-Gesellschaft;⁵ all remaining (including Neumann's twelve)⁶ came from Petrie excavations. Among these, the nineteen glasses given Brill⁷ by B. Adams of the Petrie Museum at University

1. The librarians of the Thomas J. Watson, Charles Edwin Wilbour, and Rakow libraries have provided much help in obtaining references.

2. Although more than 400 samples were eventually analyzed (Sayre 1967, p. 280), the published reports specify only fifteen 2nd-millennium B.C. glasses (Sayre with R. Smith, "Compositional categories of ancient glass," *Science* 133 [1961], pp. 1-3) and three of these must be Mycenaean (ibid., p. 10). The 2nd-millennium Egyptian samples provided by the MMA were colorless, two from Malkata (TR 781, 782), and three from Lisht (TR 788, 789 [two samples]). The Brooklyn Museum's Egyptian samples were two cobalt blues (TR 554, 556), a turquoise (TR 760, no doubt our Part 2, no. 2), and a fourth sample (TR 555). In two articles, however, TR 555 is also said to be the number of a yellow and white, and TR 554 of another yellow. These probably make up the fifteen (twelve additional samples from Lisht donated by the MMA no doubt included 2nd-millennium glass, but were part of a later group). The nine are probably those in Sayre, "Compositional categories," p. 1 and table 1.

3. For the mention of glass manufacturing by the Tytus/Newberry and MMA missions see C. A. Keller, "Problems in dating glass industries of the Egyptian New Kingdom; Examples from Malkata and Lisht," *JGS* 25 (1983), pp. 20f. G. Daressy mentions finding "fragments de fioles en verre émaillé" in 1888 but no manufacturing evidence: Daressy, "Le Palais d'Amenophis III et le Birket Habou," *ASAE* 4 (1903), p. 168. R. de P. Tytus, *A preliminary report on the re-excavation of the palace of Amenhetep III*. (New York, 1902), mentions houses and a factory of faience workers south of the palace (pp. 8, 25), and states "with the exception of one glass bead about 5 centimeters long, of a strange twisted design, nothing dissimilar to the Tel el Amarna finds was discovered."

4. It is assumed that occupation at both sites centered in the reigns of Amenhotep III and Akhenaten respectively, although Roman material has been found at Malkata, and Dynasty 19 occupation occurred in some sections of Amarna: M. Bell, "A Hittite pendant from Amarna," *American Journal of Archaeology* 90 (1986), p. 150 vs Kemp/Merrillees 1981, n. 485.

5. Kühne, *Zur Kenntnis silikatischer Werkstoffe und der Technologie ihrer Herstellung im 2. Jahrtausend vor unserer Zeitrechnung* (Berlin, 1969), p. 30.

6. B. Neumann, "Antike Gläser, ihre Zusammensetzung und Färbung," *Z. angew. Chem.* 38 (1925), pp. 858-59. C.-B. Arnst has kindly confirmed that the Berlin Museum did receive glass from Petrie's excavations at Amarna as well as from the Deutsche Orient-Gesellschaft, but states that the museum has no records of which glasses Neumann analyzed.

7. CMG 1515, 3350-67: "A red opaque glass from Sardis and some thoughts on red opaques in general," *JGS* 30 (1988), p. 20, no. 3355. For isotope studies see R. H. Brill et al., "Lead isotopes in some ancient Egyptian objects," *Recent advances in science and technology of materials*, 3 (New York, 1973), pp. 9-27; sample 455 is from the yellow thread on the glass fish Brooklyn 37.316 (which should date, because of parallels excavated at Malkata [now in the MMA] and at Amarna [now in the British Museum; Cooney 1976, no. 1753], to the

College London, and the three glasses I. M. Freestone analyzed in the British Museum⁸ are probably the best provenanced. W. E. S. Turner's samples for glassmaking studies came from University College,⁹ as did P. Vandiver's seven via C. Stanley Smith;¹⁰ Farnsworth/Ritchie's many samples (from H. Beck and S. Glanville) may also have come from University College.¹¹ Nonspecific samples were supplied to Turner by T. Haevernick,¹² and to M. R. Cowell and E. K. Werner by the British Museum;¹³ the source of Brill's earlier samples was probably the fragment collection at The Corning Museum of Glass.¹⁴

For Malkata glass, the most surely dated are Brill's unpublished eleven analyses¹⁵ and Sayre's two samples¹⁶ from the MMA excavations. Sayre also had samples from The Brooklyn Museum (believed to go back to Tytus's work);¹⁷ the analyses of these were completely published.¹⁸ Turner and Rooksby's specific values were extracted from a sample in the Victoria and Albert said to have been found at Malkata.¹⁹ The source of samples acquired by Farnsworth/Ritchie through Glanville and Beck is unclear: Glanville was associated with University College, but B. Adams states that there is no Malkata glass there.

general period). See also Brill, "Lead and oxygen isotopes in ancient objects," *Philosophical Transactions of the Royal Society London* 269 (1970), pp. 152, 161, also p. 163, no. O-37; and "New directions in lead isotope research," *Application of science in examination of works of art* (Boston, 1970), p. 74, fig. 1; cf. pp. 79, 81f.

8. Freestone 1987, p. 176.

9. In addition to the crucible studies from University College, Turner also sought specific values in a sample from F. L. Griffith's excavations, one collected by G. J. Chester (presumably at Amarna), and two from trays labeled "Tell el Amarna" in University College: Turner, "Ancient sealing-wax red glasses," *JEA* 43 (1957), p. 111; W. E. S. Turner and N. P. Rooksby, "A study of opalising agents in ancient opal glasses throughout three thousand four hundred years, Part 1," *Glastechnische Berichte*, special volume 32K, no. 8 (1959), pp. 17-28, nos. 15-16, 18-20.

10. Vandiver/Swann/Cranmer 1991; Vandiver, communication 1992.

11. M. Farnsworth and P. Ritchie, "Spectrographic studies on ancient glass," *Technical Studies* 6 (1937), pp. 155-68.

12. W. E. S. Turner, "Further historical studies based on X-ray diffraction methods of the reagents employed in making opal and opaque glasses," *Jahrbuch des römisch-germanischen Zentralmuseums Mainz* (VIIIth annual, 1961), p. 3.

13. Cowell and Werner, "Analysis of some Egyptian glass," *Annales du 6e Congrès de l'Association internationale pour l'Histoire du Verre, Cologne 1973* (Liège, 1974), pp. 295-98. The authors state that the glass was 18th dynasty, which had been collected by H. Carter, and do not give its location. M. Bimson indicates that it was thought to come from Amarna: cf. Werner, "Glass in the Tutankhamun treasure," *idem*, p. 294; Bimson and Werner, "Problems in Egyptian core glasses," p. 121, in *Studies in glass history and design*.

14. R. H. Brill and S. Moll, "The electron-beam probe microanalysis of ancient glass," *Recent advances in conservation, Rome 1961* (London, 1963), pp. 147f., table 4; p. 149, table 5. See also n. 29 below.

15. CMG 3900-05/07-8/10-11/13; see Figs. 46, 48-53 here; noted in Keller, "Problems in dating," p. 23.

16. Lump of colorless glass suggested to be factory refuse (no. 781; MMA 12.180.338) and the colorless backing on a twisted handle (no. 782); Sayre 1963, p. 270, table 3, nos. 781-82.

17. In 1948 The Brooklyn Museum acquired certain material from Dumbarton Oaks, which had received it from Mrs. Mildred Bliss, and she in turn from her friend Mrs. Lawrence Coolidge, a relative of Tytus. A letter by J. Cooney indicates that he believed this material to be from Tytus's excavations at Malkata; it is presumably from this group that Cooney selected samples to give R. W. Smith for analysis, although pharaonic glass is not mentioned in the records from Dumbarton Oaks. In general, the faience and glass fragments today in Brooklyn are consistent with Malkata Palace material in the MMA, but note the bead mentioned by Tytus in n. 3 above. Items in the Tytus collection now in Brooklyn that do not date to the time of Amenthotep III are a multicolored glass cylinder-bead of Roman date and several late-Islamic glass vessels. P. O'Rourke and S. Zwirn kindly helped research this.

18. Sayre 1964, pp. 9, 10, nos. 554/56; some elements in Sayre 1963, pp. 267f.; also reported with different numbers in Sayre 1967, p. 298, table 3. Sample 555 was, like 554/56, presumably from The Brooklyn Museum; specific elements appeared in Sayre 1963 and 1967, but also with different numbers.

19. Acc. no. C.8-1946: Turner/Rooksby, "A study of opalising agents," pp. 19, nos. 1a-c; 20, fig. 2; 21f.

Of the pre-Malkata period, only the colorless bead in the British Museum has a complete compositional analysis published.²⁰ Specific values were published for a plaque in Boston²¹ and for no. 2 of Part 2.²²

For New Kingdom glasses generally, one can assume that those analyzed by Benrath and Parodi were broadly dated;²³ so also Neumann's glasses from Thebes (supplied by M. Todros),²⁴ and from Gurob (location unspecified);²⁵ H. Jackson's scarlet red (from Beck); the samples of W. Geilmann (the Cairo Museum); Rooksby (Turner and possibly the Victoria and Albert);²⁶ Lambert/McLaughlin (British Museum);²⁷ and Stone/Thomas ("Tell el Amarna?" and EEF excavations, but provenance vague and date broad).²⁸ The source of Brill's earlier Amarna references was probably University College.²⁹

20. M. Bimson and I. M. Freestone, "Some Egyptian glasses dated by royal inscriptions," *JGS* 30 (1988), p. 15.

21. A. Gordon, "A glass bead of Ahmose and Amenhotep I," *Journal of Near Eastern Studies* 41 (1982), pp. 295-98.

22. Sayre 1963, p. 268, table 2, no. 760; Sayre 1967, pp. 298, 308, table 6, specimen 760.

23. Lucas/Harris 1962, pp. 476, 478.

24. Neumann, "Antike Gläser II.," *Z. angew. Chem.* 40 (1927), p. 963.

25. "Antike Gläser. IV," *Z. angew. Chem.* 42 (1929), p. 835. W. F. Petrie referred to looting at the site when he began the British excavations there in 1888 (Petrie, *Kahun, Gurob, and Hawara* [London, 1890], pp. 5, 12). After finding a "blue glass vase with yellow lines, usually called Phoenician," in a grave with late Dynasty 18 and 19 objects at Kahun, the town north of the canal, he found in the town of Gurob "many pieces of the so-called Phoenician glass common in the XIXth dynasty . . . generally with the basis blue, but also brown, green, and black, and the threads and streaks on it . . . generally white and yellow, but also blue and black" (ibid., pp. 32, 38). The next year Petrie had W. O. Hughes-Hughes excavate back at Kahun, and the latter found three vessels in a burned deposit that Petrie assigned to the time of Tutankhamun (Petrie 1891, pp. 7, 17; Cooney 1976, nos. 1744/47/66); and two vessels in another burned deposit dated stylistically to the same period (Petrie 1891, p. 19; Nolte 1968, p. 73, nos. 1, 2). Following Petrie, Daninos Pasha found a vessel at Gurob from the time of Amenophis III ("A tomb at Hawaret el Gurob," *ASAE* 2 [1901], p. 141; Nolte 1968, p. 68, no. 1); and Loat found palm tubes (Loat 1905, p. 7, no. 21; Nolte 1968, p. 148, no. 45; cf. also her p. 143 n. 16 and his p. 7, no. 25, Nolte's p. 145, no. 25). R. Engelbach and G. Brunton, at Gurob in 1920, illustrated a combed blue and white amphoriskos apparently from Petrie's work of 1920 (Engelbach and Brunton, *Gurob*, pl. 53; Nolte 1968, p. 119, no. 39), and mentioned remains of a glass factory in the town (their p. 3, §7) but without specific date for it (P. Simpson, Edinburgh, is preparing a study of this glass). Cooney published fragments and vessels from Petrie in the British Museum (Cooney 1976, nos. 435-60, and 1770); and Nolte cites two interesting shapes (Nolte 1968, p. 138, no. 11; p. 139 n. 8). Ramesside contexts in the above excavations also yielded glass vessels.

26. Rooksby, "Opacifiers in opal glasses through the ages" *G[eneral] E[lectric] C[ompany] Journal* 29 (1962), pp. 20-26.

27. J. Lambert and C. McLaughlin, "Analysis of early Egyptian glass by atomic absorption and X-Ray photoelectron spectroscopy," in *Archaeological Chemistry II* (Washington, D. C., 1978), pp. 192f.

28. J. F. S. Stone "The use and distribution of faience in the ancient east and prehistoric Europe," and L. C. Thomas, "With notes on the spectrochemical analysis of faience," in *Proceedings of the Prehistoric Society* 22 (1956), pp. 63/5/7, nos. 37, 63, pl. 6-9 and -10.

29. "The scientific investigation of ancient glasses," in *Eighth International Congress on Glass, 1968* [lectures] (Sheffield, England, 1969), p. 64, fig. 14-1. The British Museum, University College, and the fragment collection at The Corning Museum of Glass were all sources for Brill's early samples.

Part 2, Appendix 2

Analytical Procedures

Thirty-nine samples (Table 2, nos. 1–35) were analyzed using a Kevex model Delta IV energy dispersive X-ray spectrometer attached to a modified AmRay model 1100 (1600T) scanning electron microscope. Very small samples of the glasses, on the order of one cubic millimeter in size, were removed from the objects and embedded in epoxy. The embedded samples were ground with silicon carbide paper to expose the glass samples, polished with alumina polish, and carbon coated. The samples were analyzed at 15KV to determine the major elements (Na, Mg, Al, Si, K, and Ca), and at 30 KV to determine the minor elements (P, S, Cl, Ti, Fe, etc.). The various weight percentage oxide values were calculated from the net X-ray count-per-second data for each oxide by comparison with well-characterized reference glasses. With this procedure the variation for the major element oxides has been determined to be less than 2 percent for silica; about 5 percent for sodium, potassium, and calcium; and about 10 percent for magnesium and aluminum. The minimum detection limits for the elements titanium through zinc were found to be under 0.1 percent. The minimum detection limits of phosphorus, lead, barium, arsenic, antimony, and tin oxides were found to be much higher, about 0.5 percent by weight, mainly due to peak overlap problems. For details of this procedure, see Verità et al. 1993. Phosphorus (P_2O_5) was sought but not detected in any of these glasses; similar glasses analyzed by different methods have been found to contain about 0.1–0.3 % P_2O_5 .

Deteriorated glass samples (Table 1, nos. B and F), and objects which could not be sampled (nos. A, C–E) were also analyzed by comparison to reference standards. The two deteriorated glass samples were prepared and examined in cross-section, as were the normal glass samples 1–35. The other four small glass objects were polished on a small area in an attempt to get below the weathered surface and were analyzed on the polished areas. Ranges are given for their results to account for the variations seen due to surface charging effects, uncertainty in the specific angle of the surface to the X-ray detector, and possible problems with weathering of the material.



Fig.20 Toggle pin with glass inlay; eastern Delta; MMA; no. A

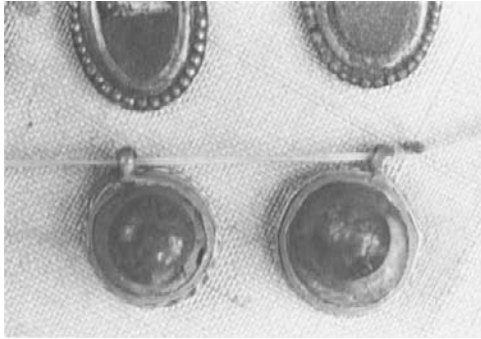


Fig.21 Pendants with glass eye-inlays; tomb of Ahhotep; Cairo Museum

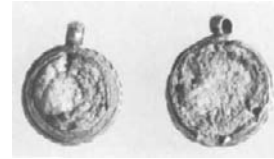


Fig.22 Subject as Figure 21; MMA; no. B



Fig.23 Ahmose pectoral with glass inlay; tomb of Ahhotep; Cairo Museum



Fig.24 Glass plaque naming Ahmose. MMA; no. C



Fig.25 Tire-shaped glass beads; Qau 902; Ashmolean Museum

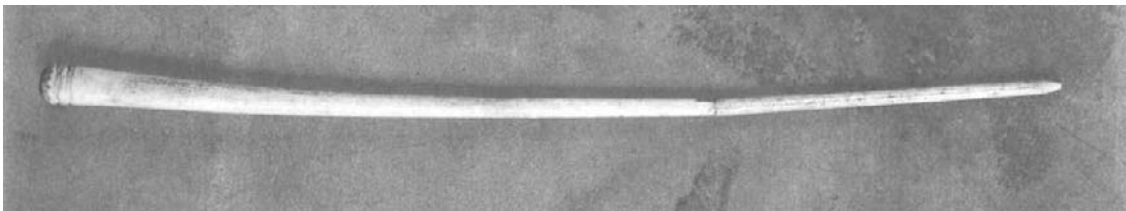


Fig.26 Hairpin; Thebes, MMA 5A pit 3 burial B 4; Cairo Museum



Fig.27 Bead naming
Senenmut; MMA; no. 1



Fig.28 Fish amulets; Thebes, Carter/Carnarvon
37, pit D, no. 53; MMA; nos. D and E



Fig.29 Vessel sherd; Thebes, near KV 38 (pre-
sumed tomb of Tuthmosis I); Cairo Museum



Fig.30 Kohl-jar lid; KV 34 (tomb of Tuthmosis III); Cairo Museum

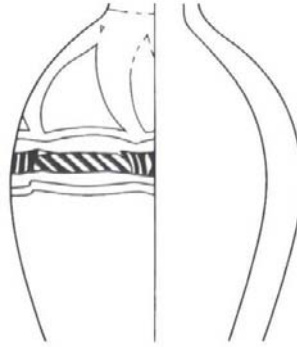


Fig.31 Vessel sherd matching one from KV 34, with 1:1 drawing; The Brooklyn Museum; nos. 2-4



Fig.32 Persea fruit inscribed for Tuthmosis III; KV 62 (tomb of Tutankhamun); Cairo Museum



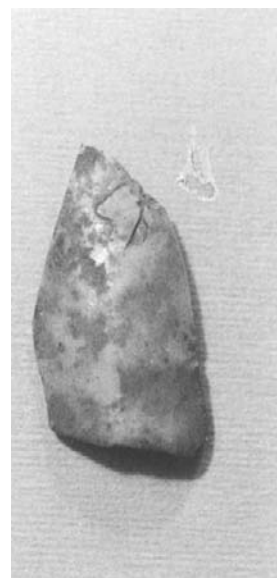
Fig.33 Plaque inscribed Tuthmosis III; MMA; no. 5



Fig.34 Lotiform cup inscribed Tuthmosis III; Wady Qirud; MMA; no. 11



Fig.35 Vessel sherds labeled "from the tomb of Tuthmosis III"; Cairo Museum



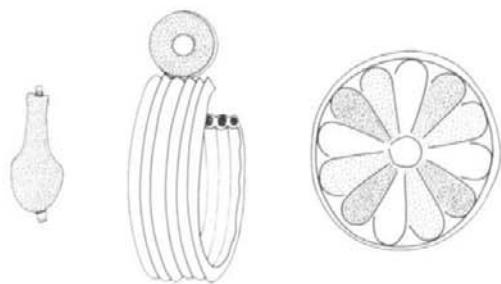
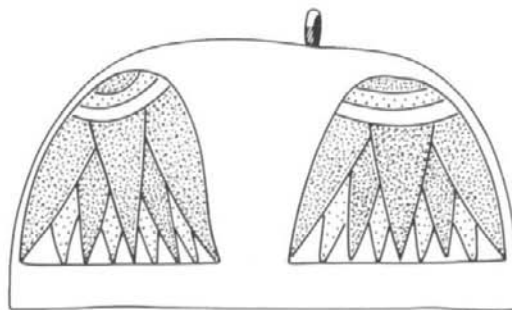
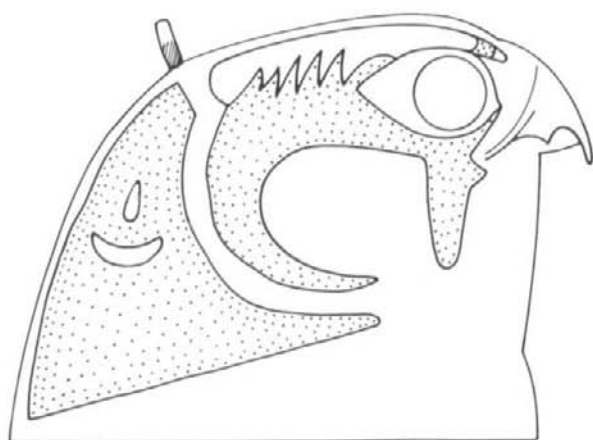


Fig.36 Glass-inlaid jewels; MMA

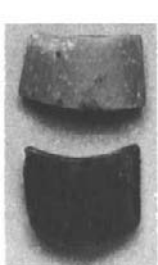
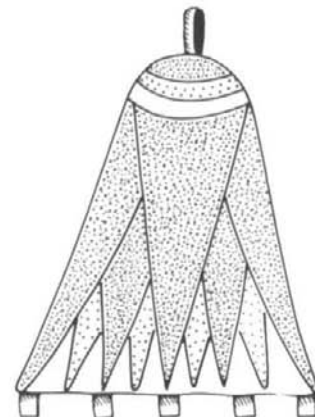
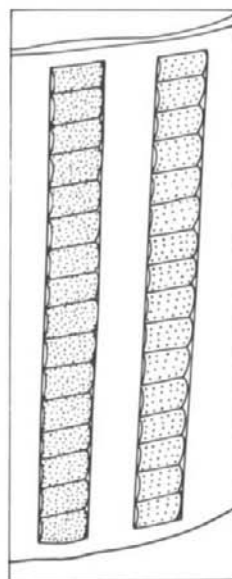
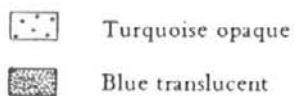


Fig.37 Trapezoidal inlay no. 8 (top); semi circular inlay no. 10 (bottom); MMA



Fig.38 Fragments of turquoise and amber glass; MMA; nos. 6 (right) and 7 (left)

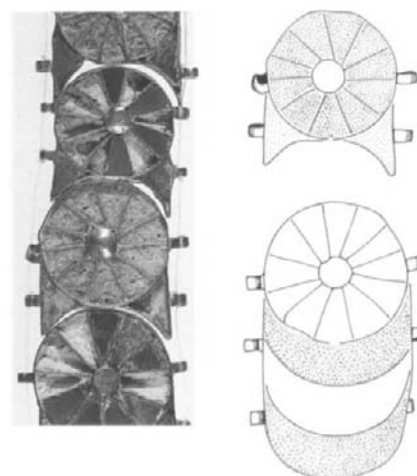
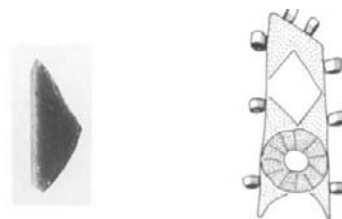


Fig.40 Glass-inlaid jewels; triangular inlay no. 8 (top), rosette inlay no. F (center); MMA

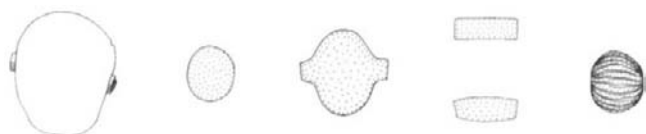
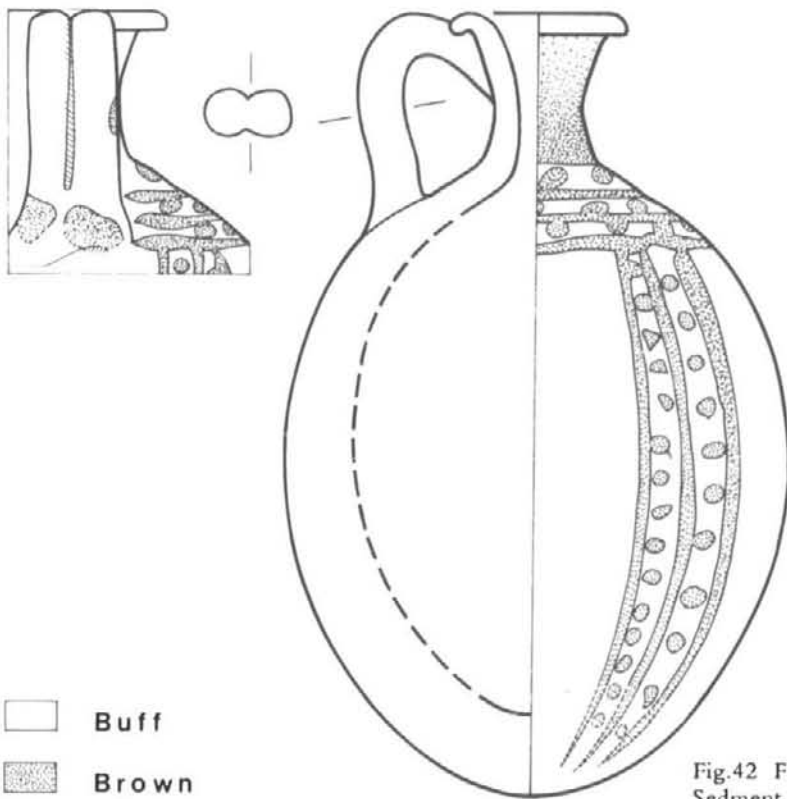
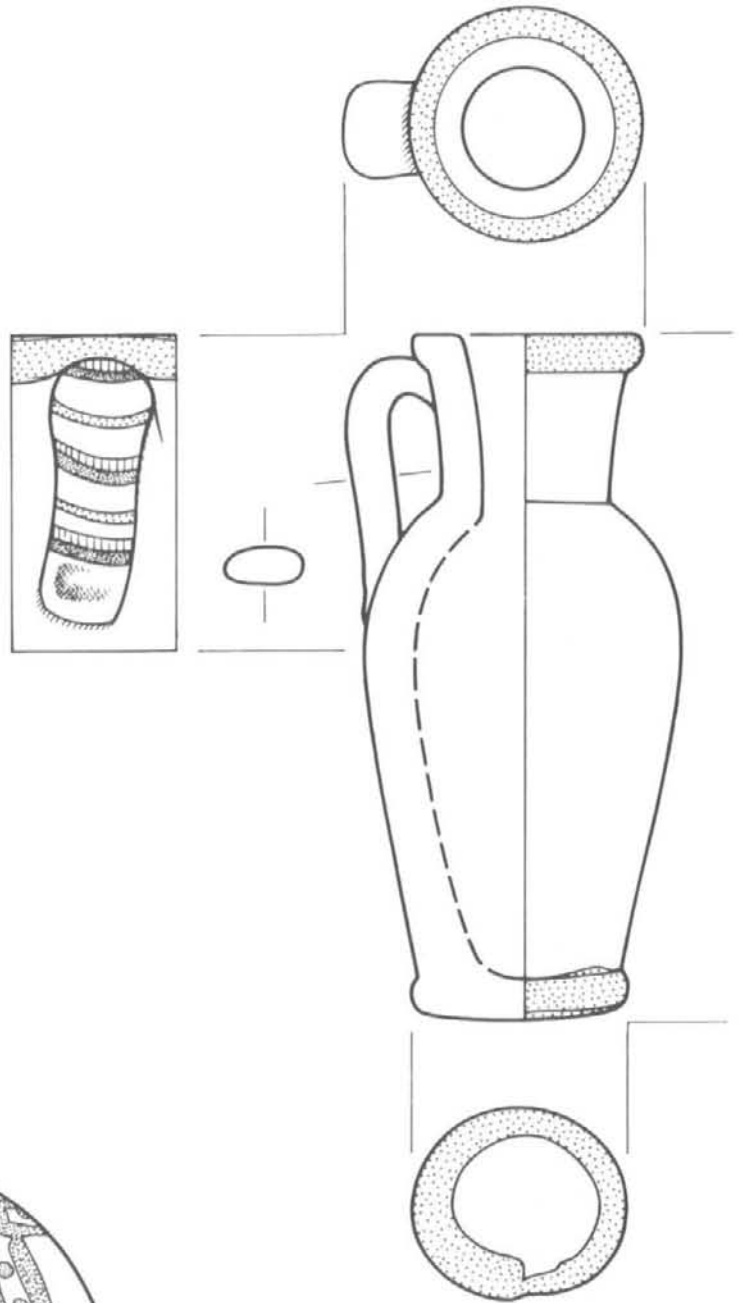


Fig.39 Glass bead-types; Cairo Museum and MMA



Fig.41 Faience juglet; Sedment 1270; Ashmolean Museum



Buff
 Brown

Fig.42 Foreign pottery juglet, 1:1 drawing; Sedment 1300; Petrie Museum

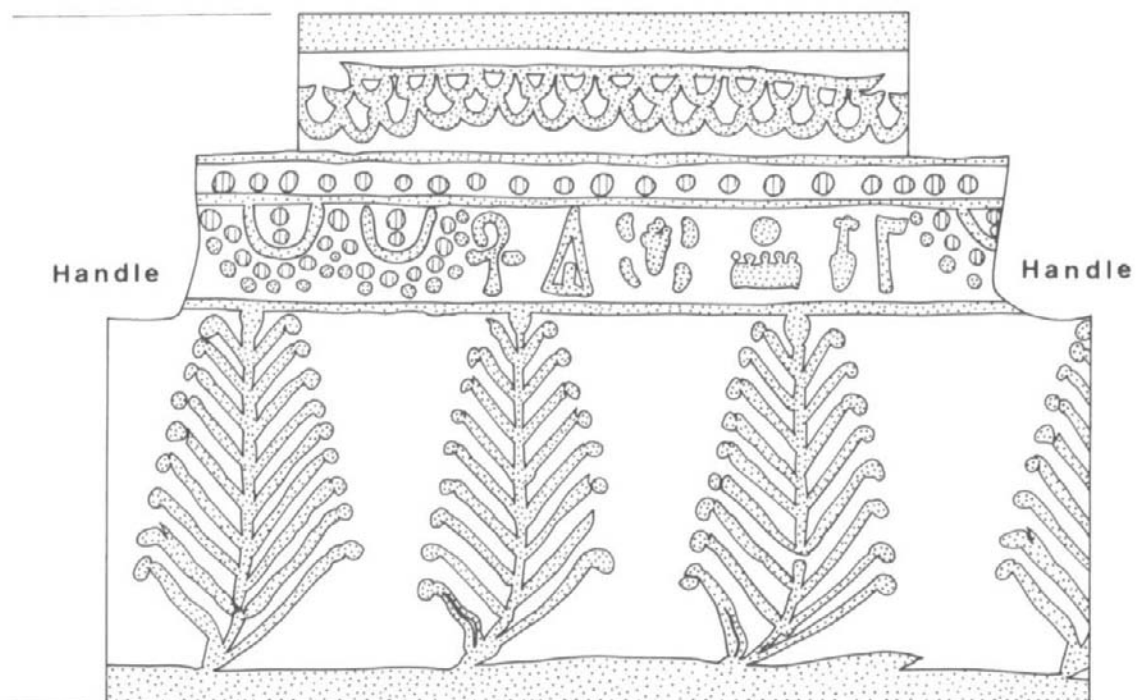


Fig.43 Glass pitcher with the name of Tuthmosis III,
1:1 drawing; British Museum





-  **White**
-  **Yellow**
-  **Dark Blue**
-  **Light Blue**



Fig.44 Pottery jar of Bichrome ware;
Qau 619; Ashmolean Museum

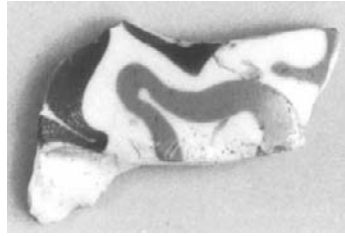


Fig.45 Wall-sherd matching vessel from KV 35
(tomb of Amenhotep II); MMA; nos. 12–14

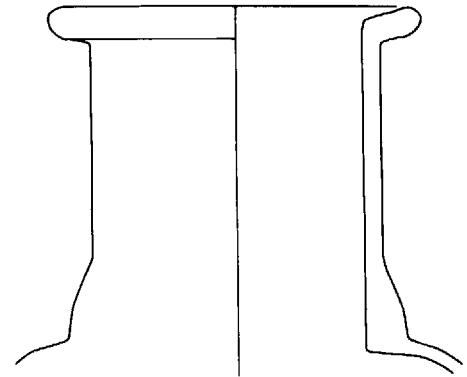
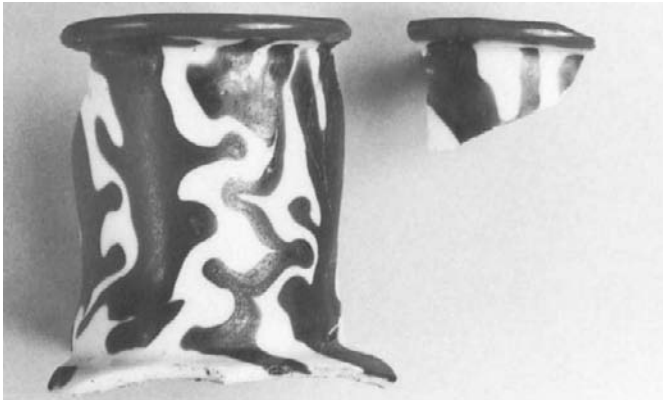


Fig.46 Rim sherd of ware found in KV 35; MMA; nos. 15–17. Neck of same vessel, 1:1 drawing; MMA



Fig.47 Bowl sherds (interior) matching examples
from KV 35; all MMA; nos. 23–27 (top),
nos. 18–22 (bottom), nos. 28–30 (right)

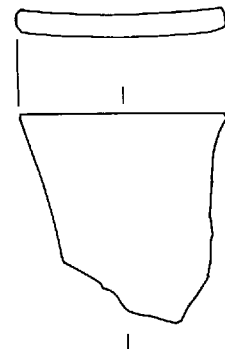


Fig.48 Rim sherd with the name
of Amenhotep II; MMA; no. 31



**Fig.49 Vessel parts from KV 43 (tomb
of Tuthmosis IV); MMA; nos. 32-35**

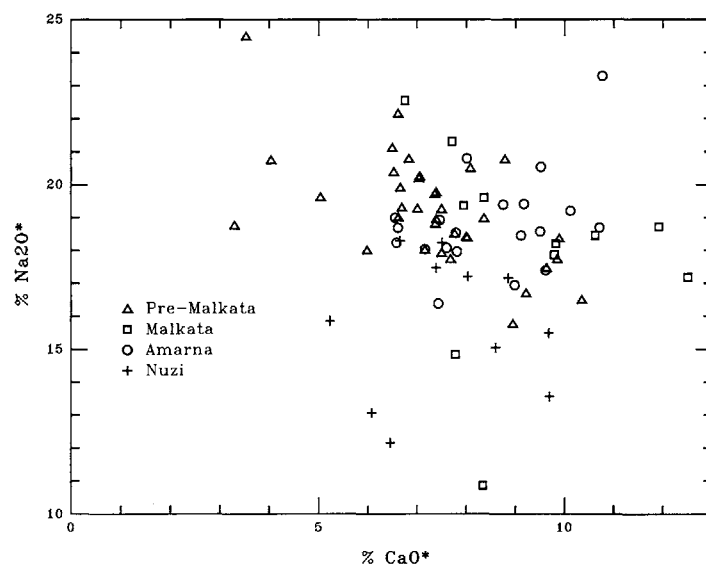


Fig.50 Normalized sodium and calcium oxide contents for all glasses, showing variation in calcium

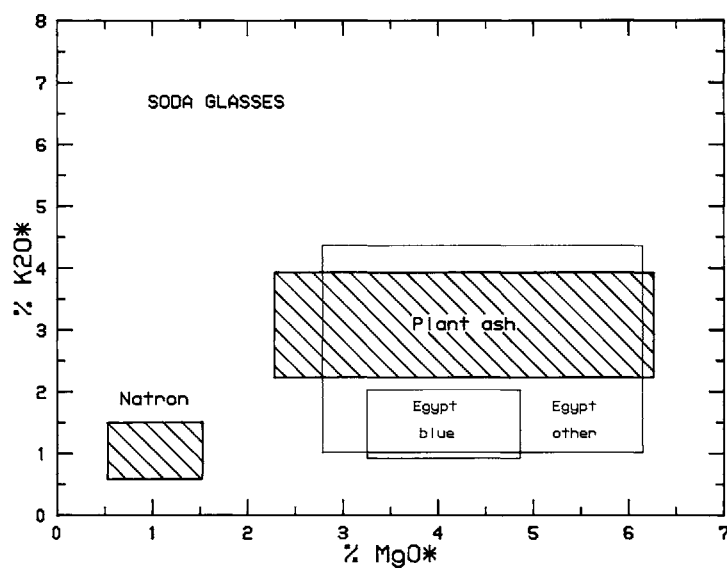
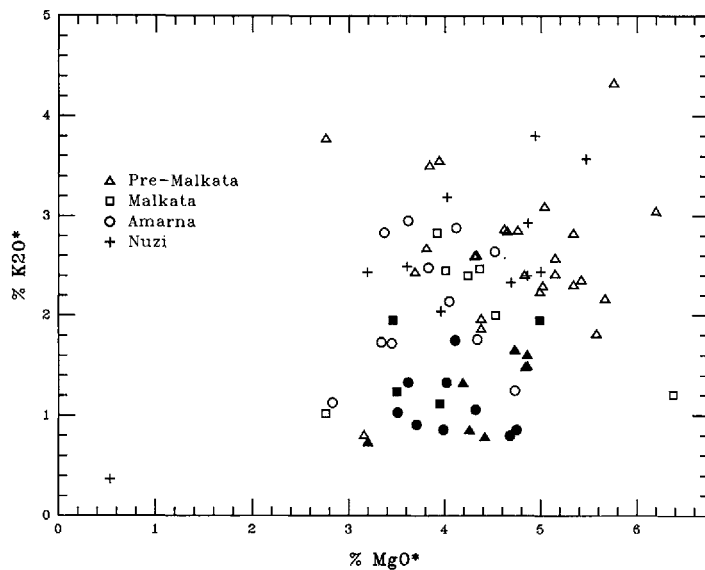
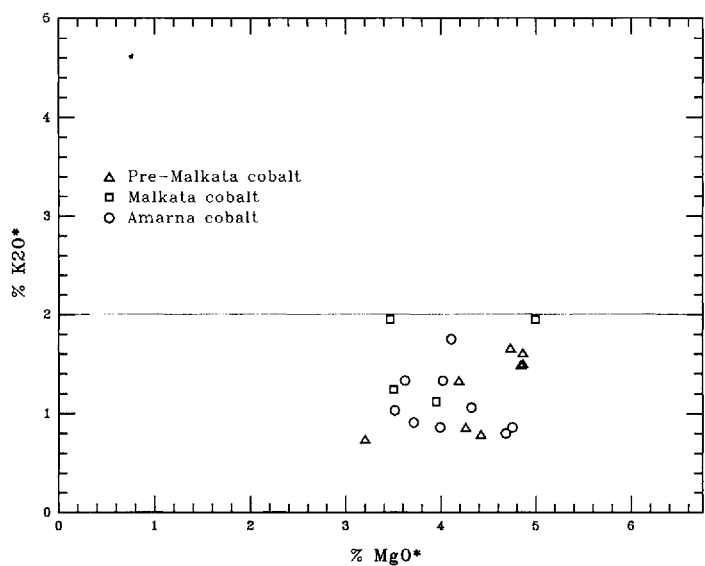


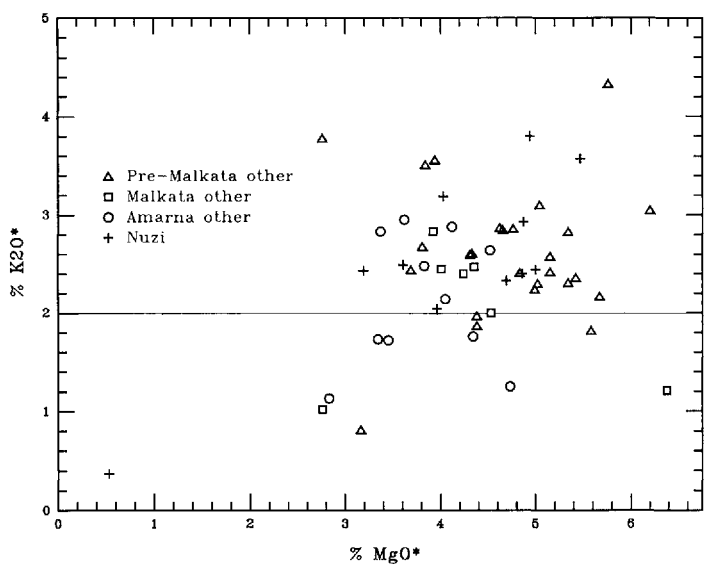
Fig.51 Ranges of normalized potassium and magnesium oxides for soda-lime glasses of natron and plant-ash types, with Egyptian cobalt and noncobalt glasses superimposed



52. Darkened symbols are cobalt glasses

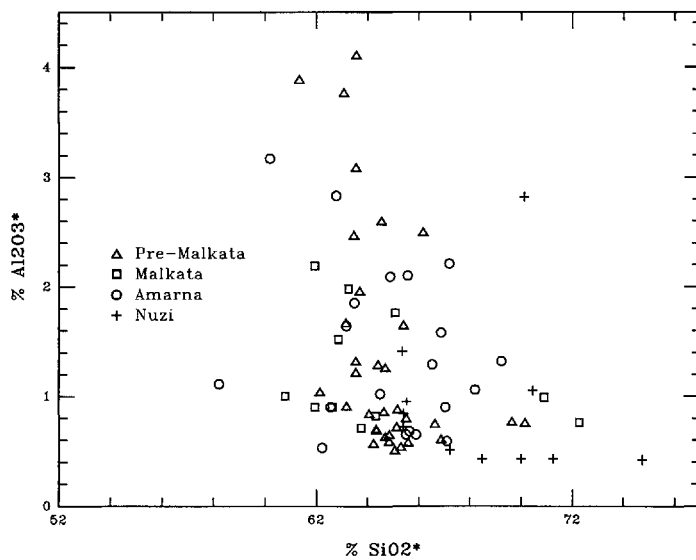


53. All Egyptian cobalt glasses lie below 2% K₂O* (no Nuzi glass has cobalt)

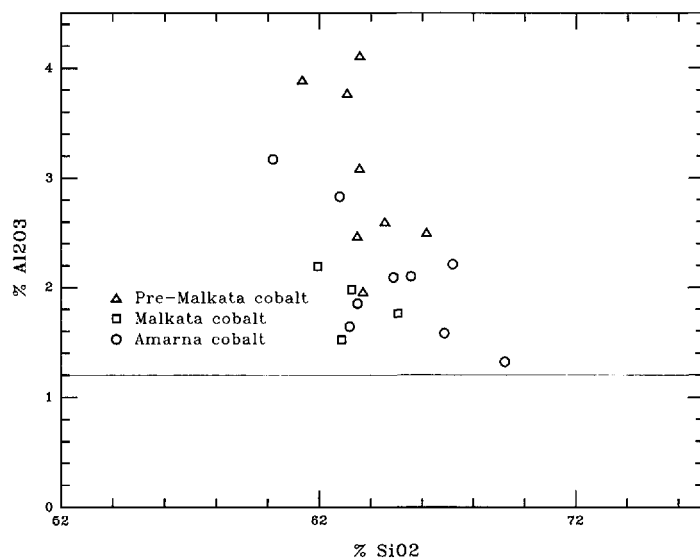


54. Twelve Egyptian noncobalt glasses also lie below 2% K₂O*

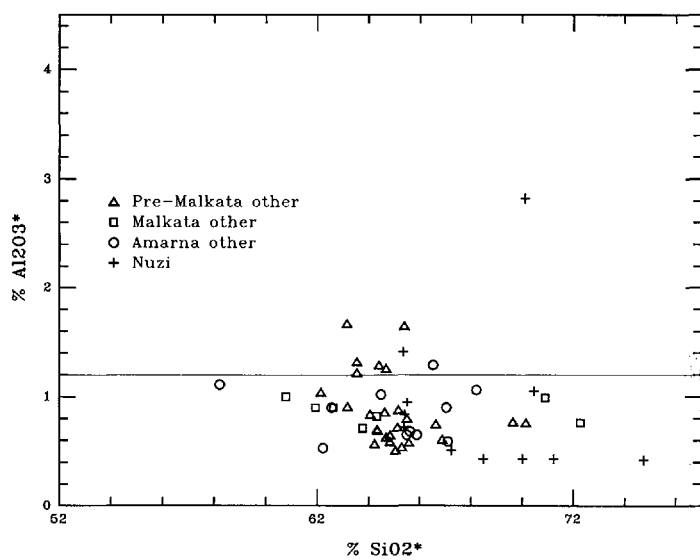
Figs.52-54 Normalized potassium and magnesium oxide contents for cobalt vs noncobalt glasses



55. All Egyptian and Nuzi glasses of Fig. 50



56. All Egyptian cobalt glasses lie above 1.2% Al_2O_3^*



57. Seven Egyptian noncobalt glasses also lie above 1.2% Al_2O_3^*

Figs.55-57 Normalized alumina and silica contents for cobalt vs noncobalt glasses

Part 3. Lead-Isotope Analyses of Some Objects from Egypt and the Near East

R. H. Brill,¹

H. Shirahata, C. Lilyquist, and R. D. Vocke, Jr.

Lead-isotope analyses can be very useful for classifying ancient lead-containing artifacts and materials according to the mining regions where the leads originated.² In the most straightforward instances, leads with matching isotope ratios are likely to have come from the same mining region, while those with ratios that do not match probably came from different regions.³ Under favorable circumstances, it is often possible to identify the actual mining regions which produced particular leads. In any event, these analyses can often be utilized for confirming or ruling out, either directly or indirectly, probable locations of manufacture for the parent artifacts.

In previous studies, ranges of isotope ratios were established for leads in several Dynasty 18 glasses and glazes (from Amarna and the Fayum area) and for kohl (mainly of earlier dates).⁴ Even though exact matches were not found for these 18 items, the leads presumably came from galena deposits in either the Eastern Desert or, possibly, along the coast of the Arabian Peninsula.⁵ Sometime after Dynasty 18 these particular mines appear to have been abandoned, and instead other mines provided the lead used for later Egyptian glassmaking. Analyses of glasses, glazes, and metallic leads from Mesopotamia and Iran have shown that they are easily distinguished, isotopically, from the leads used for making Egyptian Dynasty 18 glasses and glazes. The findings

1. We are grateful to our friend Kazuo Yamasaki whose interest in lead-isotope research was largely responsible for bringing about the collaboration of the laboratory scientists involved in this research. While the donors of samples for new data are thanked individually below, the donors of the Mesopotamian and Iranian samples, and the analysts who analyzed them, are so numerous that we shall only thank them collectively here with the promise that their contributions, which are genuinely appreciated, will be acknowledged more suitably in the complete publication of that research in the future. J. Crowfoot Payne provided the Naqada sample, and B. Adams provided and dated the numerous Egyptian samples from the University College collection which formed the basis of the previous study. We should also like to thank M. Townsley for assistance with many aspects of this paper.

2. For some applications to ancient glasses, see: R. H. Brill, W. R. Shields, and J. M. Wampler, "New directions in lead isotope research," in *Application of science in examination of works of art* (Boston, 1970), pp. 73-83; R. H. Brill, "Scientific studies of the panel materials," in L. Ibrahim, R. Scranton, and R. Brill, *Kendreei: Eastern port of Corinth* (Leiden, 1976), pp. 225-55; I. L. Barnes, R. H. Brill, E. C. Deal, and G. V. Piercy, "Lead isotope studies of some of the finds from the Serçe Liman shipwreck," in Olin/Blackman 1986, pp. 1-12.

3. The major advantages of the method are that the analyses can be performed on very small samples of virtually any lead-containing material and that the isotope ratios are unaffected, for all practical purposes, by the chemical history of the artifacts, providing only that no additional lead from external sources has been introduced. The main disadvantages are overlapping and mixing effects. While individual ore deposits are characterized by their own isotope ratios, these ratios are not necessarily unique to those deposits and leads from different regions—sometimes widely separated geographically—can have very similar ratios numerically. Mixing of leads, particularly that resulting from recycling scrap metal, produces ratios intermediate between those of the original leads. In most instances, one cannot be certain that mixing has not occurred.

4. R. H. Brill, I. L. Barnes, and B. Adams, "Lead isotopes in some ancient Egyptian objects," in Bishay 1974, pp. 9-26; R. H. Brill, "A note on lead-isotope analyses of faience beads from China," *JGS* 33 (1991), pp. 116-18; Brill/Barnes 1988.

5. One noteworthy point is that the few Egyptian ores we have analyzed so far fall below the trend generated by the glasses and kohl.

on the Near Eastern leads, as well as those for the later Egyptian glasses, have not yet been published in full,⁶ but are outlined here in Tables 4 and 5 along with six leads of the present study.

Figure 58 shows an overall summary of leads from some 800 ancient artifacts made from a wide variety of materials. The Dynasty 18 and earlier Egyptian leads analyzed are included in one ellipse. Two subgroups of Mesopotamian and Iranian leads, about 35 samples in all, are included here as a single group marked M. (The terms "Mesopotamian" and "Iranian" are used rather loosely in this connection.)

Lead-isotope analyses have now been carried out on sixteen additional objects: one from a marbled glassy faience vessel in Part 1 (no. 10), a tin bead contemporaneous with it, and a Susa object that also seems to be contemporary; four yellow glasses discussed in Part 2 (nos. 3, 26, 30, 35); two yellow glasses from Malkata and four from Lisht; and two glasses and a faience object from Egypt without specific provenance.⁷ A concordance and sample descriptions, which include figure references, are given in Table 1. (There are seventeen samples, two having come from the same vessel sherd, cf. Part 2, nos. 2–4). The analyses were carried out at the Muroran Institute of Technology in Muroran, Japan. The data are reported in Tables 2 and 3, and plotted in Figures 58–61.⁸ Two samples (one from the marbled vessel and one from the tin bead) were analyzed at the National Institute of Science and Technology in Gaithersburg, Maryland.

The reason for analyzing these particular objects (indicated by open circles in Figs. 59–61) was to see how the leads in Pre-Malkata, Malkata, and Lisht Egyptian glasses compared to those in Amarna and Fayum-area glasses and glazes which had been analyzed previously (indicated by crosses in Fig. 59). It can be seen in Figure 59 and in Table 3 that the leads in five of the newly analyzed objects are close matches for the Amarna/Fayum leads; two of these objects are from Malkata and the others are of unknown provenance. It is very likely that the leads used to make the lead antimonate ($\text{Pb}_2\text{Sb}_2\text{O}_7$) yellow pigments in all of these glasses and glazes came from galena deposits in a single mining region, not yet identified but probably, as suggested above, located in the Eastern Desert.

The overall range of the $^{207}\text{Pb}/^{206}\text{Pb}$ ratios of the Egyptian glasses and glazes analyzed previously is approximately 0.0066. That is about 4.8 times greater than the range of the same ratio within a group of 17 ores from the vicinity of Laurion, Greece, that we also analyzed previously.⁹ If those Laurion ores are taken as being representative of the variation expected within a related group of mines in closely associated deposits, then we are inclined to see the pigments in the previous Egyptian samples as having been made with lead from different deposits within a mining region, rather than with lead from a single deposit or single mine. On the other hand, the five newly analyzed samples Pb-1116 to 2180 (Fig. 59) have an isotopic spread of only 0.0002, leading us to believe that they probably were made with lead from a single deposit or single mine. For that matter, as far as the isotopic data are concerned, the leads in any of the

6. Because it may be some time before these findings are thoroughly published, it was decided to include a cursory summary of the data here, as it might prove useful to some readers. However, some of the data have been reported in R. H. Brill, "Lead and oxygen isotopes in ancient objects," in *The impact of the natural sciences on archaeology* (London, 1970), pp. 143–64; "Some miniature glass plaques from Fort Shalmaneser, Nimrud, part II; Laboratory studies," *Iraq* 40 (1978), pp. 23–39; and "A report on lead isotope ratios in a Babylonian glaze," in *Ceramics and civilization; Ancient technology to modern science*, v. 2 (Cincinnati, 1986), pp. 152–56. The results were also presented at the 79th General Meeting of The Archaeological Institute of America held in Atlanta, Ga., 28–30 Dec., 1977.

7. The 16 new samples from the Metropolitan Museum were provided by Lilyquist, while the Malkata and Lisht samples from that institution were assembled by C. Keller. The samples of the vessel in The Brooklyn Museum were kindly made available by R. Fazzini and J. Romano.

8. We routinely plot $^{204}\text{Pb}/^{206}\text{Pb}$ ratios also, but unless they provide further help in classifying the data, do not usually publish them. In the case of the samples involved here, the $^{204}\text{Pb}/^{206}\text{Pb}$ vs $^{207}\text{Pb}/^{206}\text{Pb}$ plots did not add any information useful for classification.

9. R. H. Brill, I. L. Barnes, W. R. Shields, and T. J. Murphy, "Isotopic analysis of Laurion lead ores," in *Archaeological chemistry, Advances in Chemistry*, 138 (Washington, D.C., 1974), pp. 1–10.

closely matching glasses made nearly contemporaneously could even have come from a single batch of the colorant-opacifier prepared by glassmakers (and/or faience makers) who moved from one location to another.

It will be seen that the leads in two other newly analyzed glasses (Pb-2181 and 2182 from the time of Amenhotep II; Fig. 19), which come from two very similar objects, differ slightly from one another and slightly from the glasses just discussed. One reasonable explanation is that these two objects—made in a mosaic technique and having slightly different chemical compositions than the cored and swirled vessels—are colored with lead antimonate made from leads which were obtained from different mines within the same general region. Pb-2183, from a Tuthmosis IV glass (Fig. 19), is probably about ten years later in date than the two Amenhotep II mosaic glasses. It is not clear, based on its position on the graph, whether Pb-2183 belongs with those two glasses isotopically, or with the Amarna/Fayum area/Malkata leads.

It is worth emphasizing that the yellow pigments in all eight of the newly analyzed glasses contain leads which we can presume were mined in Egypt. However, as we shall see below, this cannot be concluded for the marbled goblet from the tomb of the foreign wives of Tuthmosis III located in the Wady Qirud or, for that matter, several other objects of this study found in Egypt.

In Figure 60 the leads in Group M are plotted as squares on a scale expanded from that of Figure 58. Most of the samples are of glasses or glazes, and most date before 700 B.C. They come from sites such as Nuzi, Nimrud, Tell al-Rimah, Babylon, and Hasanlu.¹⁰ In order to make it easier to see isotopic relationships among the samples, they are listed in Table 4 in approximate order of increasing $^{207}\text{Pb}/^{206}\text{Pb}$ ratios.

Sample Pb-2168 is from a red region of the marbled Wady Qirud goblet (Part 1, nos. 9–13; Cover, right), and Pb-2169 is from a tiny metallic bead from a contemporaneous and nearby private tomb in the Assasif that also yielded some copper-blue glass amulets (nos. D–E in Part 2). Although the two lead samples fall somewhat below the borderline of the M-type leads as seen in Figures 58 and 60 (perhaps owing to a slightly different instrumental calibration, since they were analyzed several years later), the lead of the Wady Qirud goblet clearly seems similar to the "Mesopotamian" type; it surely does not belong with the early Egyptian leads discussed above. Pb-2169, however, the tiny metal bead found in the private tomb, can be interpreted differently. It falls farther below the M-type lead when plotted (that is, beneath the general trend) and therefore this lead probably came from a different source. It is a very close match for two other leads reported in Table 4: an Egyptian yellow opaque cored-vessel fragment bearing a blue and white eyelike motif (Pb-407),¹¹ and a metallic ingot-shaped piece of lead from Tell al-Rimah (Pb-203). Both of these, in turn, are a similarly close match for some ores and slags from the Taurus mountains (the so-called Taurus 1A type) and two lead fishing weights from the Ulu

10. There appears to be a general trend in which the samples from northern Mesopotamia form a rather tight cluster at the upper left of Group M, while the samples from more southerly sites string down toward the right. The cluster of six samples that falls close to the label "TYPE L" is, in fact, indistinguishable, isotopically, from Laurion lead. Whether they are actually from Laurion or from some overlapping Near Eastern mines is still an open question in our view. Two are from Babylon, two from Tell al-Rimah, one from Hasanlu, and one from Susa. The other is a Near Eastern eye-bead. Leads from other artifacts of Iranian origin, particularly around the Lake Van region, are off the graph to the right.

Two objects which contain Laurion or Laurion-like lead have a direct relationship to this study. They are faience plaques from Mycenae that bear cartouches of Amenhotep III. Why they should contain this type of lead, unless they were locally made or coincidentally contain an overlapping lead, is puzzling. See, E. Cline, "An unpublished Amenhotep III faience plaque from Mycenae," *Journal of the American Oriental Society* 110, no. 2 (1990), pp. 200–212. Lilyquist comments that the paleography of the National Museum plaques is convincing, but that the glaze colors, as they exist today, are not typical of Egyptian faience from the reign of Amenhotep III.

11. Brill, Barnes, and Adams, "Lead Isotopes," p. 22; probably from the fragment collection of The Corning Museum of Glass. The excellent state of preservation speaks for an Egyptian provenance, and the deep yellow color of the matrix for the Ramesside period.

Burun wreck.¹² The bead is essentially made of tin, with only about 0.6% lead and 2.1% copper. Because the low level of lead suggests that it may be only an impurity, the isotope ratios are really most useful as an indicator of the source of the tin, rather than where the bead itself was made. Tentatively, then, one might infer that the bead was made of tin mined somewhere in the vicinity of the deposits that provided the Taurus 1A lead-containing samples.

Sample Pb-1095 (Fig. 60) is from the beige region of one of the small Nuzi marbled sherds we analyzed chemically (CMG 1201; Part 1, Fig. 12, right). This is one of the Nuzi fragments which first raised the likelihood that the goblet of the foreign wives (Pb-2168) had a non-Egyptian origin. Although the leads in Pb-1095 and Pb-2168 are somewhat different, both are "Mesopotamian" isotopic types. We do not know just where the Type M leads originated, because we have not yet found any ores matching them. But somewhere in the Near East was a mining region which supplied lead of this isotopic type to glassmakers and glazemakers for over a thousand years—and possibly as long as 2500 years.¹³

A third sample, Pb-2166, must also be compared to the goblet of the foreign wives. It comes from the yellow opaque region of an unstratified marbled beaker base excavated at Susa (Part 1, Figs. 13–14). Physically, the material is strikingly similar to that of the Nuzi marbled sherds, and, therefore, also to that of the goblet of the three foreign wives.¹⁴ However, the lead in the Susa sample differs from those in the Nuzi and Wady Qirud samples. It falls in an isotopic range where glasses we term "Late Egyptian" (mostly Ptolemaic and Roman but several earlier) and additional "Mesopotamian"/Iranian leads overlap extensively. It is difficult to know quite what to make of the results for the Susa piece because, as can be seen in Tables 4 and 5, as well as in Figures 60 and 61, it closely resembles the leads in glasses and glazes found in Persepolis, Hasanlu, and 1st-millennium-B.C. Egypt.¹⁵ Whether all these leads came from a single source or whether the resemblance can be attributed to overlapping and/or mixing has not as yet been resolved. This overlapping is also unfortunate in the broader view because so many of the glasses involved are of special interest; it would be interesting to know if—and how—they relate to one another.

Our main point is that the results of the lead-isotope analysis of the marbled goblet from the tomb of the three foreign wives confirm, to our satisfaction, that the glass was not made in Egypt but was imported from a Near Eastern place of manufacture. This is in agreement with independent conclusions from stylistic, textual, and archaeological studies.

Up to this point the interpretation of the data has been relatively straightforward, but for the remaining newly analyzed samples that is not quite the case. Four of these (Pb-1118, 1119, 2177, and 2178) were excavated at Lisht and are considered to be later than the glasses discussed so far. Isotopically, there is a wide range. Pb-1118 and 2177 are from the walls of two different cored vessels. They have much higher ratios than any of the other samples reported here (see Fig. 58, to the right of the S ellipse). Although they are so different from the Egyptian glasses just discussed, they do fall in with some interesting company, being fairly close isotopic matches for the

12. K. A. Yener, E. V. Sayre, E. C. Joel, H. Ozbal, I. L. Barnes, and R. H. Brill, "Stable lead isotope studies of central Taurus ore sources and related artifacts from eastern Mediterranean Chalcolithic and Bronze Age sites," *Journal of Archaeological Science* 18, no. 5 (Sept. 1991), pp. 541–77. Incidentally, although these two particular Ulu Burun leads match the Taurus Type 1A ores, some analyses among a suite of other Ulu Burun leads resemble instead the Taurus 2B ores that fall in an isotopic range overlapping Laurion leads. (As yet uncompleted analyses by two of the authors, RDV and RHB.)

13. The earliest examples are the Rimah glasses (ca. 1500 B.C.) and the latest example a single high-lead, emerald green, Islamic cameo glass of the 11th century A.D.

14. Two of the authors (CL and RHB) have independently examined the Louvre fragment and are convinced that the object is very like the Nuzi faience fragments and a product of the same technology if not the same workshop.

15. Interestingly, it also resembles three metallic leads excavated by M. Tosi at the Shahr-i-Sokhta in the Sistan Basin close to the Iran-Afghanistan border. These metals are dated 2500–3000 B.C. See R. H. Brill, C. Felker, E. C. Joel, and H. Shirahata, "Lead isotope analyses of Central Asian pigments," in *Conservation of ancient sites on the silk road (Dunhuang)*, in press.

trace-minor levels of lead in two metallic coppers from the Negev (Pb-1229 and 643). Also, they are not very different from the lead in a yellow opaque glass from a cored vessel excavated at Timna (Pb-1079).¹⁶ It seems likely to us that there is some sort of connection between the three vessel glasses from Timna and Lisht; all could have been made with yellow pigments containing lead that came from a single mining region, perhaps the Negev. It should be noted, however, that we are also discussing here isotopic values which are seriously confounded by overlapping. Certain galena ores from Iran, Sardinia, and the Arabian Peninsula also fall within this general range.

A third Lisht sample, Pb-1119 (Figs. 59–61, Tables 3–5), is not from a vessel, but from a cane of yellow opaque glass. Its isotope ratios place it with the group of later Egyptian glasses mentioned above: an assembly of about 30 glasses, mostly yellow, orange, and red opaques, which date from the Late Period to Roman times (see Fig. 60 and Table 5). The same complications which applied to the above-mentioned sample from Susa also come into play here, for the Lisht cane is a fairly close match for the Susa sample (Pb-2166). As was pointed out above, all these items contain leads from ore deposits other than those which provided the lead for the Amarna/Fayum area/Malkata glasses and glazes of Dynasty 18. We do not know where the mines associated with the later Egyptian glasses were located, but there were probably several of them, because they cover a wide isotope range. They resemble some leads from Roman artifacts found around the Levant, as well as some from Italy (not tabulated here). The nearest neighbors to the Susa fragment and Lisht cane on the graph are a rather motley group: two yellow Ptolemaic amulets and one red opaque amulet in Corning,¹⁷ a lump of red opaque cullet found at Persepolis, and a yellow glaze from Hasanlu. It is not known either whether mixing has played any part in producing some of these somewhat puzzling results.

The remaining sample from Lisht, Pb-2178—a yellow glass from a purple cored vessel—contains a lead distinctly different not only from the other Lisht glasses but also from all of the other samples reviewed in connection with this study (Table 3). In Figure 61 it can be seen that this sample lies above the general trend of the data, accompanied very closely by a single other sample, Pb-2140, a yellow opaque glass bead from Hasanlu (Table 4). The displacement above the general trend is significant because it suggests an ore genesis different from that which yielded the leads lying along the general trend. The Type M leads also lie above that trend.

Another surprising result is that for Pb-2184, which is the last sample to be discussed here (Tables 3–5, Figs. 59–61). Thought to belong to a vessel fragment excavated in the tomb of Tuthmosis III (Part 2, nos. 2–4, Fig. 19), this object from The Brooklyn Museum also falls among the later Egyptian glasses and/or higher-range Mesopotamian and Iranian leads that now include the Lisht cane and Susa sample. This is quite unexpected because one would expect the Tuthmoside glass to match the other earlier Egyptian glasses, that is to say, those plotted in Figure 59.¹⁸ As Lilyquist believes the vessel is stylistically Egyptian, at present we can offer no explanation for this result¹⁹ other than to observe that this is one of the earliest glass vessels from Egypt; it is contemporaneous with the tin bead Pb-2169 that is near the M-group (see Fig. 60);

16. Brill/Barnes 1988.

17. See S. M. Goldstein, *Pre-Roman and early Roman glass in The Corning Museum of Glass* (Corning, N.Y., 1979).

18. Core residues in Egyptian cored vessels are often readily distinguishable from those in other cored vessels by microscopic examination. Unfortunately, that does not help much in this instance, because the only residue apparent on the fragment in question appears to be traces of the original contents. See, R. H. Brill and J. F. Wosinski, "A petrographic study of Egyptian and other cored vessels," pp. 123–24, in *Studies in glass history and design*.

19. We do not include our sample Pb-462 in this group. From a yellow bead in The Brooklyn Museum, said to be from the Palace of Amenhotep III (Table 5), that glass has an unusually high lead content (PbO = 76.0%) and is opacified with PbSnO₃ instead of Pb₂Sb₂O₇. Therefore, we are suspicious of the accuracy of its early attribution; cf. Part 2, Appendix 1 for discussion of glasses attributed to this palace.

and inlaid pendants and a glass pitcher from the same period have some relation to Palestine (Part 2). It is therefore of interest that we have occasionally found leads with roughly similar ratios in Roman artifacts from the Levant.

It is worth pointing out again that Figures 60 and 61 illustrate that when the $^{207}\text{Pb}/^{206}\text{Pb}$ ratios exceed the upper limits of the Type L leads, overlapping of the later Egyptian leads and the higher-range Mesopotamian-Iranian leads can pose a problem. But we should also note that several samples from Egypt, dating to various periods, occur in these same areas (see Tables 4 and 5): Pb-1359, Predynastic hematite; Pb-240, later Middle Kingdom kohl; Pb-407, New Kingdom glass; and Pb-458, -459, -1316, Late Period faience and glass.

In summary, the results obtained by these analyses have proved very useful because they have verified that the marbled goblet from the tomb of the three foreign wives has a Mesopotamian—or at least a non-Egyptian—origin. At the same time they have placed Malkata glasses in the same classification as the Amarna/Fayum-area glasses and glazes analyzed previously, and positioned Tuthmosis IV and Amenhotep II glasses nearby. However, the analyses also point out the problems that can arise when having to deal with small numbers of samples. The widely differing results for the Lisht samples, for example, lead to two quite different interpretations. Two analyses appear to establish a connection with Timna, while the others appear to connect with two different zones of the overlapping "Mesopotamian" and later Egyptian glasses. Furthermore, the interpretation of the Tuthmosis III sample (Pb-2184) remains an open question. It would certainly be helpful to carry out additional analyses in order to see if the situation can be clarified.

Table 1

Concordance and Sample Descriptions¹

Lead isotope number (CMG)	Number in Parts 1, 2	Museum record number	Chem. anal. number (CMG)	SMG catalogue number ²	Source/Date
Pb-1116	----	MMA M10	CMG 3910	----	Malkata, MMA excavations
Pb-1117	----	MMA M21	CMG 3911	----	" "
Pb-1118	----	MMA L12	CMG 3956	----	Lisht, MMA excavations
Pb-1119	----	----	CMG 3954	----	" "
Pb-1368	----	CMG 66.1.213	----	26	Unprov., Dyn. 18/19
Pb-1369	----	CMG 59.1.91	----	163	Unprov., Amenhotep III
Pb-2166	----	Louvre MAO S.1241	----	----	Susa, French excavations
Pb-2168	Part 1, no. 10	MMA 26.7.1175	----	----	[foreign wives, Wady Qirud]
Pb-2169	----	MMA 26.7.1375	----	----	Assasif, C/C excavations
Pb-2177	----	MMA 22.1.1189	----	----	Lisht, MMA excavations
Pb-2178	----	MMA L1	----	----	" "
Pb-2180	----	MMA X 620	----	----	Unprov., Dyn. 18
Pb-2181	Part 2, no. 26	MMA 26.7.1164	----	----	[Amenhotep II tomb]
Pb-2182	no. 30	MMA 26.7.1165	----	----	" "
Pb-2183	no. 35	MMA 30.8.44a	----	----	Tuthmosis IV tomb
Pb-2184	no. 3	Brooklyn 53.176.4	----	----	[Tuthmosis III tomb]
Pb-2185	"	"	----	----	" "

1. Samples removed by RHB unless otherwise noted.

2. S. M. Goldstein, *Pre-Roman and early Roman glass in The Coming Museum of Glass* (Corning, N.Y., 1979).

- Pb-1116 Malkata, cored vessel, rim. Yellow opaque, dulled surface.
- Pb-1117 Malkata, cored vessel, rim. Dark blue opaque (= Lilyquist "blue") with yellow, white, and light blue (=Lilyquist "turquoise") opaque bands, dulled surface. Sample consists of yellow opaque glass.
- Pb-1118 Lisht, cored vessel, wall. Yellow opaque, without decoration, bubbly, core residue remaining, unweathered.
- Pb-1119 Lisht, cane. Yellow opaque.
- Pb-1368 Unprovenanced cored vessel, Egypt, late 18th–early 19th dynasty (SMG). Sample is of yellow opaque threading.
- Pb-1369 Unprovenanced pendant, Egypt, reign of Amenhotep III (SMG). Yellow faience plaque with insets of blue glass partially fused into place, forming an inscription.
- Pb-2166 Susa, unstratified find, Louvre MAO S.1241; probably 15th cent. B.C. (Part 1; Figs. 13, 14). Glassy faience (or glass[?]) marbled object, probably bottom of a beaker. Resembles Nuzi marbled vessel sherds and MMA goblet found in Wady Qirud tomb of Tuthmosis III's three foreign wives (Pb-2168). The nature of the material, colors, and method of manufacture are all identical to those of the MMA and Nuzi pieces (see Part 1). Sample of yellow opaque region taken by RHB in Paris, 11/22/91.
- Pb-2168 Button-based goblet from tomb of foreign wives of Tuthmosis III (Part 1, no. 10; Cover and Fig. 10, right). Marbleizing pastes of brick red, cream, turquoise, ochre. Sample is of red on bottom of foot; taken by MTW.
- Pb-2169 Very small tin bead from an amuletic necklace; excavations of Carter/Carnarvon from Assasif tomb 37; roughly contemporary with foreign wives tomb (see Pb-2168). Diam. ~ 0.7 mm; with longitudinal seam as if made by wrapping metal around a round core. Somewhat corroded with waxy, resinous, or bituminous material adhering. Primarily tin with 0.6% Pb, 2.1% Cu, 0.4% Fe. Chemical analysis by MTW.
- Pb-2177 Lisht, cored vessel fragment. Light blue translucent with yellow opaque and white opaque decoration. Sample is of yellow opaque, taken by MTW.
- Pb-2178 Lisht, cored vessel, wall. Pale purple with feathered white opaque and pale yellow opaque bands, traces of core residue remaining, dulled surface. Purple glass = CMG 3950; sample is of yellow opaque.
- Pb-2180 Unprovenanced cored vessel fragment, Egyptian. Translucent purple matrix with swirls of opaque white, yellow, and light blue on surface; sample removed by MTW.
- Pb-2181 Mosaic bowl fragment stylistically correlated with fragments from the tomb of Amenhotep II at Thebes (Part 2, no. 26; Figs. 19, 47). Dark blue opaque matrix with red, light blue, white, and yellow opaque squares; sample removed by MTW.
- Pb-2182 Fragment from a different mosaic bowl (Part 2, no. 30; Figs. 19, 47). Dark blue matrix with light blue and yellow opaque squares. Sample removed by MTW.
- Pb-2183 Cored vessel fragment from the tomb of Tuthmosis IV at Thebes (Part 2, no. 35; Figs. 19, 49). Light blue matrix; combing of opaque dark blue, yellow, and white; yellow opaque thread around circumference of foot; sample from yellow combing removed from bottom part by MTW.
- Pb-2184, -2185 Cored vessel fragment probably belonging to fragment excavated in tomb of Tuthmosis III at Thebes (Part 2, no. 3; Figs. 19, 31). Opaque light blue matrix, threads of opaque yellow and translucent black, petals of opaque yellow. Samples removed by MTW, kindness of The Brooklyn Museum, 3/90 and 12/92.

Table 2

**Lead-Isotope Analyses in this Study,
all from Egypt except 2166¹**

Sample no.	Source	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{204}\text{Pb}/^{206}\text{Pb}$
Pb-1116	Malkata excavations	2.02229	0.80958	0.051674
1117	" "	2.01877	0.80880	0.051779
1118	Lisht excavations	2.11898	0.87143	0.055776
1119	" "	2.07669	0.83506	0.053248
1368 ²	Dyn. 18/19	2.02045	0.80909	0.051730
1369 ²	Amenhotep III	2.02350	0.81023	0.051728
2166	Susa excavations	2.07410	0.83427	0.053126
2168 ³	[Wady Qirud]	2.06130	0.82263	0.052350
2169 ³	Assasif excavations	2.05740	0.82527	0.052530
2177	Lisht excavations	2.12072	0.87201	0.055751
2178	" "	2.09878	0.84377	0.053257
2180	[Amenhotep II tomb]	2.02148	0.80979	0.051792
2181	[" "]	2.02910	0.81261	0.051840
2182	[" "]	2.03176	0.81464	0.052040
2183	Tuthmosis IV tomb	2.02155	0.81134	0.052032
2184	[Tuthmosis III tomb]	2.07912	0.83805	0.053593
2185	[" "]	2.07886	0.83800	0.053596

1. All analyses are by Hiroshi Shirahata and co-workers at the Muroran Institute of Technology except for Pb-2168 and -2169. Estimated 2 sigma values for the Muroran data are:

$$^{208}\text{Pb}/^{206}\text{Pb} = 0.00006$$

$$^{207}\text{Pb}/^{206}\text{Pb} = 0.000015$$

$$^{204}\text{Pb}/^{206}\text{Pb} = 0.000005$$

2. Corning Museum of Glass samples.

3. Analyzed by R. D. Vocke, Jr., at the National Institute of Science and Technology (NIST). NIST values are similar to those at the Muroran Institute of Technology.

Table 3

Samples from Table 2 Grouped by Lead-isotope Ratios
Refer to Figures 59-60; samples are listed according to increasing $^{207}\text{Pb}/^{206}\text{Pb}$ ratios

Samples in this study	Sources	Matches from previous studies
(0.79-0.82)		
Pb-1116	Malkata vessel	Dyn. 18 glasses and faience
1117	Malkata vessel	(Amarna and Fayum area)
1368	Dyn. 18/19 vessel	"
1369	Amenhotep III pendant	"
2180	Dyn. 18 vessel	"
----- (?)		
2183 borderline	Tuthmosis IV vessel	

2181	Amenhotep II bowl	Amarna/Fayum glasses and glazes;
2182	Amenhotep II bowl	Brooklyn fish
(0.82-0.834)		
Pb-2168	Foreign wives goblet	Type M "Mesopotamian"
----- (?)		
2169	Assasif tin bead	glasses, glazes, etc.
(0.834-0.85)		
Pb-2166	Susa marbleized vessel	"Later" Egyptian glasses
1119	Lisht cane	and other "Mesopotamian"/
2184 and -2185	Tuthmosis III vessel	Iranian leads
Pb-2178	Lisht vessel	Hasanlu YO
(>0.85)		
Pb-1118	Lisht vessel	Timna cored vessel
2177	Lisht vessel	and Negev metals
-----	slightly different	
-----	distinctly different	
-----	very different	

Table 4

Six Samples from this Study Grouped with Mesopotamian and Iranian Leads by Lead-isotope Ratios¹

Samples are grouped approximately according to increasing $^{207}\text{Pb}/^{206}\text{Pb}$ ratios; refer to Figures 60, 61

Sample No.	Description	Source and date
(0.822-0.830)		
Pb-1344	Lead ring	Tell Taya; ca. 2200 B.C.
2168 ²	Marbleized goblet (red)	Wady Qirud; ca. 1425 B.C.
350	Lead driblet	Nimrud; 9th-7th cent. B.C.
351	Lead rod	Nimrud; 18th cent.(?) or 9th-7th cents. B.C.
414	YO glass	Hasanlu; 1000-800 B.C.
457	Glass	Nimrud; 7th cent. B.C.
423	RO glass	Nimrud; 7th cent. B.C.
408	YO glass	Nuzi; 1450-1400 B.C.
409	YO decorated glass	Tell al-Rimah; 1500 B.C.
90	RO glass	Nimrud; 7th cent. B.C.
413	Yellow frit bead	Hasanlu; 850 B.C.
543	Paint on glass plaque	Nimrud; 7th cent. B.C.
1090	Glaze	Nimrud, Ninurta Temple; 800-700 B.C.
1093	YO glaze	Nuzi; 1450-1400 B.C.
1177	Dark blue glass	Nimrud; 7th cent. B.C.
1094	Red and white faience	Nuzi; 1450-1400 B.C.
2109	Pottery glaze	Siraf; 10th cent. A.D.
2111	Pottery glaze	Sumatra; 10th cent. A.D.
1087	YO glaze	Hasanlu; 1100-800 B.C.

Pb-1075	Honeycomb faience	Hasanlu; 9th cent. B.C.
1359	Hematite	Naqada; Predynastic

Pb- 203	Small lead "ingot"	Tell al-Rimah; ca. 1500 B.C.
407	YO cored vessel (eye decoration)	Egyptian, unprovenanced; New Kingdom
2169 ²	Small tin bead	Assasif; ca. 1460 B.C.
NOTE: Samples 203-2169 are all close matches for two lead fishing weights from the Ulu Burun wreck, and ore samples of the Taurus 1A type		

Pb-1179	Dark blue opaque glass	Nimrud; 7th cent. B.C.
1178	Dark blue opaque glass	Nimrud; 7th cent. B.C.
1111	Emerald green cameo	Islamic; 10th-12th cents. A.D.

Pb- 425	RO glass	Nimrud; 7th cent. B.C.
427	RO glass	Nimrud; 7th cent. B.C.
452	YO glass	Nimrud; 7th cent. B.C.
464	RO glass	Persepolis; 5th cent. B.C.
1032	OO glass	Islamic; 8th-10th cents. A.D.
1095	Marbleized ware (beige)	Nuzi; 1450-1400 B.C.
(0.830-0.835) Type L; these leads overlap Taurus 2B ores.		
Pb-1556	YO glass	Mediterranean; 1st cent. B.C.-1st cent. A.D.
1115	Yellow glaze	Ishtar Gate, Babylon; 7th cent. B.C.
1088	Yellow glaze	Babylon; 605-562 B.C.
202	Lead wire	Tell al-Rimah; 1500 B.C.
1332	Lead medallion	Tell al-Rimah; 1500 B.C.
1337	Metallic lead	Susa; undated.
2138	RO lump	Hasanlu; ca. 900 B.C.(?)

NOTE: The groups of samples immediately following (through Pb-2140) are from Mesopotamia and Iran. They overlap, in part, the late Egyptian glasses. For legibility they are plotted separately on Figure 61.

(0.833-0.837)

Pb-1099	Yellow glazed brick	Ishtar Gate, Babylon; 7th cent. B.C.
2166 ²	Marbleized beaker	Susa; unstratified
1086	Yellow glaze	Hasanlu; 750-600 B.C.
463	RO cullet	Persepolis; 5th cent. B.C.
1119 ²	YO cane	Lisht; later New Kingdom
----- (?)		
Pb-1096	Yellow glaze, faience pyxis	Nippur; ca. 1600 B.C.(?)
411	RO glass, mosaic bowl	Hasanlu; ca. 850 B.C.
412	Weathered product from 411	Hasanlu; ca. 850 B.C.

(0.837-0.855)

Pb- 43	Lead fragment	Nippur; ca. 3500 B.C.
222	Lead fragment	Jalame; ca. A.D. 360
1184	Dark blue tessera	St. Demetrius; 7th-12th cents. A.D.
1196	Dark blue glass vessel fragment	Nishapur; Islamic
1129	YO eye-bead	Nishapur; 8th-9th cents. A.D.
2184 ²	YO from cored vessel	Tuthmosis III, ca. 1425 B.C.
1175	Dark blue cameo glass	Unprov.; 1st cent. A.D.
1199	Diatretum, dark blue glass	Conimbriga; 4th cent. A.D.
724	Bronze bull	Urartu; 8th cent. B.C.
127	Kohl from bronze pot	Hasanlu; 1100-800 B.C.

Pb-1091	Wall tile	Hasanlu; 9th cent. B.C.

Pb-1238	Copper pin	Larsa; undated.
1031	YO millefiore vessel	Unprov.; 8th-10th cents. A.D.(?)
1110	Green cameo glass	Unprov.; 11th cent. A.D.
1098	Yellow glaze	Azerbaijan; ca. 1000 B.C.
218	Lead bowl(?)	Tepe Hissar; ca. 1900 B.C.
122	Lead pottery cover	Jemdet Nasr; ca. 3000 B.C.
123	Lead pottery cover	Jemdet Nasr; ca. 3000 B.C.
125	Lead pottery cover	Jemdet Nasr; ca. 3000 B.C.
1089	Yellow glaze	Barsippa; 6th cent. B.C.
217	Lead bowl(?)	Tepe Hissar; ca. 1900 B.C.
410	YO glass, mosaic beaker	Tell al-Rimah; 1500 B.C.

Pb-2178 ²	YO from cored vessel	Lisht; later New Kingdom
2140	YO glass	Hasanlu; ca. 900 B.C.(?)

Pb-1334	Lead fragment	Bard-i-Nishanda; 2nd cent. A.D.
1335	Lead drippings	Bard-i-Nishanda; 2nd cent. A.D.
1336	Lead fragment	Bard-i-Nishanda; 2nd cent. A.D.
1338	Litharge or slag	Susa; undated

Pb- 429	YO inlay	Nimrud; 7th cent. B.C.
447	YO inlay	Nimrud; 7th cent. B.C.

YO = Yellow opaque; RO = Red opaque; OO = Orange opaque; GO = Green opaque

----- slightly different
----- distinctly different
----- very different

1. Some of these data have been reported previously. See n. 6 on page 60.
2. Leads in this study.

Table 5
Four Samples from this Study Grouped with some Late Egyptian and Roman
Glasses by Lead-isotope Ratios¹

Samples are grouped approximately according to
increasing $^{207}\text{Pb}/^{206}\text{Pb}$ ratios; refer to Figure 60

Sample No.	Description	Source and date
(0.834–0.850)		
Pb- 459	YO bead	Kafr Amar; Dyn. 23 or 26.
----- (?)		
416	Lump of RO glass	Memphis; 100 B.C.–A.D. 300
458	Tiny YO faience beads	Kafr Amar; Dyn. 23 or 26.
----- (?)		
2166 ²	Marbleized vessel	Susa; undated.
1077	RO from inlay	Egyptian; 4th–1st cents. B.C.
174	RO cullet	Tara Hill; Roman
463	RO cullet	Persepolis; 5th cent. B.C.
1028	YO amulet (falcon)	Egyptian; Ptolemaic
1029	YO amulet (baboon)	Egyptian; Ptolemaic
1119 ²	YO cane	Lisht; later New Kingdom
Pb-1026	RO amulet (Imsety)	Egyptian; Ptolemaic
1012	YO cane	Egyptian; 1st cent. B.C.–1st cent. A.D.

1316	RO head	Egyptian; 7th–5th cents. B.C.
240	Kohl (galena)	Abydos(?); late Middle Kingdom
----- (?)		
1027	OO amulet (deity)	Egyptian; Ptolemaic
1025	RO amulet (trussed cow)	Egyptian; Ptolemaic
462	YO bead	Malkata Palace; Roman?
1315	Lead strip	Fara'in; Roman(?)
2184 ²	YO from cored vessel	Tuthmosis III; ca. 1425 B.C.
1013	RO cane	Egyptian; 3rd cent. B.C.–1st cent. A.D.
1011	RO fragment	Cosa; Roman
Pb- 415	YO column	Egyptian; 4th–2nd cents. B.C.
1030	Dark green cameo	Poss. Fustat; 10th–12th cents. A.D.
1015	YO ribbon glass	Unprov.; 1st cent. A.D.
434	GO tessera	Beth She'an; 5th cent. A.D.
----- (?)		
Pb- 418	OO inlay	Denderah; 1st cent. B.C.–2nd cent. A.D.
433	YO tessera	Beth She'an; 5th cent. A.D.
Pb-2178 ²	YO from cored vessel	Lisht; later New Kingdom
Pb- 419	YO inlay	Denderah; 1st cent. B.C.–2nd cent. A.D.
1014	YO ribbon glass	Unprov.; 1st cent. A.D.
410	GO from mosaic beaker	Tell al-Rimah; ca. 1500 B.C.
417	RO inlay	Denderah; 1st cent. B.C.–2nd cent. A.D.
1017	RO millefiore	Unprov.; 1st cent. B.C.–1st cent. A.D.
1016	YO (same as 1017)	Unprov.; 1st cent. B.C.–1st cent. A.D.

YO = Yellow opaque; RO = Red opaque; OO = Orange opaque; GO = Green opaque

----- slightly different

----- distinctly different

1. Some of these data have been reported previously. See n. 6 on page 60.

2. Leads in this study.

Part 3, Appendix

Analytical Procedures

The tiny chips or powders of glass samples to be analyzed were rinsed with pure water in an FEP teflon beaker under ultrasonic vibration and then dried at room temperature. The dried samples were completely dissolved in a mixture of HF, HNO₃, and HClO₄ in an FEP teflon beaker and evaporated to dryness. The residues were redissolved in nitric acid, evaporated to dryness, and again taken up in dilute nitric acid. The separation and purification of lead in the sample solutions were accomplished by dithizone-chloroform extraction in the presence of both ammonium citrate and potassium cyanide. Aliquots (200–300ng Pb) of the isolated sample lead were loaded onto rhenium filaments with a mixture of silica-gel and phosphoric acid and analyzed in a surface ionization mass spectrometer. Laboratory wares used were soaked beforehand in (1:1) HNO₃ and subsequently in 0.5% pure nitric acid for a week each, before being washed thoroughly with our purest water. The analytical procedures were carried out in the ultraclean laboratory at the Muroran Institute of Technology by lead contamination control techniques initially developed by C. C. Patterson.¹ A procedural blank of Pb was estimated to be 0.1ng.

Isotope ratios of lead in the sample materials were measured by using a surface ionization mass spectrometer (Finnigan Mat 262) with typical precisions of $\pm 0.02\%$ (2σ) for 208/204, 207/204, and 206/204, and $\pm 0.002\%$ for 208/206 and 207/206. The Pb isotope ratios obtained were normalized by multiplying correction factors determined by periodic analyses of the NBS lead standard SRM 981 every five to seven sample runs.

1. C. C. Patterson and D. M. Settle, "The reduction of order of magnitude errors in lead analyses of biological materials and natural waters by evaluation and controlling the extent and sources of industrial lead contamination introduced during sample collecting, handling, and analysis," in P. LaFleur, ed., *Accuracy in trace analysis: Sampling, sample handling, and analysis*, National Bureau of Standards, U. S. Special Publications, 422 (Washington, D.C., 1976), pp. 321–51.

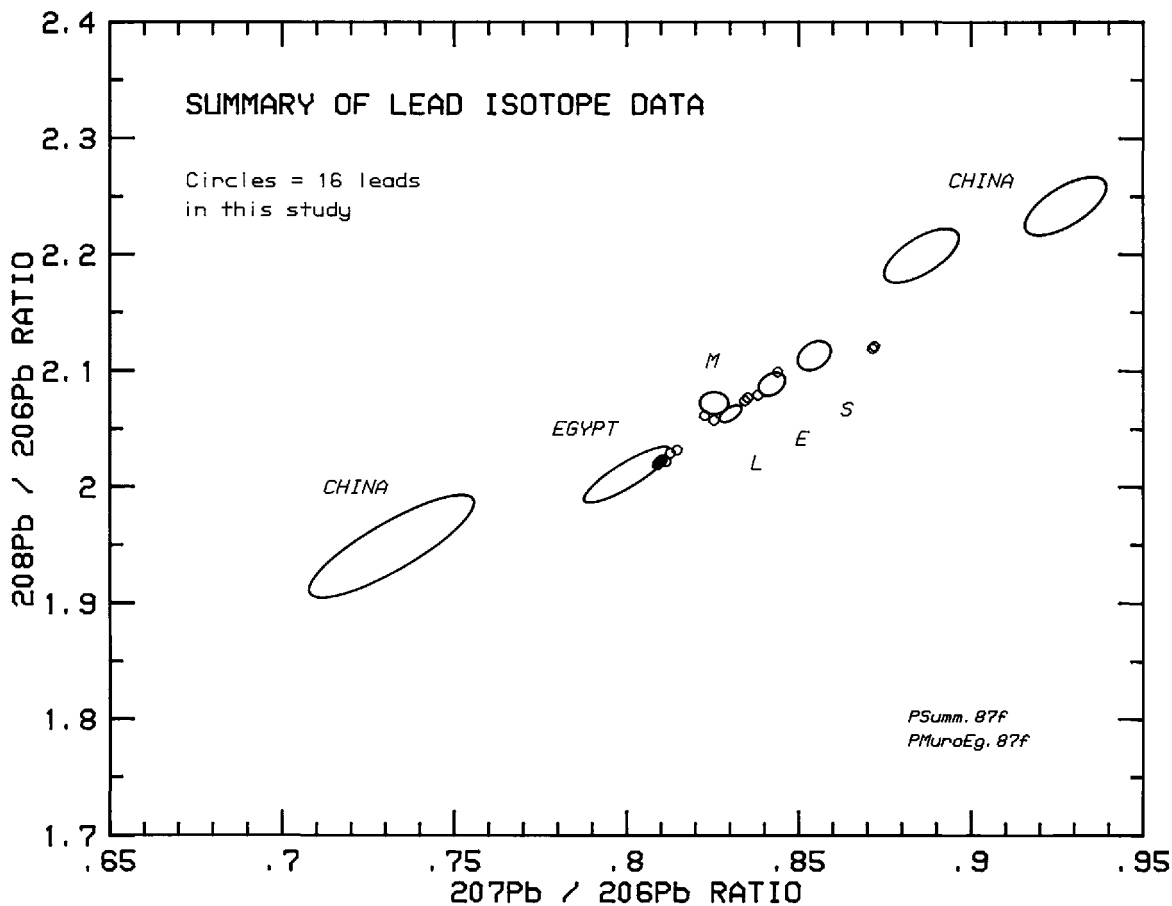


Fig.58 Summary of lead-isotope data for some 800 ancient artifacts, including those of this study. Objects are of a wide variety of materials, periods, and provenances. Some ores are also included. The ellipse marked "Egypt" contains 50 Egyptian samples dating from Dynasty 18 or earlier. The ellipse marked "M" contains about 40 artifacts, mostly of Mesopotamian and Iranian origin. L, E, and S are groups established previously, but now used mainly by the primary author as reference markers. "L" denotes Laurion (or Laurion-like) leads in both ores and provenanced artifacts; "E" English and some European leads; "S" Spanish and certain other leads. Late Egyptian glasses fall between L and E. All data for composing this graph are from the National Institute of Science and Technology (formerly the National Bureau of Standards). Superimposed on the graph as circles are 16 leads (yielding 17 points) reported in this study. Samples 1118 and 2177 from Lisht are the two points to the right of the ellipse labeled "S".

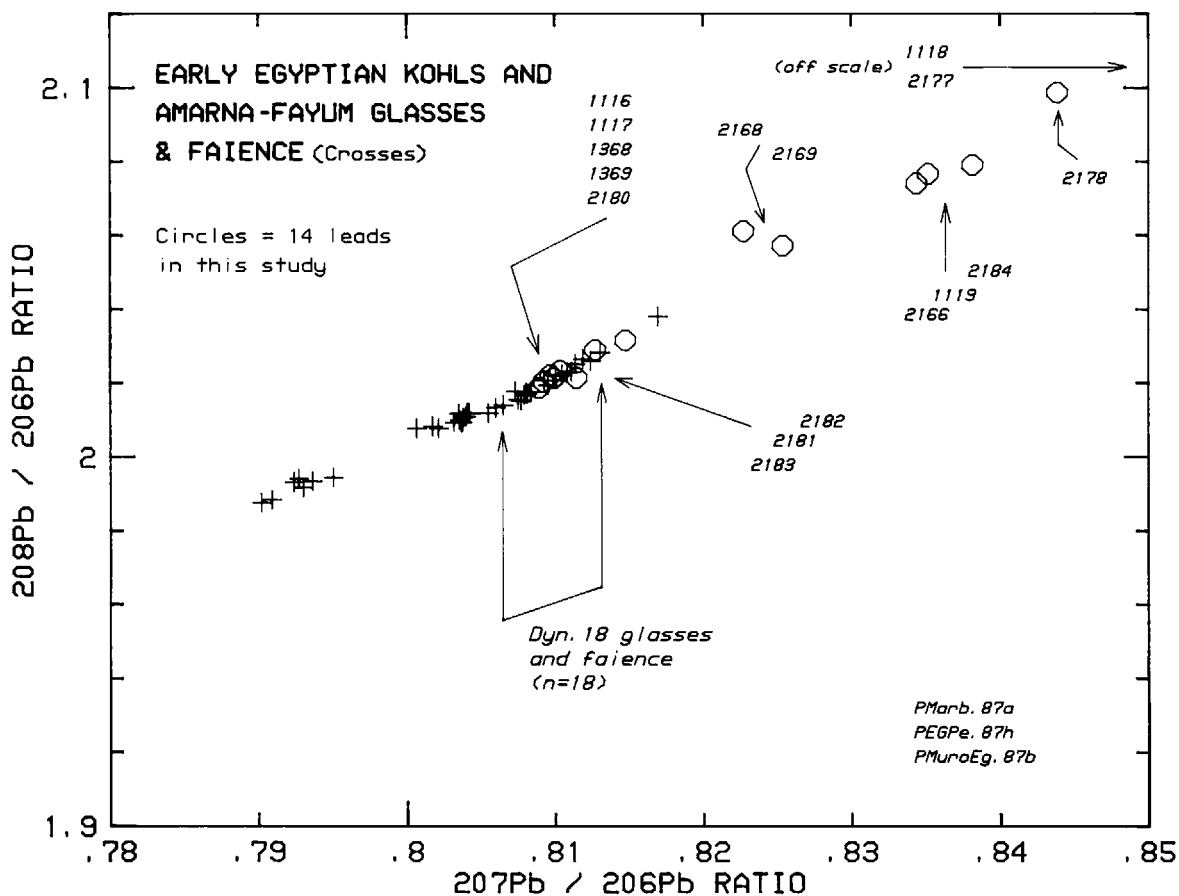


Fig.59 Expanded portion of Figure 58, showing Dynasty 18 and earlier leads from Egypt. Crosses denote Egyptian lead-containing artifacts and materials from an earlier study; 18 Dynasty 18 glasses and faience glazes (and, as yet, no other materials) from Amarna and the Fayum area fall within the range marked by brackets. The remaining crosses denote samples of kohl from various sites and of dates ranging from the Protodynastic period through Dynasty 18. Objects in the present isotope study are denoted by open circles. Five of these clearly fall within the same Amarna-Fayum range (including two Malkata samples), while 2181 and 2182 (Amenhotep II, nos. 26, 30) fall just outside it. No. 2183 (Tuthmosis IV, no. 35), falling slightly below the trend, might be considered borderline. Sizes of individual points are about $\pm 0.1\%$ of nominal values.

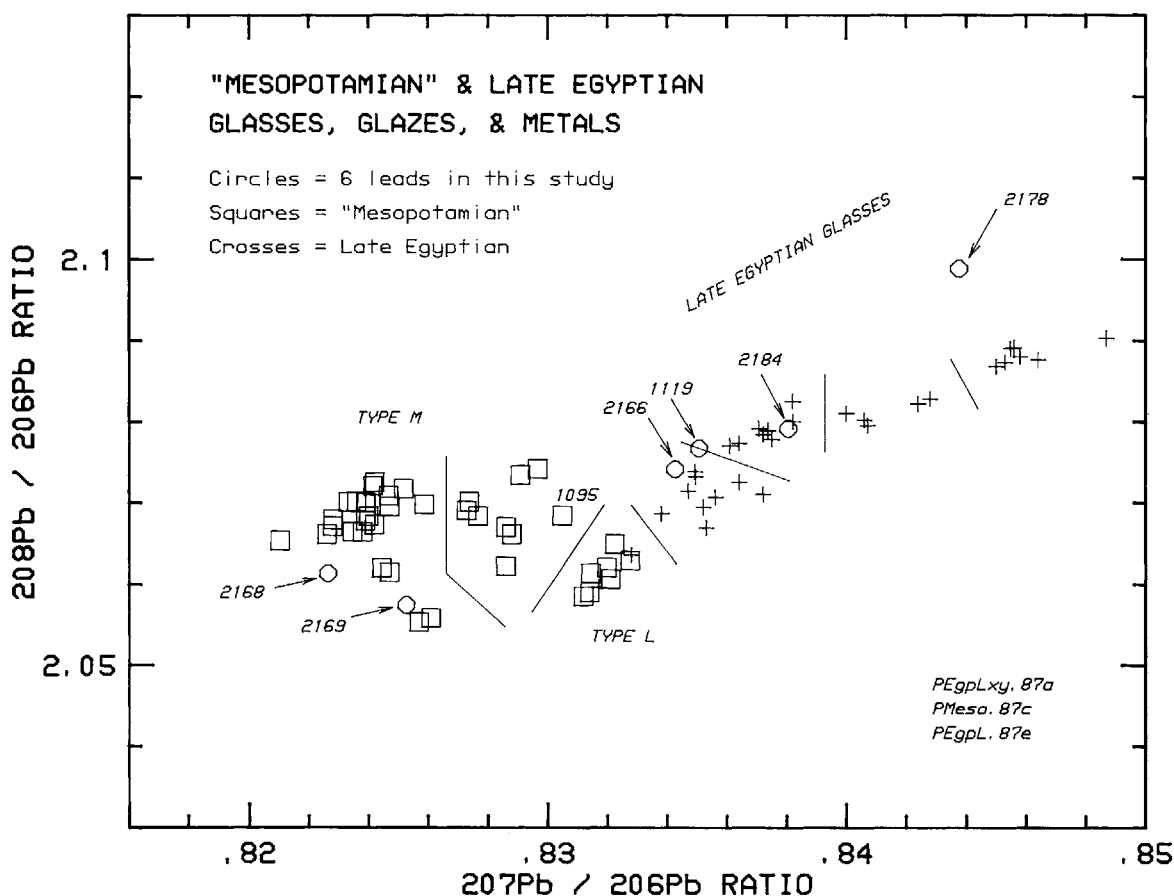


Fig.60 Expanded portion of Figure 58 showing Type M "Mesopotamian" and "late Egyptian" leads. Mesopotamian and Iranian samples are denoted by squares; late Egyptian glasses (chiefly Ptolemaic and Roman but also Dynasties 23 or 26) by crosses. Samples 1119 (Lisht) and 2184 (Tuthmosis III) resemble leads in the late Egyptian glasses. Samples 2168 (foreign wives goblet) and 2169 (tin bead) are on the borderline of Group M, and are clearly more like "Mesopotamian" artifacts than they are like their contemporaneous Egyptian counterparts which lie off this graph to the left. No. 1095 is from a marbled vessel sherd from Nuzi; 2166 from a marbled vessel sherd from Susa. Lines separate groups more or less as indicated in Tables 4 and 5. Sizes of individual points are about $\pm 0.05\%$ of nominal values.

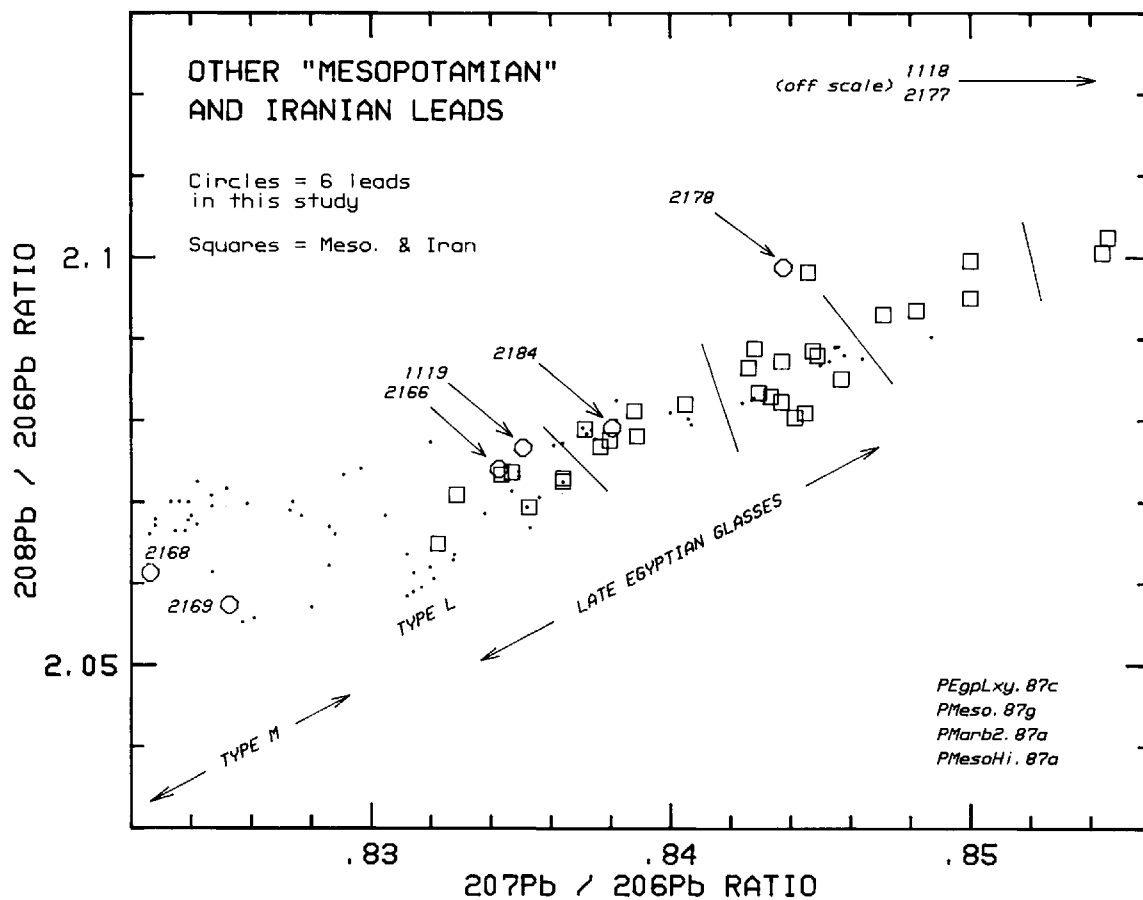


Fig.61 "Mesopotamian" and Iranian leads in addition to those in Group M, here denoted by squares. Lines separate groups more or less as indicated in last part of Table 4. Many of these leads generally overlap the late Egyptian glasses. Dots are Egyptian and Type M leads replotted from Figure 60. Axes are shifted slightly from Figure 60.

Chronology¹

	High	Low	Number of years
Dynasty 12	1963–1786	1937–1759	177/178
Amenemhat I through Amenemhat II:			
	1963–1866	1937–1840	97
Senwosret II	1868–1862	1842–1836	6
Senwosret III	1862–1843	1836–1817	19
Amenemhat III	1843–1798	1817–1772	45 minimum
Amenemhat IV	1798–1789	1772–1763	9
Sebekneferu	1789–1786	1763–1759	3/4
Dynasty 13	1786–1648	1759–1606	138/153
First 21 kings, including Sebekhotep III/ Kitchen's II (<i>Shm-r' sw3d-t3wy</i>) at 3 years:			
	1786–1723	1759–1696	63
Neferhotep I	1723–1712	1696–1685	11
Sihathor	1712	1685	3 months
Sebekhotep IV/Kitchen's III (<i>H'-nfr-r'</i>):			
	1712–1705	1685–1678	7
Sebekhotep V and ² I'-ib:			
	1705–1691	1678–1664	14
Merneferre	1691–1668	1664–1641	23
Later kings	1668–1648	1641–1606	20/35
Dynasty 15 (Hyksos)	1648–1540	1637–1529	108
and			
Dynasty 17	1648–1550	1606–1539	98/67
Known reigns:			
Sebekemsaf I (<i>Shm-r' w3d-h3w</i>)			16
Sebekemsaf II (<i>Shm-r' 3d-t3wy</i>)			1(+ x?)
Intef V (<i>Nwb-hpr-r'</i>)			2
Kamose			2
Dynasty 18	1550–1295	1539–1295	255/244
Ahmose	1550–1525	1539–1514	25
Amenhotep I	1525–1504	1514–1493	21
Tuthmosis I	1504–1492	1493–1481	12
Tuthmosis II	1492–1479	1481–1479	13/2
	No coregency A III/IV	Coregency	
Hatshepsut	1479–1457		22
Tuthmosis III	1479–1425		54
Amenhotep II	1427–1401	1427–1393	26/35
Tuthmosis IV	1401–1391	1393–1383	10
Amenhotep III	1391–1353	1383–1345	38
Akhenaton	1353–1337	1353–1337	16
Semenkhkare	1338–1336		2
Tutankhamun	1336–1327		9
Aye	1327–1323		4
Haremheb	1323–1295		28

1. Based on Kitchen 1987: pp. 49–52, 1989: pp. 152f., and letter of Feb. 5, 1990. The present state of knowledge allows for both a high and low chronology and for the existence of coregencies.

Frequently Cited Sources

Abbreviations:

- ASAE—*Annales du Service des Antiquités égyptiennes*
BM—British Museum
BMFA—Museum of Fine Arts Boston
BSA[E]—British School of Archaeology [in Egypt]
CG—Catalogue général des Antiquités égyptiennes du Musée du Caire, a publication project for objects in the Cairo Museum; not all objects numbered have been published
CMG—The Corning Museum of Glass
EEF—Egypt Exploration Fund
ERA—Egyptian Research Account
HSM—Harvard Semitic Museum
JdE—Journal d'Entrée, the register book of the Cairo Museum
JEA—*Journal of Egyptian Archaeology*
JGS—*Journal of Glass Studies*
KV—King's Valley, the Valley of the Kings at Thebes
LNP—Lisht North Pyramid, the site of MMA excavations
MÄS—*Münchener Ägyptologische Studien*
MMA—The Metropolitan Museum of Art
SR—Special Register, an inventory of the objects in each section of the Cairo Museum, made by the keeper of that section; understood to have been compiled in the 1960s
UC—University College London, location of the Petrie Museum
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E. Simpson, Figure 31 drawing

J. Wood, Figures 46 and 48 drawings

M. T. Wypyski, Table 1 with M. T. Wypyski data and R. H. Brill template; Table 3 with
R. H. Brill and M. T. Wypyski data and R. H. Brill template

Part 3:

R. H. Brill, Tables 1–5; Figures 58–61, with National Institute of Science and Technology data
and data of 17 new samples from H. Shirahata and R. D. Vocke, Jr.

