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GLASS OF AMENHOTEP II FROM TOMB KV55 IN THE VALLEY OF THE KINGS*

By PAUL T. NICHOLSON *and* CAROLINE JACKSON

Among the purported finds from KV55 is a piece of glass bearing the cartouche of Amenhotep II. This paper reviews the evidence for the discovery of this early fragment, and examines its composition with a view to determining its likely manufacturing origin. Comparison of the glass with some of the earliest Egyptian glass from reign of Thutmose III establishes that it may have been one of the earliest glasses actually manufactured in Egypt.

In 1907 the wealthy American businessman and Egyptologist Theodore Davis (1838–1915) and his assistant, professional Egyptologist Edward Ayrton (1882–1914), discovered a tomb in the Valley of the Kings. This they published in 1910[1] as the 'Tomb of Queen Tiyi', wife of Amenhotep III (1390–1352 BC), mother of Amenhotep IV/Akhenaten (1352–1336 BC), and grandmother of Tutankhamun (1336–1327 BC). The discovery has subsequently found fame, if not notoriety, as tomb KV 55, and debate has raged as to its occupant.[2] Recent work on the human remains found in the tomb[3] suggests that it may actually be the burial place of the 'heretic pharaoh' Akhenaten (1352–1336 BC) although this too is disputed.

Rather than discuss the tomb's owner, this paper examines an important piece of glass which is thought to have come from it.

The glass

The piece of glass in question (fig. 1) is from the collection of the Swansea Museum (accession number 959.3). It was first described by Bosse-Griffiths in 1961[4] and the details of its rediscovery as presented here come from her publication. The glass came

* Thanks are due to the Swansea Museum for their permission to sample the glass fragment during the time it was on loan to the Egypt Centre at Swansea University. The museum also kindly tried to trace the original box in which the material was donated by Sprake Jones. Thanks also to Steven Cross for information on the flood debris in the Valley of the Kings, and to Aidan Dodson for his views on KV55. Dylan Bickerstaffe kindly drew our attention to Aldred's paper on the Jones collection. The authors thank Phil Parkes (Cardiff University) for the production of the reference standards spectra and help with analysis. Panagiota Manti also assisted in the running of the S.E.M. Thanks are also given to the (formerly NERC) ICP-MS facility in Ascot, especially Beniot Disch and Kym Jarvis, and to NERC for supporting the trace element analysis (NERC OSS/ 340/ 0207).

[1] T. M. Davis, *The Tomb of Queen Tîyi* (London, 1910).

[2] See amongst others G. Daressy, 'Le cercueil de Khu-en-aten', *BIFAO* 12 (1916), 145–6; D. E. Derry, 'Note on the Skeleton Hitherto Believed to be that of King Akhenaten', *ASAE* 31 (1931), 115–9; R. Engelbach, 'The So-called Coffin of Akhenaten', *ASAE* 31 (1931), 98–114; A. Dodson, *Amarna Sunset* (Cairo, 2009).

[3] Z. Hawass, Y. Z. Gad, S. Ismail, R.Khairat, D. Fathalla, N. Hasan, A. Ahmed, E. Hisham, M. Ball, F. Gaballa, S. Wasef, M. Fateen, H. Amer, P. Gostner, A. Selim, A. Zink, and C. M. Pusch, 'Ancestry and Pathology in King Tutankhamun's Family', *Journal of the American Medical Association* 303/7 (2010), 638–47.

[4] K. Bosse-Griffiths, 'Finds from "The Tomb of Queen Tiye" in the Swansea Museum', *JEA* 47 (1961), 66–70.

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into the Swansea collection in a box marked 'gold dust from the tomb of Queen Tiye', given by Annie Sprake Jones.[5] Bosse-Griffiths recorded that Sprake Jones was the sister of Harold Jones (1877–1911) who served as an illustrator to Theodore Davis at the time that KV55 was discovered. Seeing that Davis was allowing visitors to the tomb to take 'souvenirs', Jones asked if he too might be permitted to take a handful of the dust from the tomb and was told 'Certainly, take two'.[6]

It is these handfuls of dust which Bosse-Griffiths believed to have yielded the glass fragment in question. The fragment is roughly triangular and measures 43 mm on its long side with shorter sides of 37 and 35 mm. The maximum thickness is 8 mm.[7] The body glass is opaque white, into which is marvered a swirl of brown or amber glass and—more significantly—a blue panel bearing cartouches in red and yellow.

The cartouches, which are surmounted by yellow plumes and red sun discs, are broken but the left one can still be read as *Imn* (Amun) and the right as *ꜥꜣ-ḫprw-rꜥ*, the name of Amenhotep II (1427–1400 BC).[8] According to Davis,[9] three small vases or parts of them, of white glass, were found in KV55.[10] However, these white vessels were

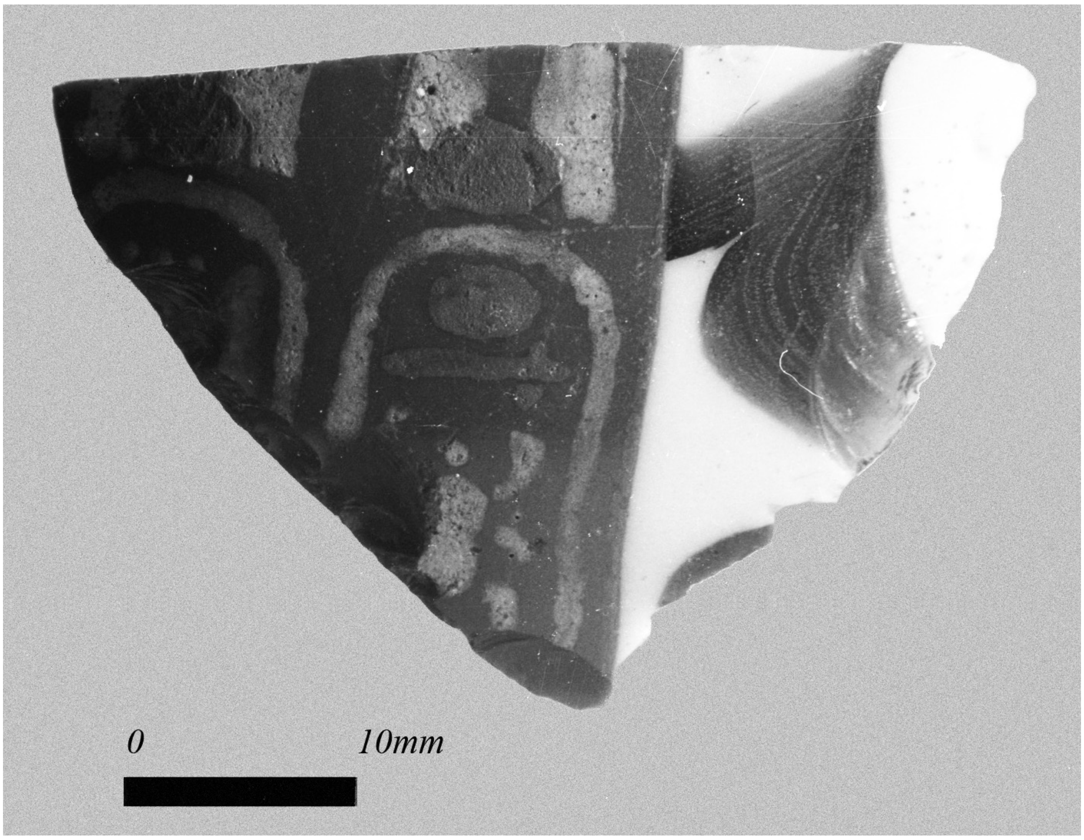

Fig. 1. Glass vessel fragment now in the collection of Swansea Museum (Swansea 959.3) and originally in the possession of Harold Jones. The piece was believed to have come from tomb KV 55 (photo: P. T. Nicholson).

5 Bosse-Griffiths, *JEA* 47, 66.
6 Ibid., 66 quoting from a conversation with Sprake Jones.
7 Ibid., 67.
8 Ibid., 67.
9 Davis, *Tîyi*.
10 Bosse-Griffiths, *JEA* 47, 67.

not decorated and so this sherd cannot be from one of them. A smashed oblong box which is recorded as having been 'full of small vases, wands and figures of blue glaze'[11] might seem to have been its source but whilst the names of Amenhotep III, Tiye, and of Akhenaten are known from objects from this box, nothing from it is recorded as bearing the name of Amenhotep II.

Bosse-Griffiths[12] noted that from the tomb of Amenhotep II himself (KV35), which had been discovered by Victor Loret (1859–1946) in 1898,[13] came vessels with the same colour combination and with the cartouches of the king. She discovered that one of these vessels lacked a small triangular fragment of glass with the same hieroglyphs as those on the Swansea fragment. It thus belonged to the vessel now in the Egyptian Museum.[14]

It has long been accepted that tomb KV55 was entered at some time in antiquity so that there is a possibility that material was removed at that time.[15] Forbes believes that this accidental discovery took place under Ramesses IX (1126–1108 BC) at which time the tomb's contents were defaced.[16] Similarly, the tomb of Amenhotep II himself (KV 35) served not only for his burial but was later opened and used as a royal mummy cache.[17]

Since no other objects bearing the name of Amenhotep II were found in tomb KV55, one must question the find spot of the Swansea fragment. Whilst the glass was clearly made for Amenhotep II, is it possible that it was originally part of the burial equipment of the occupant of tomb KV55? If so the vessel must have been broken before it was later moved to KV35 with just one sherd remaining in the dust where it was collected by Harold Jones. If, however, it were always in KV35 then one must wonder how the sherd came into the possession of Jones given that that tomb was cleared in 1898 some 5 years before he first went to Egypt to work for John Garstang (1876–1956),[18] and then subsequently for Davis.

The original burial place of the Cairo 24804 vessel (when complete) is of considerable significance in helping to understand the pattern of re-burials/re-entrances to KV55 and may have a bearing on the mummy known as 'the Elder Lady' found in KV35[19] and accepted by many as the mummy of Tiye herself,[20] probably moved from KV55.

There are at least two possible interpretations: first, the glass vessel comprising Cairo 24804 and Swansea 959.3 formed part of the original burial equipment of the occupant

[11] Davis, *Tîyi*.

[12] Bosse-Griffiths, *JEA* 47, 68.

[13] V. Loret, 'Le tombeau de Thoutmès III à Biban-el-Molouk: Le tombeau de Aménophis II et la cachette royale de Biban-el-Molouk', *BIE* 9 (1899), 3–24.

[14] Bosse-Griffiths, *JEA* 47, 68 (Cairo 24804).

[15] D. Forbes, 'The Phantom Pharaoh: Ankhkheperure Smenkhkare Djoserkheperure', *KMT* 19/1 (2008), 52–67.

[16] Forbes, *KMT* 19/1, 65.

[17] J. Baikie, *Egyptian Antiquities in the Nile Valley* (London, 1932), 68; Bosse-Griffiths, *JEA* 47, 68.

[18] W. R. Dawson, E. P. Uphill, and M. L. Bierbrier, *Who Was Who in Egyptology* (3rd edition; London, 1995), 219–20; C. Delaney, *A Son to Luxor's Sand* (Carmarthen, 1986).

[19] G. E. Smith, *The Royal Mummies* (Cairo1912), 39 and pl. xcvii.

[20] J. E. Harris, C. Kowalski, and G. F. Walker, 'Craniofacial Variation in the Royal Mummies', in J. E. Harris and E. F. Wente (eds), *An X-Ray Atlas of the Royal Mummies* (Chicago, 1980), 354, cited in D. Bickerstaffe, *Refugees for Eternity: The Royal Mummies of Thebes*, IV: *Identifying the Royal Mummies* (Loughborough, 2009), 105 n. 25; J. Fletcher, *The Search for Nefertiti* (London, 2004); Hawass et al., *JAMA* 303/7.

or occupants of KV55. When the tomb was re-entered and a decision made to move some of the material elsewhere for safekeeping, the vessel was broken. Since glass was precious, the fragments were collected up and moved to KV35 possibly along with the body of Queen Tiye. Only the Swansea fragment was missed. Cross[21] believes that this removal could not have taken place later than the reign of Ay (1327–1323 BC) since after that date the KV55 tomb was sealed by compacted flood debris which was still *in situ* at the time of Davis's excavation in 1907. Cross[22] therefore believes that this is the most likely scenario and that the glass fragment lost from the vessel was then collected by Harold Jones in the handfuls of dust which he collected from the tomb floor of KV55. Against this view is the fact that Jones was a member of the Davis expedition and should therefore have realised the importance of the glass fragment which, as the only artefact with the name of Amenhotep II, would have added to the discussion of the tomb. If this scenario is correct it must be assumed either (1) that in the darkness of the tomb Jones put the dust straight into a box and did not realise he had picked up the glass,[23] or (2) that he showed it to Davis who rejected it as of no significance, or (3) that Jones himself thought it of too little significance to bring to the attention of Davis or Ayrton.

In the second possible interpretation, the sherd was never in KV55 but was always part of the burial equipment of Amenhotep II in KV35. Lilyquist and Brill[24] quote Loret[25] as stating that fragments of faience and of a shabti were found outside the door of KV35, and a trail of fragments was found in the corridors, but glass fragments seem to have been confined to the burial chamber itself.[26] Given that the fragment collected by Jones joins the vessel Cairo 24804, it too should have come from the burial chamber. It could have come into Jones's possession having been picked up on a spoil heap by him or perhaps having been pilfered by one of Loret's workmen for later re-sale. If taken by a workman in 1898, it seems unlikely that it took around 9 years before it was offered for sale to Jones. This might suggest that it was picked up, possibly by Jones himself, amongst spoil form Loret's excavations in KV35 during the time that Davis was clearing KV55.

Aldred[27] offers what may be a third interpretation, namely that the glass fragment was purchased by Davis from a workman who claimed to have taken items from KV55 during the work. Aldred argues that Davis bought a job lot of items from this person since he was not able to differentiate between them sufficiently well to know whether or not they had actually come from the tomb. On looking at them more closely, Davis rejected several as coming from other sources and among them may have been the glass fragment now in Swansea. This, Aldred suggests, was given by Davis to Jones.[28]

[21] S. Cross, 'The Hydrology of the Valley of the Kings', *JEA* 94 (2008), 303–12; S. Cross, 'The Workmen's Huts and Stratigraphy in the Valley of the Kings: Dating the Flood', *JEA* forthcoming.

[22] Personal communication.

[23] This would only be likely if the box were fairly tall and deep so that the sherd was buried amongst the dust. Enquiries at the Swansea museum suggest that the box was discarded in the 1960s or later.

[24] C. Lilyquist and R. H. Brill, *Studies in Early Egyptian Glass* (New York, 1993), 28 n. 56.

[25] Loret, *BIE* 9, 3–24.

[26] Loret, *BIE* 9, 18 quoted in Lilyquist and Brill, *Studies*, 28 n. 56.

[27] C. Aldred, 'The Harold Jones Collection', *JEA* 48 (1962), 160–2.We are grateful to Aidan Dodson and Dylan Bickerstaffe for a discussion on the possibilities for the acquisition of the sherd.

[28] Ibid., 162.

The purchase of such a job lot of items is recorded in the diary of Emma B. Andrews, a copy of which is held by the Metropolitan Museum of Art in New York.[29] Whilst this view apparently provides a likely explanation for the origin of the sherd, it is not unequivocal. First, it was Howard Carter (1874–1939) who acted as 'honest broker'[30] between the dealer selling the antiquities and Davis. Carter might well have warned Davis that some of the pieces were not likely to be from KV55, and one might have expected Davis to be accompanied by Ayrton on his visit to the dealer. The diary says that 'Theo [Davis] went' to the dealers but doesn't specifically say that he did so alone.

Whilst Fairman[31] accepted Bosse-Griffiths' view of the glass, Aldred also drew attention to the faience pieces amongst the Jones collection which he says are much better preserved than any faience known to have come from the tomb itself, and that some are stylistically later.[32] Whilst this may be true, and so illustrate that not everything in Jones's collection came from KV55, they do not of themselves prove that the glass did not. Since the 1960s most scholars have taken the view that material was removed from KV55 into KV35 rather than *vice versa*. Aldred's view cannot, therefore, be taken as the last word on the subject. It certainly supports the view that the glass fragment had been stolen from KV35, but it does not prove that it was purchased as part of a job lot of material by Davis and then given to Jones. Like the other interpretations, there is not enough evidence to be sure, although the balance of evidence does tend to support an origin in KV35 and a later boxing with material from KV55.

Jones died at Luxor in 1911 and his property was returned to his family.[33] It is possible that those returning the items put the glass sherd amongst the 'gold dust from the tomb of Queen Tiye' or that Jones had done so himself.

It should be noted, however, that this is not the only glass from tomb KV55. There remain the three pieces recorded by Davis (see above). A small vase of white glass was reconstructed and stood some 6.5 cm high, and is described as having a 'violet tint denoting the use of manganese to some considerable extent for whitening it during the process of manufacture',[34] along with two other broken vases also of white glass. These were not illustrated by Davis but are said to have been similar to a faience piece in the shape of an *ankh*.

Whilst glass is clearly recorded in KV55, it has not been scientifically examined. The same is true of the early glass of Amenhotep II represented by Cairo 24804. Scientific analyses of glass in the Cairo collection is not generally permitted, but the Swansea fragment is able to serve as a proxy for this important early glass.

Glass had only been introduced to Egypt in around 1500 BC,[35] and we are only now beginning to fully appreciate that the Egyptians themselves may have quickly begun their own production[36] as early as the reign of Thutmose III (1479–1425 BC).

29 Aldred, *JEA* 48, 161.

30 Ibid., 162.

31 H. W. Fairman, 'Once Again the So-called Coffin of Akhenaten', *JEA* 47 (1961), 39.

32 Aldred, *JEA* 48, 161.

33 Bosse-Griffiths, *JEA* 47.

34 Davis, *Tîyi*, 36–7 and pl.iii.

35 H. C. Beck 'Glass Before 1500 B.C.', *Ancient Egypt and the Near East* (1934), 7–21; P. T. Nicholson, *Brilliant Things for Akhenaten: The Production of Glass, Vitreous Materials and Pottery at Amarna Site O45.1*. (London, 2007), 1–9.

36 P. T. Nicholson and C. M. Jackson, 'The Harrow Chalice: Early Glass or Early Fake?', *Annales of the AIHV* 18 (2012), 41–6.

Irrespective of whether it was ever in tomb KV55, it originally belongs to a period of time during which it seems that there were significant developments in the production of glass.

Despite the newness of this material there are signs that already by the reign of Amenhotep II the refinement of glass production and the re-modelling of the industry may already have begun.[37] The tomb of Amenhotep II is particularly rich in glass, with some 76 vessels represented, the tallest being *c.* 40 cm in height.[38] Although Nolte[39] has suggested individual workshops based on stylistic similarities between products, one need not assume that the scale of glass production was greatly enlarged at this time. Rather, it may be that we are seeing for the first time glass being worked as a material in its own right rather than being viewed as a kind of substitute stone.[40] This increased confidence in glass production might then be expected to yield confident experiments in glass making, but was all the raw glass used in these products actually made in Egypt?

Pieces of a similar design to the Cairo/Swansea piece and from KV35 have been analysed by Lilyquist and Brill,[41] but the Swansea fragment offers the opportunity to gain further information on the pieces in Cairo.

Whilst it is sometimes possible to suggest Egyptian provenance of glasses based on stylistic criteria, at other times this has proved difficult; some styles being attributed to a Near Eastern or Western Asiatic origin because they appear 'un-Egyptian', although sometimes the stylistic traits are similar between both provenances. By the Amarna period, even though furnaces and manufacturing debris have been recovered suggesting large scale production of glass and hence the inference that glass would be made in Egypt by this time,[42] there are still references to the importation of glass from outside Egypt in the *Amarna Letters*.[43] This makes assigning provenance purely on stylistic or find location grounds particularly difficult even at this later period. This separation of regions is particularly problematic in the pre-Amarna period (before about 1350 BC), when glass is known in Egypt and some is certainly being made there, but for which we have no identified furnaces. It is also known that at this time there was some import of glass to Egypt from the Near East, but the scale of this trade is not known.

Scientific techniques, however, can elucidate broad provenance based on differences in the raw materials used to manufacture the glasses. The premise for discrimination between glasses from Egypt and the Near East is that glass is made from raw materials procured locally in each region which will be reflected as differences in composition within the finished glass.[44]

[37] B. Nolte-Refior, 'Ägyptische Glasgefäße des Neuen Reiches', *Glastechnische Berichte* 40 (1967), 151.

[38] B. Nolte, *Die Glasgefäße im alten Ägypten* (Berlin, 1968), 54 and table II:2.

[39] Nolte, *Glasgefäße*.

[40] P. T. Nicholson, 'Glass Vessels from the Reign of Thutmose III and a Hitherto Unknown Glass Chalice', *Journal of Glass Studies* 48 (2006), 11–21; P. T. Nicholson, 'Stone That Flows: Faience and Glass in Egypt as Man Made Stones', *Journal of Glass Studies* 54 (2012), 11–23.

[41] Lilyquist and Brill, *Studies*.

[42] Nicholson, *Brilliant Things*; E. Pusch and T. Rehren, *Rubinglas für den Pharao* (Forschungen in der Ramses-Stadt 6; Hildesheim, 2007).

[43] W. L. Moran, *The Amarna Letters* (Baltimore, 1992).

[44] E. V. Sayre, 'Some Materials of Glass Manufacturing in Antiquity', in M. Levey (ed.), *Archaeological Chemistry* (Philadelphia, 1967), 287–90; C. M. Jackson, J. W. Smedley, and C. M. Booth, 'Glass by Design? Raw Materials, Recipes and Compositional Data', *Archaeometry* 47/4 (2005), 781–95; T. Rehren, 'A Review of Factors

Chemical analyses have shown that Bronze Age Egyptian and Near Eastern glasses are produced using silica derived from quartz pebbles or sand as the main glass former, and a plant ash, rich in sodium.[45] The most likely glass former used in Egyptian glasses may be pure quartz pebbles which contain little in the form of impurities which will be transferred to the glass.[46] As a result it is the plant ash which is thought to be the most promising discriminator between these early glasses, as plants grown in differing geological environments should display different compositions which should then be transferred to the glasses.[47]

Most analytical research on Egyptian glasses has concentrated on the Amarna period or later.[48] These studies have measured the *major and minor* elements in the glass with a view to differentiating between glasses found in different locations. The results suggest that some glasses, such as those coloured blue with cobalt, could be differentiated on the basis of the colouring minerals used. However, for those colours of glass where the colourant did not have any specific, provenance-related, features the composition was so similar as to prevent discrimination. This applies to the copper blue glasses. This lack of discrimination may be explained in part by the increase in trade at this time in the late Bronze Age. Until recently it was accepted that whilst glass production in the two regions was well established, and glass from each region *should* exhibit compositional differences, the movement of peoples, ideas, raw materials, and finished goods at this time may be blurring any compositional or even stylistic differences—hence the compositional differences, using major and minor elements, were not clear.

However, more recent analytical research, using laser ablation inductively coupled plasma mass spectrometry, on glasses of the mid-fourteenth century BC has shown that there are some differences in the *trace* element compositions between glasses from Egypt and the Near East,[49] which have subsequently been reinforced by isotope analysis of glasses from the same regions.[50] These elemental differences have again been attributed to the differing geology between the two areas, and potentially to the use of different plants or to the clay fraction incorporated into the glass from the crucible. Whilst specific provenance to a particular manufacturing *site* cannot be established, these differences indicate that the raw materials used to manufacture glass found in Egypt have different

Affecting the Composition of Early Egyptian Glasses and Faience: Alkali and Alkali Earth Oxides', *Journal of Archaeological Science* 35 (2008), 1345–54.

45 W. E. S. Turner, 'Studies of Ancient Glass and Glassmaking Processes, V: Raw Materials and Melting Processes', *Journal of the Society of Glass Technology* 40 (1956), 277–300; R. H. Brill, 'The Chemical Interpretation of the Texts', in A. L. Oppenheim, R. H. Brill, D. Barag, and A. Von Saldern, *Glass and Glassmaking in Ancient Mesopotamia* (Corning, 1970), 122; Lilyquist and Brill, *Studies*, 42.

46 C. M. Jackson and P. T. Nicholson, 'Compositional Analysis of the Vitreous Materials Found at Amarna', in Nicholson, *Brilliant Things for Akhenaten*, 102.

47 Jackson et al., *Archaeometry* 47/4, 781–95.

48 W. E. S. Turner, 'Studies of Ancient Glasses and Glassmaking Processes, I: Crucibles and Melting Temperatures Employed in Ancient Egypt at about 1370 B.C.', *Journal of the Society of Glass Technology* 38 (1954), 436–44; E. V. Sayre and R. W. Smith, 'Analytical Studies of Ancient Egyptian Glass', in A. Bishay (ed.), *Recent Advances in Science and Technology of Materials: Proceedings, Cairo Second Solid State Conference, 1973* (New York, 1974), 47–70; M. J. Tite and A. J. Shortland, 'Production Technology for Copper–and Cobalt–Blue Vitreous Materials from the New Kingdom Site of Amarna: A Reappraisal', *Archaeometry* 45/2 (2003), 285–312; A. Shortland, N. Rogers, and K. Eremin, 'Trace Element Discriminants between Egyptian and Mesopotamian Late Bronze Age Glasses', *JAS* 34 (2007), 781–9.

49 Shortland et al., *JAS* 34.

50 J. Henderson, 'Isotopic Evidence for the Primary Production, Provenance and Trade of Late Bronze Age Glass in the Mediterranean', *Mediterranean Archaeology and Archaeometry* 10/1 (2010), 1–24.

trace element compositions to those used in the Near East, and thus different regions of manufacture can be defined using trace elements whose characteristics have been transferred to the glass.

These trace element datasets were compiled from the analysis of glasses from Amarna and Malkata in Egypt, and from Nuzi and Tell Brak in the Near East,[51] all of them sites with glass of a later date than that analysed here. However, this data, based as it is on underlying geology, can be used as a first indication for possible provenance as the differences relating to geology should be similar over relatively long periods of time. The differences in compositional patterning in the glasses from the two regions relates to the ratios of chromium and lanthanum and the total concentrations of titanium and zirconium in the glasses. These indicators of provenance can be used to inform the analysis of the Amenhotep II glass from the Swansea collection[52] and to suggest a broad link to either an Egyptian or Near Eastern source for this glass. To shed further light upon the possible origin of the Swansea vessel, and to establish whether this glass could have been manufactured in Egypt, a small sample of glass was analysed to determine its major, minor, and trace element composition. A tiny fragment of the vessel was removed, mounted in epoxy resin and polished to 1.4 micron using diamond paste. The sample contained dark blue, white, and amber glass and each colour was analysed separately.

Analytical procedure

The major and minor elements were determined using a *CamScan Maxim 2040* scanning electron microscope equipped with an *Oxford Instruments ISIS* energy dispersive X-ray spectrometer (SEM-EDX) at the School of History, Archaeology, and Religion, Cardiff University, Wales. For elemental analysis, the electron beam was rastered at a magnification of 500× over an area of fresh glass for 100 s, at 20 kV accelerating voltage. Standards used to calibrate the spectrometer were pure oxides and minerals, and quantification was carried out using the ZAF method. Oxide weight percents were calculated stoichiometrically. A *Corning A* standard was run every four analyses to calculate accuracy and precision of the data, the results of which are reported in table 1. The precision and accuracy for most analyses are within 10%; that for aluminium oxide falls within this band when the revised figures from Brill[53] are used. Each colour on the Swansea fragment was analysed four times to obtain a mean composition because of glass heterogeneity (which is usual in archaeological samples); two different areas of the white glass were analysed.

Trace elements were determined using a *CETAC LSX-100* laser ablation system (working wavelength of 266 nm, quadrupled from Nd:YAG laser fundamental at 1064 nm) in conjunction with an *Agilent 7500c* ICP-MS instrument at Imperial College, Ascot (LA-ICP-MS). Samples were mounted in standard electron microprobe resin blocks and ablated under an atmosphere of argon. Ablation conditions and equipment parameters are reported in Jackson and Nicholson.[54] Analyses were calibrated against

[51] Shortland et al., *JAS* 34.

[52] Shortland et al., *JAS* 34; C. M. Jackson and P. T. Nicholson, 'The Provenance of Some Glass Ingots from the Uluburun Shipwreck', *JAS* 37 (2010), 295–301.

[53] R. H. Brill, *Chemical Analyses of Early Glasses* (Corning, 1999), II.

[54] Jackson and Nicholson, *JAS* 37, 297.

NIST SRM 610 glass reference material, doped with a nominal concentration of 500 ppm for most trace elements, and using the consensus values.[55] NIST 610 was measured throughout the duration of the session to allow for correction of instrument drift. Detection levels were calculated using a blank and only those values which are above 3 standard deviations above the mean background concentrations (3 sigma, 99% confidence) were reported. Data was normalised using Ca. Repeat measurements of SRM NIST 612 were made throughout to assess accuracy for the total run (which included many more samples, hence 30 replicates of NIST 612 are reported) and the results of those analyses are reported in table 2. Trace elements show a good correspondence with the consensus values for NIST 612,[56] and thirty replicates over the run showed precision and accuracy generally better than 10% (although it must be noted that these figures are regularly challenged in the literature) and therefore should be used as a guideline.[57] Each colour in the sample was analysed three times and a mean of the three analyses used; moreover two different areas of white glass were analysed. In figs 2 and 3, showing the Swansea trace element data, the symbols used to denote each colour are enlarged to demonstrate an error around the mean (centre) value.

TABLE 1 *Corning A Reference (values in wt%) (consensus from R.H. Brill, 'A Chemical-Analytical Round-Robin of Four Synthetic Ancient Glasses', in* Proceedings of the IXth International Congress on Glass *(Paris, 1971), 93–110)*
**The value for aluminium oxide was revised by Brill,* Chemical Analyses*, 544 and the accuracy using these revised figures would be -9.18 wt%*

Analyte	Concensus	Mean	1SD	RDS (precision)	Relative Error (accuracy)
NA_2O	14.40	13.42	0.92	6.85	-6.79
MgO	2.75	2.50	0.18	7.07	-9.26
Al_2O_3	1.14	0.91	0.05	5.86	-20.33*
SiO_2	66.4	64.51	3.59	5.56	-2.85
K_2O	2.88	2.92	0.18	6.03	1.39
CaO	5.29	5.17	0.34	6.64	-2.32
Fe_2O_3	1.07	1.04	0.06	5.60	-2.89
Sb_2O_5	1.76	1.49	0.23	15.60	-15.24

[55] N. J. G. Pearce, W. T. Perkins, J. A. Westgate, M. P. Gorton, S. E. Jackson, C. R. Neal, S. P. Chenery, 'A Compilation of New and Published Major and Trace Element Data for NIST SRM 610 and NIST SRM 612 Glass Reference Materials', *Geostandards Newsletter: The Journal of Geostandards and Geoanalysis* 21/1 (1997), 115–44.

[56] Ibid.

[57] E.g. K. P. Jochum, U. Weis, B. Stoll, D. Kuzmin, Q. Yang, I. Raczek, D. E. Jacob, A. Stracke, K. Birbaum, D. A. Frick, D. Günther, and J. Enzweiler, 'Determination of Reference Values for NIST SRM 610–617 Glasses Following ISO Guidelines', *Geostandards and Geoanalytical Research* 35/4 (2011), 397–429.

TABLE 2 *NIST 612 Reference (values in ppm) (consensus from Pearce et al.,* Geostandards Newsletter: The Journal of Geostandards and Geoanalysis *21/1)*

Analyte	Concensus	Mean (n=30)	1SD	RDS (precision)	Relative Error (accuracy)
Cu	37	44.8	9.47	21.2	20.9
Mn	38	39.9	6.02	15.1	5.1
Ti	48	41.5	6.20	14.9	6.4
Cr	36	40.2	5.30	11.7	11.7
Co	35	35.4	2.84	8.0	1.2
Ni	39	43.1	3.66	8.5	10.5
Zn	38	43.3	9.31	21.5	13.8
Ga	36	39.8	3.97	10.0	10.6
Rb	31	35.7	4.06	11.4	15.3
Sr	78	75.4	5.49	7.3	-3.3
Zr	38	36.6	3.09	8.5	-3.7
Ba	40	36.8	3.36	9.1	-7.9
La	36	36.8	2.16	5.9	2.1
Ce	39	31.8	1.90	6.0	-18.4
Pr	37	35.7	2.20	6.2	-3.5
Nd	36	34.6	3.45	10.0	-3.9
Sm	38	36.6	3.12	8.5	-3.6
Eu	35	35.6	2.40	6.7	1.6
Gd	37	33.7	3.34	9.9	-8.8
Tb	36	36.0	2.42	6.7	0.0
Dy	36	33.6	2.47	7.4	-6.6
Ho	38	36.8	3.01	8.2	-3.2
Er	38	34.1	2.54	7.4	-10.2
Tm	38	34.2	2.62	7.7	-10.1
Yb	39	37.9	3.19	8.4	-2.9
Lu	37	34.6	2.81	8.1	-6.6
Pb	39	40.4	7.42	18.4	3.5
U	37	41.0	4.17	10.2	10.9

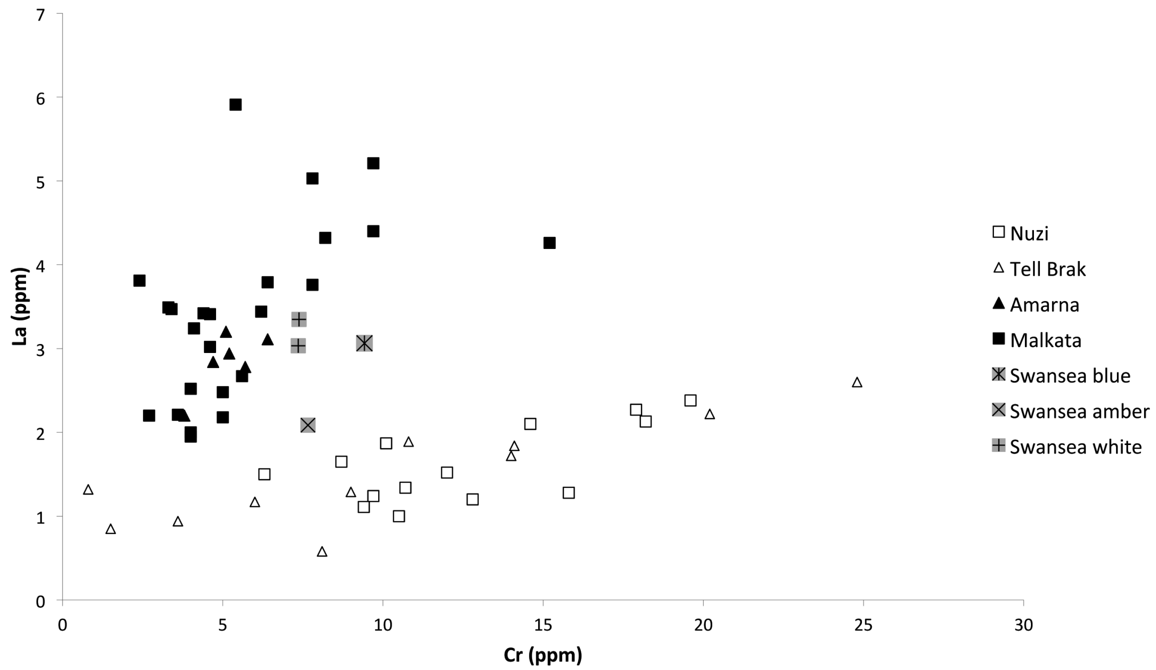

Fig. 2. Trace element analysis of glass from Egypt and the Near East analysed by Shortland et al., *JAS* 34, showing the different ratios of Cr and La for glasses from the two regions. The trace element concentrations of Cr and La for the blue, amber, and opaque white from the Swansea glass are superimposed on the distribution.

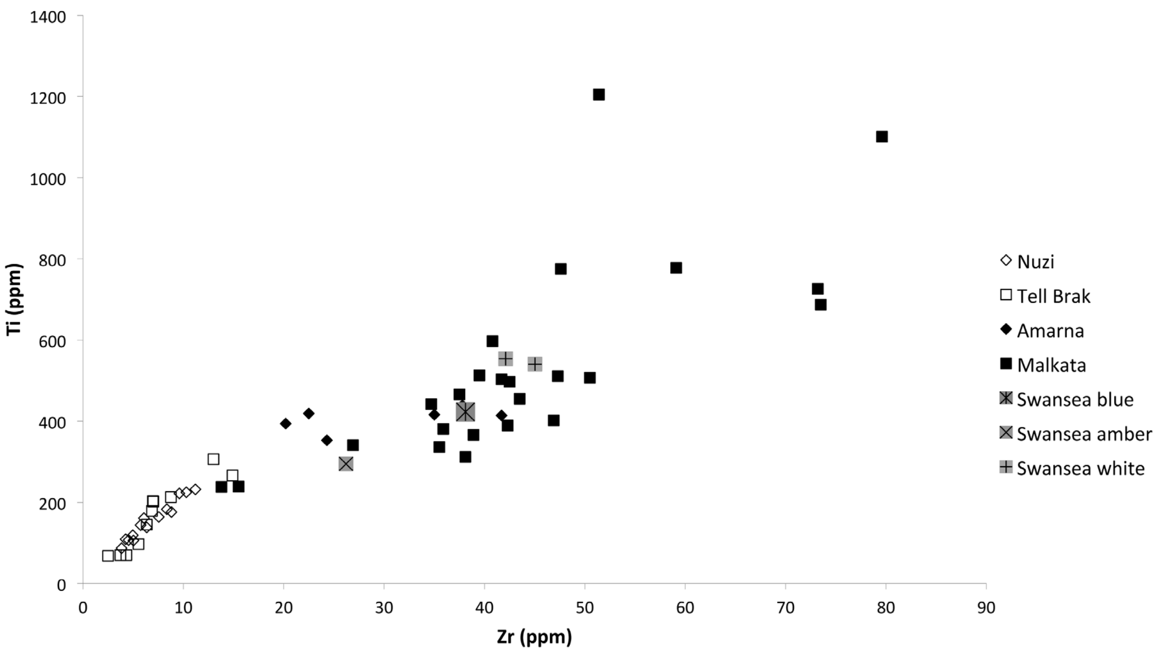

Fig. 3. Trace element analysis of glass from Egypt and the Near East analysed by Shortland et al., *JAS* 34, showing the different concentrations of Ti and Zr for glasses from the two regions. The trace element concentrations of Cr and La for the blue, amber, and opaque white from the Swansea glass are superimposed on the distribution.

Results

The results of the analyses of the glass from the Swansea vessel are presented in table 3 which shows both major and minor elements determined by SEM-EDX and trace elements determined by LA-ICP-MS. The major elements show that this is a soda-ash plant glass typical of glass of this period and locale. In order to explore this composition within context, analyses of analogous published glasses are discussed below along with the composition of the Swansea fragment.

TABLE 3 *Major, minor, and trace element concentrations for the Swansea vessel by colour (oxides reported in wt%, elements in ppm; n.d.—below detection)*

Analyte	Blue	Amber	White	White
Na2O	14.37	19.24	18.09	17.79
MgO	3.06	4.40	4.52	4.48
Al2O3	2.29	0.56	0.80	0.76
SiO2	62.29	64.77	62.30	61.12
K2O	1.43	2.55	2.55	2.44
CaO	6.21	6.84	7.78	7.96
Fe2O3	0.46	0.37	0.38	0.46
Sb2O5	1.07	0.27	2.25	2.98
Cu	129.0	66.9	119.7	134.7
Mn	1659.1	257.9	244.2	232.3
Ti	422.7	294.7	553.9	540.5
Cr	9.4	7.7	7.4	7.4
Co	2402.2	10.5	6.6	6.5
Ni	1115.9	11.6	10.8	9.2
Zn	1788.0	43.3	29.1	29.9
Ga	1.2	0.6	2.7	1.2
Rb	4.5	8.8	10.1	10.3
Sr	404.1	518.8	665.1	661.2
Zr	38.1	26.2	42.1	45.0
Ba	32.7	33.5	41.7	47.1
La	3.1	2.1	3.0	3.3
Ce	7.1	3.0	5.5	4.9
Pr	1.3	0.5	0.8	0.8
Nd	6.0	1.4	3.5	3.7
Sm	2.0	0.8	0.9	0.7

Analyte	Blue	Amber	White	White
Eu	0.7	n.d.	0.2	0.2
Gd	3.2	0.6	0.5	0.9
Tb	0.4	n.d.	0.1	0.1
Dy	2.4	0.3	0.5	0.6
Ho	0.4	n.d.	0.1	0.1
Er	0.8	0.3	0.4	0.3
Tm	0.1	n.d.	0.1	0.0
Yb	0.6	0.3	0.4	n.d.
Lu	0.1	0.1	0.1	0.1
Pb	193.1	3.0	620.1	634.8
U	0.9	0.2	0.4	0.4

Analysis of glass of the period from the Tomb of Amenhotep II (KV35) by Scanning electron microscopy using an analytical energy dispersive X-ray fluorescence spectrometer by Lilyquist and Brill[58] provides comparative major and minor oxide data with which to compare the Swansea sherd; it is stylistically similar and of a similar date. Their analyses show that the vessels from the tomb followed a tradition of glass production which can be traced back to those of Tuthmosis III.[59] There are no compositional traits in the earlier glasses from Tuthmosis III, nor the later ones from Amenhotep II, which would suggest a change in manufacturing practices, *except* that the compositions become more homogenous and more standardised as glass production in Egypt develops. They suggest that although some of these glasses may have been made in Egypt their influence was Asiatic.

In terms of the major element composition the white, blue, and amber glass of the Swansea fragment is similar in composition to the same colours seen in the fragments from KV35 analysed by Lilyquist and Brill;[60] both are glasses produced with very similar types of soda-rich plant ashes. The Swansea fragment cannot be distinguished from the glasses analysed from the tomb of Amenhotep II—and the same lower potassium concentrations can be observed in all the dark blue glasses (table 3). The white glasses in the samples from KV35 and from Swansea are opacified using antimonates, and the blue coloured with a cobalt mineral probably derived from an Egyptian cobalt aluminate.[61] The cobalt blue glass from Swansea also displays the characteristic trace concentrations of zinc observed by Lilyquist and Brill[62] in other pre-Malkata cobalt blue glasses from Egypt (table 3). Furthermore, lead isotope analysis of two of their pre-Malkata samples indicated a presumed Egyptian provenance for the lead in the glass

[58] Lilyquist and Brill, *Studies*.
[59] Ibid., 43.
[60] Ibid., 37–9.
[61] A. Kaczmarczyk, 'The Source of Cobalt in Ancient Egyptian Pigments', in J. S. Olin and M. J. Blackman (eds), *Proceedings of the 24th International Archaeometry Symposium* (Washington, 1986), 369–76.
[62] Lilyquist and Brill, *Studies*, 42.

although this could not be matched to known Egyptian sources.[63] Whilst Lilyquist and Brill[64] infer an Egyptian origin for their glasses from the tomb of Amenhotep II, their conclusions are based on major element analysis and tentative lead isotope analysis of the yellow glasses, and are not unequivocal. Thus, although the glass from Swansea is similar to other contemporary glass from Egypt, that alone does not firmly establish its provenance. In fact, the major and minor element compositions for all of these early glasses, including the Swansea fragment, are not distinguishable from later Egyptian glasses analysed by other authors *or* from glasses from the Near East[65]

The analysis of trace elements using very small samples was not available or developed for use on archaeological material at the time Lilyquist and Brill[66] published their analyses of early glasses. As a result, there is no comparative trace element data from very early glasses to compare with those trace elements measured in the Swansea fragment. However, the trace element data from the Swansea fragment can be compared to that of *later* Egyptian and Near Eastern glasses.[67] The trace element compositions from the blue, white, and amber glass from the Swansea sample are plotted alongside data taken from Shortland et al.[68] (table 3, figs 2 and 3). It is clear that the chromium and lanthanum values in the Swansea fragment plot nearer to the later Egyptian glasses than those from the Near East (fig. 2). The blue and white glasses are clearly within an Egyptian distribution, although the amber fragment falls between the later Egyptian and Near Eastern samples. However, when the zirconium and titanium values are plotted all fragments fall clearly within the Egyptian glasses analysed (fig. 3). It could be argued that the amber fragment, although securely within the Egyptian distributions for zirconium and titanium, falls nearer to those of the Near East. Although the reason for this is not clear, one explanation is that it *may* be due to glass being produced in 'colour centred' complexes. Each of these centres may have been manufacturing raw glass from local raw materials, some specialising in particular colours, which were then traded as ingots or blocks and used to produce vessels at another location; some of these secondary glass working locations would have been within Egypt.[69] This would present itself compositionally within the glass as slightly different ratios of trace elements in different glass colours, but all within a broad Egyptian origin. Using our present understanding of the published data, it is unlikely this amber glass originated in the Near East, although further studies may elucidate this. Whatever the history of manufacture of the different glass colours which have been used to manufacture this vessel, these combined analytical results substantiate an Egyptian origin for this piece.

[63] Ibid., 61.
[64] Ibid.
[65] E.g. Sayre and Smith, *Recent Advances*; Brill, *Chemical Analyses of Early Glasses* II; J. Henderson, 'Chemical Analysis of Ancient Egyptian Glass and its Interpretation', in P. Nicholson and I. Shaw (eds), *Ancient Egyptian Materials and Technology* (Cambridge, 2000), 206–24; Shortland et al., *JAS* 34.
[66] Lilyquist and Brill, *Studies*.
[67] Shortland et al., *JAS* 34.
[68] Shortland et al., *JAS* 34.
[69] Rehren and Pusch, *Science*; C. M Jackson, 'Archaeology: Glassmaking in Bronze-Age Egypt', *Science* 308 (2005), 1750–2.

Conclusions

Whilst the original provenance of the Swansea sherd cannot be proven beyond doubt it seems to us likely that it was always part of the burial equipment of Amenhotep II in KV35 and was subsequently acquired by Jones. Whilst the argument made by Cross for the sealing of tomb KV55 by flood debris around the reign of Ay is convincing in its own right, the glass fragment cannot, we feel, be used to help substantiate the move of the mummy of Queen Tiye (if the 'Elder Lady' is accepted as she) to KV35. Rather, the significance of the glass lies in its ability to stand proxy for analyses of vessel Cairo 24804 which belongs to a time of important developments in the Egyptian glass industry.

The stylistic and compositional evidence from the Swansea sherd, and thus vessel Cairo 24804, points to an Egyptian origin for its manufacture, and to the use of local raw materials which are comparable with other Egyptian vessels manufactured using plant ashes. In the case of the colour, the cobalt mineral used to colour the blue glass matches that seen in other Egyptian vessels of varying dates. Contemporary glasses analysed by Lilyquist and Brill[70] have a similar major element composition to this piece, including the use of a local colorant in the form of a cobalt alum, probably derived from the Kharga or Dakhla oases.[71] The gaining of this important raw material may indicate an established production network associated with royal control. Further trace element analysis of the contemporary Amenhotep II vessels examined by Lilyquist and Brill in 1993 would help to establish an unequivocal foundation for an Egyptian origin for all these vessels.

The history of Egyptian production of glass can be extended further back in time, at least to the reign of Thutmosis III with the analysis of a sample from the Harrow Chalice.[72] This strongly suggests that glass was produced from a relatively early period in Egypt, and was well accepted in Egypt long before the Amarna period when glass production becomes an established industry, as indicated by the discovery of furnaces at Amarna itself and of the wide range of glass objects of this period.

Whilst the early date by which local glass production is established in Egypt may be surprising, we should probably be less surprised by the complexity of the trade in glass in the ancient world. Glass was a desirable, high-status commodity, and a material which was evidently considered fit for exchange between kings. The view, based on a narrow reading of the *Amarna Letters*, that glass must always have been an import to Egypt and that the Egyptians could only *work* (rather than *make*) glass should be abandoned.[73] It is evident that the Egyptians quickly established an industry in the country and, whilst they may have initially depended on some foreign raw materials, this dependency reduced over time. It is not unlikely that as further analyses are undertaken we will see a pattern of replacement of, for example, Near Eastern lead with local Egyptian sources.

That foreign designs have influence in Egypt should also not be surprising. During the New Kingdom there are increasing influences from abroad, including a broader colour palette in vitreous materials. The influence of these foreign colours and motifs is exactly that—influence rather than dependence.

[70] Lilyquist and Brill, *Studies*.
[71] Kaczmarczyk, in Olin and Blackman (eds), *Proceedings*, 369–76.
[72] Nicholson and Jackson, *Annales of the AIHV* 18, 41–46.
[73] See R. Newton. and S. Davison, *Conservation of Glass* (London, 1989),62.