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The investigation and provenance of glass vessel fragments attributed to the tomb of Amenhotep II, KV35, Valley of the Kings.

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Abstract

Four polychrome glass fragments, excavated from tomb KV35 in the Valley of the Kings, attributed to Amenhotep II, were analysed to further investigate the composition and provenance of early Late Bronze Age glasses. An additional fragment, EA64163, cited by the British Museum as being stylistically analogous to the fragments from KV35, although with a findspot simply recorded as "Thebes", was also analysed. LA-ICP-MS analysis was used to analyse multiple colours on the fragments to determine the major element composition, the colouring strategies and establish provenance using trace element analysis. The resulting data obtained was compared with four polychrome fragments of standard LBA Egyptian composition, excavated from the palace of Amenhotep III at Malkata, previously analysed by SEM-WDS. Analysis showed that the glasses excavated from KV35 are standard LBA glass of Egyptian composition and were most likely produced in Egypt in the 18th Dynasty. The fragment EA64163 is a low magnesia, low potash glass, comparable with Iron Age composition, therefore should be reconsidered as a later glass. The analysis of glasses, excavated from a reliable, early Egyptian context supports the proposition that glass technology for multiple colours was established in Egypt at least as early as 1400 BCE.

Introduction

The first man-made glass appears in the archaeological record in quantity in the Late Bronze Age (LBA) of Egypt and the Near East. There are early, sporadic finds of glass stretching back to the third millennium BCE (Beck, 1934; Peltenburg, 1987; Moorey, 1994 p190-2), but it is fifteenth century contexts where the first glass in any quantity is found. Most commentators of the last thirty or so years have placed the source of the glassmaking innovation in the Near East, perhaps in Northern Syria (Lilyquist, Brill and Wypyski, 1993; Nicholson, 1993; Moorey, 1994; Shortland *et al.*, 2017). However, recent re-examination of finds and their contexts have suggested that this is by no means as clear as first thought and proposed that it is difficult to determine whether Egypt or the Near East was the source of the first glass (Shortland *et al.*, 2017). Certainly, there are good textual and iconographic sources that show that glass was a prized commodity in the LBA, with a value similar to a precious stone, at least in the first century of its production (Oppenheim, 1973; Nicholson, Jackson and Trott, 1997). As such, glass was used for several purposes, including beads, inlays, and amulets. However, the most significant object produced in glass was the core-formed glass vessel, manufactured by hot-working the glass around a clay/dung core (Nicholson and Henderson, 2000, p203). The most common body colour was blue, ranging from light to very dark blue hues, and vessels were often decorated with contrasting colours including yellow and white. Glass in green, red, brown, colourless, and black were also used, but less often in vessels (Nolte, 1968). It is also often the case that vessels that appear black are in fact very dark purple, blue, or brown.

Because of its perceived high value and portability as beads, jewellery and ingots, glass was therefore part of a wide-ranging exchange network, with evidence that Egyptian and Near Eastern glass was being transported as far as Mycenae (Walton *et al.*, 2009) and later as far as northern Europe (Varberg, Gratuze and Kaul, 2015; Varberg *et al.*, 2016). The Ulu Burun shipwreck found off the southern coast of Turkey and dating to around 1300 BCE contained a large consignment of glass ingots, some or all of which originated in Egypt (Nicholson, Jackson and Trott, 1997; Pulak, 2001; Jackson and Nicholson, 2010) Glass is therefore an interesting material to attempt to provenance, being of markedly high-value and apparently widely traded.

Glass discovered in Egypt tends to be almost always found in royal tombs in this earliest period, with the first regular finds of glass to be recovered in palaces, temples, workshops, or other urban settings not common until the fourteenth century BCE. Early glass objects excavated in Egypt, such as beads, are seen from the tomb of Queen Ahhotep, mother of Ahmose (1550-1525 BCE), and from contemporary tombs in Qau (Lilyquist *et al.*, 1993, p23). Blue transparent beads and a glass scarab were excavated from a later tomb from the site of Gurob, the location of the Harem palace established during the reign of Tuthmosis III (1479-1425 BCE) although these were items were determined as being Mesopotamian in origin (Kemp, McDonald, A and Shortland, 2017; Kemp *et al.*, 2019). It is during the reign of Tuthmosis III where glass vessels appear in quantity and from multiple sources, such as the tomb of the three foreign wives and the tomb of Tuthmosis III, KV34 (Lilyquist *et al.*, 1993, p25-6). *Die Glassgefässe im alten Ägypten* describes and dates (where possible) the largely intact early glass vessels excavated or acquired in Egypt, thereby establishing a timeline (Nolte, 1968).

We are fortunate to have an excellent chronology for the Egyptian kings, which means many of these tombs can be dated to a particular decade, or with even greater accuracy. In the Near

East, the pattern is more mixed, and the dating can be problematic, in part due to the less expedient preservation conditions. Work by Dardeniz extends the glassmaking regions to northern Syria, specifically Tell Atchana, Ancient Alalakh, proposing that production in this area may pre-date workshops at Amarna (Dardeniz, 2018). Further evidence is pending to support an early glassmaking industry, specifically a detailed chronology for the site and the dating of pyrotechnic installations at Tell Atchana. It is therefore to Egypt that one first looks in order to investigate the beginning of glass production.

This paper analyses glass attributed to KV35, the Tomb of Amenhotep II (1427-1401 BCE) with the aim of demonstrating whether this early glass might have been made in an Egyptian workshop or imported from the Near East.

Dating glass

Attempts to date early glass objects stylistically have been problematic. As mentioned above, there seems a preference for many early glass vessels in blue, but certainly not all blue glasses are among the first vessels produced. A safer method of dating is to resort to the classic archaeological procedure of context. For example, it is very likely that glass recovered from the Valley of the Kings tombs of Tuthmosis III (KV34) and Amenhotep II (KV35) dates to those kings' reigns. A second way of dating the glass is where the glass object has a king's name inscribed upon it. Egyptian kings of this period have distinguishing names which are represented in a "cartouche". It is likely that an object that bears a king's cartouche dates to his reign, but some kings were the subject of cults after their death, so it is possible, if unlikely, that they could be later.

This represents the simple pattern for dating an object, but it should be noted that it can be more complex than this. Good examples are two small, turquoise-coloured glass persea fruits which were found by Howard Carter in KV62, the Tomb of Tutankhamen (Lilyquist *et al.*, 1993, p25-6). This tomb dates to 1327 BCE, plus or minus a year or two, but one fruit bears the cartouche of Tuthmosis III, who had been dead for nearly 100 years at this point. It is likely that this is a curated object, saved from his reign, but Tuthmosis III was the subject of a significant cult, so it could have been produced later. It is certainly no later than the completion of Tutankhamen's tomb. It is therefore safer to regard cartouches as a *terminus post quem*, whereas a secure tomb is a *terminus ante quem.*

Provenancing glass

Glassworking sites might reveal themselves by having distinctive object types or producing distinctive styles of decoration, although ultimately this has been exceedingly difficult to prove with LBA sites (Rehren, 2000; Rehren, Pusch and Herold, 2001; Jackson, 2005). However, glassmaking sites can only be determined by something distinctive in the composition of the glass that they produce. Much work has been devoted to analysing LBA glass in an attempt to determine where it was made and trace element analysis, therefore, has proved useful for provenance studies.

The production of glass objects can be divided into two distinct stages: glass*making* and glass*working*. Glassmaking is the production of glass from its raw materials, in this period quartz pebbles, plant ash, colorant(s) and perhaps a lime source (Brill, 1999). It requires a furnace capable of temperatures in excess of 1000°C to produce. LBA glasses discovered in Egypt, the Near East and ancient Greece have a silica content of 62-65%, a high soda content of between 15-20% and elevated levels of magnesia, approximately 2-5%, with a similar potash content of between 2-4% and a lime content of 4% (Sayre and Smith, 1961; Lilyquist *et al.*, 1993; Shortland and Eremin, 2006). However, trace element analysis of LBA glasses has shown a distinct compositional difference between LBA glass found in the Near East and Egypt. The first element shown to distinguish between these two groups was titanium, which is high in Egyptian glasses, but relatively low in Near Eastern glasses (Shortland, Rogers and Eremin, 2007). Further analysis of a full suite of trace elements showed that almost a clear distinction could be drawn between glasses of the Near East and Egypt by plotting covariates of titanium, chromium, lanthanum, and zirconium. It is this method that was successfully used in the provenancing of Mycenaean, Ulu Burun and Levantine glasses (Shortland, Rogers and Eremin, 2007; Walton *et al.*, 2009; Jackson and Nicholson, 2010; Kemp *et al.*, 2020).

Previous analysis of Amenhotep II glass

The most recent analysis of glass thought to be from the reign of Amenhotep II is by Nicholson and Jackson (Nicholson and Jackson, 2013). The analysis was of a single sherd of a glass vessel now in the Swansea Museum (Swansea 959.3), believed to have originally been part of CG 24804, a particularly fine vessel which was later reconstructed in Cairo Museum (Nolte, 1968, p53; Stern and Schlick-Nolte, 1994, p25). It is 43mm across and features what is quite clearly part of the two cartouches of Amenhotep II. However, the object was recorded as being originally found in KV55, a hotly debated tomb in the Valley of the Kings with connections to the Amarna Royal family (Reeves and Wilkinson, 2008, p120-121; Saleem and Hawass, 2015, p119) Although curatorial history of the sherd is equivocal, it is likely that the piece dates from the reign of Amenhotep II and was originally part of his burial equipment (Nicholson and Jackson, 2013). Nicholson and Jackson carried out trace element analysis using LA-ICP-MS on the piece and compare the trace element plots with Shortland et al (2007). They conclude that it has much in common with the Egyptian composition with relatively high lanthanum and titanium, but in the Cr/La plot, the concentrations of the amber and white samples from the Swansea glass sit slightly outside the general compositional group for Egypt.

This paper provides additional analyses of early glass material on a range of colours from nine fragments from and attributed to tomb KV35 and the palace at Malkata (Newberry, 1900, 1902; Tytus, 1903). The Malkata material is of standard Egyptian LBA glass composition and was analysed as a control to observe whether a small offset from the Egyptian field was directly comparable or reflected slightly different analytical settings in two different LA-ICP-MS systems. By analysing the Malkata controls in the same machine and at the same time as the KV35 unknown small differences in minor and trace elements, indicative of composition, can be observed and compared as well as negating any potential detection drift.

Methodology

The objects analysed in this paper were originally sampled for Shortland et al (2006) and analysed by SEM-WDS. The same SEM blocks and samples were used here (Table 1). A total of nine objects were selected, all glass vessel fragments. Four are securely provenanced to KV35, the Tomb of Amenophis II, by the British Museum who describe the provenance as “probable”(Cooney, 1976, p52, p143) however it is known that KV35 was later opened and used as a cache for royal mummies (Baikie, 1932). The provenance of fragment EA64163 is given as “probably Thebes” by the British Museum and is described as having “a chequer-board pattern closely following those found in fused bowls from the tomb of Amenhotep II" (Cooney, 1976, p53), being stylistically comparable to the bowl sherd MMA 26.7.1164 from KV35 (Lilyquist *et al.*, 1993, p29, p35)Three of the fragments attributed to KV35 can be viewed on the British Museum website: https://www.britishmuseum.org/collection/object/Y_EA64163; EA64125 is shown in the top right, EA64124 middle right, EA64163 is pictured on the bottom right (also see table 1 for descriptions). Four other vessels from the Palace of Malkata dating to Amenhotep III (1390-1352 BCE) were also analysed as controls – by all expectations these should be Egyptian in composition.

The samples were subjected to LA-ICP-MS analysis at the Natural History Museum, London. The instruments used were an Agilent 7700 ICP-Q-MS mass spectrometer coupled to an ESI NWR193 with laser type ArF excimer with an ablation spot of 50µm, as detailed in table 2.

Each sample was analysed at five different spots, avoiding any obvious weathered areas. Corning A standard was run throughout the LA-ICP-MS analysis to check for accuracy and drift. The results on Corning A secondary standards show good agreement for the most elements, with the standards averaging less 10% error on the accuracy. Results consistent with Kemp et al. 2020 (Kemp *et al.*, 2020).

Results

The results are presented in Table 3 and 4, showing analyses of the glasses excavated from KV35 and fragment EA64163, which has been stylistically ascribed to KV35, and glasses from the palace at Malkata.

Discussion

High magnesia/high potash glasses

All samples apart from fragment EA64163 are consistent with Late Bronze Age plant ash glasses which are characterised by a high magnesia and high potash content.

Malkata

The glass samples analysed here that were excavated from the palace at Malkata are all compositionally standard LBA glasses of Egyptian composition, which have been widely published. These can therefore be used as a reference to comparatively discuss the samples attributed to KV35.

The black glass in EA64154 contains the highest concentration of manganese in the study group (2.0% MnO) with elevated levels of copper (1.6% CuO), therefore making this glass optically very deep purple-blue to achieve a black hue.

The blue glass from EA64155 is coloured with both cobalt and copper at 0.2% and 0.3% respectively, and opacified with 1.5% of an antimony opacifier, most likely calcium antimonate (Shortland, 2002). EA64155 exhibits the elevated levels of aluminium, manganese, nickel and zinc and low concentrations of potash, which is the expected composition pattern for LBA Egyptian glass coloured with cobalt (Shortland and Eremin, 2006; Shortland, Rogers and Eremin, 2007).

The Malkata turquoise glasses, EA64154 and EA64155, are similar in major element composition and colouring strategy; these glasses are coloured with a relatively higher concentration of copper (2.4% and 2.9% CuO respectively) and are opacified with an antimony constituent (containing 2.9% and 2.3% Sb_2O_3 respectively), thereby representing typical copper coloured, opacified, turquoise glasses of Egyptian composition.

The two purple glasses, EA64149 and 64151, are both coloured with a concentration of 0.6% manganese. Although there is a slight variation in the major elements, both glasses exhibit standard LBA Egyptian purple glass composition.

The red glass, EA64155, exhibits noticeably lower levels of silica and soda compared with the other coloured glasses: 53.1% (SiO_2) and 14.7% (Na_2O) respectively. However, this corresponds with the WDS analysis findings in Shortland and Eremin (2006) of LBA Egyptian red glasses. The glass is coloured with copper and represents the highest concentration of the study group (13.1% CuO). An antimony opacifier (2.11% Sb_2O_3) with some trace concentrations of lead (0.1% PbO) was also detected.

The white glass, EA64154, contains excess antimony (2.5% Sb_2O_3) suggesting this glass is opacified by calcium antimonate (Shortland, 2002), representing a typical LBA Egyptian white glass composition (Shortland and Eremin, 2006). The two yellow glasses show variation between their respective major element compositions and colouring strategies: EA64149 contains high levels of lead (11.5% PbO) whereas EA64151 contains comparatively low concentrations of lead (0.4% PbO), however both are comparable with known compositions of LBA Egyptian yellow glasses (Shortland and Eremin, 2006).

KV35

The glasses excavated from KV35 are typical high magnesia, high potash (HMHK) plant ash glasses comparable to the glasses analysed from Malkata and standard Egyptian LBA glasses produced in the 18th Dynasty (Shortland and Eremin, 2006), both in major elemental composition and colouring strategy. The two blue glasses coloured only with cobalt, EA64123 and EA59244, show the expected elevated levels of aluminium, manganese, nickel and zinc and relatively low concentrations of potash that are characteristic of LBA Egyptian cobalt coloured glass. The composition of the blue cobalt-copper coloured glass from KV35, EA64125 is comparable to that of Malkata, EA64155, specifically with regards to the colouring strategy, which is almost identical, containing similar concentrations of cobalt, copper, and antimony.

The purple glass, EA64124, is coloured with manganese and compares well with the purple glasses from Malkata, particularly EA64149 which is almost identical to the KV35 purple glass.

The white glass from KV35, EA59244, is almost compositionally identical to EA64154 from the palace at Malkata; the lime content is the only major difference which is 9.9% in the KV35 white glass and 7.6% in the Malkata glass. As mentioned above, the two yellow glasses from Malkata exhibit notably different compositions; the two yellow glasses from KV35 also show some variation between the two compositions. EA64123 from KV35, comparable with EA64149, contains lead (8.4% PbO) and antimony (1.4% Sb_2O_3), therefore likely coloured yellow by lead antimonate (Shortland, 2002). However, lead was not detected in the yellow glass in EA64124 but exhibits elevated levels of antimony (2.65% Sb_2O_3). The two KV35 glasses exhibit decreased levels of manganese compared with the two yellow glasses from Malkata.

EA64163, a low magnesia/low potash glass

Across the three glasses, EA64163 contains an average magnesia content of 1.2% MgO and an average potash content of 1.4% K_2O, which is notably different compared with the compositions of the HMHK glasses from Malkata and KV35. Natron glasses, using a soda-mineral flux, are characteristically low in magnesia and potash, containing concentrations of less than 1.5% each. Therefore, the major element composition of the glasses constituting EA64163 are comparable with natron glasses commonly produced in the Iron Age (IA) (Sayre and Smith, 1961; Freestone, 1991, p39-40).

The blue, red and white glasses comprising the EA64163 fragment exhibit over double the concentrations of the major elements aluminium, manganese and iron in addition to containing over double the average concentrations of the geologically relevant trace elements titanium, chromium, lanthanum and zirconium compared with those from the HMHK group. This elevated concentration is also seen across the rare earth and transition metal elements analysed. The cobalt-copper coloured blue glass in EA64163 exhibits elevated levels of manganese, iron, and lead, compared with the KV35 and Malkata blue glass samples in the study group. The cobalt colourant used to colour the EA64163 blue glass is compositionally consistent with cobalt sources used to colour later glasses produced in the 19^{th} and 20^{th} Dynasties (Abe *et al.*, 2012). This is significantly different to the zinc-rich Egyptian cobalt used to colour the HMHK glasses and is likely from an Iranian source, characterised by low levels of nickel and zinc, with an elevated concentration of manganese. (Kaczmarczyk, 1986; Mass, Wypyski and Stone, 2002).

The red glass in EA64163 exhibits notably low levels of silica and a low soda concentration, containing 58.7% and 13.7% respectively, comparable with the silica and sodium levels observed in the red glass EA64155 from Malkata. However, as mentioned previously, the EA64163 glass contains significantly elevated levels of aluminium (3.1% Al_2O_3), manganese (0.7% MnO), iron (0.6% FeO), copper (2.8% CuO) and lead (4.4% PbO). As discussed in the HMHK section, the composition of red glasses is known to be variable, however, the red glass from EA64163 is distinctly different from the standard LBA Egyptian glass and that of EA64155 from Malkata in both major element and colourant composition.

The white glass in EA64163 has the highest lime concentration in the study at 10.2% and contains the highest concentration of antimony in the study group (6.8% Sb_2O_3). Two studies on LBA Egyptian white glass conducted by Mass et al. (2002) and Shortland et al. (2006) showed that the antimony concentration did not exceed 3.9% and 3.3% respectively. Therefore, the antimony content of EA64163 is significantly higher than the expected antimony content in an LBA white glass. In addition, EA64163 contains 4.6% PbO compared with the white glasses from KV35 and Malkata that contain no detectable lead content.

Therefore, both major and trace element compositions, in addition to the colouring strategies for the blue, red and white glasses are notably different to the HMHK glasses from the KV35 tomb and Malkata groups, thereby making them notably distinct from standard LBA glasses produced in the 18^{th} Dynasty.

The provenance of the glass fragments from and stylistically attributed to KV35.

Titanium, chromium, lanthanum, and zinc can be used to distinguish between glasses most likely manufactured in Egypt, and those produced in the Near East. Figure 1 shows the data from the glasses excavated from KV35, the fragment stylistically attributed to KV35 and the fragments from the palace at Malkata plotted in a covariant plot of La against Cr, compared with the data from the Swansea fragment (Nicholson and Jackson, 2013) and data from the glasses in Shortland et al. (2007). As mentioned, the majority of the glasses from the study show a positive correlation with those of Egyptian composition, however, two yellow glasses, EA64123 from KV35, and EA64149 from Malkata appear to lie between the Egyptian and Near Eastern compositions due to the high chromium content. This indicates that yellow glasses may have been produced at a third site using chromium rich raw materials, or that raw yellow glass may have been imported from the Near East, which was then diluted with Egyptian colourless glass (Mass, Wypyski and Stone, 2002). The glasses comprising EA64163 can be seen as the outliers in figure 1. Figure 2 shows the same data plotted in 1000Zr/Ti against Cr/La. This plot provides greater distinction between the Egyptian and Near Eastern trace element compositions. The analysis strongly suggests that all the HMHK glasses from KV35 and the palace at Malkata are of Egyptian manufacture, paralleling the analysis of the Swansea fragment (Nicholson and Jackson, 2013).

Conclusion

The four fragments recorded as being excavated from the tomb KV35 in the Valley of the Kings are of standard LBA Egyptian composition and compare well to the glasses from Malkata. In addition, all the colours analysed on each fragment are comparable to those of Egyptian provenance, the implication being that early Egyptian glassmaking technology was refined enough at this early stage of glassmaking history to produce glasses in several colours using a range of compositions and obtaining domestically sourced raw materials distinct from the Near Eastern sources. This signifies that early glassworkers working in Egypt were not as dependent on imported glasses manufactured in the Near East as previous research has speculated. The analysis of fragment EA64163, which is only stylistically attributed to Amenhotep II, shows that the composition of all three colours is significantly different compared with the same colour groups in the LBA glasses from KV35 and Malkata. This is established in the major, minor and trace element findings in the raw materials of the glass and the colourants; the low magnesium, low potash content exhibited by EA64163 is characteristic of later glasses produced in the IA using natron as an alkali flux.

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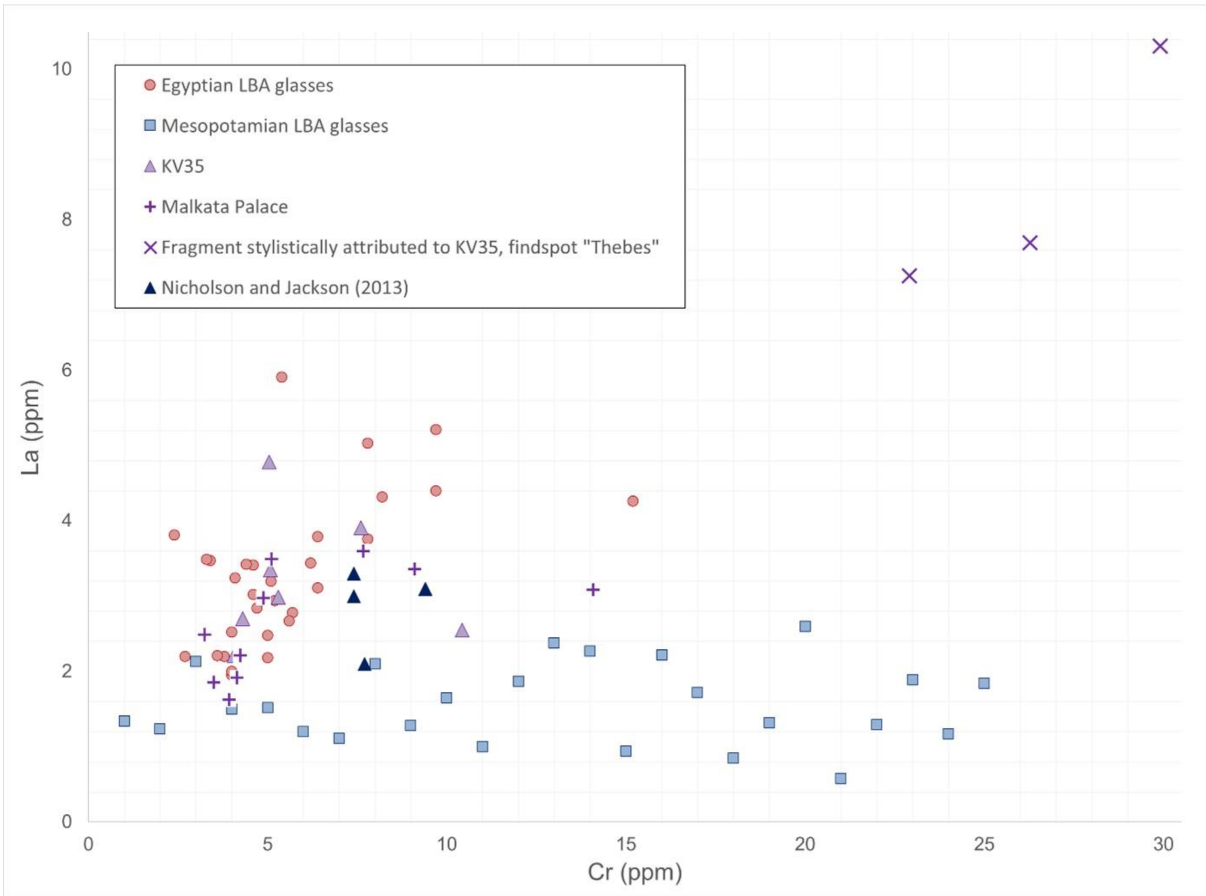

Fig 1 Covariant plot of La with Cr comparing the glasses from KV35, the palace at Malkata, the fragment attributed to KV35 (findspot described by the British Museum as "Thebes") and the Swansea fragment (Jackson and Nicholson 2013). Samples are plotted against the Egyptian and Mesopotamian glasses of known origin (Shortland, Rogers and Eremin, 2007).

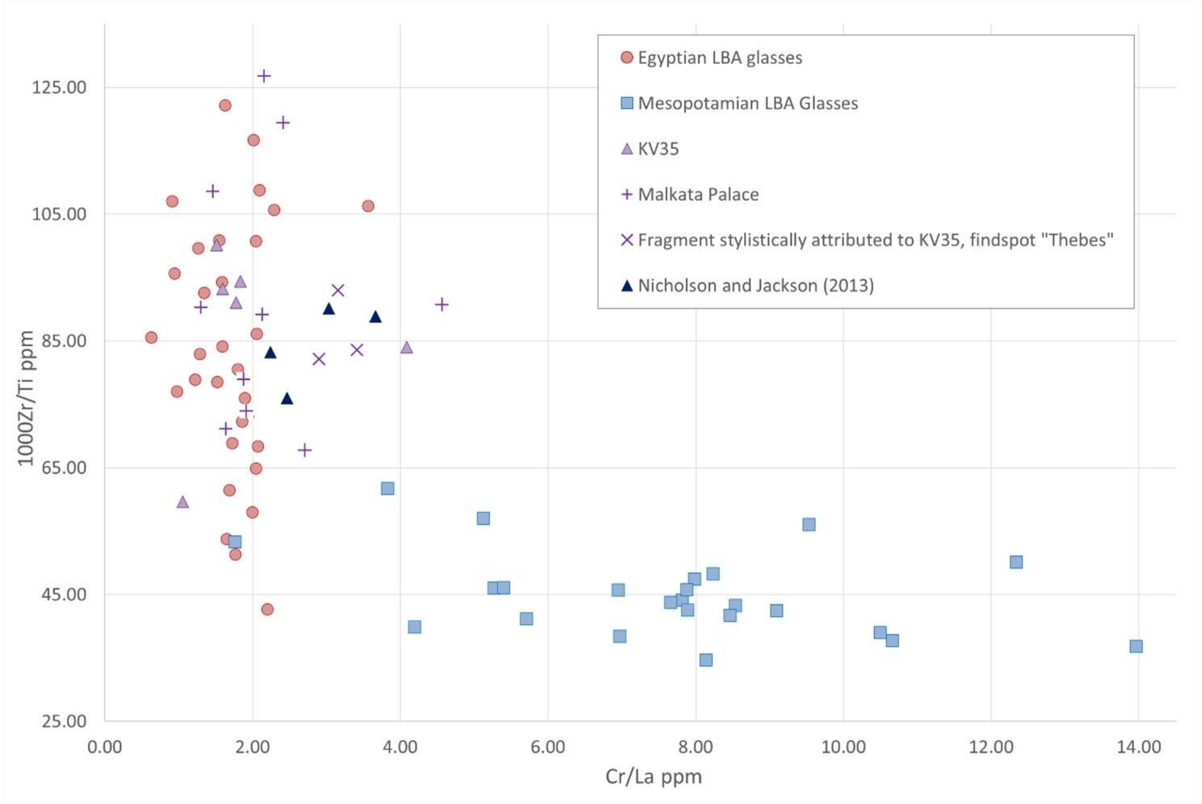

Fig 2. Covariant plot of 1000Zr/Ti with Cr/La comparing the glasses from KV35, the palace at Malkata, the fragment attributed to KV35 (findspot described by the British Museum as "Thebes") and the Swansea fragment (Jackson and Nicholson 2013). Samples are plotted against the Egyptian and Mesopotamian glasses of known origin (Shortland, Rogers and Eremin, 2007).

Table 1: Objects analysed by LA-ICP-MS, described in the Catalogue of the Egyptian antiquities of the British Museum: Volume IV, Glass (Cooney, 1976)

Museum number	Colour	Findspot	Origin
EA64123	Blue	KV35	Fragment from the neck and shoulder of a globular, amphora vessel in translucent dark-blue glass. On the neck and shoulder are decoration in turquoise-blue, yellow, and white.
	Yellow		
EA64124	Purple	KV35	Fragment of a vessel with opaque deep-violet body, decorated with wide threads in yellow, white, light green, and turquoise-blue in a marbleized pattern.
	Yellow		
EA64125	Blue	KV35	Fragment from the shoulder and neck of a vessel in opaque dark-blue glass. There are remains of four impressed units in the form of cornflowers or rosettes represented in top view.
EA59244	Blue	KV35	Fragment of a jar which had a hemispherical body. with a dark-blue ground. Decorations of chevrons on the neck, clustered festoons on the body, both combining opaque white and yellow.
	White		
EA64163	Red	Thebes (?), stylistically related to fragments in KV35	An unusual fragment with a chequer-board pattern closely following those found in moulded, fused bowls from the tomb of Amenhotep II. Impressed on both the exterior and interior surfaces are registers of opaque red squares and translucent dark-blue squares, alternating. The squares are arranged so that a red and a blue square touch only at their corners.
	White		
	Blue		
EA64149	Purple	Malkata Palace	Fragment from the body of a vessel in deep-violet glass decorated with clustered festoons in white, yellow, and light blue. Directly over these decorations vertical canes were impressed, three of which survive.
	Yellow		
EA64151	Purple	Malkata Palace	Fragment from the lower neck and body of a vessel in opaque amethyst glass, with decorations in yellow, opaque white, and turquoise-blue, probably simple festoons.
	Yellow		
EA64154	Black	Malkata Palace	Fragment of bowl: fragment of a shallow, opaque mosaic glass bowl, matt surface. Assembled from several layers of small pieces of brick-red, turquoise-blue, opaque white, yellow, and black glass. The bowl was formed by moulding either in an open mould or by press-moulding.
	Turquoise		
	White		
EA64155	Red	Malkata Palace	Fragment of a shallow mosaic glass bowl, composed of small pieces of light- and dark-blue, red, and white glass.
	Blue		
	Turquoise		

Table 2: Set up conditions for the LA-ICPMS

Laser ablation system	
Instrument	ESI NWR193
Laser type	ArF excimer
Wavelength	193 nm
Pulse duration	<4 ns
Repetition rate	10 Hz
Analysis type	Spot
Spot diameter	50 µm
Fluence	3.5 J/cm^2
Carrier gas (He)	500 ml/min
Primary reference material	NIST 612
Secondary reference material(s)	NIST 610, Corning A, Corning B

Mass spectrometer	
Instrument	Agilent 7700 ICP-Q-MS
Plasma gas flow (Ar)	1.1 l/min
Individual element dwell time	0.01s
Analysis duration	60s
Blank duration	30s

Table 3. Average results of the LA-ICP-MS analyses showing major and minor elements of the samples from KV35, the palace at Malkata and the fragment stylistically attributed to KV35, findspot cited by the British Museum as Thebes in wt%.

Sample Number	Colour	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	MnO	FeO	CoO	CuO	Sb_2O_3	PbO
							Wt%							
KV35														
EA64123	Blue	17.5	3.7	1.8	66.1	0.10	0.72	8.9	0.24	0.12	0.11	0.03	0.19	0.04
EA64125	Blue	19.5	3.9	2.9	61.6	0.22	1.24	7.5	0.29	0.18	0.25	0.21	1.5	0.02
EA59244	Blue	19.9	5.1	2.8	61.2	0.17	1.09	8.4	0.25	0.24	0.16	0.03	0.08	0.02
EA64124	Purple	19.4	3.7	0.74	65.4	0.23	2.61	6.9	0.61	0.15	0.01	0.01	0.01	0.00
EA59244	White	18.9	4.9	0.74	60.4	0.15	1.89	9.9	0.02	0.15	0.00	0.01	2.6	0.04
EA64123	Yellow	16.3	3.2	0.65	59.1	0.25	1.85	7.7	0.10	0.17	0.00	0.11	1.4	8.4
EA64124	Yellow	18.5	5.5	0.59	60.3	0.14	2.30	9.7	0.02	0.10	0.00	0.07	2.7	0.04
Malkata Palace														
EA64154	Black	15.6	3.7	0.79	65.9	0.17	2.15	7.5	1.95	0.18	0.02	1.6	0.02	0.09
EA64155	Blue	19.5	4.8	1.9	62.1	0.22	1.77	6.8	0.19	0.15	0.20	0.31	1.5	0.01
EA64149	Purple	20.3	3.7	0.73	64.5	0.24	2.71	6.8	0.61	0.16	0.01	0.06	0.01	0.00
EA64151	Purple	17.1	3.3	0.40	66.8	0.21	3.07	8.0	0.55	0.30	0.01	0.06	0.01	0.00
EA64155	Red	14.7	3.8	0.96	53.1	0.22	2.14	8.8	0.02	0.25	0.02	13.1	2.1	0.14
EA64154	Turquoise	17.6	5.2	0.65	60.2	0.17	2.41	7.8	0.02	0.15	0.01	2.4	2.9	0.05
EA64155	Turquoise	19.7	4.7	0.48	59.8	0.25	2.45	7.0	0.03	0.13	0.01	2.9	2.3	0.03
EA64154	White	19.1	4.7	0.71	62.5	0.22	2.30	7.6	0.02	0.15	0.00	0.07	2.5	0.04
EA64149	Yellow	14.9	4.3	0.73	52.6	0.21	2.43	7.5	0.22	0.30	0.00	0.06	4.0	11.5
EA64151	Yellow	18.0	3.2	0.38	67.6	0.18	3.05	6.2	0.46	0.30	0.01	0.03	0.02	0.41
Fragment stylistically related to KV35, findspot cited by the British Museum as "Thebes"														
EA64163	Blue	17.9	0.98	2.6	67.9	0.10	1.03	6.2	0.81	0.78	0.10	0.47	0.48	0.24
EA64163	Red	13.7	1.9	3.1	58.7	0.73	1.90	10.2	0.74	0.60	0.02	2.8	0.40	4.4
EA64163	White	15.4	0.79	2.2	61.7	0.14	1.12	5.8	0.85	0.25	0.02	0.04	6.8	4.6

Table 4. Average results of the LA-ICP-MS analyses in ppm.

Sample Number	Colour	Li	Be	B	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Rb	Sr	Zr	Nb	Ag	Sn	Sb	Cs	Ba	La	Ce	Au	Pb	Bi	Th	U
		ppm																												
KV35																														
EA64123	Blue	5.9	0.09	131.8	489	5.8	4.3	1884	933	888	466	251	650	5.3	4.0	670	45.6	1.4	0.34	12	1565	0.06	53.6	2.7	6.3	0.03	338	0.03	0.64	0.40
EA64125	Blue	10.2	0.00	93.8	661	11.2	7.6	2220	1432	1931	974	1711	2477	19.4	6.4	505	48.8	1.9	0.25	42	12562	0.09	57.3	3.9	10.5	0.12	18.5	0.01	1.00	0.69
EA59244	Blue	8.3	0.23	141.3	791	11.3	5.0	1899	1856	1269	848	207	1840	5.2	7.8	560	47.2	2.3	0.17	9.4	703	0.12	66.6	4.8	11.8	0.02	14.8	0.05	1.23	0.71
EA64124	Purple	9.6	0.18	70.4	588	13.8	5.1	4717	1131	4.6	4.5	110	25.3	0.9	9.8	738	58.9	1.7	0.16	1.1	6.8	0.11	75.2	3.4	6.6	0.00	1.7	0.05	0.84	0.52
EA59244	White	7.8	0.08	69.7	463	7.5	5.3	164	1181	3.9	8.1	101	26.4	55.0	11.7	985	42.1	1.5	0.29	1.1	21970	0.21	40.0	3.0	6.0	0.00	41.0	0.04	0.77	0.31
EA64123	Yellow	6.3	0.11	79.8	444	6.5	10.4	795	1349	3.1	6.3	840	3615	23.6	11.1	1294	37.4	1.3	1.7	4.2	11630	0.12	99.8	2.6	4.7	0.04	78370	3.1	0.57	0.57
EA64124	Yellow	5.5	0.00	64.5	345	6.0	4.1	178	788	1.7	6.0	57.0	22.9	66.6	10.7	1127	32.6	1.2	0.21	0.85	22153	0.28	35.5	2.2	4.2	0.06	35.9	0.04	0.54	0.22
Malkata Palace																														
EA64154	Black	6.1	0.14	49.0	656	34.6	7.7	15095	1406	11.8	17.9	12833	38.9	39.3	9.7	651	58.5	1.7	0.68	705	182	0.12	185	3.6	6.4	0.17	79.8	0.26	0.62	1.02
EA64155	Blue	9.4	0.09	79.2	421	6.2	4.2	1443	1191	1592	892	2476	1296	12	6.2	563	31.2	1.2	1.4	2.0	12386	0.07	41.7	2.2	5.4	0.04	13.4	0.02	0.52	0.18
EA64149	Purple	7.7	0.03	73.1	583	13.9	5.1	4747	1229	4.7	4.4	49.9	25.7	0.9	8.8	727	63.4	1.7	0.32	1.1	7.5	0.11	77.3	3.5	6.9	0.04	1.63	0.05	0.89	0.54
EA64151	Purple	9.2	0.10	56.7	291	5.9	4.1	4242	2367	4.7	5.6	47.3	98.9	1.3	13.2	1372	36.9	0.88	0.03	0.94	11.5	0.14	45.8	1.9	3.7	0.00	3.94	0.00	0.47	0.56
EA64155	Red	7.8	0.13	59.0	766	12.0	9.1	176	1963	18.0	89.2	104726	32.6	530	9.4	828	51.9	1.9	7.9	1993	17637	0.12	51.5	3.4	6.6	0.29	1279	0.78	0.78	0.32
EA64154	Turquoise	7.2	0.00	77.5	419	6.4	3.2	129	1145	4.4	14.8	19371	24.5	130	12.7	966	37.8	1.3	0.78	1652	24074	0.14	32.8	2.5	5.0	0.33	44.3	0.14	0.62	0.22
EA64155	Turquoise	9.6	0.06	76.3	370	5.7	3.5	243	1025	6.6	16.3	22927	25.7	111	8.8	579	29.2	1.0	1.8	571	19405	0.09	34.6	1.9	3.8	0.35	28.9	0.09	0.46	0.17
EA64154	White	6.8	0.07	73.7	419	6.4	4.9	141	1160	2.9	7.3	56.4	18.2	57.4	10.0	550	29.8	1.5	1.1	1.6	21179	0.15	43.9	3.0	5.8	0.04	38.5	0.04	0.66	0.20
EA64149	Yellow	5.7	0.08	106	441	9.2	14.1	1687	2328	3.7	19.1	495	7581	49.1	11.2	1140	40.0	1.3	1.5	3.7	33459	0.17	251	3.1	5.7	0.07	107019	0.95	0.72	0.85
EA64151	Yellow	6.6	0.28	49.9	277	5.8	3.9	3577	2358	4.4	5.1	245	82.3	1.0	11.0	969	33.1	0.87	0.67	0.96	13.0	0.11	35.1	1.6	3.4	0.06	3818	0.01	0.44	0.46
Fragment stylistically related to KV35, findspot cited by the British Museum as "Thebes"																														
EA64163	Blue	7.0	0.06	210	1188	22.7	26.3	6299	6028	754	31.0	3793	85.8	7.1	7.1	431	99.3	3.2	3.6	92	3994	0.11	218	7.7	14.7	0.04	2210	0.2	1.7	1.4
EA64163	Red	6.5	0.20	134	1764	30.0	29.9	5718	4700	178	25.2	22321	148	101	10.7	667	145	5.3	7.7	2933	3325	0.20	280	10.3	20.3	0.06	40387	3.8	2.4	1.4
EA64163	White	5.9	0.21	132	950	19.6	22.9	6552	1913	15.1	13.7	280	42.9	22.9	6.4	417	88.4	2.8	5.0	396	56556	0.08	221	7.3	13.3	0.24	42726	3.0	1.6	1.3