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ORIGINAL ARTICLE

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 (LBA) 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. Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analysis was used to analyse multiple colours on the fragments to determine the major element composition, the colouring strategies and to establish provenance using trace element analysis. The resulting data obtained were compared with four polychrome fragments of standard LBA Egyptian composition, excavated from the palace of Amenhotep III at Malkata, previously analysed by scanning electron microscopy with wavelength dispersive spectroscopy (SEM-WDS). Analysis showed that the glasses excavated from KV35 are standard LBA glass of Egyptian composition and were most likely produced in Egypt during the 18th Dynasty. The fragment EA64163 is a low magnesia, low potash glass comparable with Iron Age composition and 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.

KEYWORDS
Amenhotep II, Amenhotep III, ancient Egypt, glass, Iron Age, KV35, LA-ICP-MS, Late Bronze Age, Malkata, provenance, tomb, vessel

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, 190–192), but it is 15th-century contexts where the first glass in any quantity is found. Most commentators of the last 30 or so years have placed the source of the glass-making innovation in the Near East, perhaps in Northern Syria (Lilyquist, Brill, & Wypyski, 1993; Moorey, 1994; Nicholson, 1993; 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 (Nicholson et al., 1997; Oppenheim, 1973). 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 & Henderson, 2000, 203). 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 et al., 2015, 2016). The Ulu Burun shipwreck found off the southern coast of Turkey and dating to *c*.1300 BCE contained a large consignment of glass ingots, some or all of which originated in Egypt (Jackson & Nicholson, 2010; Nicholson et al., 1997; Pulak, 2001). Glass is therefore an interesting material 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 14th 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, Brill, Wypyski, & Koestler, 1993, 23). 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 et al., 2017, 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, Brill, Wypyski, & Koestler, 1993, 25–26). *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 glass-making 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 glass-making 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 to 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) date 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, Brill, Wypyski, & Koestler, 1993, 25–26). 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 a century 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 et al. 2001; Jackson, 2005). However, glass-making sites can only be determined by something distinctive in the composition of the glass they produce. Much work has been devoted to analysing LBA glass 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*. Glass-making 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 > 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% and 20%, and elevated levels of magnesia, approximately 2–5%, with a similar potash content of between 2% and 4% and a lime content of 4% (Lilyquist, Brill, Wypyski, & Koestler, 1993; Sayre & Smith, 1961; Shortland & 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 Ti, which is high in Egyptian glasses, but relatively low in Near Eastern glasses (Shortland et al., 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 Ti, Cr, La and Zr. This method was successfully used in the provenancing of Mycenaean, Ulu Burun and Levantine glasses (Jackson & Nicholson, 2010; Kemp et al., 2020; Shortland et al., 2007; Walton et al., 2009).

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 (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, 53; Stern & Schlick-Nolte, 1994, 25). It is 43 mm 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 & Wilkinson, 2008, 120–121; Saleem & Hawass, 2016, 119). 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 & Jackson, 2013). Nicholson and Jackson carried out trace element analysis using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) on the piece and compared the trace element plots with Shortland et al. (2007). They concluded that it had much in common with the Egyptian composition with relatively high La and Ti, but in the Cr/La plot the concentrations of the amber and white samples from the Swansea glass sat slightly outside the general compositional group for Egypt.

The present paper provides additional analyses of early glass material on a range of colours from nine fragments attributed to tomb KV35 and the palace at Malkata (Newberry 1900, 1902; de 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 scanning electron microscopy with wavelength dispersive spectroscopy (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, which describes the provenance as ‘probable’ (Cooney, 1976, 52, 143); 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, 53), being stylistically comparable with the bowl sherd MMA 26.7.1164 (The Metropolitan Museum of

TABLE 1 Objects analysed by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), described in the catalogue of the Egyptian antiquities of the British Museum (Cooney, 1976)

Museum no.	Colour	Findspot	Origin
EA64123	Blue Yellow	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
EA64124	Purple Yellow	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
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 the top view
EA59244	Blue White	KV35	Fragment of a jar with a hemispherical body, dark blue ground, decorations of chevrons on the neck and clustered festoons on the body, both combining opaque white and yellow
EA64163	Red White Blue	Thebes (?), stylistically related to fragments in KV35	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
EA64149	Purple Yellow	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
EA64151	Purple Yellow	Malkata palace	Fragment of the lower neck and body of a vessel in opaque amethyst glass, with decorations in yellow, opaque white and turquoise blue, probably simple festoons
EA64154	Black Turquoise White	Malkata palace	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
EA64155	Red Blue Turquoise	Malkata palace	Fragment of a shallow mosaic glass bowl composed of small pieces of light and dark blue, red, and white glass

Art, New York) from KV35 (Lilyquist, Brill, Wypyski, & Koestler, 1993, 29, 35). 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 a top right, EA64124 at middle right and EA64163 at 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 quadrupole inductively coupled plasma mass spectrometer (ICP-Q-MS) coupled to an ESI NWR193 with laser-type ArF excimer with an ablation spot of 50 μm, as detailed in Table 2.

TABLE 2 Set-up conditions for the laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS)

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	0.01 s
Analysis duration	60s
Blank duration	30s

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 < 10% error on the accuracy. The results were consistent with Kemp et al. (2020)).

RESULTS

The results, presented in Tables 3 and 4, show 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 (HMHK) glasses

All samples apart from fragment EA64163 are consistent with LBA plant ash glasses, which are characterized by a HMHK content.

Malkata

The glass samples analysed 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.

TABLE 3 Average results for the laser ablation inductively coupled plasma mass spectrometry (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' (wt%)

Sample no.	Colour	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	MnO	FeO	CoO	CuO	Sb_2O_3	PbO
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 for the laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analyses (ppm)

Sample no.	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
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	12,562	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	21,970	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	11,630	0.12	99.8	2.6	4.7	0.04	78,370	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	22,153	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	15,095	1406	11.8	17.9	12,833	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	12,386	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	104,726	32.6	530	9.4	828	51.9	1.9	7.9	1993	17,637	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	19,371	24.5	130	12.7	966	37.8	1.3	0.78	1652	24,074	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	22,927	25.7	111	8.8	579	29.2	1.0	1.8	571	19,405	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	21,179	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	33,459	0.17	251	3.1	5.7	0.07	107,019	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	22,321	148	101	10.7	667	145	5.3	7.7	2933	3325	0.20	280	10.3	20.3	0.06	40,387	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	56,556	0.08	221	7.3	13.3	0.24	42,726	3.0	1.6	1.3

The black glass in EA64154 contains the highest concentration of Mn in the study group (2.0% MnO) with elevated levels of Cu (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 Co and Cu at 0.2% and 0.3%, respectively, and opacified with 1.5% of an Sb opacifier, most likely Ca antimonate (Shortland, 2002). EA64155 exhibits the elevated levels of Al, Mn, Ni and Zn and low concentrations of potash, which is the expected composition pattern for LBA Egyptian glass coloured with Co (Shortland et al., 2007; Shortland & Eremin, 2006).

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 Cu (2.4% and 2.9% CuO, respectively) and are opacified with an Sb constituent (containing 2.9% and 2.3% Sb_2O_3, respectively), thereby representing typical Cu coloured, opacified, turquoise glasses of Egyptian composition.

The two purple glasses, EA64149 and EA64151, are both coloured with a concentration of 0.6% Mn. 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 Cu and represents the highest concentration of the study group (13.1% CuO). An Sb opacifier (2.11% Sb_2O_3) with some trace concentrations of Pb (0.1% PbO) was also detected.

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

KV35

The glasses excavated from KV35 are typical HMHK plant ash glasses comparable with the glasses analysed from Malkata and standard Egyptian LBA glasses produced in the 18th Dynasty (Shortland & Eremin, 2006), in both major elemental composition and colouring strategy. The two blue glasses coloured only with Co, EA64123 and EA59244, show the expected elevated levels of Al, Mn, Ni and Zn and relatively low concentrations of potash which are characteristic of LBA Egyptian Co coloured glass. The composition of the blue Co-Cu coloured glass from KV35, EA64125, is comparable with that of Malkata, EA64155, specifically with regards to the colouring strategy, which is almost identical, containing similar concentrations of Co, Cu and Sb.

The purple glass, EA64124, is coloured with Mn 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 Pb (8.4% PbO) and Sb (1.4% Sb_2O_3), therefore likely coloured yellow by Pb antimonate (Shortland, 2002). However, Pb was not detected in the yellow glass in EA64124 but exhibits elevated levels of Sb (2.65% Sb_2O_3). The two KV35 glasses exhibit decreased levels of Mn 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, each containing concentrations < 1.5%. Therefore, the major element composition of the glasses constituting EA64163 are comparable with natron glasses commonly produced in the Iron Age (Sayre & Smith, 1961; Freestone, 1991, 39–40).

The blue, red and white glasses comprising the EA64163 fragment exhibit over double the concentrations of the major elements Al, Mn and Fe in addition to containing over double the average concentrations of the geologically relevant trace elements Ti, Cr, La and Zr compared with those from the HMHK group. This elevated concentration is also seen across the rare earth and transition metal elements analysed. The Co-Cu coloured blue glass in EA64163 exhibits elevated levels of Mn, Fe and Pb compared with the KV35 and Malkata blue glass samples in the study group. The Co colourant used to colour the EA64163 blue glass is compositionally consistent with Co sources used to colour later

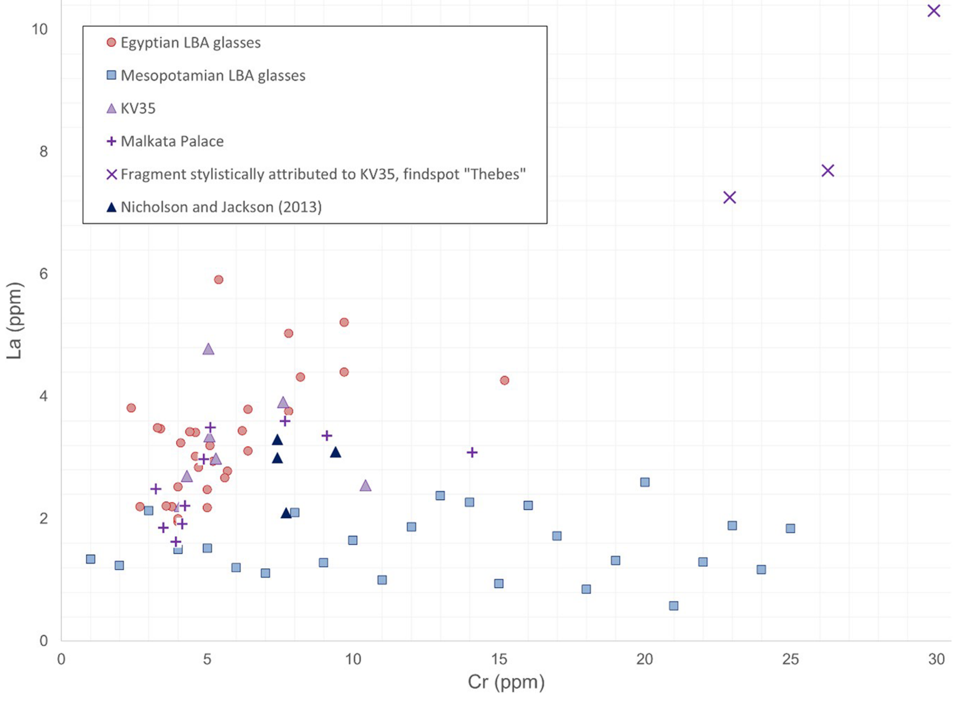

FIGURE 1 Covariant plot of La with Cr comparing the glasses from KV35, the palace at Malkata, the fragment attributed to KV35 (the findspot described by the British Museum as 'Thebes') and the Swansea fragment (Nicholson & Jackson, 2013). Samples are plotted against the Egyptian and Mesopotamian glasses of known origin (Shortland et al., 2007) [Color figure can be viewed at wileyonlinelibrary.com]

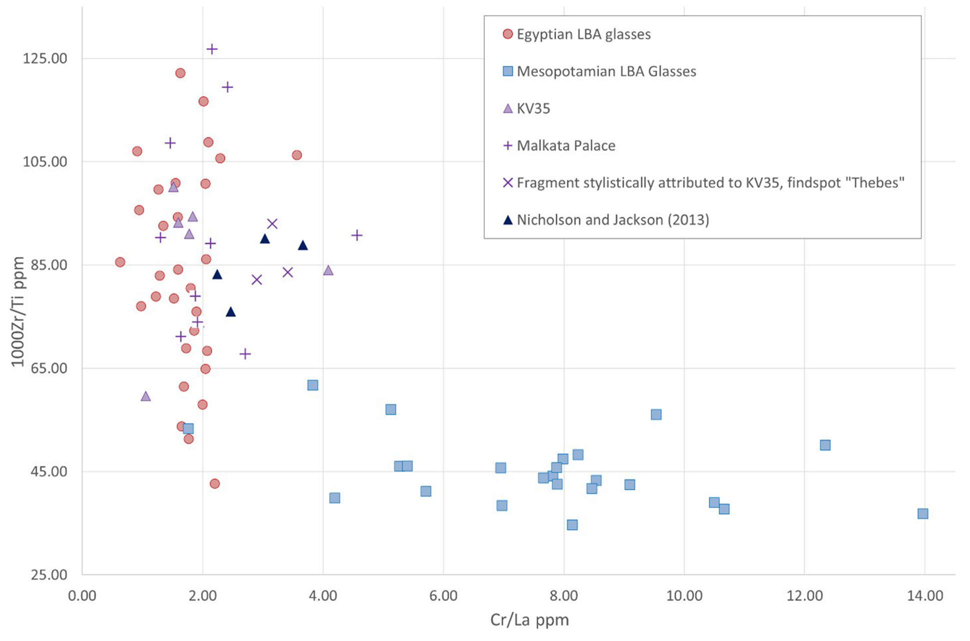

FIGURE 2 Covariant plot of 1000Zr/Ti with Cr/La comparing the glasses from KV35, the palace at Malkata, the fragment attributed to KV35 (findspot described by the British Museum as 'Thebes') and the Swansea fragment (Nicholson & Jackson, 2013). Samples are plotted against the Egyptian and Mesopotamian glasses of known origin (Shortland et al., 2007) [Color figure can be viewed at wileyonlinelibrary.com]

glasses produced in the 19th and 20th Dynasties (Abe et al., 2012). This is significantly different to the Zn-rich Egyptian Co used to colour the HMHK glasses, and is likely from an Iranian source, characterized by low levels of Ni and Zn, with an elevated concentration of Mn (Kaczmarczyk, 1986; Mass et al., 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 Na levels observed in the red glass EA64155 from Malkata. However, as mentioned previously, the EA64163 glass contains significantly elevated levels of Al (3.1% Al_2O_3), Mn (0.7% MnO), Fe (0.6% FeO), Cu (2.8% CuO) and Pb (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 Sb in the study group (6.8% Sb_2O_3). Two studies on LBA Egyptian white glass conducted by Mass et al. (2002) and Shortland and Eremin (2006) showed that the Sb concentration did not exceed 3.9% and 3.3%, respectively. Therefore, the Sb content of EA64163 is significantly higher than the expected Sb 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 Pb 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 18th Dynasty.

Provenance of the glass fragments from and stylistically attributed to KV35

Ti, Cr, La and Zn 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 & 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 Cr content. This indicates that yellow glasses may have been produced at a third site using Cr-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 et al., 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 & Jackson, 2013).

CONCLUSIONS

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 with the glasses from Malkata. In addition, all the colours analysed on each fragment are comparable with those of Egyptian provenance, the implication being that early Egyptian glass-making technology was refined enough at this early stage of glass-making 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 Mg, low potash content exhibited by EA64163 is characteristic of later glasses produced in the Iron Age using natron as an alkali flux.

PEER REVIEW
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REFERENCES

Abe, Y., Harimoto, R., Kikugawa, T., Yazawa, K., Nishisaka, A., Kawai, N., Yoshimura, S., & Nakai, I. (2012). Transition in the use of cobalt-blue colorant in the new kingdom of Egypt. *Journal of Archaeological Science*, *39*(6), 1793–1808. https://doi.org/10.1016/j.jas.2012.01.021

Baikie, J. (1932). *Egyptian antiquities in the Nile Valley: A descriptive handbook*. London: Routledge.

Beck, H. (1934). *Glass before 1500 BC, ancient Egypt*. London: Macmillan.

Brill, R. H. (1999). *Chemical analyses of early glasses: Volume 1 (tables) and 2 (catalogue)*. Corning, New York: Corning Museum of Glass.

Cooney, J. D. (1976). *Catalogue of the Egyptian antiquities of the British Museum: Volume IV*. London: Glass, British Museum.

Dardeniz, G. (2018). The Preliminary Archaeological and Scientific Evidence for Glass Making at Tell Atchana/Alalakh, Hatay (Turkey), *Anatolian Archaeological Studies, Japanese Institute of Anatolian Archaeology*, Proceedings of JIAA Late Bronze Age Glass Workshop held at 27th–28th September, 2014 in Kaman, Turkey.

de Tytus, R. P. (1903). *Preliminary report on the re-excavation of the palace of Amenhotep III*. New York: Winthrop Press.

Freestone, I. C. (1991). Looking into Glass. In S. Bowman (Ed.), *Science and the past* (pp. 37–56). London: British Museum Press.

Jackson, C. M. (2005). Glassmaking in bronze age Egypt. *Science*, *308*, 1750–1752. https://doi.org/10.1126/science.1112553

Jackson, C. M., & Nicholson, P. T. (2010). The provenance of some ingots from the Uluburun shipwreck. *Journal of Archaeological Science*, *37*(2), 295–301. https://doi.org/10.1016/j.jas.2009.09.040

Kaczmarczyk, A. (1986). The source of cobalt in ancient Egyptian pigments. In J. S. Olin & M. J. Blackman (Eds.), *Proceedings of the 24th international Archaeometry symposium* (pp. 369–376). Washington: Smithsonian.

Kemp, V., McDonald, A., Brock, F., & Shortland, A. J. (2019). LA-ICP-MS analysis of late bronze age blue glass beads from Gurob, Egypt. *Archaeometry*, *62*(1), 42–53.

Kemp, V., McDonald, A., & Shortland, A. J. (2017). Ancient biographies: Trace element analysis to investigate provenance and transportation mechanisms of late bronze age glass. *Archaeological and Environmental Forensic Science*, *1*(2), 161–174.

Kemp, V., Schmidt, K., Brownscombe, W., Soennecken, K., Vieweger, D., Haser, J., & Shortland, A. (2020). Dating and provenance of glass artefacts excavated from the ancient city of tall Zirā'a, Jordan. *Archaeometry*, *62*(6), 1164–1181. https://doi.org/10.1111/arcm.12588

Lilyquist, C., Brill, R. H., & Wypyski, M. T. (1993). *Studies in early Egyptian glass*. New York: Metropolitan Museum of Art.

Lilyquist, C., Brill, R. H., Wypyski, W. T., & Koestler, R. J. (1993). Part 2. Glass. In C. Lilyquist & R. H. Brill (Eds.), *Studies in ancient Egyptian glass* (pp. 23–58). New York: Metropolitan Museum of Art.

Mass, J. L., Wypyski, M. T., & Stone, R. E. (2002). Malkata and Lisht glassmaking technologies: Towards a specific link between second millennium BC metallurgists and glassmakers. *Archaeometry*, *44*(1), 67–82. https://doi.org/10.1111/1475-4754.00043

Moorey, P. R. S. (1994). *Ancient Mesopotamian materials and industries*. Oxford: Oxford University Press.

Newberry, P. E. (1900). Extracts from My Note-books (III). PSBA 22.

Newberry, P. E. (1902). Extracts from My Note-books (V). PBSA 24.

Nicholson, P. T. (1993). *Ancient Egyptian faience and glass*. London: Shire Egyptology.

Nicholson, P. T., & Henderson, J. (2000). Glass. In P. T. Nicholson & I. Shaw (Eds.), *Ancient Egyptian materials and technology*. Cambridge: Cambridge University Press.

Nicholson, P. T., & Jackson, C. (2013). Glass of Amenhotep II from tomb KV55 in the valley of the kings. *The Journal of Egyptian Archaeology*, *99*, 85–99. https://doi.org/10.1177/030751331309900103

Nicholson, P. T., Jackson, C. M., & Trott, K. M. (1997). The ulu Burun glass ingots, cylindrical vessels and Egyptian glass. *Journal of Egyptian Archaeology*, *83*, 143–153. https://doi.org/10.1177/030751339708300108

Nolte, B. (1968). *Die Glassgefässe im alten Ägypten, Münchner Ägyptologische Studien*. Berlin: Verlag Bruno Hessling.

Oppenheim, A. L. (1973). Towards a history of glass in the ancient near east. *Journal of the American Oriental Society*, *93*, 259–266. https://doi.org/10.2307/599459

Peltenburg, E. J. (1987). Early faience: Recent studies, origins and relations with glass. In M. Bimson & I. C. Freestone (Eds.), *Early vitreous materials* (Vol. 5–29). British Museum.

Pulak, C. (2001). The cargo of the Uluburun ship and evidence for trade with the Aegean and beyond. In L. Bonfante, V. Karageorghis, Costakis and Leto Severis Foundation, & C. Nicosia (Eds.), *Italy and Cyprus in antiquity 1500–450 BC: Proceedings of an international symposium held at the Italian academy for advanced studies in America at Columbia University, November 16–18, 2000* (pp. 13–60). Nicosia: The Costakis and Leto Severis Foundation.

Reeves, N., & Wilkinson, R. H. (2008). *The complete valley of the kings: Tombs and treasures of Egypt's greatest pharaohs*. London: Thames & Hudson.

Rehren, T. (2000). New aspects of ancient Egyptian glassmaking. *Journal of Glass Studies*, *42*, 13–24.

Rehren, T., Pusch, E., & Herold, A. (2001). Problems and possibilities in workshop reconstruction: Qantir and the organisation of LBA glass workshops. In A. J. Shortland (Ed.), *The social context of technological change*. Oxford: Oxbow books.

Saleem, S. N., & Hawass, Z. (2016). *Scanning the pharaohs: CT imaging of the new kingdom Royal Mummies*. Cairo: American University in Cairo Press.

Sayre, E. V., & Smith, R. W. (1961). Compositional categories of ancient glass. *Science*, *133*, 1824–1826.

Shortland, A. (2002). The use and origin of antimonate colorants in early Egyptian glass. *Archaeometry*, *44*(4), 517–530. https://doi.org/10.1111/1475-4754.00083

Shortland, A. J., & Eremin, K. (2006). The analysis of second millennium glass from Egypt and Mesopotamia, part 1: New WDS analyses. *Archaeometry*, *48*(4), 581–605. https://doi.org/10.1111/j.1475-4754.2006.00274.x

Shortland, A. J., Kirk, S., Eremin, K., Degryse, P., & Walton, M. S. (2017). The analysis of late bronze age glass from Nuzi and the question of the origin of glassmaking. *Archaeometry*, *60*(4), 764–783.

Shortland, A. J., Rogers, N., & Eremin, K. (2007). Trace element discriminants between Egyptian and Mesopotamian late bronze age glasses. *Journal of Archaeological Science*, *34*(5), 781–789. https://doi.org/10.1016/j.jas.2006.08.004

Stern, E. M., & Schlick-Nolte, B. (1994). *Early glass of the ancient world: 1600 B.C.–A.D. 50: Ernesto wolf collection*. Ostfildern: Verlag Gerd Hatje.

Varberg, J., Gratuze, B., & Kaul, F. (2015). Between Egypt, Mesopotamia and Scandinavia: Late bronze age glass beads found in Denmark. *Journal of Archaeological Science*, *54*, 168–181.

Varberg, J., Gratuze, B., Kaul, F., Hansen, A. H., Rotea, M., & Wittenberger, M. (2016). Mesopotamian glass from late bronze age Egypt, Romania, Germany, and Denmark. *Journal of Archaeological Science*, *74*, 184–194. https://doi.org/10.1016/j.jas.2016.04.010

Walton, M., Shortland, A. J., Kirk, S., & Degryse, P. (2009). Evidence for the trade of Mesopotamian and Egyptian glass to Mycenean Greece. *Journal of Archaeological Science*, *36*, 1496–1503. https://doi.org/10.1016/j.jas.2009.02.012

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