



The provenance of some glass ingots from the Uluburun shipwreck

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ABSTRACT

The discovery of a Late Bronze Age trading vessel at Uluburun near Kaş off the Turkish coast offers exciting possibilities for our understanding of Bronze Age trade. On board the ship was a large consignment of glass ingots that were assumed to originate either from Mesopotamia or Egypt. This paper presents the results of major and trace elemental analyses of three deep blue and turquoise glass ingots from the Uluburun wreck, and for the first time securely demonstrates that their composition is consistent with an Egyptian origin. The compositional similarity of the glass ingots to glasses from the Mycenaean world suggests that Egypt was exporting to that region via trading ships such as that from Uluburun.

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1. Introduction

A valuable contribution to our knowledge of Bronze Age glasses and trade was recently published by Walton et al. (2009). The authors reviewed the provenance of 11 Mycenaean glasses using trace element data to establish whether the glass used to produce these artefacts originated from the Near East or Egypt. Their findings indicated that glass from both production locations was represented, and it is likely this glass was brought to the Mycenaean world as ingots and then reworked locally. In their conclusions they suggest “the characterisation of trace elements from the 175 ingots excavated from the Uluburun wreck would make a significant study that may clarify if all these glasses were exclusive products of either Egypt or Mesopotamia, which would support a mechanism of direct trade. If the glasses aboard Uluburun were a collection of ingots from both of these regions this would support an indirect mechanism of material exchange” (Walton et al., 2009, 1502).

The discovery of the Uluburun wreck near Kaş, off the Turkish coast (Bass, 1987; Pulak, 2008), clearly offers exciting possibilities for our understanding of Bronze Age trade in the fourteenth

century BC. A major part of that understanding will come from determining where the vessel was travelling to, and therefore what products were being exported from, and imported into, particular regions. This paper makes a first contribution to identifying the provenance of three glass ingots from this vessel, and explores their potential destination.

Initially it was thought that the ingots must have been manufactured in Mesopotamia (Bass, 1986, 1987), the area where glass making is likely to have originated sometime in the early Bronze Age (early third millennium). Other scholars suggested they may have come from Egypt because of the dominance of the Egyptian state at the time of the shipwreck (e.g. van Dijk, 2000), although at the time of these publications no unequivocal glass factories were known in either Egypt or Mesopotamia.

The debate was reinvigorated in the mid 1990s upon the discovery at Amarna of what was believed to be one of the first glass making factories in Egypt (Nicholson, 1995), and the discovery of glass production, of a slightly later date, at Qantir (Rehren and Pusch, 1997; Nicholson et al., 1997; Rehren and Pusch, 2005; Jackson, 2005). Petrie (1894: 25) already believed that Amarna was a production centre but because the locations of the workshops he described there were not properly noted, his findings have been questioned. Work in the 1990s showed that primary production of glass at the site was likely (Nicholson, 2007). Thus, at the time the Uluburun ship was sailing around the Mediterranean, it is probable

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glass was being produced not only in Mesopotamia but also in Egypt.

Analytical investigations into major element compositions to determine whether glass from Mesopotamia and Egypt could be differentiated on the basis of their chemistry proved somewhat confusing. Raw materials with very similar compositions appear to have been used throughout the Bronze Age Near East, and the glass from the two regions could not be securely differentiated compositionally by major or minor element chemistry (Lilquist et al., 1993; Brill, 1999; Shortland and Tite, 2000; Tite and Shortland, 2003; Rehren, 2001). Therefore, the glass ingots from the Uluburun wreck could not be assigned to a provenance in either region, although a number of authors have tentatively suggested either an Egyptian (e.g. Nicholson et al., 1997) or Mesopotamian (e.g. Bass, 1987) origin, or a mixture of both (e.g. Panagiotaki, 2008; Tite et al., 2008; Pulak, 2008, 293). However, more recent research has suggested that it is possible to discriminate glasses, with respect to broad regions such as Egypt or Mesopotamia, based on trace element analysis (Shortland et al., 2007), and it is this data which allows the Uluburun ingots to be studied in a new light.

With this new trace element data as a basis for further investigation, this paper seeks to identify the provenance of the glass ingots aboard the Uluburun shipwreck through the analysis of major, minor, and trace elements. Both major and trace elements were measured to determine the general glass chemistry and as a comparative tool for use with the published data of Brill (1999). New trace element data was collected so that it could be compared with the newly published data which has been used to distinguish between Mesopotamia and Egyptian glasses (Shortland et al., 2007). The major elements were measured by scanning electron microscopy (SEM-EDS) and the trace elements by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), as both produced the least invasive quantitative measurements on extremely small samples.

2. Late bronze age glass, manufacture and trade

Current models for the production and supply of glass in the Bronze Age Mediterranean centre on the production of glass in the Near East ('Mesopotamia' according to Shortland et al., 2007) and Egypt. Although centres of production have not yet been identified in Mesopotamia, the findspots and dates of glass fragments suggest that glass was produced here before being introduced to Egypt. Somewhat later, the identification of glass production debris at a series of royal centres, including Malkata, dating to the reign of Amenhotep III (1390–1352 BC) (Keller, 1983), probable glass furnaces at Amarna dated to the mid fourteenth century BC (Nicholson, 1995, 2007), along with glassmaking debris at Qantir of the late thirteenth century BC (Rehren and Pusch, 1997; 2007), indicated that when glass was produced in Egypt, it was possibly state controlled and state administered. Each of these centres appears to have been manufacturing 'raw glass', some specialising in particular colours, which was then traded as ingots (although the evidence from Malkata is more ambiguous) (see references above and Nicholson, 2008).

The evidence for ingot moulds at Amarna with associated blue glass residues (Nicholson et al., 1997), red glass ingot(s) and reaction vessels at Qantir (Rehren and Pusch, 1997; Pusch and Rehren, 2007) and the find of the glass ingots in turquoise, deep blue, purple and amber on the Uluburun shipwreck (Bass, 1987; Pulak, 2008, 293) served to strengthen this model. The glass ingots were part of a rich trade that included copper ingots, amber, ivory, and other precious items, implying that the ship had a diverse cargo that derived from various regions throughout the Mediterranean and further afield, which Pulak (2008, 299) suggests is indicative of

commercial trade, under royal control. The ship appears to have been on a continuous voyage in an anticlockwise direction, possibly originating on the Levantine coast, with limited stops to pick up local goods or goods 'in transit' at coastal ports, a system that is termed a 'point-to-point' trade system (see Pulak, 2008, 298–299). The glass ingots, intended for subsequent remelting and working, would have been picked up at one of these coastal ports either in Egypt or the Near East, depending upon whether trade was direct or indirect (see Pulak, 2008, 298, Fig. 97; Pulak, 2005, 95; Abb.52). The manufactured glass ingots were then traded/exchanged to secondary workshops that manufactured artefacts in a local style. Thus, present evidence suggests the primary glass workshops for these ingots are likely to have been located in Egypt and perhaps Mesopotamia.

It has recently been suggested that the final destination of the Uluburun ship was the Aegean (Pulak, 2008, 299). This is supported by the compositional similarity of the major elements seen in Egyptian and Mycenaean glasses, which was noted by Sayre (1964, 9) and a suggestion by Barag (1970, 193) from his work on Aegean glasses, that blue glass ingots were brought from Mesopotamia to the Aegean also lends weight to this idea. More recent analysis by Walton et al. (2009) has linked Egyptian and Mesopotamian blue glasses with Mycenaean glass compositions from Tyrins using trace element analysis. Therefore, it is likely that the Mycenaean palaces were one such destination for this glass, although other centres cannot be discounted.

3. Chemical analysis of glasses from Egypt and Mesopotamia

Many recent analytical studies of Bronze Age glasses from Egypt and Mesopotamia have focussed on the provenance of the glasses or minerals used as colourants (e.g. Tite and Shortland, 2003; Rehren, 2001; Shortland and Eremine, 2006). As the most common colour of glass at this time is blue (deep blue through to turquoise blue), the majority of studies have focussed on this particular colour. These blue glasses can be divided into two broad groups: those coloured with cobalt and those coloured with copper. Both colours initially derive from mineral additives. Copper minerals are relatively widespread, being found at many locations throughout Europe, the Mediterranean, and the Near East. Copper can also be added to the glass as scrap metal. However, cobaltiferous deposits have a more limited distribution. Although European cobalt sources are known (Dayton, 1993), the most well known deposits around Egypt and the Near East are in the Egyptian western desert oases of Kharga and Dakhla, and analytical studies have suggested these sources were used in Egyptian glass manufacture in the Late Bronze Age (Kaczmarczyk, 1986; Shortland et al., 2007).

Copper and cobalt glasses can be differentiated compositionally not only by their colouring agents, but also by their base glass chemistries (Lilquist et al., 1993). Cobalt blue glasses have lower concentrations of potash and higher concentrations of alumina than those coloured with copper. This compositional distinction was attributed by Shortland and Tite (2000) to the production of the cobalt-coloured glass using a natron flux and cobalt alum, and the copper-coloured glass using plant ash and copper or bronze. Different provenances were suggested for the two blue glasses. The cobalt blue glasses were given an Egyptian provenance and the copper blue a Mesopotamian one (based upon the consumption context in which the glass was found). However, the difference seen in the two glass compositions is more likely to indicate the use of different plant ashes in manufacture, or the use of plants that grew in differing geological environments (Turner, 1956; Lilquist et al., 1993; Rehren, 2001; Barkoudah and Henderson, 2006). Furthermore, the two colour groups could not be attributed convincingly to different regions on the basis of major element chemistry alone

(although Shortland and Eremin (2006) have recently shown that glasses from Mesopotamia tend to be higher in potash than those from Egypt, regardless of colourant, although there is overlap between the colour groups and the different finds provenances). More recent work by Shortland (2005), Shortland et al. (2007) and Walton et al. (2009) has suggested that Egyptian and Mesopotamian blue glasses can be differentiated by their trace element chemistry, most notably the differing concentrations and ratios of lanthanum, titanium, zirconium, and chromium. The different concentrations of these trace elements are related to the underlying geology on which the alkali-containing plants grew, together with the contribution of the clay minerals from the crucibles during melting.

Questions relating to the provenance and trade of Bronze Age Egyptian and Mesopotamian glasses are central to the origin of the ingots found on the Uluburun shipwreck (Bass, 1986, 1987, 1989).¹ Analytical work carried out on some of the blue ingots by Jackson et al. (1998), Brill (1999, 53–54) and Jackson and Nicholson (2007), indicated that they fall into the same compositional group as the cobalt blue glasses from Amarna and other Egyptian sites of the period (although other provenances could not be ruled out).

A further indication that these cobalt blue ingots are likely to be Egyptian is that their size corresponds with that of the internal diameter of cylindrical vessels from Amarna, which are believed to have been used as crucibles (Nicholson et al., 1997). The underside of the ingots preserves casts of finger grooves that are seen in the interior of the base of these ceramic vessels. One fragment of cylindrical vessel has been recognized recently within the Uluburun finds, which was probably stuck to one of the glass ingots (Pulak 2001, 29–30). It is similar to those from Amarna and is likely to be of Egyptian origin. Further analysis of the ceramic may help to elucidate whether its specific provenance can be found within Egypt.

4. Analysis and instrumentation

Three samples of Uluburun ingots, sampled by Professor Cemal Pulak, were analysed. Two of these samples are deep dark blue, the third is turquoise (or light blue). The samples were taken by chipping off small fragments from the ingot, allowing a fresh fractured surface, minimally affected by corrosion, to be analysed. The glasses were mounted in epoxy resin.

Major and minor elements were determined on a Carl Zeiss SMT S360 scanning electron microscope fitted with an Oxford Instruments AN 10000 analyser housed in the Department of Geology, University of Cardiff. Corning A standard glass was run after every 10 samples to check for accuracy and precision (Jackson and Nicholson, 2007, 111). 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. Samples were mounted in standard electron microprobe resin blocks and ablated under an atmosphere of argon. Ablation conditions were: laser spot operated at 10 Hz and a laser power delivery of ~0.2 mJ. Each sample was analysed in raster mode. Ablated material was transported to the plasma source using the gas flow control system on the 7500c at a flow rate of 1.38 l min⁻¹ and the plasma operated at a power of 1500 W. These conditions produce a beam with a ThO/Th ratio of <0.3%. Analyses were calibrated against NIST SRM 610 glass reference material,

doped with a nominal concentration of 500 ppm for most trace elements, and using the consensus values (Pearce et al., 1997). 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 were above three standard deviations above the mean background concentrations (3 sigma, 99% confidence) were reported. Repeat measurements of SRM NIST 612 were made throughout to assess accuracy, and the results of those analyses are reported in Table 1. Data was normalised using Ca. Trace elements show a good correspondence with the consensus values for NIST 612 (Pearce et al., 1997) and 30 replicates over the run showed precision generally better than 10% (Table 1).

5. Composition of the Uluburun ingots

5.1. Major element compositions

Analyses of the three glasses (TURQ, LOT4110, and KW1422²) from Uluburun are presented in Table 2. Taking into account the alternating theories about the use of plant ashes and natron in the production of early Bronze Age glasses in Egypt and Mesopotamia reviewed above (Lilyquist et al., 1993; Shortland and Tite, 2000; Rehren, 2001; Tite and Shortland, 2003; Jackson and Nicholson, 2007) it is likely that these early glasses were produced using plant ashes. The major element concentrations found in the Uluburun glasses are consistent with sodium-rich plant ashes, typical of the period from approximately 1600 to 1000 BC (Nicholson and Henderson, 2000). The use of a plant ash alkali introduces potash and magnesia into the glass, in contrast to mineral alkalis such as natron, which contain negligible concentrations of these components (Turner, 1956). Calcium and other impurities in the glass, such as phosphorus and manganese, can also be explained by the use of a plant ash alkali. The low impurity pattern attributable to the silica, especially the low concentration of iron oxide at an average of 0.5 wt%, could argue for either the use of quartz pebbles or a 'pure' silica sand as the main glass former, as Tite and Shortland (2003) suggest. The alumina (below ~2%) present in these glasses would derive from the silica source and/or possibly be introduced with the plant ash (Barkoudah and Henderson, 2006, 314). This composition represents what could be termed a 'typical Near Eastern glass composition' and is consistent, with very minor variation, for glasses from Egypt and Mesopotamia, discussed above (Fig. 1).

Cobalt (Co) and copper (Cu) concentrations in glass LOT 4110 are 539 and 702 ppm respectively, and are indicative of colouring using both elements, a characteristic reported previously in Egyptian blue glasses (Tite and Shortland, 2003; Jackson and Nicholson, 2007, 104). KW1422 has similar concentrations of cobalt (501 ppm) but lower copper (185 ppm), which may suggest that cobalt is the dominant colourant in this sample. The turquoise sample is coloured with copper at 4830 ppm (Table 2).

It has been suggested that cobalt- and copper-coloured glasses fall into two broad compositional bands based upon potash and magnesia concentrations (Shortland and Tite, 2000; Shortland and Eremin, 2006, see above), and that finished glasses from Mesopotamia tend to be higher in potash regardless of whether they are coloured with cobalt or copper. Egyptian cobalt-coloured glasses are generally lower in potash, (illustrated in Fig. 1). When crucible glasses from the manufacturing site at Amarna are plotted with this

¹ Egyptian finds on the wreck (including a gold ring of Nefertiti – Weinstein, 1989) suggested that the ship had already visited Egypt, although Pulak (2008) suggests finds such as these may have been ornaments picked up on the Levantine coast.

² These were the museum/sample names/numbers given by Cemal Pulak who provided the samples. The turquoise sample has not been given a museum number as it is a fragment of an ingot.

Table 1
NIST 612 reference standard.

Analyte	Consensus	Average ($n = 30$)	1SD	RSD (precision)
Mn	38	39.9	6.0	15.1
Ti	48	47.7	4.7	9.2
V	39	40.2	5.3	13.2
Co	35	35.4	2.8	8.0
Ni	39	43.1	3.7	8.5
Zn	38	45.9	10.7	23.3
Ga	36	39.8	4.0	10.0
Rb	31	35.7	4.1	11.4
Sr	78	75.4	5.5	7.3
Zr	38	36.6	3.1	8.5
Ba	40	36.8	3.4	9.1
La	36	36.8	2.2	5.9
Ce	39	31.8	1.9	6.0
Pr	37	35.7	2.2	6.2
Nd	36	34.6	3.5	10.0
Sm	38	36.6	3.1	8.5
Eu	35	35.6	2.4	6.7
Gd	37	33.7	3.3	9.9
Tb	36	36.0	2.4	6.7
Dy	36	33.6	2.5	7.4
Ho	38	36.8	3.0	8.2
Er	38	34.1	2.5	7.4
Tm	38	34.2	2.6	7.7
Yb	39	37.9	3.2	8.4
Lu	37	34.6	2.8	8.1
Bi	30	36.6	3.3	9.0
U	37	41.0	4.2	10.2

Values in ppm. Consensus from Pearce et al. (1997).

data set they fall within the Egyptian cobalt-coloured glasses (Jackson and Nicholson, 2007, Appendix 5) as might be expected.

Interestingly, however, when the concentrations of potash and magnesia of the Uluburun ingots are plotted in Fig. 1, all three glasses plot in the low potash range, regardless of colour. These three analyses compare well with the 11 blue Uluburun ingots analysed by Brill (1999, 53–54), which all have potash concentrations below 1.6 wt% (although one purple ingot analysed by Brill (1999, 54) contains potash at 2.18 wt%). Therefore, the combined compositions of the Uluburun ingots suggests the cobalt- and the copper-coloured ingots fall into the same compositional group as the cobalt-coloured glasses from Egypt and glass manufacturing waste from the recently excavated workshop at Amarna. Indeed, the copper-coloured ingots contain lower concentrations of potash than is generally found in the copper blue glasses from Egypt or Mesopotamia. Brill originally suggested these low concentrations of potash in the copper glasses were due to weathering (Pulak, 2001, 29) but the trace element patterning discussed below does not support this theory. Thus, the low concentrations of potash and the similarities in base glass composition between the copper and cobalt glasses of the Uluburun ingots is best explained by the use of a similar plant ash in manufacture. However, as noted by Rehren (2008) and Walton et al. (2009), there is a wide overlap between the major and minor element compositions of Mesopotamian and Egyptian glasses, which makes assigning provenance to the Uluburun ingots, even to a regional level, difficult.

5.2. Trace element compositions

Shortland et al. (2007), suggest that it is possible to discriminate between glasses manufactured in Egypt and Mesopotamia based upon concentrations of chromium (Cr), lanthanum (La), titanium (Ti) and zirconium (Zr). In glasses from Mesopotamia, concentrations of Cr are higher than those for Egyptian glasses and La, Ti, and Zr are lower. These differences are related to the underlying geology and soil/clay compositions on which the halophytic plants

Table 2
Major and trace element chemistry of Uluburun ingots.

Sample	LOT4110 Co. blue	KW1422 Co. blue	Uluburun turquoise
<i>Oxide (wt%)</i>			
SiO ₂	69.5	67.2	67.7
Na ₂ O	17.0	17.8	19.0
CaO	6.9	6.0	5.7
K ₂ O	0.5	0.8	0.8
MgO	2.5	2.9	2.6
Al ₂ O ₃	1.99	1.98	0.69
Fe ₂ O ₃	0.56	0.62	0.39
SnO ₂ ^a	b.d.	b.d.	0.08
SO ₃	0.27	0.25	0.28
Cl	1.12	1.01	1.38
P ₂ O ₅ ^a	0	0.05	0.03
Total SEM-EDS	100.84	98.93	99.32
<i>ppm</i>			
47 Ti	616.3	408.7	378.4
52 Cr	4.8	6.0	4.7
55 Mn	1006.2	850.4	84.2
59 Co	539.4	501.6	4.8
60 Ni	441.3	383.6	8.2
65 Cu	702.7	185.2	4830.0
66 Zn	865	675	16
71 Ga	1.1	0.9	0.8
85 Rb	5.1	5.3	3.4
88 Sr	1034.4	686.0	616.9
90 Zr	39.0	26.8	42.6
137 Ba	54.3	37.2	34.8
139 La	3.3	3.2	2.2
140 Ce	6.9	7.1	3.8
141 Pr	1.2	1.1	0.5
146 Nd	5.2	5.0	1.9
147 Sm	0.9	1.2	0.3
151 Eu	0.4	0.3	0.1
157 Gd	1.6	1.6	0.3
159 Tb	0.3	0.2	0.1
163 Dy	1.6	1.6	0.4
165 Ho	0.3	0.3	0.1
166 Er	1.0	1.0	0.3
169 Tm	0.1	0.1	0.0
172 Yb	0.9	0.6	0.2
175 Lu	0.1	0.1	0.0
232 Th	0.7	0.8	0.5
238 U	0.8	0.9	0.4

b.d., below detection.

^a Values below 0.1 wt% SEM-EDS are semi-quantitative as they are near the 3 sigma confidence limits for detection.

used to produce the ash grew, together with contamination of the glasses from the crucibles during manufacture, which might introduce contamination again reflecting the local geology (Turner, 1956; Jackson et al., 2005; Shortland et al., 2007; Barkoudah and Henderson, 2006; Merkel and Rehren, 2007).

When La and Cr are plotted for glasses deriving from Mesopotamia (Nuzi and Tell Brak) and from Egypt (Amarna and Malkata) (Shortland et al., 2007), two discrete groups are observed relating to their origin (Fig. 2; note that the Egyptian glasses plotted include colourless in addition to blue glasses, but these fall within the same compositional group; the Mesopotamian glasses are all blue glasses). The Egyptian glasses generally have higher concentrations of La (>3 ppm) and lower concentrations of Cr (<15 ppm), but, more importantly, the ratios of the two elements are distinctly different for Egyptian and Mesopotamian glasses. Using the data published by Shortland et al. (2007), the mean Cr:La ratio for the Mesopotamian glasses is 7.7:1, and that for the Egyptian glasses is 1.7:1. In both cases La and Cr are correlated, which suggests they probably entered the glass in the same raw material (which may have been related to the local geology and/or the contamination from the local clays of the crucibles used to manufacture the glass (Merkel and Rehren, 2007). When the three Uluburun glasses are

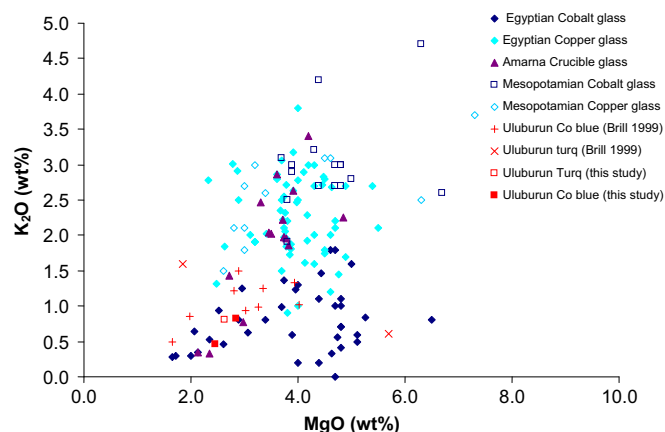


Fig. 1. Major element composition of blue glasses from Egypt and Mesopotamia, glass in crucibles from Amarna, and the Uluburun ingots analysed in this study (Egyptian glass compiled from Jackson and Nicholson, 2007 and Shortland and Eremin, 2006, Uluburun ingots from Brill, 1999, and Mesopotamian glass from Shortland and Eremin, 2006).

plotted with the Egyptian and Mesopotamian glasses, all three, regardless of colourant, fall within the range of the Egyptian glasses, with ratios of Cr:La between 1.4:1 and 2.1:1. They also have concentrations of Ti (378–616 ppm) and Zr (26–42 ppm) that are consistent with the higher concentrations found in Egyptian glasses (Shortland et al., 2007, 784–785); these compositional similarities between the three ingot compositions would suggest a common provenance, presumably Egypt.

Rare earth elements (REE) are often used to discriminate between geological materials from differing locations, and have been used successfully in glass studies in recent years to differentiate between different raw materials used in glass manufacture or to discriminate between compositional groups (Jackson, 1987; Freestone et al., 2002; Mirti et al., 2008). Walton et al. (2009) showed that in cobalt-coloured glasses, the light REE elements (LREE) La, Ce, and Pr are depleted when the data is normalised to the Post-Archean Australian Shales (PAAS; Taylor and McLennan, 1985). These same patterns are not observed in the copper-coloured glasses that exhibit flat normalised distributions. This flat distribution can be attributed to the clay or mineral component (from weathering of sediments in soil/clay formation) introduced

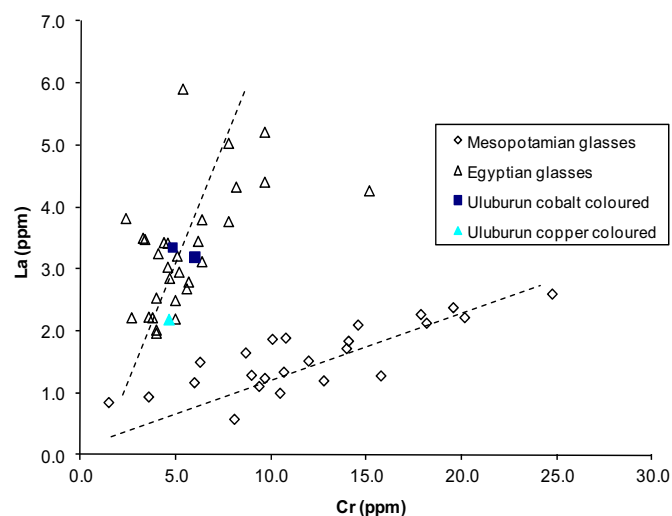


Fig. 2. La vs Cr bi-plot showing glass from Egypt and Mesopotamia and the Uluburun ingots (Mesopotamian and Egyptian trace element data taken from Shortland et al., 2007).

through the raw materials or melting processes. The REE profiles in the cobalt-coloured Egyptian glasses reflects the use of a heterogeneous mineral alum as the colourant, which Walton et al., (2009, 1501) attribute to an Egyptian origin for the cobalt alum, possibly the alums from the Kharga oasis. This pattern is also reflected here, which, for the cobalt blue glasses, would suggest they had been manufactured using an Egyptian cobalt alum (Fig. 3). Although this does not differentiate between Egyptian and Mycenaean glasses, it does lend weight to the common use of an Egyptian source for this colourant.

6. Discussion

The concentrations of major, minor, and trace elements in the glass ingots from the Uluburun shipwreck analysed in this study are comparable to Egyptian glasses and glassmaking and working debris identified from production centres (most notably Amarna), from finished glasses found in Egyptian consumption contexts and from glass found in ingot moulds from known production centres and elsewhere. This suggests that at least some of the glass ingots on the ship were of Egyptian origin. Whether these ingots were loaded directly onto the Uluburun ship at an Egyptian port, or transported out of Egypt to be loaded at a foreign port, is not known (Pulak, 2008, 299).

Walton et al. (2009) showed that some blue Mycenaean glasses appear to be compositionally similar to those found in Mesopotamia and others are compositionally undistinguishable from Egyptian glasses. They conclude that some of the Mycenaean glasses they analysed probably originated from Egypt, as has been suspected previously (Tite et al., 2008, 118; Panagiotaki, 2008, 47; Jackson and Wager, 2008, xv). Since the base glass of these Mycenaean cobalt glasses has also been linked to Egypt, as determined by their La and Cr contents, this suggests that the finished glass, and not simply the colourant, was the product of exchange. The similarity of the compositions of these Uluburun glasses with the Egyptian glasses analysed by Shortland et al. (2007), and some of the Mycenaean glasses identified as of Egyptian origin by Walton et al. (2009), suggests that sites in Mycenaean Greece, the Aegean, and perhaps throughout the Mediterranean used Egyptian raw glass to manufacture at least some of their finished objects (although local production of some Mycenaean glasses, using local raw materials, was probably also taking place (Nikita and Henderson, 2006; Panagiotaki, 2008)). The compositional parallels of trace elements, in particular between Egyptian glass, Mycenaean glass,

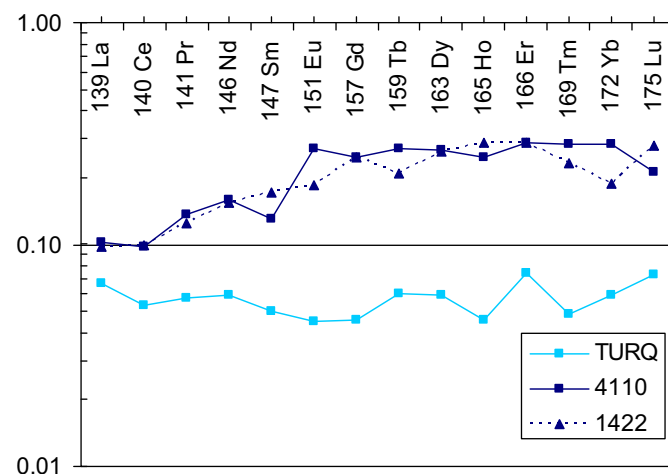


Fig. 3. REE distribution patterns normalised to Mud of Queensland (MUQ) (Kamber et al. 2005, 1046) for the Uluburun ingots.

and the glass on the Uluburun shipwreck, indicates that ingots were moved by sea for working into artefacts in the Aegean world, and possibly elsewhere.

Although the final destination of the ship cannot be confirmed, Pulak (2008, 300) suggests that one of the few Mycenaean centres that could have absorbed and have disseminated this volume and nature of goods would have been Mycenae. Goods from Mycenae would then be distributed to ports such as Tiryns in the south, which fits neatly with the analytical results linking Egyptian glasses to those of Tiryns (analysed by Walton et al., 2009), probably via traders such as those on the Uluburun ship. Whether the ship was that of a diplomatic envoy engaged in a trade in commodities rather than exclusive royal gift exchange as suggested by Walton et al. (2009) is difficult to assess using this data, although Pulak (2008, 298–299) suggests that the shipment was probably royal or elite, probably gift exchange, such as those described in the Amarna letters (Moran, 1992), and suggests directional trade with specific destinations, rather than opportunistic trade (although also see Collins (2008, 70) who suggests the situation may have been more complex). Certainly glass rises to prominence in the Mycenaean world at the time of the rise of the palaces, and it has been suggested that there is a direct link with glass and other high-prestige items to the social networks surrounding the Mycenaean palaces (Bennet, 2008; Nightingale, 2008). The Egyptian provenance of the three ingots analysed here would fit with a mechanism of direct trade (Walton et al., 2009, quoted in our opening paragraph, and see Pulak, 2008), although analysis of more ingots may show that some were of Near Eastern origin, which may fit with the model of indirect trade.

The evidence of the movement of glass ingots from Egypt to other Mediterranean centres is strongly supported by the analysis of three samples of blue glass that are representative of the main colours found in the Uluburun glass cargo. Whether this same conclusion can be reached with a larger sample remains to be seen. At least one site where glass of an Egyptian composition, but an Aegean style, has been identified is Tiryns (Walton et al., 2009; Panagiotaki, 2008, 47), and there may be evidence of glass working at Knossos (Panagiotaki, 2008, 47). However, as yet, centres that received these glass ingots for reworking have yet to be securely identified in the Aegean, although the palaces are likely locations.

7. Conclusions

Three samples of the glass ingots from the Uluburun wreck show a common trace element composition that is consistent with glasses manufactured in Egypt. These glasses consist of two deep blue ingots coloured with cobalt and one turquoise ingot coloured with copper. Furthermore, although the major element compositions of these glasses may indicate the use of slightly different, but similar, plant ash raw materials, the trace elements suggest a common geology indicative of glasses from the same region. This evidence confirms, for the first time, an Egyptian origin for some of the glass ingots found on the Uluburun wreck. The trace element compositions are also consistent with some Mycenaean glasses, suggesting the movement of glass in ingot form from Egypt for fabrication in the Mycenaean world. This evidence shows a direct link from general regional location of manufacture through the production of ingots to the finished goods, and suggests one possible trade route for the glass ingots.

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