

DATING AND PROVENANCE OF GLASS ARTEFACTS EXCAVATED FROM THE ANCIENT CITY OF TALL ZIRĀ'A, JORDAN*

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Fourteen glass objects recovered from excavations at the ancient city of Tall Zirā'a, Jordan, were analysed using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to determine the period and origin of manufacture. The composition of glasses manufactured in the Late Bronze Age (LBA) and Iron Age are distinctly different, therefore major element analysis can be used to distinguish between the groups relatively easily. The LA-ICP-MS analysis provided quantitative trace element data which were used to determine the provenance of those glasses identified as LBA. This research discusses the implications of the presence of both Egyptian and Mesopotamian LBA glasses and examines the varying compositions and colour strategies employed in both the LBA and Iron Age objects. Specifically, glass in the LBA was considered to be one of the highest status items attainable, playing an instrumental role in diplomatic gift-giving. When considered with the archaeological information, the significance of these finds

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at Tall Zirā'a indicates that this city was a settlement of high status, not primarily a convenient trading stop on the Transjordan route.

KEYWORDS: TALL ZIRĀ'A, GLASS, LATE BRONZE AGE, IRON AGE, LA-ICP-MS, EGYPT, MESOPOTAMIA

INTRODUCTION

The first deliberate manufacture of glass occurs in the 16th century BCE, although the origin of the material is still a focus of debate—Egypt or Mesopotamia being the most likely innovator. The conventional approach is that glass technology first developed in Mesopotamia (Barag 1970, 131–4; Moorey 1994, 192; Shortland *et al.* 2017) and that the subsequent transfer to Egypt could be ascribed to tribute associated with the successful military campaigns in the Levant by the Egyptian king Tuthmosis III (1479–1425 BCE). Although there is textual and iconographic evidence for the production, supply and transport of glass between Egypt, its vassal Levantine states and Mesopotamia, it is very rare to find Egyptian glass in Mesopotamia, or vice versa (Walton *et al.* 2009). The exceptions to date are two green glass rods found in Amarna, Egypt, which have trace element compositions consistent with Mesopotamian glass, and a collection of blue glass beads and a scarab recovered from a tomb in Gurob, Egypt, which also showed compositional consistency with glasses of known Mesopotamian origin (Varberg *et al.* 2016; Kemp *et al.* 2017, 2019). Although ubiquitous in modern life, glass in the Late Bronze Age (LBA) was meticulously controlled by the Egyptian royal court (Moorey 2001, 4). Glass in the LBA denoted high status and had sufficient value and importance to be a gift appropriate for the upper Egyptian elite, therefore playing an instrumental role in the etiquette of diplomatic gift-giving and tribute (Na'aman 2000; Shortland *et al.* 2001). To date, no glass of Egyptian trace element composition has been identified in the Levant or Mesopotamia. However, Egyptian glass has been identified in the Uluburun shipwreck, a vessel which sank in the late 14th century off the south-west Turkish coast with a large consignment of internationally sourced goods, including ebony, pottery from several states, elephant and hippopotamus tusks, copper ingots, tin ingots, and 175 glass ingots (Pulak 2001; Jackson and Nicholson 2010). Glass of both Egyptian and Mesopotamian compositions has also been identified at Tiryns in Mycenae (Walton *et al.* 2009; Smirniou and Rehren 2013; Varberg *et al.* 2016).

These observations strongly suggest that Egyptian and Mesopotamian glasses were extensively traded outside of their production areas, and this paper attempts to identify such glasses at Tall Zirā'a, Jordan. When referring to glasses as 'Mesopotamian', it should be noted that the samples analysed by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analysis in Shortland *et al.* (2007) were excavated from the sites of Nuzi and Tell Brak specifically, therefore the term 'Mesopotamia' is used here to describe the collective LBA Near Eastern states that ruled the lands near the Euphrates and Tigris, including Assyria and Babylonia (Oppenheim 1977, 35–48). LA-ICP-MS provides a quantitative analysis of geologically relevant trace elements including, most importantly, Cr, La, Ti and Zr, which form a 'compositional fingerprint' that can be used to ascertain the region of manufacture (Shortland *et al.* 2007). Samples analysed from Tall Zirā'a are compared with glasses from known centres of LBA glass production: Egypt and Mesopotamia.

When considered with the contextual and historical data of the Tall Zirā'a site, the provenance data of early glass technology is pertinent to key research questions such as exchange mechanisms between foreign states, and relationships between proximate and distant areas of a single state. Therefore, the provenance information can be used to investigate the connections

and diplomatic affiliations that this ancient city maintained with both Egypt and Mesopotamia through the LBA and Iron Age (IA). In addition, the presence of LBA glass would infer that Tall Zirā'a was more than a convenient stopping point on a trading route, but an important city in its own right, which was rewarded with the one of the highest accolades in the LBA.

The Levant

The Levant became the centre of an LBA international communication system, with long-distance trade routes playing an integral part (Pfälzner 2012, 770). The relationship between LBA Levantine potentates of the 'city-states' and the Egyptian royal administration can be perceived from the Amarna Letters, cuneiform tablets which contained the diplomatic correspondences between states (Moran 1992). From the language used in the Amarna Letters, the Levant was considered as a subordinate vassal state and was persistently subjected to the competing, dominating influences of the Egyptians, Mitanni and Hittites, and endured routine military campaigns which maintained Egyptian and then other supremacy over the Levant (Reader 2003, 349). However, trade and improved diplomatic relations between Egypt and Mesopotamia provided the Levant with stability, peace and prosperity, with only minor quarrels forming between neighbouring Levantine cities. The political landscape changed in 1350–1200 BCE when the Hittites conquered northern Syria by defeating the Mitanni, thereby initiating critical civil and political disorder.

After the Battle of Qadesh (1275 BCE) between the Egyptian and Hittite armies, and the subsequent collapse of the LBA, the southern Levant endured an extended period of complex social change during the IA; the great powers of Egypt and Mesopotamia withdrew, resulting in urban decline. The resulting power vacuum allowed the Levantine elite to re-establish their power and assume positions of rule, subsequently allowing the city-states to assert their independence and expand their international connections (Joffe 2002). Some central Levantine cities also continued in a contracted state but were quickly reoccupied by the Philistines, Teukrians and incumbent tribal factions that joined to form the states of Israel (Redford 1992, 289, 298). The Levant accumulated independent wealth and the Egyptian nation rekindled its interest in goods provided by the lucrative Phoenician trade, maintaining relations to secure the supply of imported and luxury commodities (Goedicke 1975).

Tall Zirā'a

Tall Zirā'a is located in the Wādī al-ḫ0201B;Arab situated in northern Jordan, approximately 5 km from the ancient Decapolis city of Gadara in modern-day Umm Qēs (Fig. 1). Excavations were carried out by the German Protestant Institute of Archaeology, Amman (GPIA), and the Biblical Archaeological Institute in Wuppertal (BAI), University of Wuppertal. The current excavations are supported by the Department of Antiquities of Jordan and financed by the German Archaeological Institute (DAI).

The site is located in the middle of the Wādī al-ḫ0201B;Arab, providing excellent living conditions with its numerous springs, fertile soil and temperate climate (Hanbury-Tenison 1984). The Tall measures approximately 200 m in diameter, with the highest point located 17 m below sea level. The significance of the site can be directly attributed to the artesian spring situated in the centre. The advantageous settlement conditions meant that Tall Zirā'a was consistently occupied from the Early Bronze Age to the Islamic period, providing the singular opportunity to examine an unbroken comparative stratigraphy (Steuernagel 1926; Vieweger and Häser 2017, 16–19). Notably, Tall Zirā'a was located on an LBA and IA trade route, which connected

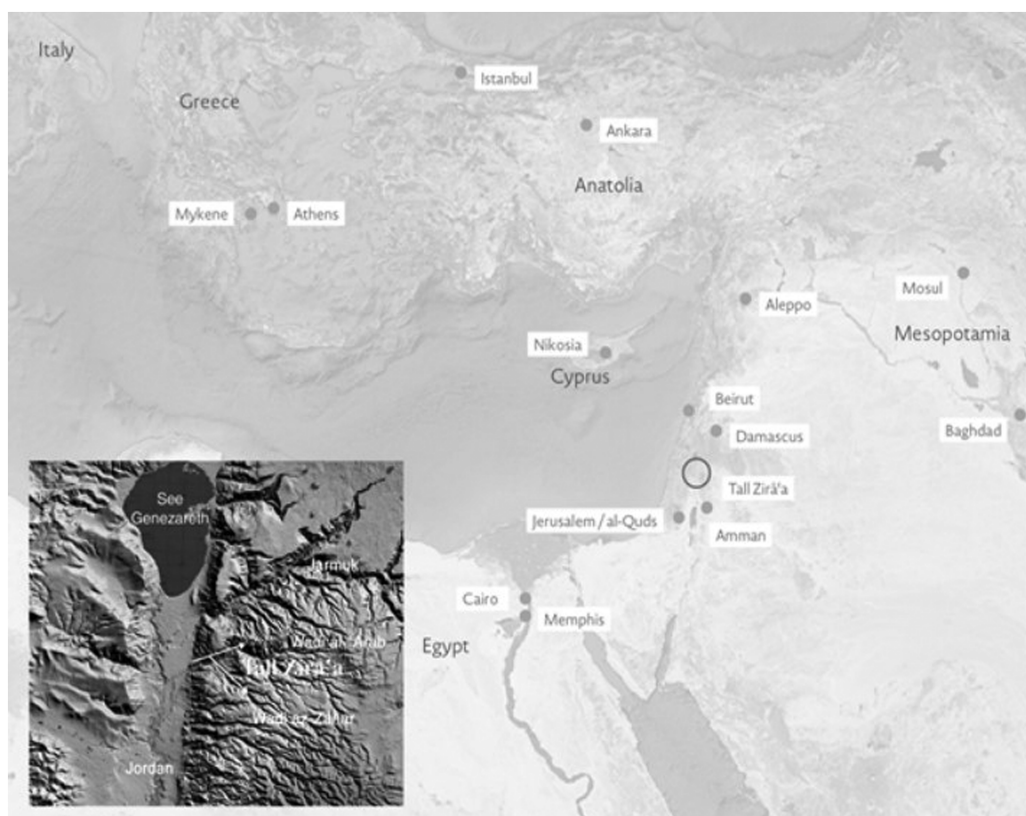


Figure 1 Location of Tall Zirā'a in the Wādī al-'Arab. Design: after Walter, in Vieweger and Häser (2019), 29, fig. 1.5.

the Jordan Valley with the Mediterranean coast via the Jezreel plain and Tall al-*ʿAṣī* (Beth Shean) in the west and with the Jordanian highlands in the east (Fig. 1). Owing to this favourable geography as well as to numerous finds that testify to the trade between the inhabitants of Tall Zirā'a with neighbouring regions, the excavators infer that the Wādī al-*ʿArab* was part of an important trade route connecting Egypt with Syria and Mesopotamia (Vieweger and Häser 2017, 14, 21–22).

SAMPLES AND METHODOLOGY

The glass objects analysed were excavated from Area I on the western slope of the Tell. Overall, approximately 142 pieces of glass from the LBA (stratum 14, 1500/1450–1200/1150 BCE) and approximately 287 pieces from the IA period were recovered: 92 from IA I (stratum 13, 1200/1150–1000/980 BCE) and 195 from IA IIA–C (stratum 12–10, 1000/980–520 BCE) period.

The LBA settlement (strata 16–14) consists of agglutinating domestic buildings and a casemate wall with an attaching tower. The LBA temple (complex D) was built on a terrace in the last phase of the LBA period; the radiocarbon samples from the *cella* of the temple indicating a date between 1450 and 1300 BCE. The discovery in this area of a scarab with the cartouche of Egyptian king Amenhotep III (1388–1351 BCE) confirms this date (Vieweger and Häser 2019,

57–59). The final LBA phase can be attributed to *c.*1200–1150 BCE, again according to radiocarbon dating (Soenneken 2017, 223).

The temple consists of a rectangular *cella* (2.15×3.40m) with a central column to carry the roof, a portico, a staircase (numbered D2), a large well-paved courtyard (D4) (150 m²) and four small rooms in the east (D5–8). The solid foundations of the temple, as well as the staircase, indicate that the building had at least two stories (Soenneken 2017, 171–88, 327; Vieweger and Häser 2017, 56). Five of the glass objects analysed were found in deposition layers in the temple *cella*, and one was excavated from the courtyard area (Table 1).

Unfortunately, many contexts around the temple area which yielded glass finds appear to be disturbed by later building activities, and thus do not provide a precise date, for example: contexts 4674, 6343 and 2726. Around 1200 BCE, the LBA temple together with the entire city was destroyed; shortly after but still during the IA I period, the temple was re-erected, but changed its outline. In the IA II period, the temple was abandoned and residences were built directly on the former IA I temple using its foundation walls. The two glass finds from the IA II period (stratum 12) were found in a deposition layer (locus 2650) of one of these domestic building complexes, complex B (room B3) (Soenneken 2017, 588–90).

The 15 glass or related objects selected for LA-ICP-MS analysis were chosen primarily to represent a range of object types and periods from the site, with the emphasis on the LBA period. Second, these objects were selected as they appeared to show a good level of preservation, the criteria of which included no obvious degradation or weathering, strong colour and clarity. Previous experience of work by inductively coupled plasma mass spectrometry (ICP-MS) on glass has shown that weathered, white, powdery glasses (which is often the norm) rarely produce interpretable results and should be avoided.

Small samples around a few millimetres across were clipped from the 15 glass objects and fragments with a pair of wire cutters. The samples were mounted in resin blocks and polished flat. 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 50 µm, as detailed in the in the additional supporting information.

Each sample was analysed at different 12 spots, avoiding any obvious weathered areas. Rarely, where low Na values suggested that weathered areas were sampled, these points have been removed to standardize the consistency of the samples and ensure the accuracy of the results. Corning A standard was run throughout the LA-ICP-MS analysis to check for accuracy and drift. The results are shown in Table 2, where they are compared with established values for the standards. The values for the major elements for Corning A were taken from Vicenzi *et al.* (2002). The results show good agreement for the most elements, with the standards averaging < 10% error on accuracy. Elements that greatly exceed these values can be split into two groups: elements where the standard only contains parts per billion and it is not well determined (e.g., Au and Cs) and elements where the ICP struggles because of interferences, monoisotopic elements and/or other factors (e.g., P).

RESULTS

The average compositions of the major elements in Table 3 show that 14 samples were glasses, and that they fall into three distinct compositional groups: high magnesia/high potash (HMHK), high magnesium/low potash (HMLK) and low magnesia/low potash (LMLK). The remaining sample (16622a) was not glass and is discussed below.

Table 1 Summary of the objects excavated at Tall Zirā'a, Jordan

Sample number	Find number	Object description	Colour	Locus	Context
<i>Iron Age context</i>					
15329	TZ 015329-001	Fragment of a spacer bead	Opaque turquoise	4674	Stratum 10 (IA IIC) Deposition layer located in the area above the Late Bronze Age (LBA) temple courtyard
16753	TZ 016753-001	Core-formed vessel fragment	Opaque (?), black/dark blue and white	5410	Stratum 12 (IA IIA/B) Deposition layer located in 'complex A', room A3
10047	TZ 010047-001	Fragment of a spacer bead	Translucent turquoise	2726	Stratum 12 (IA II A/B) Deposition layer located west of the large complex B; most probably mixed with earlier layers that belong to the LBA temple
10048	TZ 010048-001	Fragment of a round bead	Translucent yellow/brown	2728	Stratum 13 (IA I) Round silo in complex G; domestic context with storage facilities and working areas
18802	TZ 018802-001	Core-formed vessel fragment	Translucent dark blue	5942	Stratum 13 (IA I) Filling layer located in 'complex C' east of the paved temple courtyard C1
16622b	TZ 016622-001	Irregular fragment	Translucent colourless	5105	Stratum 13 (IA I) Floor level of area B2, on the outside
16622a	TZ 016622-001	Fragment of a hemisphere bead	Translucent yellow	5105	(north) of the IA I temple
<i>Late Bronze Age context</i>					
10779	TZ 010779-001	Fragment of a naked female figurine pendant	Translucent turquoise	2796	Stratum 14 (LBA) Deposition layer in the <i>cella</i> of the temple
10772	TZ 010772-001	Irregular fragment, probably a piece of raw glass	Opaque white with opaque blue centre	2777	Stratum 14 d (final LBA)
10170	TZ 010170-001	Fragment of a disc pendant	Opaque turquoise		Deposition layer in the <i>cella</i> of the temple
10762	TZ 010762-001	Fragment of a bead	Translucent dark blue		Stratum 14 d (final LBA)
10765	TZ 010765-001	Fragment of a spherical bead	Opaque turquoise		Deposition layer in the <i>cella</i> of the temple
16759	TZ 016759-001	Irregular lump	Translucent light green	5520	Stratum 14 d (final LBA) Deposition layer in courtyard D4 of the LBA temple complex
19322	TZ 019322-001	Fragment of a spacer bead	Translucent turquoise	6416	Stratum 16, 15, 14 (Middle Bronze Age (MBA) C-LBA) 'Complex A', room 4, mixed filling layer
19320	TZ 019320-001	Fragment of a bead	Opaque turquoise	6343	Stratum 16 (MBA C) Deposition layer in the area of room 9 'complex B'

Table 2 Average results of the Corning A standard compared with two sets of reference values

Analyte measured	Atomic mass	Average Corning A values from Tall Zirā'a (n = 15)	Shortland et al. (2007) and Vicenzi et al. (2002)		Wagner et al. (2012)	
			Accepted value (mg kg ⁻¹)	Relative error	Accepted value (mg kg ⁻¹)	Relative error
Na ₂ O	Na23	14.3	14.3	−0.1	13.4	6.2
MgO	Mg24	2.4	2.7	−11.4	2.5	−4.7
Al ₂ O ₃	Al27	0.9	1.0	−9.0	0.8	10.6
SiO ₂	Si29	67.2	66.5	1.1	67.8	−0.8
P ₂ O ₅	P31	0.1	0.1	24.3	0.1	17.6
K ₂ O	K39	3.0	2.7	8.8	3.5	−15.6
CaO	Ca43	5.2	5.0	2.8	4.9	4.5
MnO	Mn55	1.0	0.9	10.1	1.1	−13.7
FeO	Fe57	0.8	0.8	−1.0	0.9	−5.7
CoO	Co59	0.2	0.2	12.2	0.2	1.3
CuO	Cu65	1.2	1.0	19.4	1.1	9.7
Sb ₂ O ₃	Sb121	1.6	1.3	18.8	1.7	−6.8
PbO	Pb208	0.1	0.1	18.1	0.1	n.r.
Li	Li7	51.3	46.0	51.0	10.3	0.5
Be	Be9	0.1	0.1	n.r.	31.8	n.r.
B	B11	751	537	851	28.5	−13.3
Ti	Ti47	4867	4426	4428	13.2	9.0
V	V51	36.0	34.0	39.0	5.5	−8.4
Cr	Cr52	21.2	18.0	21.0	14.9	0.8
Ni	Ni60	186	160	181	13.8	2.5
Zn	Zn66	413	410	386	0.8	6.6
As	As75	30.7	25.0	n.r.	18.5	n.r.
Rb	Rb85	85.8	82.0	82.0	4.5	4.5
Sr	Sr88	935.0	860.0	897.0	8.0	4.1
Zr	Zr90	38.2	40.0	37.0	−4.8	3.1
Nb	Nb93	0.6	0.6	n.r.	−6.3	n.r.
Ag	Ag107	17.2	14.0	n.r.	18.4	n.r.
Sn	Sn118	1482	1194	1357	19.4	8.4
Sb	Sb121	13,109	10,649	14,002	18.8	−6.8
Cs	Cs133	0.3	0.2	n.r.	26.4	n.r.
Ba	Ba137	4651	3905	4122	16.0	11.4
La	La139	0.3	0.3	n.r.	−6.5	n.r.
Ce	Ce140	0.2	0.2	n.r.	19.3	n.r.
Au	Au197	0.2	0.1	n.r.	41.4	n.r.
Bi	Bi209	9.1	7.8	9.0	14.4	1.3
Th	Th232	0.3	0.3	n.r.	−6.8	n.r.
U	U238	0.2	0.2	n.r.	−5.8	n.r.

Note: Oxides values (wt%); elemental values (ppm). n.r., Not reported. Sources: Vicenzi *et al.* (2002); Shortland *et al.* (2007); Wagner *et al.* (2012).

DISCUSSION

LBA glasses found in Egypt and Mesopotamia that date from the mid-second millennium typically have high soda (15–20%) and significant magnesia (2–5%) and potash (2–4%) (Lilyquist *et al.* 1993, 41; Shortland and Eremin 2006), suggesting they were produced using

Table 3 Results of the laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analyses of the major and minor elements of the Tall Zirā'a's samples (wt%)

Sample number	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	K ₂ O	CaO	MnO	FeO	CoO	CuO	Sb ₂ O ₃	PbO
<i>High magnesia/high potash</i>													
10772	15.8	3.9	0.93	58.5	0.19	3.4	9.9	0.03	0.73	0.01	1.04	5.21	0.02
10170	14.1	3.4	0.43	65.3	0.12	2.9	10.4	0.02	0.19	0.00	1.19	1.75	0.02
19322	17.6	3.8	0.54	66.6	0.18	4.4	5.5	0.02	0.35	0.00	0.93	0.00	0.00
10048	19.3	4.8	0.72	65.6	0.19	3.7	5.1	0.05	0.24	0.00	0.00	0.00	0.00
10079	18.2	5.0	0.66	66.8	0.11	3.0	4.7	0.03	0.29	0.00	1.13	0.00	0.00
15329	12.4	3.2	0.39	69.0	0.18	2.4	9.2	0.02	0.16	0.00	1.15	1.72	0.00
19320	12.4	3.1	0.38	69.1	0.18	2.3	9.2	0.02	0.16	0.00	1.16	1.78	0.00
10765	18.2	4.0	1.76	67.2	0.10	2.9	4.1	0.04	0.33	0.00	1.20	0.00	0.00
10047	17.63	5.34	0.70	65.38	0.17	3.48	5.70	0.03	0.19	0.00	1.24	0.00	0.00
<i>Low magnesia/low potash</i>													
18802	17.0	0.6	2.16	65.8	0.11	1.0	8.1	1.20	1.31	0.19	0.32	0.68	1.35
16759	16.5	0.6	2.33	68.7	0.23	1.0	9.0	0.58	0.51	0.00	0.01	0.29	0.02
16622b	11.83	0.94	2.25	72.65	0.06	0.56	11.31	0.01	0.05	0.00	0.00	0.00	0.00
<i>High magnesia/low potash</i>													
16753	18.0	3.5	1.63	66.0	0.12	0.9	8.2	0.16	0.39	0.09	0.10	0.26	0.04
10762	20.6	2.7	2.35	64.6	0.11	1.3	6.2	0.21	0.49	0.14	0.33	0.37	0.02
<i>Non-glass</i>													
16622a	0.2	0.0	0.33	99.2	0.00	0.0	0.1	0.00	0.1	0.00	0.00	0.00	0.00

plant ash glass as the principal source of soda, perhaps from the genera *Salicornia* or *Salsola*, which are both found in Egypt and the Middle East. Later glasses from the first millennium BCE, or IA, used a different source, for example, Na-rich evaporite minerals which occur in Wadi el-Natron or Beheira province both located in Egypt (Turner 1954, 1956; Henderson 1985). Natron glasses are characteristically low in both magnesia and potash, with both components at levels of approximately 0.5%, and therefore compositionally distinct from plant ash glasses (Sayre and Smith 1974). The elemental composition of both plant ash and natron glasses are well published and can be used to distinguish between these glass-making periods (Sayre and Smith 1961; Lilyquist *et al.* 1993; Brill 1999; Henderson 2000; Shortland and Tite 2000).

HMHK and HMLK

The HMHK group is consistent with the typical composition of high magnesia glasses produced in the LBA using a plant ash flux, glasses that are relatively common through Egypt, Mesopotamia and the Greek world. These glasses are low in Al, indicating that a relatively pure source of silica was used, such as ground quartz pebbles. The HMHK glasses coloured with Cu are relatively low in Sn, indicating that an unalloyed source of copper was used. This Sn-free copper source is more consistent with Mesopotamian Cu-coloured glasses from sites such as Nuzi and Tell Brak (Walton *et al.* 2012), than Egyptian Cu-coloured glasses which tend to have higher Sn contents, although not always (Shortland and Eremin 2006). Four of the Cu-coloured glasses contain Sb, which was used to make opaque glasses in this period (Nicholson and Henderson 2000, 197; Shortland and Eremin 2006). The addition of an Sb compound creates Ca antimonate crystals in the glass which render it opaque, and at least two different methods of achieving this are known in this period. In Egypt, an Sb compound alone appears to be added to the glass, whereas in Mesopotamia, both a Ca compound and an Sb compound (perhaps combined before addition) are added. This means that whilst in Egyptian sourced glasses the lime content of both the non-opacified and opacified glasses are very similar, in Mesopotamia, the lime content of Sb-opacified glasses tends to be greater than that of the non-opacified glass (Shortland 2002; Shortland and Eremin 2006; Shortland *et al.* 2017). In the blue glasses from this site, it can clearly be seen that the lime content of the opacified glass (averaging 9.7% CaO) is higher and distinct from the translucent glass (averaging 4.9% CaO). This once again suggests that at least the four opaque blue glasses are more consistent with Mesopotamian technology than Egyptian. The composition of 10765 is consistent with the HMHK group, but shows an elevated Al and Nb content and is discussed further below.

The single yellow-brown glass, 100488, is the only non-blue glass in the HMHK group. Yellow-brown glasses are relatively rare, but analyses are available from Amarna, Malkata and Lisht (Shortland and Eremin 2006) and from Nuzi (Kirk 2009). These glasses range in colour from very pale amber to deep brown due to the presence of relatively low levels of Fe in varying oxidization conditions. The yellow-brown glass in the HMHK group is consistent with the composition of other LBA brown glasses, containing low concentrations of Fe (< 0.25% FeO) and no other colouring elements in significant concentrations.

Interestingly, two objects of the HMHK group, 15329 and 19320, both spacer-beads, exhibited almost identical compositions for all elements. The compositions are so close that this cannot be mere chance; indeed, the variation is so small as to fall within the range that would be expected if the analysis were carried out on the same piece of glass. It is probable, therefore, that the objects were made from the same glass ingot or glass batch. The contexts in which they were found are different, however, as discussed below. The composition of the HMLK glasses, 16753 and

10762, is consistent with Cu-Co coloured plant ash glass manufactured in Egypt in the LBA (Shortland and Eremin 2006). The HMLK group exhibits elevated levels of Al, Mn, Fe, Ni, and Zn with accompanying low levels of K ($> 1.6\%$ K₂O), which is characteristic of Egyptian Co-coloured glasses, made from an Egyptian Oasis-sourced Co alum-based colourant (Sayre and Smith 1961; Kaczmarczyk 1986; Shortland and Eremin 2006; Walton *et al.* 2012). The HMLK glasses were also coloured with Cu and contained elevated levels of Sn, indicating that a Sn-bearing source of copper was used, such as bronze. Sb is present once again as an opacifier and at consistent levels compared with the Cu/Co-coloured glasses analysed previously (Shortland and Eremin 2006).

As mentioned above, concentrations of Cr, La, Ti and Zr can be used to discriminate between glasses produced of Egyptian and Mesopotamian origin (Shortland *et al.* 2007); Egyptian glasses have relatively low Cr and La concentrations with elevated, but varying, Zr and Ti concentrations, whereas Mesopotamian glasses have the opposite (Table 4). Figure 2 shows the HMLK and HMLK groups plotted against data from Shortland *et al.* (2007). The HMLK group shows compositional similarities with the glasses from Mesopotamia, whereas the HMLK group showed a strong correlation with Egyptian compositions. This is consistent with the different colouring strategies discussed above and the evidence from the major elemental compositions. The analysis strongly suggests that the nine HMLK glasses, blue and yellow-brown, come from Mesopotamia, whereas the two HMLK Co/Cu-coloured glasses come from Egypt. HMLK glass 10765 exhibits the lowest concentrations of Cr with the highest concentrations of La in the HMLK group, which are comparable with Egyptian composition; however, the Ti and Zr levels are consistent with Mesopotamian composition. However, this could be an outlier and without a larger sample group, it cannot be said that this sample represents a Levantine glass composition.

LMLK

The LMLK group is compositionally consistent with low magnesia glasses produced in the IA and later using natron as an alkali flux and sand as a silica source. The LMLK group has significantly higher levels of Al compared with the HMLK group, but comparable with that of the HMLK group (where alumina is introduced with the Co colourant). The Co-coloured glass (18802) has relatively high levels of a range of elements including Co, Cu, Mn, Fe, lead, Sb, Sn and even Ag when compared with the other HMLK glasses and such glasses in general. This trace element pattern for the Co used to colour the glass has been identified before in other glasses found in Europe from the early IA until the end of the 12th century CE (Gratuze 2013). It is very distinct from the standard, Egyptian Oasis-sourced Co used in the HMLK glasses and bears compositional similarities with the 'Type N' Co colourant defined by Abe *et al.* (2012). Cobalt Type N is recognized as the Co colorant used after the Late Period, and is distinguished by its relatively low amounts of Zn and a deficiency of Ni. Both levels of Zn and Ni in the Co-coloured glass 18802 conform with this composition (Abe *et al.* 2012).

The pale translucent green and colourless translucent glasses appear to have no deliberate colourant added, but in detail they are very different glasses. The translucent green glass (16759) has significant Mn (4469ppm Mn) and Sb (2381ppm Sb), suggesting that the glass may have been deliberately decolourized with these elements. The occurrence of both Mn and Sb at intentional levels could also indicate a Roman glass composition. The colourless translucent glass 16622b contains only a 10th of the Fe (352ppm Fe) of 16759 and only traces Mn and Sb. The Zr content is also high in 16622b. It does, however, contain significant As at 1130ppm. The Rb/Sr ratio of the two-colourant-free LMLK glasses are very different, with

Table 4 Results of the laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analyses of the trace elements of the Tall Zirā'a's samples (ppm)

Sample no.	Li	Be	B	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Rb	Sr
<i>High magnesia/high potash</i>															
10772	15.4	0.2	163	352	11	18	260	5662	48.8	151	8309	78.4	463.7	22.9	554
10170	16.0	0.1	104	163	5	17	167	1466	4.5	35.5	9507	15.7	137.5	10.5	443
19322	19.5	0.0	125	198	6	14	166	2756	7.1	18.6	7442	24.4	29.7	15.3	411
10048	26.7	0.1	168	190	6	17	360	1863	1.2	9.2	15.0	16.0	1.18	12.7	501
10079	19.4	0.1	172	249	6	19	229	2293	19.4	14.6	9014	20.2	20.2	6.3	342
15329	16.2	0.0	95	147	4	14	119	1220	1.3	13.8	9227	15.1	82.4	18.4	605
19320	14.6	0.1	95	146	4	14	118	1231	1.3	13.7	9310	14.7	81.7	17.7	601
10765	24.8	0.4	215	271	8	10	320	2557	7.9	13.9	9628	18.3	19.6	18.7	312
10047	11.9	0.1	119	286	8	23	201	1439	4.2	16.8	9898	24.3	4.5	16.7	337
<i>Low magnesia/low potash</i>															
18802	5.6	0.3	146	390	17	10	9307	10197	1527	50.3	2575	78.6	36.4	11.6	556
16759	4.6	0.3	183	528	20	15	4468	3928	5.3	10.7	41.7	29.6	9.9	9.6	459
16622b	24.6	12.9	20.9	272	6	10	47	352	2.5	4.5	7.3	16.9	1130	149	51
<i>High magnesia/low potash</i>															
16753	8.0	1.6	149	589	8	7	1250	3050	735	695	816	2316	10.1	5.7	631
10762	11.2	1.4	243	636	11	9	1655	3789	1063	710	2638	1904	27.7	7.5	511
<i>Non-glass</i>															
16622a	0.0	0.0	67	269	4	1	1	662	0.9	0.4	1.9	5.8	0.0	0.2	8.1

Sample no.	Zr	Nb	Ag	Sn	Sb	Cs	Ba	La	Ce	Au	Pb	Bi	Th	U
<i>High magnesia/high potash</i>														
10772	13.6	1.0	0.9	17.9	43516	0.65	104	2.4	4.6	0.1	209	0.1	0.6	0.3
10170	5.9	0.4	3.9	31.7	14607	0.41	33.3	1.1	2.1	0.6	147	1.0	0.2	0.1
19322	7.0	0.5	1.1	3.97	9.3	0.37	43.8	1.4	2.8	0.4	5	0.3	0.3	0.1
10048	9.6	0.7	0.1	1.81	0.2	0.31	37.8	1.9	3.8	0.0	5	0.0	0.4	0.2
10079	7.8	0.7	0.5	2.59	3.3	0.18	33.8	1.9	3.7	0.1	3	0.1	0.4	0.2
15329	6.5	0.4	1.1	2.44	14408	0.52	42.1	1.2	2.4	0.1	21	0.2	0.2	0.1
19320	6.4	0.4	1.1	2.48	14868	0.48	41.9	1.2	2.4	0.1	20	0.2	0.2	0.1
10765	12.1	2.0	0.4	3.75	6.30	0.31	55.0	2.9	5.9	0.1	9	0.3	1.2	0.6
10047	9.6	0.7	1.8	2.1	32.6	0.3	40.5	1.7	3.5	0.3	9	0.4	0.4	0.2
<i>Low magnesia/low potash</i>														
18802	34.8	1.3	1.24	113.5	5707	0.1	255	5.91	10.6	0.11	12496	0.3	0.8	0.8
16759	45.6	1.8	0.09	60.4	2381	0.1	269	6.0	10.8	0.0	206	0.0	0.9	1.1
16622b	247	7.8	0.1	12.9	9.2	11.8	597	8.5	11.5	0.0	41	0.5	6.8	2.7
<i>High magnesia/low potash</i>														
16753	48.3	1.8	0.4	41.5	2176	0.1	64.1	3.5	8.2	0.1	362	0.1	0.9	0.6
10762	48.9	1.8	0.6	38.2	3102	0.1	63.4	3.4	8.5	0.2	151	0.2	1.0	1.0
<i>Non-glass</i>														
16622a	40	0.9	0.0	1.8	0.9	0.0	0.7	0.0	0.2	0.0	0.84	0.0	0.2	0.0

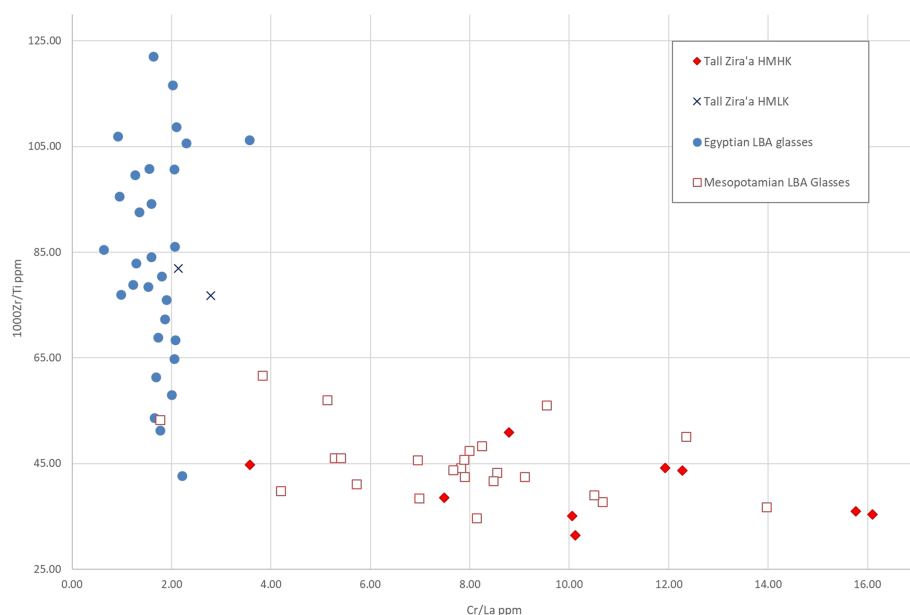


Figure 2 Covariant plot of 1000 Zr/Ti with Cr/La of the Tall Zirā'a high magnesia/high potash (HMK) and high magnesia/low potash (HMLK) groups compared with Egyptian and Mesopotamian glasses of known origin. Source: Shortland *et al.* (2007). [Colour figure can be viewed at wileyonlinelibrary.com]

16759 having a ratio of 0.02 and 16622b much higher at 2.9. 16622b was excavated from an IA context; however, the composition is comparable with late nineteenth-century CE glasses decolourized with As.

Archaeological implications

The trace elements of the nine Tall Zirā'a glasses in the HMK group match the composition of LBA glasses originating from Mesopotamia, whereas the two HMLK glasses analysed match the composition of LBA glasses originating from Egypt. The pieces belonging to the HMK group allow good parallels to glass finds from Mesopotamia (e.g., disc pendant, spacer bead) and partly also from the Levant (e.g., naked female figurine pendant). The findings as well as the analysis show that Tall Zirā'a was the recipient of glass exports from both Egypt and Mesopotamia. The Egyptian and Mesopotamian origins of the glasses are furthermore also reflected in other finds from the *cella*, for example: 24 cylinder seals which can be attributed to the Syrian or Syro-Palestinian style of the Mitanni glyptic (Syro-Palestine), a silver pendant depicting a goddess with parallels in Ugarti, Tall al-'Ajjul and Megiddo, a scarab with the cartouche of Amenhotep III, and various faience objects (scarabs, vessel fragments) which originate from Egypt.

Only one other LBA site has been identified to contain glasses from both Egypt and Mesopotamia: Mycenae. Beads excavated from the palatial centre of Tiryns, Mycenae, were analysed and identified as coming from both Egypt and Mesopotamia (Walton *et al.* 2009). No other site in the Levant has yet been identified with a similar pattern, although further work would surely indicate that this was the case. Tall Zirā'a was on a significant trading route connecting Egypt with Mesopotamia. The trading route started in Egypt, traversed the Sinai Peninsula, diverted north along

the Mediterranean further on to Damascus to arrive at the Euphrates in Mesopotamia. Therefore, it can be inferred that high-value items such as glass and other materials were transported via this route and, at least partly, arrived at Tall Zirā'a as tribute to the temple.

Seven of the 12 glass objects identified as being LBA plant ash glass were excavated from the LBA stratum 14 and are therefore consistent with the stratigraphy. Five were found in the *cella* of the temple or in close proximity: a fragment of a naked female figurine pendant (10779), a disc pendant (10170) (Fig. 3), a fragment of a bead (10762), a suspected piece of raw glass (10772), and a spherical bead (10765). These pieces can also be dated according to typological comparisons: for example, 10779 can be identified as the arm of a typically LBA naked female figurine. The best comparable pieces comes from Tall Zirā'a itself (Schmidt 2019, 46), as well as from Tall al-Fukhar (Jensen 2015, 331), Lachish (Tufnell 1958, pl. 27: 3), and Tall al-*x01E24;išn* (Beth Shean) (Rowe 1940, pl. LXVIII: 7). In addition, a large number of sites are known to yield naked female figurine pendants (Brill 1970, appendix II). Owing to the thickness and rounded shape, it is credible to identify 10170 as part of disc pendant, as they were similarly found in LBA contexts in Nuzi, where they were decorated with stars (Starr 1939, pl. 120; Barag 1970, figs 100, 101). In Nuzi, the star-pendants are connected with the cult of the Goddess Ishtar, a similar function as temple dedication can also be suggested for the piece from Tall Zirā'a.

Glass beads, amulets and pendants could be purchased by those who could afford them and were eminently tradable as objects of elevated status. Numerous glass fragments identified as parts of disc pendants found at the site supporting the inference that smaller glass objects were transported from Mesopotamia to Tall Zirā'a.

According to chemical analysis, four LBA glass objects were primarily classified to have been retrieved from IA deposition layers. However, in each case it was observed by the excavators that probable mixing of the deposition layers had occurred. The production of plant ash glass continued into the IA; however, the HMK glasses excavated from the IA contexts exhibit



Figure 3 Fragment of a disc pendant (10170). [Colour figure can be viewed at wileyonlinelibrary.com]

characteristic LBA composition: the spacer bead fragment 15329 was found in the IA deposition layer in close proximity to fragment 19320, which has an almost identical composition but originates in an adjacent LBA context. The HMK composition of 15329, typical of an LBA glass, therefore adds credence to the excavators' interpretation that these contexts were mixed during later construction works. Likewise, another fragment of a spacer bead (10047) of LBA composition was found in IA stratum 12, again thought to be disturbed by the digging of a later pit. The round bead 10048 of LBA plant ash composition was excavated from an IA I stratum; however, there is evidence yet again of later works on this area, including the conversion of the structure into a residence. The core-formed vessel fragment (16753) was located north of the former temple (IA II A) and can also be identified as being excavated from a mixed stratum, and has a typical LBA Egyptian Co glass composition. Once again, this supports the excavators' interpretation that these contexts were mixed.

The presence of Egyptian composition LBA core-formed vessels (16753) at the site also implies that Tall Zīrā'a was connected with influential individuals, equivalent to the second-rank elite of Egypt. Although the Levant was considered as vassal, and subject to the influences of Egypt and Mesopotamia, the presence of core-formed vessels indicates that Tall Zīrā'a was considered to be an LBA city of particular significance.

Object 16759, a translucent light green object described as an 'irregular lump', is consistent with IA natron glass, but was excavated from the deposition layer in the courtyard of the LBA temple complex. However, stratum 14d is described as being a very late phase of the LBA, therefore it can be inferred that this is an early example of IA glass at Tall Zīrā'a. The natron glass core-formed vessel fragment (18802) was excavated from stratum 13 (IA I), which is attributed to the 13th–12th centuries BCE, and therefore the composition of this glass is consistent with the date of the phases. The translucent, colourless glass fragment (16622b) was excavated from the north outside area of the temple also from stratum 13 (IA I); however, the composition is atypical for LMLK glass.

16622a, a yellowish, translucent hemisphere, likely quartz, and 16622b, a translucent, colourless glass fragment, were found mixed, and in large number, on a floor to the north of the IA I temple (stratum 13) of an area identified as a possible workshop. The composition of the translucent, colourless glass fragment 16622b is however atypical for LMLK glass. The area was interpreted as workshop area indicated by the presence of a large number of working stones, slags and fireplaces, but containing no vessels associated with cooking or food preparation. The presence of these numerous glass fragments and quartz pebbles suggest that craftsmen at Tall Zīrā'a may have used these quartz pebbles as raw material and incorporated glass fragments as part of the glassworking process. Further evidence for glassworking at the site comes from 10772, identified as a piece of raw glass (or part of an ingot) of plant ash composition. This suggests that glassworking may have occurred on-site from the LBA and continued into the IA. The continued presence of glass at Tall Zīrā'a during the IA suggests that the city was affluent enough to sustain the trade of luxury items after the collapse of the LBA and had sufficient resources to support a craft industry encompassing vitreous materials.

CONCLUSIONS

The chronological classification of the glass finds from Tall Zīrā'a shows that glass analyses can be used as a method for dating finds. This is an additional source of information in view of the stratigraphic contexts, which are often difficult to date, as they are often strongly mixed. Of the 14 glass objects analysed, nine plant ash glasses show a positive correlation with the

composition of LBA glasses manufactured in Mesopotamia. The remaining two plant ash glasses are consistent with the composition of LBA Egyptian-made glasses. Therefore, Tall Zirā'a represents one of only two LBA sites which are known to have received glass objects from both Egypt and Mesopotamia. This goes hand in hand with the archaeological findings, both with the glass objects themselves as well as with the other finds made in the *cella* of the LBA temple. There is also some evidence of glassworking at the site, suggesting that raw glass, possibly in the form of ingots, was transported to the city. The presence of an LBA core-formed vessel with an Egyptian composition indicates an affiliation directly or indirectly with the upper elite of Egypt. The presence of natron glass confirms that the trade of luxury goods continued at Tall Zirā'a into the IA after the collapse of the LBA, and that the city was prosperous enough to sustain craftsmen who probably provided glassworking. The presence of these three types of glass demonstrates that Tall Zirā'a was a well-connected settlement of significant social importance during the LBA, maintaining affluence and trade links into the IA.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1: Operating conditions of the ESI NWR193 laser ablation system and the Agilent 7700 ICP-Q-MS mass spectrometer.

Data S2: Plan of the Late Bronze Age settlement, stratum 14d.

Data S3: Plan of the Late Bronze Age temple, stratum 14d, complex D.



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The dating and provenance of glass artefacts excavated from the ancient city of Tall Zira, Jordan

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