The dating and provenance of glass artefacts excavated from the ancient city of Tall Zirā’a, Jordan.

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Introduction

The first deliberate manufacture of glass occurs in the sixteenth century BC, 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, p131-4; Moorey, 1994, p192; 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 BC). 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, McDonald, A and Shortland, 2017; Kemp et al., 2019). Although ubiquitous in modern life, glass in the Late Bronze Age (LBA) was meticulously controlled by the Egyptian royal court (Moorey, 2001, p 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, Nicholson and Jackson, 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 southwest 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 Tyrins, 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. When referring to glasses as “Mesopotamian”, it should be noted that the samples analysed by 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 in this paper to describe the collective LBA Near Eastern states that ruled the lands near the Euphrates and Tigris, including Assyria and Babylonia (Oppenheim, 1977, p35-48). Laser Ablation Inductively Coupled Plasma Mass Spectrometry (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, Rogers and Eremin, 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 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, p770). 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

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Egyptians, Mitanni and Hittites, and endured routine military campaigns which maintained Egyptian and then other supremacy over the Levant (Reader, 2003, p 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 BC when the Hittites conquered northern Syria by defeating the Mitanni, thereby initiating critical civil and political disorder.

After the battle of Qadesh in 1275 BC 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, p289, p298). The Levant accumulated independent wealth and the Egyptian nation rekindled their 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-’Arab situated in northern Jordan approximately 5km 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-’Arab, providing excellent living conditions with its numerous springs, fertile soil and temperate climate (Hanbury-Tenison, 1984). The Tall measures approximately 200m in diameter, with the highest point located 17m 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, p16-19). Notably, Tall Zirā’a was located on a LBA and IA trade route, which connected the Jordan Valley with the Mediterranean coast via the Jezerel plain and Tall al-Ḥiṣn (Beth Shean) in the west and with the Jordanian highlands in the east (Figure 1). Owing to this favourable geography as well as to numerous finds that testify the trade between the inhabitants of Tall Zirā’a with neighbouring regions, the excavators infer that the Wādī
al-’Arab was part of an important trade route connecting Egypt with Syria and Mesopotamia (Vieweger and Häser, 2017, p14, p21–22).

Figure 1. Map showing the location of Tall Zirā‘a in the Wādī al-’Arab (Design after Walter, in Vieweger and Häser, 2019, 29, fig. 1.5)

Samples and methodology

The glass objects analysed in this paper 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 BC) and approximately 287 pieces from the IA period were recovered: 92 from IA I (stratum 13, 1200/1150–1000/980 BC) and 195 from IA IIA–C (stratum 12–10, 1000/980–520 BC) 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 the date between 1450 and 1300 BC. The discovery in this area of a scarab with the cartouche of the Egyptian king Amenhotep III (1388–1351 BC) confirms this date (Vieweger and Häser, 2019, p57-59). The final
LBA phase can be attributed to c. 1200–1150 BC, again according to radiocarbon dating (Soennecken, 2017, p223).

The Temple consists of a rectangular cella (2.15m × 3.40m) with a central column for carrying the roof, a portico, a staircase (numbered D2), a large well-paved courtyard (D4) (150m²) 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 (Soennecken, 2017, p171–188, p327; Vieweger and Häser, 2017, p56). Five of the glass objects analysed were found in deposition layers in the Temple cella and one was excavated from the courtyard area, see Table 1. Summary of objects excavated from Tall Zirā’a

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, 2726. Around 1200 BC, 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) (Soennecken, 2017, p588-590).

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. Secondly, 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 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 50μm, as detailed in the supplementary material.

Each sample was analysed at different 12 spots, avoiding any obvious weathered areas. Rarely, where low sodium values suggested that weathered areas were sampled, these points have been removed to standardise 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 to established values for the standards. The values for the major
elements for Corning A were taken from Vincenzi et al. (2002). The results show good agreement for the most elements, with the standards averaging less 10% error on the 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.

Discussion

LBA glasses found in Egypt and Mesopotamia that date from the middle of the second millennium typically have high soda (15-20%) and significant magnesia (2-5%) and potash (2-4%) (Lilyquist, Brill and Wypyski, 1993, p41; Shortland and Eremin, 2006), suggesting that they were produced using 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 BC, or Iron Age (IA), used a different source, for example sodium rich evaporite minerals which occur in the Wadi el-Natrun or the 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 glassmaking periods (Sayre and Smith, 1961; Lilyquist, Brill and Wypyski, 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 aluminium, indicating that a relatively pure source of silica was used, such as ground quartz pebbles. The HMHK glasses coloured with copper are relatively low in tin, indicating that an unalloyed source of copper was used. This tin-free copper source is more consistent with Mesopotamian copper coloured glasses from sites such as Nuzi and Tell Brak (Walton et al., 2012), than Egyptian copper coloured glasses which tend to have higher tin contents, although not always (Shortland and Eremin, 2006). Four of the copper coloured glasses contain antimony,
which was used to make opaque glasses in this period (Nicholson and Henderson, 2000, p197; Shortland and Eremin, 2006). The addition of an antimony compound creates calcium 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 antimony compound alone appears to be added to the glass, whereas in Mesopotamia, both a calcium compound and an antimony 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 antimony 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 iron in varying oxidisation conditions. The yellow-brown glass in the HMHK group is consistent with the composition of other LBA brown glasses, containing low concentrations of iron (<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 was 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 later. The composition of the HMLK glasses, 16753 and 10762, is consistent with copper-cobalt coloured plant ash glass manufactured in Egypt in the LBA (Shortland and Eremin, 2006). The HMLK group exhibits elevated levels of aluminium, manganese, iron, nickel, and zinc with accompanying low levels of potassium (>1.6 % K2O), which is characteristic of Egyptian cobalt-coloured glasses, made from an Egyptian Oasis sourced cobalt alum-based colourant (Sayre and Smith, 1961; Kaczmarczyk, 1986; Shortland and Eremin, 2006; Walton et al., 2012). The HMLK glasses were also coloured with copper and contained elevated levels of tin, indicating that a tin bearing source of copper was used, such as bronze. Antimony is present once again as an opacifier and at consistent levels to copper/cobalt 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 HMHK and HMLK groups plotted against data from Shortland et al. (2007). The HMHK 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 HMHK glasses, blue and yellow-brown, come from Mesopotamia, whereas the two HMLK cobalt/copper coloured glasses come from Egypt. HMHK glass 10765 exhibits the lowest concentrations of Cr with the highest concentrations of La in the HMHK 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.

Figure 2. Covariant plot of 1000Zr/Ti with Cr/La of the Tall Zirā’a HMHK and HMLK groups compared with Egyptian and Mesopotamian glasses of known origin (Shortland, Rogers and Eremin, 2007).
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 aluminium compared with the HMHK group, but comparable with that of the HMLK group (where alumina is introduced with the cobalt colourant). The cobalt coloured glass (18802) has relatively high levels of a range of elements including cobalt, copper, manganese, iron, lead, antimony, tin and even silver when compared to the other HMLK glasses and such glasses in general. This trace element pattern for the cobalt used to colour the glass has been identified before in other glasses found in Europe from the early IA until the end of the twelfth century (Gratuze, 2013). It is very distinct from the standard, Egyptian Oasis sourced cobalt used in the HMLK glasses and bears compositional similarities with the “Type N” cobalt colourant defined by Abe (2012). Cobalt Type N is recognised as the cobalt colorant that was used after the Late Period, and in distinguished by its relatively low amounts of zinc and a deficiency of nickel. Both levels of zinc and nickel in the cobalt 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 manganese (4469 ppm Mn) and antimony (2381 ppm Sb), suggesting that the glass may have been deliberately decolourised 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 tenth of the iron (352 ppm Fe) of 16759 and only trace manganese and antimony. The zirconium content is also high in 16622b. It does, however, contain significant arsenic at 1130 ppm As. The Rb/Sr ratio of the two colourant-free LMLK glasses are very different, with 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 19th Century glasses decolourised with As.

Archaeological implications

The trace elements of the nine Tall Zirā’a glasses in the HMHK 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 HMHK 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 Ugarit, 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, Greece 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 twelve 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) (Figure 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 come from Tall Zirā’a itself (Schmidt 2019, 46), as well as from Tall al-Fukhar (Jensen, 2015, p331), Lachish (Tufnell, 1958, pl. 27: 3), and Tall al-Ḥiṣn (Beth Shean) (Rowe, 1940, pl. LXVIIIA: 7). In addition, a large number of sites are known to yield naked female figurine pendants (Brill, 1970, appendix II). Due 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, fig 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 HMHK glasses excavated from the IA contexts exhibit 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 HMHK composition of 15329, typical of a 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 cobalt 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 Zirā’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 Zirā’a was considered to be a 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 Zirā’a. The natron glass core formed vessel fragment (18802) was excavated from stratum 13 (IA I) which is attributed to the 13-12th century BC, 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, colorless 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 Zirā’a may have used these quartz pebbles as raw material and incorporated glass fragments as part of the glass working process. Further evidence for glass working 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 Zirā’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.

Conclusion

The chronological classification of the glass finds from Tall Zirā’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 in this study, 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

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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 a LBA core formed vessel with an Egyptian composition indicates and 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 which probably provided glass working. 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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Table 1. Summary of objects excavated from Tall Zirā’a

| Sample number | Find number | Object description                  | Colour      | Locus | Context                                      |
|---------------|-------------|--------------------------------------|-------------|-------|----------------------------------------------|
| Iron Age context |             |                                      |             |       |                                              |
| 15329         | TZ 015329-001 | Fragment of a spacer bead            | Opaque turquoise | 4674  | Stratum 10 (IA IIIC)                       |
|               |             |                                      |             |       | Deposition layer located in the area above the Late Bronze Age 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 (north) of the IA I Temple. |
| 16622a        | TZ 016622-001 | Fragment of a hemisphere bead        | Translucent yellow | 5105  |                                              |
| Late Bronze Age context |             |                                      |             |       |                                              |
| 10779         | TZ 010779-001 | Fragment of a naked female figurine pendant | Translucent turquoise | 2796  | Stratum 14 (LBA)                            |
|               |             |                                      |             |       | Deposition layer in the cella 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)                     |
| Code  | TZ  | Description                      | Color         | Location                                           | Stratigraphic Layer                          |
|-------|-----|----------------------------------|---------------|---------------------------------------------------|---------------------------------------------|
| 10170 | 010170-001 | Fragment of a disc pendant      | Opaque turquoise | Deposition layer in the cella of the Temple.       |                                             |
| 10762 | 010762-001 | Fragment of a bead              | Translucent dark blue | Stratum 14 d (final LBA)                          |                                             |
| 10765 | 010765-001 | Fragment of a spherical bead    | Opaque turquoise | Deposition layer in the cella of the Temple.       |                                             |
| 16759 | 016759-001 | Irregular lump                   | Translucent light green | Stratum 14 d (final LBA)                          | Deposition layer in courtyard D4 of the LBA Temple complex. |
| 19322 | 019322-001 | Fragment of a spacer bead        | Translucent turquoise | Stratum 16, 15, 14 (MBA C–LBA)                    | “Complex A”, room 4, mixed filling layer. |
| 19320 | 019320-001 | Fragment of a bead              | Opaque turquoise | Stratum 16 (MBA C)                                | Deposition layer in the area of room 9 “Complex B”. |

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Table 2. Average results of the Corning A standard, compared with two sets of reference values (Vicenzi et al., 2002; Shortland, Rogers and Eremin, 2007; Wagner et al., 2012). Oxides values in wt%, elemental values in ppm.

| 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) |
|------------------|-------------|-----------------------------------------------|-------------------------------------------------|---------------------|
| Na2O             | Na23        | 14.3                                          | 14.3                                            | -0.1                |
|                  |             |                                               |                                                 | 13.4                |
| MgO              | Mg24        | 2.4                                           | 2.7                                             | -11.4               |
|                  |             |                                               |                                                 | 2.5                 |
| Al2O3            | Al27        | 0.9                                           | 1.0                                             | -9.0                |
|                  |             |                                               |                                                 | 0.8                 |
| SiO2             | Si29        | 67.2                                          | 66.5                                            | 1.1                 |
|                  |             |                                               |                                                 | 67.8                |
| P2O5             | P31         | 0.1                                           | 0.1                                             | 24.3                |
|                  |             |                                               |                                                 | 0.1                 |
| K2O              | K39         | 3.0                                           | 2.7                                             | 8.8                 |
|                  |             |                                               |                                                 | 3.5                 |
| CaO              | Ca43        | 5.2                                           | 5.0                                             | 2.8                 |
|                  |             |                                               |                                                 | 4.9                 |
| MnO              | Mn55        | 1.0                                           | 0.9                                             | 10.1                |
|                  |             |                                               |                                                 | 1.1                 |
| FeO              | Fe57        | 0.8                                           | 0.8                                             | -1.0                |
|                  |             |                                               |                                                 | 0.9                 |
| CoO              | Co59        | 0.2                                           | 0.2                                             | 12.2                |
|                  |             |                                               |                                                 | 0.2                 |
| CuO              | Cu65        | 1.2                                           | 1.0                                             | 19.4                |
|                  |             |                                               |                                                 | 1.1                 |
| Sb2O3            | Sb121       | 1.6                                           | 1.3                                             | 18.8                |
|                  |             |                                               |                                                 | 1.7                 |
| PbO              | Pb208       | 0.1                                           | 0.1                                             | 18.1                |
|                  |             |                                               |                                                 | 0.1                 |
| Li                | Li7         | 51.3                                          | 46.0                                            | 51.0                |
|                  |             |                                               |                                                 | 10.3                |
| Be                | Be9         | 0.1                                           | 0.1                                             | NR                  |
|                  |             |                                               |                                                 | 31.8                |
| B                 | B11         | 751                                           | 537                                             | 851                 |
|                  |             |                                               |                                                 | 28.5                |
| Ti                | Ti47        | 4867                                          | 4226                                            | 4428                |
|                  |             |                                               |                                                 | 13.2                |
| V                 | V51         | 36.0                                          | 34.0                                            | 39.0                |
|                  |             |                                               |                                                 | 5.5                 |
| Cr                | Cr52        | 21.2                                          | 18.0                                            | 21.0                |
|                  |             |                                               |                                                 | 14.9                |
| Ni                | Ni60        | 186                                           | 160                                             | 181                 |
|                  |             |                                               |                                                 | 13.8                |
| Zn                | Zn66        | 413                                           | 410                                             | 386                 |
|                  |             |                                               |                                                 | 0.8                 |
| As                | As75        | 30.7                                          | 25.0                                            | NR                  |
|                  |             |                                               |                                                 | 18.5                |
| Rb                | Rb85        | 85.8                                          | 82.0                                            | 82.0                |
|                  |             |                                               |                                                 | 4.5                 |
| Sr                | Sr88        | 935.0                                         | 860.0                                           | 897.0               |
|                  |             |                                               |                                                 | 8.0                 |
| Zr                | Zr90        | 38.2                                          | 40.0                                            | 37.0                |
|                  |             |                                               |                                                 | -4.8                |
| Nb                | Nb93        | 0.6                                           | 0.6                                             | NR                  |
|                  |             |                                               |                                                 | -6.3                |
| Ag                | Ag107       | 17.2                                          | 14.0                                            | NR                  |
|                  |             |                                               |                                                 | 18.4                |
| Sn                | Sn118       | 1482                                          | 1194                                            | 1357                |
|                  |             |                                               |                                                 | 19.4                |
| Sb                | Sb121       | 13109                                         | 10649                                           | 14002               |
|                  |             |                                               |                                                 | 18.8                |
| Cs                | Cs133       | 0.3                                           | 0.2                                             | NR                  |
|                  |             |                                               |                                                 | 26.4                |
| Ba                | Ba137       | 4651                                          | 3905                                            | 4122                |
|                  |             |                                               |                                                 | 16.0                |
| La                | La139       | 0.3                                           | 0.3                                             | NR                  |
|                  |             |                                               |                                                 | -6.5                |
| Ce                | Ce140       | 0.2                                           | 0.2                                             | NR                  |
|                  |             |                                               |                                                 | 19.3                |
| Au                | Au197       | 0.2                                           | 0.1                                             | NR                  |
|                  |             |                                               |                                                 | 41.4                |
| Bi  | Bi209 | 9.1 | 7.8 | 9.0 | 14.4 | 1.3 |
|-----|-------|-----|-----|-----|------|-----|
| Th  | Th232 | 0.3 | 0.3 | NR  | -6.8 | NR  |
| U   | U238  | 0.2 | 0.2 | NR  | -5.8 | NR  |
Table 3. Results of the LA-ICP-MS analyses of the major and minor elements of the Tall Zira’s samples in wt%.

| Sample number | Na₂O | MgO | Al₂O₃ | SiO₂ | P₂O₅ | K₂O | CaO | MnO | FeO |
|---------------|------|-----|-------|------|------|-----|-----|-----|-----|
| **High Magnesia/High Potash** |      |     |       |      |      |     |     |     |     |
| 10772         | 15.8 | 3.9 | 0.93  | 58.5 | 0.19 | 3.4 | 9.9 | 0.03| 0.72|
| 10170         | 14.1 | 3.4 | 0.43  | 65.3 | 0.12 | 2.9 | 10.4| 0.02| 0.19|
| 19322         | 17.6 | 3.8 | 0.54  | 66.6 | 0.18 | 4.4 | 5.5 | 0.02| 0.35|
| 10048         | 19.3 | 4.8 | 0.72  | 65.6 | 0.19 | 3.7 | 5.1 | 0.05| 0.28|
| 10079         | 18.2 | 5.0 | 0.66  | 66.8 | 0.11 | 3.0 | 4.7 | 0.03| 0.29|
| 15329         | 12.4 | 3.2 | 0.39  | 69.0 | 0.18 | 2.4 | 9.2 | 0.02| 0.16|
| 19320         | 12.4 | 3.1 | 0.38  | 69.1 | 0.18 | 2.3 | 9.2 | 0.02| 0.16|
| 10765         | 18.2 | 4.0 | 1.76  | 67.2 | 0.10 | 2.9 | 4.1 | 0.04| 0.33|
| 10047         | 17.63| 5.34| 0.70  | 65.38| 0.17 | 3.48| 5.70| 0.03| 0.19|
| **Low Magnesia/Low Potash** |      |     |       |      |      |     |     |     |     |
| 18802         | 17.0 | 0.6 | 2.16  | 65.8 | 0.11 | 1.0 | 8.1 | 1.20| 1.35|
| 16759         | 16.5 | 0.6 | 2.33  | 68.7 | 0.23 | 1.0 | 9.0 | 0.58| 0.50|
| 16622b        | 11.83| 0.94| 2.25  | 72.65| 0.06 | 0.56| 11.31| 0.01| 0.02|
| **High Magnesia/Low Potash** |      |     |       |      |      |     |     |     |     |
| 16753         | 18.0 | 3.5 | 1.63  | 66.0 | 0.12 | 0.9 | 8.2 | 0.16| 0.39|
| 10762         | 20.6 | 2.7 | 2.35  | 64.6 | 0.11 | 1.3 | 6.2 | 0.21| 0.49|
| **Non glass** |      |     |       |      |      |     |     |     |     |
| 16622a        | 0.2  | 0.0 | 0.33  | 99.2 | 0.00 | 0.0 | 0.1 | 0.00| 0.15|

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Table 4. Results of the LA-ICP-MS analyses of the trace elements of the Tall Zira’s samples in ppm.

| Sample number | Li  | Be  | B   | Ti  | V   | Cr  | Mn  | Fe  | Co  | Ni  | Cu  | Zn  | As  | Rb  | Sr  | Zr  | Nb  | Ag  | Sn  | Sb  | Cs  |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|               | ppm |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| High Magnesia/High Potash |
| 10772 | 15.4 | 0.2 | 163 | 352 | 11  | 18  | 260 | 5662 | 48.8 | 151 | 8309 | 78.4 | 463.7 | 22.9 | 554 | 13.6 | 1.0 | 0.9 | 17.9 | 43516 | 0.65 |
| 10170 | 16.0 | 0.1 | 104 | 163 | 5   | 17  | 167 | 1466 | 4.5  | 35.5 | 9507 | 15.7 | 137.5 | 10.5 | 443 | 5.9  | 0.4 | 3.9 | 31.7 | 14607 | 0.41 |
| 19322 | 19.5 | 0.0 | 125 | 198 | 6   | 14  | 166 | 2756 | 7.1  | 18.6 | 7442 | 24.4 | 29.7  | 15.3 | 411 | 7.0  | 0.5 | 1.1 | 3.97 | 9.3  | 0.37 |
| 10048 | 26.7 | 0.1 | 168 | 190 | 6   | 17  | 360 | 1863 | 1.2  | 9.2  | 15.0 | 16.0 | 1.18  | 12.7 | 501 | 9.6  | 0.7 | 0.1 | 1.81 | 0.2  | 0.31 |
| 10079 | 19.4 | 0.1 | 172 | 249 | 6   | 19  | 229 | 2293 | 19.4 | 14.6 | 9014 | 20.2 | 20.2  | 6.3  | 342 | 7.8  | 0.7 | 0.5 | 2.59 | 3.3  | 0.18 |
| 15329 | 16.2 | 0.0 | 95  | 147 | 4   | 14  | 119 | 1220 | 1.3  | 13.8 | 9227 | 15.1 | 82.4  | 18.4 | 605 | 6.5  | 0.4 | 1.1 | 2.44 | 14408 | 0.52 |
| 19320 | 14.6 | 0.1 | 95  | 146 | 4   | 14  | 118 | 1231 | 1.3  | 13.7 | 9310 | 14.7 | 81.7  | 17.7 | 601 | 6.4  | 0.4 | 1.1 | 2.48 | 14868 | 0.48 |
| 10765 | 24.8 | 0.4 | 215 | 271 | 8   | 10  | 320 | 2557 | 7.9  | 13.9 | 9628 | 18.3 | 19.6  | 18.7 | 312 | 12.1 | 2.0 | 0.4 | 3.75 | 6.3  | 0.31 |
| 10047 | 11.9 | 0.1 | 119 | 286 | 8   | 23  | 201 | 1439 | 4.2  | 16.8 | 9898 | 24.3 | 4.5   | 16.7 | 337 | 9.6  | 0.7 | 1.8 | 2.1  | 32.6 | 0.3  |
| Low Magnesia/Low Potash |
| 18802 | 5.6  | 0.3 | 146 | 390 | 17  | 10  | 9307| 10197| 1527 | 50.3 | 2575 | 78.6 | 36.4  | 11.6 | 556 | 34.8 | 1.3 | 1.24 | 113.5 | 5707 | 0.1  |
| 16759 | 4.6  | 0.3 | 183 | 528 | 20  | 15  | 4468| 3928 | 5.3  | 10.7 | 41.7 | 29.6 | 9.9   | 9.6  | 459 | 45.6 | 1.8 | 0.09 | 60.4  | 2381 | 0.1  |
| 16622b| 24.6 | 12.9 | 20.9 | 272 | 6  | 10  | 47  | 352  | 2.5  | 4.5  | 7.3  | 16.9 | 1130 | 149  | 51  | 247 | 7.8 | 0.1 | 12.9 | 9.2  | 11.8 |
| High Magnesia/Low Potash |
| 15753 | 8.0  | 1.6 | 149 | 589 | 8   | 7   | 1250| 3050 | 735  | 695 | 816  | 2316 | 10.1  | 5.7  | 631 | 48.3 | 1.8 | 0.4 | 41.5 | 2176 | 0.1  |
| 10762 | 11.2 | 1.4 | 243 | 636 | 11  | 9   | 1655| 3789 | 1063 | 710 | 2638 | 1904 | 27.7  | 7.5  | 511 | 48.9 | 1.8 | 0.6 | 38.2 | 3102 | 0.1  |
| Non-Glass |
| 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 | 40  | 0.9 | 0.0 | 1.8  | 0.9  | 0.0  |

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