Archaeometry, Available online 29 June 2020
DOI:10.1111/arcm.12588

Kemp Victoria (Orcid ID: 0000-0002-6447-1624)

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

Victoria Kemp [1], Katharina Schmidt [2], Will Brownscombe [3], Katja Soennecken [4], Dieter Vieweger [5], Jutta Häser [2], Andrew Shortland [1].

1. Cranfield Forensic Institute, Cranfield University, Defence Academy of the United Kingdom, Shrivenham, SN6 8LA, UK.

2. German Protestant Institute of Archaeology, P.O. Box 183, 11118 Amman.

3. The Natural History Museum, Cromwell Road, London, SW7 5BD, UK.

4. Biblisch Archäologisches Institut, Bergische Universität Wuppertal, Campus Freudenberg, Haus FD, Rain er-Gruenter-Straße 21, 42119 Wuppertal.

5. German Protestant Institute of Archaeology, Auguste-Victoria-Compound, P.O. Box 18 463, 91184 Jerusalem .

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 denotated 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 Zirāʿa. 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 Zirāʿa 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 Zirāʿa 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 Zirāʿa 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.

<u>The Levant</u>

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

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).

<u>Tall Zirāʿa</u>

Tall Zirāʿa is located in the Wādī al-ʿArab 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-ʿArab, 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 Zirāʿa 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 Zirāʿa was located on a LBA and IA trade route, which connected the Jordan Valley with the Mediterranean coast via the Jezreel 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-ʿArab 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-ʿArab (Design after Walter, in Vieweger and Häser, 2019, 29, fig. 1.5)

<u>Samples and methodology</u>

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) (150m^2) 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 Zirāʿa

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 % K_2O), 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.

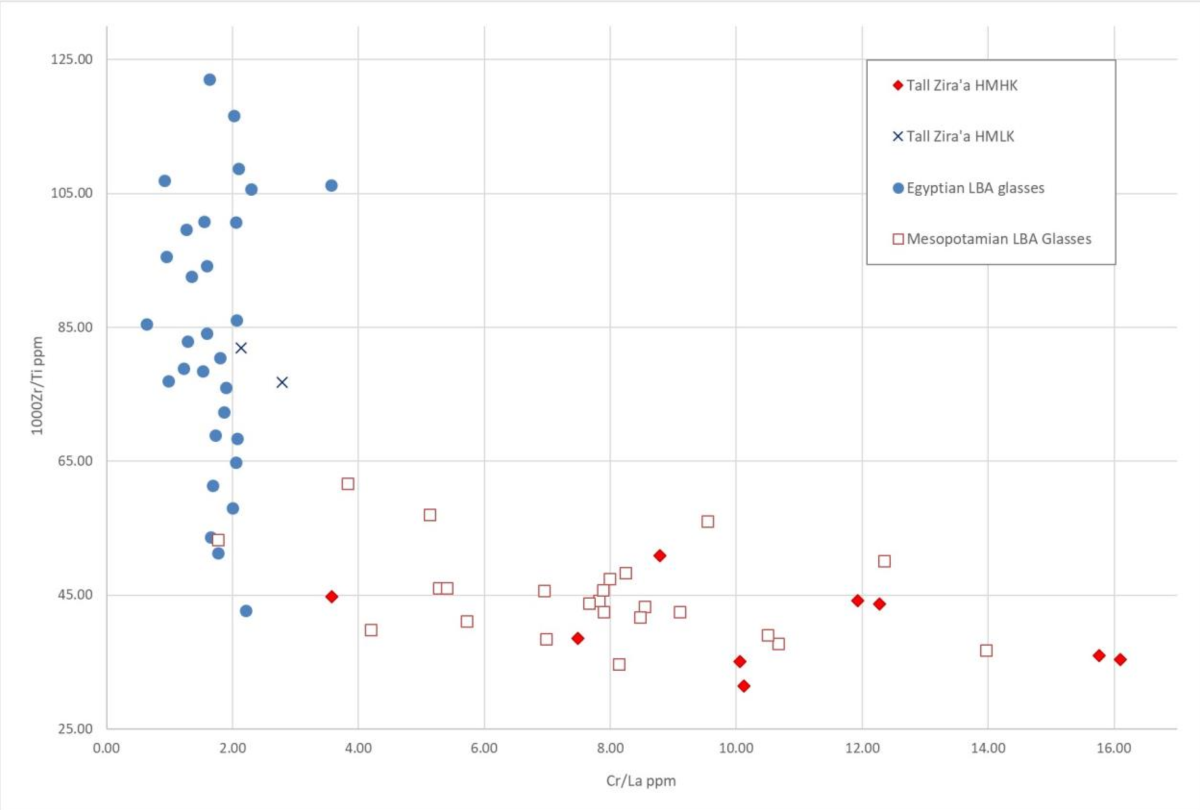

Figure 2. Covariant plot of 1000Zr/Ti with Cr/La of the Tall Zirāʿa HMHK and HMLK groups compared with Egyptian and Mesopotamian glasses of known origin (Shortland, Rogers and Eremin, 2007).

<u>LMLK</u>

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.

<u>Archaeological implications</u>

The trace elements of the nine Tall Zirāʿa 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 Zirāʿa 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, 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 Zirāʿa 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 Zirāʿa 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 comes from Tall Zirāʿa 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 Zirāʿa.

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 Zirāʿa.

Figure 3. Fragment of a disc pendant (10170)

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 Zirāʿa 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 Zirāʿa 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 Zirāʿa. 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 Zirāʿa 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 Zirāʿa 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 Zirāʿa 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 Zirāʿa 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 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 Zirāʿa 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 Zirāʿa was a well-connected settlement of significant social importance during the LBA, maintaining affluence and trade links into the IA.

Bibliography

Abe, Y. *et al.* (2012) 'Transition in the use of cobalt-blue colorant in the New Kingdom of Egypt', *Journal of Archaeological Science*, 39(6), pp. 1793–1808.

Barag, D. (1970) 'Mesopotamian Core-Formed Glass Vessels (1500-500 BC)', in Oppenheim, A. L. et al. (eds) *Glass and glass-making in ancient Mesopotamia*. New York: Corning Museum of Glass.

Brill, R. H. (1970) 'The Chemical Interpretation of the Texts', in Oppenheim, A. L. et al. (eds) *Glass and glass-making in ancient Mesopotamia*. New York: Corning Museum of Glass.

Brill, R. H. (1999) *Chemical analyses of early glasses: Volume 1, the tables*. Corning, NY: Corning Museum of Glass.

Goedicke, H. (1975) *The report of Wenamun*. Johns Hopkins Press (Near Eastern studies).

Gratuze, B. (2013) 'Provenance Analysis of Glass Artefacts', in Jannsens, K. (ed.) *Modern Methods for Analysing Archaeological and Historical Glass, Volume I*. John Wiley and Sons, pp. 311–343. doi: 10.1002/9781118314234.ch14.

Hanbury-Tenison, J. W. (1984) 'Exploration du Wadi el-Arab', *Chronique archéologique,* RB, 91, pp. 230–231.

Henderson, J. (1985) 'The raw materials of early glass production', *Oxford Journal of Archaeology*, 4(3), pp. 267–291.

Henderson, J. (2000) 'Chemical analysis of ancient Egyptian glass and its interpretation', in Nicholson, P. T. and Shaw, I. (eds) *Ancient Egyptian materials and technology*. Cambridge: Cambridge University Press, pp. 206–224.

Jackson, C. M. and Nicholson, P. T. (2010) 'The provenance of some ingots from the Uluburun shipwreck', *Journal of Archaeological Science*, 37(2), pp. 295–301.

Jensen, L. W. (2015) 'Basalt and small finds', in Strange, J. and Andersen, F. G. (eds) *Tall al-Fukhār.*

Results from excavations 1990-93 and 2002. Aarhaus: Aarhus University Press, pp. 329–365.

Joffe, A. H. (2002) ‘The Rise of Secondary States in the Iron Age Levant’, *Journal of the Economic and Social History of the Orient*. Brill, 45(4), pp. 425–467. Available at: http://www.jstor.org/stable/3632872.

Kaczmarczyk, A. (1986) ‘The source of cobalt in ancient Egyptian pigments’, in Olin, J. S. and Blackman, M. J. (eds) *Proceedings of the 24th International Archaeometry Symposium*. Washington: Smithsonian, pp. 369–376.

Kemp, V. *et al.* (2019) ‘LA-ICP-MS analysis of Late Bronze Age blue glass beads from Gurob, Egypt’, *Archaeometry*, 62(1), pp. 42–53. doi: 10.1111/arcm.12501.

Kemp, V., McDonald, A and Shortland, A. J. (2017) ‘Ancient Biographies: Trace Element Analysis to Investigate Provenance and Transportation Mechanisms of Late Bronze Age Glass.’, *Archaeological and Environmental Forensic Science*, 1.2, pp. 161–174.

Kirk, S. (2009) *The Vitreous materials from the 2nd Millennium BC City of Nuzi: Their Preservation, Technology and Distribution*. Cranfield University.

Lilyquist, C., Brill, R. H. and Wypyski, M. T. (1993) *Studies in Early Egyptian Glass*. Metropolitan Museum of Art.

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

Moorey, P. R. S. (2001) ‘The Mobility of Artisans and Opportunities for Technology Transfer between Western Asia and Egypt in the Late Bronze Age’, in Shortland, A. J. (ed.) *The Social Context of Technological Change*. Oxford: Oxbow books, pp. 39–58.

Moran, W. L. (1992) *The Amarna Letters*. Baltimore: The Johns Hopkins Press.

Na’aman, N. (2000) ‘The Egyptian-Canaanite Correspondence’, in Cohen, R. and Westbrook, R. (eds) *Amarna Diplomacy: The Beginnings of International Relations*. Baltimore: Johns Hopkins University Press, pp. 125–138.

Nicholson, P. T. and Henderson, J. (2000) ‘Glass’, in Nicholson, P. T. and Shaw, I. (eds) *Ancient Egyptian materials and technology*. Cambridge: Cambridge University Press, pp. 195–226.

Oppenheim, A. L. (1977) *Ancient Mesopotamia: portrait of a dead civilization*. Revised ed. Edited by Revised by E. Reiner. Chicago: University of Chicago Press.

Pfälzner, P. (2012) ‘Levantine Kingdoms of the Late Bronze Age’, in Potts, D. T. (ed.) *A Companion to the Archaeology of the Ancient Near East*. Oxford: Blackwell, pp. 770–796.

Pulak, C. (2001) 'The cargo of the Uluburun ship and evidence for trade with the Aegean and beyond', in Bonfante, L., Karageorghis, V., and Costakis and Leto Severis Foundation (Nicosia, C. (eds) *Italy and Cyprus in antiquity 1500-450 BC: proceedings of an international symposium held at the Italian Academy for Advanced Studies in America at Columbia University, November 16-18, 2000*. Nicosia: The Costakis and Leto Severis Foundation, pp. 13–60.

Reader, A. (2003) *Near Eastern Archaeology: A Reader*. Edited by S. Richard. Pennsylvania State University Press.

Redford, D. (1992) *Egypt, Canaan, and Israel in ancient times*. Princeton: Princeton University Press.

Rowe, A. (1940) *The four Canaanite temples of Beth-Shan. 1. The temples and cult objects.* Philadelphia: The University Museum.

Sayre, E. V and Smith, R. W. (1961a) 'Compositional catagories of ancient glass', *Science 133*, pp. 1824–1826.

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

Sayre, E. V and Smith, R. W. (1974) 'Analytical studies in ancient Egyptian glass', in Bishay, A. (ed.) *Recent Advances in the Science and Technology of Materials*. New York.

Shortland, A. J. (2002) 'The use and origin of antmonate colorants in early Egyptian glass', *Archaeometry*, 44(4), pp. 517–531.

Shortland, A. J. *et al.* (2017) 'The analysis of Late Bronze Age glass from Nuzi and the question of the origin of glassmaking', *Archaeometry*, 60(4), pp. 764–783.

Shortland, A. J. and Eremin, K. (2006) 'The analysis of second millennium glass from Egypt and Mesopotamia, Part 1: new WDS analyses', *Archaeometry*, 48(4), pp. 581–605.

Shortland, A. J., Nicholson, P. T. and Jackson, C. M. (2001) 'Glass and Faience at Amarna: different methods of both supply for production, and subsequent distribution.', in Shortland, A. J. (ed.) *The Social Context of Technological Change*. Oxford: Oxbow Books, pp. 147–160.

Shortland, A. J., Rogers, N. and Eremin, K. (2007) 'Trace element discriminants between Egyptian and Mesopotamian Late Bronze Age glasses', *Journal of Archaeological Science*, 34(5), pp. 781–789.

Shortland, A. J. and Tite, M. S. (2000) 'Raw materials of glass from Amarna and implications for the origins of Egyptian glass', *Archaeometry*, 42(1), pp. 141–153.

Smirniou, M. and Rehren, T. (2013) 'Shades of blue - cobalt-copper coloured blue glass from New Kingdom Egypt and the Mycenaean world: A matter of production or colourant source?', *Journal of*

Archaeological Science, 40, pp. 4731–4743.

Soennecken, K. A. P. (2017) *Kulturelle Umbrüche in der südlichen Levante. Der Übergang von der Bronze- zur Eisenzeit unter besonderer Berücksichtigung des Tall Zirāʿa.* Universitätsbibliothek Wuppertal.

Starr, R. F. (1939) *Nuzi. Report on the excavations at Yorgan Tepa near Kirkuk, Iraq, conducted by Harvard Univ. in conjunction with the American Schools of Oriental Research and the Univ. Museum of Philadelphia 1927-1931. With app. by Ruth Sears Chute and others.* Cambridge, MA: Harvard University Press.

Steuernagel, C. (1926) 'Der 'Adschlūn.', *Zeitschrift des Deutschen Palästina-Vereins*, pp. 1–162.

Tufnell, O. (1958) *Lachish (Tell ed-Duweir): The Bronze Age. Text and Plates*. London: Oxford University.

Turner, W. E. S. (1954) 'Studies in ancient glasses and glass making processes. Part I. Crucibles and melting temperatures employed in Ancient Egypt at about 1370 BC', *Journal of the Society of Glass Technology*, 38.

Turner, W. E. S. (1956) 'Studies in ancient glasses and glass making processes. Part IV. The chemical composition of ancient glasses', *Journal of the Society of Glass Technology*, 40, pp. 162–184.

Varberg, J. *et al.* (2016) 'Mesopotamian glass from Late Bronze Age Egypt, Romania, Germany, and Denmark', *Journal of Archaeological Science*, 74, pp. 184–194.

Vicenzi, E. P. *et al.* (2002) 'Microbeam characterisation of Corning archaeological reference glasses: new additions to the Smithsonian Microbeam standard collection', *Journal of Research of the National Institute Standards and Technology*, 107, pp. 719–727.

Vieweger, D. and Häser, J. (2017) *Tall Zirā'a The Gadara Region Project (2001–2011) Final Report.* Gütersloh.

Vieweger, D. and Häser, J. (2019) 'Tall Zirāʿa - Mirror of Jordan's history.', in Häser, J. and Schmidt, K. (eds) *Tall Zirāʿa*. Berlin: Wichern Verlag, pp. 12–53.

Wagner, B. *et al.* (2012) 'Critical assessment of the elemental composition of Corning archeological reference glasses by LA-ICP-MS', *Analytical and Bioanalytical Chemistry*, 402(4), pp. 1667–1677.

Walton, M. *et al.* (2009) 'Evidence for the trade of Mesopotamian and Egyptian glass to Mycenean Greece', *Journal of Archaeological Science*, 36, pp. 1496–1503.

Walton, M. *et al.* (2012) 'Analysis of Late Bronze Age Glass Axes From Nippur - A New Cobalt Colourant', *Archaeometry*, 54(5), pp. 835–852.

Table 1. Summary of objects excavated from Tall Zirāʿa

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 IIC)** 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)**

10170	TZ 010170-001	Fragment of a disc pendant	Opaque turquoise		Deposition layer in the cella 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 cella 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** (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 (Vicenzi *et al.*, 2002; Shortland, Rogers and Eremin, 2007; Wagner *et al.*, 2012). Oxides values in wt%, elemental values in ppm.

			Shortland et al. (2007) and Vicenzi et al. (2002)		Wagner et al. (2012)	
Analyte Measured	Atomic mass	Average Corning A values from Tall Zirāʿa (n=15)	Accepted value mg kg -1	Relative error	Accepted value mg kg -1	Relative error
Na2O	Na23	14.3	14.3	-0.1	13.4	6.2
MgO	Mg24	2.4	2.7	-11.4	2.5	-4.7
Al2O3	Al27	0.9	1.0	-9.0	0.8	10.6
SiO2	Si29	67.2	66.5	1.1	67.8	-0.8
P2O5	P31	0.1	0.1	24.3	0.1	17.6
K2O	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
Sb2O3	Sb121	1.6	1.3	18.8	1.7	-6.8
PbO	Pb208	0.1	0.1	18.1	0.1	NR
Li	Li7	51.3	46.0	51.0	10.3	0.5
Be	Be9	0.1	0.1	NR	31.8	NR
B	B11	751	537	851	28.5	-13.3
Ti	Ti47	4867	4226	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	NR	18.5	NR
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	NR	-6.3	NR
Ag	Ag107	17.2	14.0	NR	18.4	NR
Sn	Sn118	1482	1194	1357	19.4	8.4
Sb	Sb121	13109	10649	14002	18.8	-6.8
Cs	Cs133	0.3	0.2	NR	26.4	NR
Ba	Ba137	4651	3905	4122	16.0	11.4
La	La139	0.3	0.3	NR	-6.5	NR
Ce	Ce140	0.2	0.2	NR	19.3	NR
Au	Au197	0.2	0.1	NR	41.4	NR

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	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	MnO	FeO
						%			
High Magnesia/High Potash									
10772	15.8	3.9	0.93	58.5	0.19	3.4	9.9	0.03	0.73
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	0.24
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	0.10
19320	12.4	3.1	0.38	69.1	0.18	2.3	9.2	0.02	0.10
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	1.3
16759	16.5	0.6	2.33	68.7	0.23	1.0	9.0	0.58	0.5
16622b	11.83	0.94	2.25	72.65	0.06	0.56	11.31	0.01	0.05
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	0.1

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	6.30	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																					
16753	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