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Considering the effects of the Byzantine-Islamic transition: Umayyad glass tesserae and vessels from the qasr of Khirbat al-Mafjar (Jericho, Palestine)

--Manuscript Draft--

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Abstract:	<p>The paper reports and discusses data obtained by archaeological and archaeometric studies of glass vessels and tesserae from the qasr of Khirbat al-Mafjar (near Jericho, Palestine). Archaeological contextualisation of the site and chrono-typological study of glass vessels were associated to EPMA and LA-ICP-MS analyses, performed to characterise the composition of the glassy matrix (major and minor components as well as trace elements). Analyses allowed achieving meaningful and intriguing results, which gain insights into the production and consumption of glass vessels and tesserae in the near East during the Umayyad period (7-8th centuries). Within the analysed samples, both an Egyptian and a Levantine manufacture have been identified: such data provide evidence of a double supply of glass from Egypt and the Syro-Palestinian coast in the Umayyad period occurring not only in the glassware manufacture, but also in the production of base glass intended to be used in the manufacture of mosaic tesserae. Thus, the achieved results represent the first material evidence of a non-univocal gathering of glass tesserae from Byzantium and the Byzantines in the manufacture of early Islamic mosaics.</p>
Response to Reviewers:	see attachment

Dear Editor,
please find enclosed the revised version of the manuscript titled: Considering the effects of the Byzantine-Islamic transition: Umayyad glass tesserae and vessels from the *qasr* of Khirbet al-Mafjar (Jericho, Palestine).

All the reviewers' suggestions are commented below and/or corrected in the revised version of the manuscript.

We hope that now our paper will be suitable for publication.

We are very grateful to the reviewers and to the editor for the useful comments which will improve our paper.

Best regards

Mariangela Vandini

Ravenna, 25th February 2017



Reviewer #1

The majority of suggestions and comments of Reviewer #1 were considered and text modified accordingly.

A few exceptions are commented in detail.

Major changes are directly reported in the manuscript by using **red** characters (please note: lines numbers referring to the revised version - in bold – and to the original submitted manuscript are reported).

Abstract

24-25 (were 26-27): a clarifying sentence was inserted. Authors are aware that the manufacture of artefacts and tesserae occurred in secondary workshops, often located far away from the primary workshops where the base glass was produced.

Introduction

45-74 (were 49-52): this section was reviewed and improved as requested, relevant references were added.

90-92 (was 71): previously omitted early Islamic sites indicated in Neri et al. 2016 are now properly indicated in the text. Concerning data from Neri et al. 2017 (Kilise Tepe), the paper was not cited in the manuscript as it was published after its submission to JAAS. This reference is now quoted when Levantine tesserae are discussed (line 440).

On the other hand, authors are not able to access the forthcoming paper by Verità et al. Scientific investigation of glass tesserae from the 8th century AD archaeological site of Qusayr Amra (Jordan) as the book “The colours of the Prince” has not been published yet by ISCR.

113-114 (was 90): “old style” has been replaced with “not stratigraphic”

113-129 (were 90-105): authors do not mention cullets, but tesserae and vessel fragments. The discussion concerns a consumption site and no evidence for a secondary workshop has been discovered. It is not possible to know if the tesserae originally belonged to a wall or floor decoration because no decoration is preserved. The authors are aware that the chronology of the materials found in a layer of the second phase could be a controversial issue but this does not necessarily imply they were used and produced before. The chrono-typological and archaeometric study reported in the following parts of the paper add data to aid the interpretation.

Fig. 1a. Figure was changed

Fig. 1b. Figure provided in grayscale.

Materials and methods

131-171 (were 116-134): in the authors' opinion, the aim of the *Introduction* of the paper is to contextualize the study and introduce the material selection. We are aware that the *Materials* section is, generally, a list of objects and samples whereas, in this case, it represents a chrono-typological study of the analysed materials. For this reason, we prefer to keep the section of material description separated from the *Introduction* and a re-naming of sections was proposed by introducing Section 2. *Chrono-typology of glass findings* and naming the following section 3. *Experimental*

Typologies and comparisons were revised according to reviewer's comments and suggested references.

Tab. 2a,b: authors would prefer to keep tables in the text.

A6 tessera can be better defined as "weak turquoise", as authors agree that "pale blue" could be confusing.

A15 is not a cobalt-coloured blue tessera. Authors believe it could be better described as "weak turquoise" rather than "pale blue" so as to avoid misunderstanding.

168 (was 141): there are no indication about Am12 and Am14 being gold leaf tesserae. Only Am/Au11 is a gold leaf one, that lost cartellina and shows traces of the gold leaf on one side.

184-205 (were 158 and 160): standard deviation and accuracy are now provided. Standard materials used as references are indicated in the text, in the Experimental section. Text was changed and requested information added.

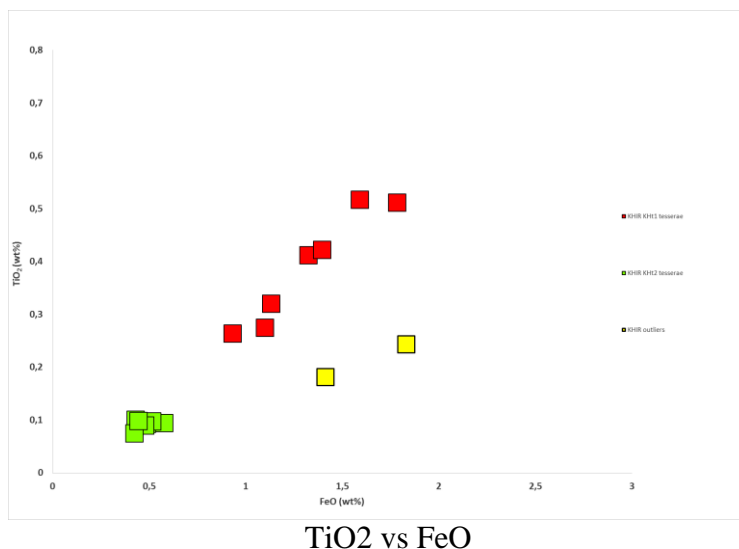
Ten measurements were performed to test homogeneity, because we are also analysing opaque coloured tesserae. As inserted in the revised version (lines 94-96), an in-depth characterisation of colourants and opacifiers used in the secondary manufacture of the tesserae is currently being carried out, by means of a multi-analytical approach (VIS-RS, OM, SEM-EDS, micro-Raman), and not reported here.

Results

Tab.2 and **Tab.3** have been improved according to the requests.

216-218 (were 185-188): in the Egypt I opaque tesserae, FeO is always correlated to TiO₂ (see the scatter plot reported below) and it was not subtracted; concerning the Levantine tesserae, the only

samples not displaying a correlation between FeO and TiO₂ are Am12 (translucent weak brown) and A15 (translucent weak turquoise). However, following a homogeneity criteria, we propose to maintain the choice of non-subtracting FeO, after having checked that the effect on data and discussion for the two samples is negligible.



223-226 (were 192-194): we agree that, in the case of A15 tessera, the higher MgO, K₂O, and P₂O₅ contents could also indicate a recycling process and, consequently, we took this interpretation into account. Authors would prefer to keep this sentence in the original position, because it is linked to the previous one.

Were 195-197: these lines have been deleted as requested.

231-267 (were 199-236): The opinion of the authors is that the results concerning the glassy matrices of vessels and tesserae need to be separated because different compositional categories were identified (Egypt I, Apollonia-type and Bet Eli'ezer-type for the tesserae; Egypt II, Apollonia-type and Bet Eli'ezer-type for the vessels). The reason for discussing trace element data before major oxides primarily stems from the fact that trace element patterns and REE distributions allow to precisely define the type of sand employed in the manufacture of the base glass, providing a precise indication on the provenance of the raw materials. This approach in discussing data has recently been proposed by Phelps et al. 2016 and authors believe it could be incisive also in this case.

Figure 4a: four samples are shown because, as specified in the text and in the caption of the figure itself, LA-ICP-MS did not provide useful data for samples KH02 and KH07.

Discussion

Authors are aware that the discussion of the achieved data is quite complicated. Instead of rewriting the whole section, we would like to propose some changes to the original text according to the reviewer's comment. Figures were changed and improved.

317: authors accept the reviewer's comment and suggest to remove this topic.

342-360 (were 368-376): text was improved, with the opinion that this paragraph is useful to valorise the achieved data concerning this peculiar set of tesserae, belonging to the Egypt I category.

388-446 (were 404-459): authors do not state that the raw glass necessarily indicate the production area of the tesserae, but of the raw materials employed in the base glass manufacture.

436-446 (were 452-453): authors are aware that in the quoted references Levantine compositional categories also occur with others; changes were made in the text to make this statement clearer.

444 (was 459): authors apologise for having also quoted the study case of Sagalassos. The quote has now been removed from the text.

447-460 (were 462-474): text was rewritten according to the reviewer's comments.

Conclusions

As requested, conclusions have been reviewed.

Reviewer #2

All the reviewer's suggestions are accepted and reported in the revised version of the manuscript.

Introduction was improved and the still open questions discussed more thoroughly.

VIS-RS data were removed. Actually, the entire part on colourants and opacifiers was removed since preliminary data were improperly presented. Authors agree with the reviewer that data on colour and opacity should be discussed in depth. Therefore, an in-depth characterisation of colourants and opacifiers used in the secondary manufacture of the tesserae is currently being carried out, by means of a multi-analytical approach (VIS-RS, OM, SEM-EDS, micro-Raman), and is not reported here (see revised version lines 94-96).

Figures were improved as suggested and references added when requested.

In paragraph 4.1, the discussion on natron shortage was removed since this issue requires further in-depth analysis.

Changes are directly reported in the manuscript by using **blue** characters.

1 Considering the effects of the Byzantine-Islamic transition: Umayyad glass 2 tesserae and vessels from the *qasr* of Khirbet al-Mafjar (Jericho, Palestine)

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14 Abstract

15 The paper reports and discusses data obtained by archaeological and [archaeometric studies](#) of glass
16 vessels and tesserae from the *qasr* of Khirbet al-Mafjar (near Jericho, Palestine). Archaeological
17 contextualisation of the site and chrono-typological study of glass vessels were associated to EPMA
18 and LA-ICP-MS analyses, performed to characterise the composition of the glassy matrix (major and
19 minor components as well as trace elements). Analyses allowed achieving [meaningful](#) and intriguing
20 results, which gain insights into the production and consumption of glass vessels and tesserae in the
21 near East during the Umayyad period (7-8th centuries). Within the analysed samples, both an Egyptian
22 and a Levantine manufacture have been identified: such data provide evidence of a double supply of
23 glass from Egypt and the Syro-Palestinian coast in the Umayyad period occurring not only in the
24 glassware manufacture, but also [in the production of base glass intended to be used in the](#)
25 [manufacture of mosaic tesserae](#). Thus, the achieved results represent the first material evidence of a
26 non-exclusive gathering of glass tesserae from Byzantium and the Byzantines in the manufacture of
27 early Islamic mosaics.

28 Keywords

29 Umayyad glass vessels/tesserae

30 Byzantine-Islamic transition

31 Early Islamic period

32 EPMA

33 LA-ICP-MS

34 1. Introduction

35 Research over the last decades has led to the emergence of quite a colourful and complex picture
36 concerning manufacture and supply of early Islamic glass (7th – early 9th centuries) in the Near East.
37 [Previous studies have demonstrated](#) that a remarkable change in glass technology started occurring
38 at the beginning of the 9th century (or slightly earlier) in the Near East, when plant ash was
39 reintroduced as main fluxing agent in substitution to natron [and the production of glass objects with](#)
40 [distinctive Islamic features began](#) (Henderson 2002; Whitehouse 2002; Henderson et al. 2004;
41 Shortland et al. 2006; Henderson 2013). [Prior to this change, the glass industry of 7th and 8th centuries](#)
42 had been strongly influenced by both Sasanian and Roman-Byzantine traditions (Carboni 2001;
43 Carboni and Whitehouse 2001; Tait 2012; Henderson 2013). [Sasanian influence over early Islamic](#)

46 glass production is clearly visible, for instance, in the so-called facet-cut bowls, a kind of decoration
47 the Sasanian glasshouses excelled in (Brill 1999; Mirti et al. 2008; Tait 2012; Henderson 2013;
48 Simpson 2014). The other main influence may come from the Romans and the Byzantines, regarded
49 as masters of glass technology. The use of earlier Roman glass techniques and traditions, like mosaic
50 glass tileworks, the intricate animal-shaped “cage flasks” and the sandwiched gold-glass, has indeed
51 been largely attested (Tait 2012). However, the need to introduce new traditions can be recognizable
52 in the early experimentation of both new forms, like the so-called “dromedary flasks” or the mallet-
53 and bell-shaped flasks, and decoration, as pincer glasses and the re-elaborated version of the Roman
54 “gold-glass” (Tait 2012; Whitehouse 2012).

55 A pivotal issue to be investigated is the current relationship between early Islamic and Byzantine
56 mosaic manufacture and technology, with specific reference to both craftsmen and tesserae supply.
57 At the dawn the Umayyad caliphate, the relations with the Byzantines were ruled by both attraction
58 and opposition; besides, it is known that the most noticeable legacy of the Byzantine imperial heritage
59 is the Umayyad policy of erecting imperial religious monuments. Muslim literary sources, like the
60 10th century *Chronicle* of al-Tabarī, the *History of Medina*, composed in 814 AD by the scholar Ibn
61 Zabāla, and the 10th century *The best divisions for knowledge of the regions* by the geographer al-
62 Maqdisī, claim that Umayyad caliphs requested and got from the King of the Greeks both workmen
63 and mosaic cubes in order to construct and decorate religious buildings, like the Prophet’s Mosque at
64 Medina and the Great Mosque of Damascus (Gibb 1958). Also, tesserae at the Great Mosque in
65 Còrdoba, are likely to come from Byzantium too (James 2006).

66 Nevertheless, the issue of the sent tesserae has arisen several problems due to the reliability - as well
67 as the interpretation - of the sources themselves: should these texts be read as propaganda pieces
68 aimed at enlightening the power of the Muslim rulers or, on the contrary, could they imply that the
69 trade between Muslims and Byzantines went on despite their rivalry? (Gibb 1958; Cutler 2001; James
70 2006). Answers to these questions still need to be provided. Besides, in 1927-1928 after deep
71 investigations about the Dome of the Rock in Jerusalem, Marguerite Gautier-Van Berckem came to
72 the conclusion to be in front of “an autochthonous work of art, not executed by mosaicists from
73 Byzantium, but by Syrian artists” (Gautier-Van Berckem 1969); later, she made the same assertion
74 about the original mosaics of the Great Mosque of Damascus.

75 A recently published paper by Phelps and co-workers (Phelps et al. 2016) has given a fundamental
76 contribution to the examination of the so-called Byzantine-Islamic transition, addressing to the issue
77 of typo-chronological distribution and chemical characterisation of glass production groups during
78 the 7-9th centuries. As regards the Umayyad period, research has showed a break with the Byzantine
79 glass technology between the late 7th – early 8th centuries, which brought to recipe changes: a
80 contraction in the Levantine glass industry, an import of Egyptian glass and the first (re)-appearance
81 of plant ash technology.

82 Thus, even though Umayyad glass vessels are particularly under-represented in literature, existing
83 research has outlined quite a heterogeneous scenario to deal with, providing clear evidence for glass
84 production occurring both in Egypt and in Syria-Palestine region, as well as the use of a variety of
85 chemical compositions Furthermore, when considering mosaic glass tesserae, the state of the art still
86 remains obscure, since no scientific analyses are recorded in literature regarding Umayyad mosaic
87 tesserae dealing with the composition of the glassy matrix, the raw materials provenance and the
88 study of colourants and opacifiers. The only existing information concerning early Islamic mosaic
89 glass tesserae are reported in a recent paper dealing with the study of the gilding technique of 4th-12th
90 centuries Levantine tesserae: among other assemblages dating back to the late Byzantine period, it

91 also includes a set of 11 samples from the Great Mosque of Damascus (8th century) and 5 tesserae
92 from the 8th century Baths of Qsayr Amra (Neri et al. 2016).

93 The present paper reports and discusses base glass compositional data about naturally coloured glass
94 vessels and *tesserae* from the *qasr* of Khirbet al-Mafjar. **An in-depth characterisation of colourants
95 and opacifiers used in the secondary manufacture of the tesserae is currently being carried out, by
96 means of a multi-analytical approach, not reported here.**

97 Also known as Hisham's Palace, by the name of the Umayyad caliph who ordered its construction in
98 the first half of the 8th century, the *qasr* of Khirbet al-Mafjar is an amazing example of Desert Castles,
99 winter residences of the Islamic caliphs. Located in the plain of Jericho (3.5 km north of the city -
100 Fig. 1a), it is considered to be one of the most significant archaeological evidence of the early Islamic
101 period in Palestine (Whitcomb and Taha 2013).

102 Archaeological research has demonstrated that the *qasr* went through different phases of construction
103 and occupation. It was built between 736 and 746 AD and in 747/748 an earthquake seriously
104 damaged the site without interrupting its occupation. **The Palace's major period of occupation** was
105 during the Abbasid caliphate (ca. from 800 until 950 AD), when new buildings were constructed and
106 added to the pre-existent structures (Grabar 1955; Grabar 1963; Whitcomb 1988; Grabar 1993; Cirelli
107 and Zagari 2000; Hattstein and Delius 2001; Whitcomb and Taha 2013). Firstly excavated between
108 1934 and 1948 and again in the 1960's (Grabar 1955; Whitcomb 1988; Hawari 2010; Whitcomb and
109 Taha 2013), the *qasr* has recently been the focus of the *Jericho Mafjar Project*¹ (Hawari 2010;
110 Whitcomb 2013; Whitcomb 2014).

111 During the 2011 season, glass vessels and tesserae were found inside the so-called Original Residence
112 or Northern Building, completely excavated by Awni Dajani (under Jordanian authority) at the
113 beginning of the 1960s, but there are no published records and no reports of the massive **not
114 stratigraphic** excavation have been found up to now. Thanks to recent analyses and surveys on the
115 structures and some trenches within small parts of the site (not previously investigated), a new
116 drawing of the building has been provided (Fig.1b), with a wider comprehension of the phasing.
117 According to archaeological evidence, it can now be stated that the Original Residence was
118 contemporaneous with a Grape Press for wine production, recently discovered and early Umayyad in
119 date. Moreover, during the last research seasons, it also emerged that this phase was probably
120 connected to a wider building, identified by remote sensing investigations that highlighted several
121 differently orientated hidden structures, in a middle area between the palatial complex and the
122 northern building. The central area of the new building was never excavated and it is probably
123 connected to an earlier period of occupation, dating back to the Late Roman (end of the 7th century)
124 or early Umayyad (7th – 8th century), possibly belonging to the period of Sulayman ibn Abd al-Malik
125 (715-717 AD). The mosaic tesserae and the other glass fragments belong to a second phase, dated to
126 the Hisham's caliphate (724-743 AD), and they were connected to the court of the Northern Building,
127 soon after the abandon of the large agricultural estate. Moreover, the Northern Building was
128 abandoned after having been damaged by the earthquake, and, consequently, the findings can be
129 confidently ascribed to the period between 724-748\9 AD (Whitcomb 2013).

130 **2. Chrono-typology of glass findings**

131 A set of 21 fragments of naturally coloured glass vessels and 16 mosaic glass tesserae was collected
132 from the northern side of the Northern Building. Among the whole set of vessels, 7 fragments were
133 selected to be investigated through a multi-analytical approach. This selection was made on the basis
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62 ¹ A detailed overview of the Project and its results is provided at www.jerichomafjarproject.org.

135 of archaeological and chrono-typological criteria, by preferably choosing the samples referable to
136 documented or recognisable forms. About the tesserae, the whole set of available samples was
137 investigated, **due to the variety of** the different colours and **degrees** of opacity.

138 **Concerning** the recovered vessels, 2 rims, 2 bottoms, 1 handle and 2 fragments of decorated walls
139 were selected to be analysed. All of them were accurately micro-sampled, to preserve the integrity of
140 the profile. The identified forms are summarised in Table 1.a and sketched in Fig. 2. **Among the most**
141 **interesting selected finds** is a loop handle with a slightly pinched thumb-rest, preserved as two
142 contiguous fragments (KH01) made of weak green glass. Attributable to a cup, **or a cup-shaped oil**
143 **lamp**, the handle has different possible comparisons in the Islamic world, with or without the thumb-
144 rest, **generally dated to the Umayyad period (Gorin-Rosen and Katsnelson 2005; Gorin-Rosen and**
145 **Katsnelson 2007; Gorin-Rosen 2008; Gorin-Rosen 2010)**. However, the closest similarity is shown
146 with an handle found at Bet Shean (or Bet She'an – Israel), recovered under the debris of the 749 AD
147 earthquake **from the *sūq* of Hishām (Hadad 2005)**. **Datable back to Late Byzantine-Umayyad period**
148 **is a small neck with an infolded rim, made of weak turquoise glass (KH05). Fragment KH04 is**
149 **consistent in a straight rim with wall folded towards the inside, quite common in the glass productions**
150 **of Byzantine and Umayyad period; this fragment can be referred to a small bottle made of weak olive**
151 **green glass (Dussart 1998; Hadad 2005). Find KH06 is a slightly concave base of weak turquoise**
152 **glass, resembling those documented in archaeological contexts dated from the Late Byzantine-**
153 **Umayyad period onwards and often occurring as a reproduction of earlier typologies (Katsnelson**
154 **1999; Foy 2012). KH02 and KH03 are two fragment of weak green-coloured walls, showing traces**
155 **of a trailed decoration made in the same colour of the body, probably referable to a bifurcated ribs**
156 **decoration. This kind of decorative motif, showing either vertical or horizontal orientation, is**
157 **frequently attested from the Roman to the Umayyad period, documented for different typologies of**
158 **vessels (Harden 1936; Crowfoot 1957; Clairmont 1963; Barag 1978; Weinberg and Goldstein 1988;**
159 **Dussart 1998; Gorin-Rosen 2006; Gorin-Rosen and Katsnelson 2007; Antonaras 2010). The set also**
160 **includes a small fragment of the central part of a base, made of weak turquoise glass (KH07). The**
161 **find resembles a concave base of bottle identified by Hadad in the *sūq* of Hishām and dated to the**
162 **Umayyad period (Hadad 2005); however, the small dimensions of fragment KH07 do not allow a**
163 **certain identification of the original typology.**

164 Among the tesserae, a set of 16 coloured samples (11 opaque and 5 translucent) was selected (Table
165 1.b). The opaque sub-group **comprises** 4 tesserae in various shades of green (Vsr4, V5, Vc8, Vc9), 3
166 in different tones of **weak turquoise** (A6, A7, A7 bis), 1 of a deep red glass (R1), 1 of a greenish-
167 yellow glass (G/V3), 1 of a yellow glass (G2), and 1 of a greyish pale blue glass (Ga10). The
168 transparent sub-group is formed by: 2 tesserae of brown glass (Am14, Am12), 1 of brown glass with
169 golden leaf (Am/Au11), 1 of a **weak turquoise** glass (A15) and 1 of greenish-yellow glass (G/V13).

171 **3. Experimental**

172 All samples were preliminary cleaned by using demineralized water and dentist tools, softly scraping
173 the surfaces to remove remains of soil and dirt.

174 An Olympus S761 stereomicroscope (magnification up to 45x) associated with an Olympus Soft
175 Imaging Solutions GMBH model SC100 camera was used for a preliminary morphological
176 observations and documentation.

177 A NCS (Natural Colour System) chart was used to provide a preliminary objective definition of the
178 colour of the tesserae.

179 Polished sections were prepared by embedding samples in a polyester resin. After polishing, sections
180 were carbon-coated to perform **Electron Probe Micro-Analysis (EPMA)**. EPMA analyses were

181 carried out to determine the bulk chemistry of all samples. The chemical analyses of major and minor
182 elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, S, Cl, Cr, Co, Cu, Sn, Sb, and Pb) were performed
183 using a Cameca SX 50 microprobe equipped with four scanning wavelength-dispersive spectrometers
184 (WDS). A beam current of 20nA and an acceleration voltage of 20KV were used. The reference
185 Smithsonian glass A standard (Jarosewich 2002) was employed as primary reference sample. Ten
186 points were analysed on each sample and the mean value was calculated. The measured accuracy for
187 the analysed elements was better than 3%. The standard deviations among the analysed points
188 resulted to be between 1-3 and 3-5% for major and minor constituents, respectively, showing a good
189 homogeneity in the main constituents. The detection limit for the minor elements was between 0.01
190 and 0.04 wt%. The correction program is based on the PAP method (Pouchou and Pichoir 1988) and
191 was used to process the results for matrix effects.

192 LA-ICP-MS was carried out to determine the concentration of 37 trace elements. The analyses were
193 performed by a Thermo Fisher X- SeriesII quadrupole based ICP-MS coupled with a New Wave
194 ablation system with a frequency quintupled ($\lambda=213$ nm) Nd:YAG laser. The laser repetition rate and
195 laser energy density on the sample surface were fixed at 20 Hz and ~ 18 J/cm², respectively. The
196 analyses were carried out using a laser spot diameter of 100 μ m on the same polished samples used
197 for EPMA, after carbon coating removal. External calibration was performed using NIST SRM 610
198 and 614 glass as external standard, and ²⁹Si, previously determined by EPMA, as internal standard,
199 following the method proposed by Longerich et al. (Longerich et al. 1996). Six points were analysed
200 on each sample to test homogeneity and the mean value was calculated. The standard deviations
201 among the acquired points on the same sample were below 10% for all the elements, with the
202 exclusion of Cu, Sn and Pb with more variable SD. Standard Reference Material NIST612 (Pearce et
203 al. 1997) was used as a secondary reference sample to check precision and accuracy. The distribution
204 of REE and of the other trace elements was analysed by normalizing the data to the upper continental
205 crust (Wedepohl 1995).

206 207 **4. Results**

208 The composition of the major and minor elements, obtained by EPMA, is reported in Table 2a and
209 LA-ICP-MS chemical data for trace elements are shown in Table 3.

210 In order to compare the base glass composition of the opaque tesserae with the categories reported in
211 literature for naturally coloured glass, compositional data were recalculated to minimise any effect
212 caused by elements intentionally added as colourants/decolourants and/or opacifiers. The reduced
213 composition was obtained by subtracting the oxides of the elements probably due to additives, and
214 by normalising to 100 the remaining data (Table 2b). In particular, the subtracted oxides were CuO,
215 SnO₂ and PbO. Sb₂O₃ and CoO were not subtracted since their values are negligible (below 0.01
216 wt%). FeO and TiO₂ were not subtracted when calculating the reduced composition (even though the
217 presence of iron may be due to an intentional addition) since these elements are typically found as
218 sand contaminants related to heavy minerals. For the opaque tesserae, the following discussion is
219 based on reduced compositional data.

220 The analysed samples are all of natron type glass, being MgO and K₂O contents below 1.5 wt%, (Fig.
221 3) (Lyliquist and Brill 1993). The pale blue tessera A15 is the only one showing higher MgO and
222 K₂O (respectively 2.23 wt% and 1.68 wt%), even though below the value of 2.5 wt%, unequivocally
223 referable to the use of plant ash as flux (Lyliquist and Brill 1993). The higher MgO (2.23 wt%) and
224 K₂O (1.67 wt%) contents, together with the higher P₂O₅ (0.38 wt%), could indicate either the

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225 occurrence of a contamination during the production process (Paynter 2008), or the melting of soda
226 plant-ash mixed with silica (Neri et al. 2016).

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4.1 Vessels

229 Trace element patterns (Fig. 4a,b) show that KH01, KH03 and KH05 exhibit lower strontium (146.85
230 – 209.20 ppm), higher zirconium (129.05 – 258.40 ppm) and a less depleted REE pattern, relative to
231 continental crust. Considerable quantities of titanium (0.27 – 0.33 wt%) and iron oxides (0.81 – 0.91
232 wt%) can also be observed (Table 2a). Contrariwise, KH04 and KH06 are characterised by higher Sr
233 contents (305.47 – 321.93 ppm) together with relatively lower Zr amounts (35.30 – 63.95 ppm);
234 higher alumina and higher depletion of REE (particularly heavy REE) can also be noticed when
235 compared to KH01, KH03 and KH05. Due to scarcity of material, no LA-ICP-MS data are available
236 for sample KH02 and KH07; therefore, they are only discussed according to their major and minor
237 oxides values.

238 From now on, the first group of vessel samples (KH01, KH03, KH05 – and KH02) will be referred
239 to as KHv1, whilst the second group (KH04, KH06 – and KH07) will be named KHv2.

240 CaO/Al₂O₃:Na₂O/SiO₂, TiO₂/Al₂O₃:Al₂O₃/SiO₂ and FeO/TiO₂:FeO/Al₂O₃ bi-plots (Fig.5-7) further
241 enhance the distinctive features showed by the samples under study: KHv1 vessels have higher
242 CaO/Al₂O₃ than KHv2, whilst Na₂O/SiO₂ does not show significant shifts; KHv1 vessels also show
243 consistently higher TiO₂/Al₂O₃ and FeO/Al₂O₃ ratios when compared to KHv2 vessels.

244 Sample KH06 is characterised by lower Na₂O/SiO₂ and CaO/Al₂O₃ than the other KHv2 vessels.
245 Vessel KH02 shows features comparable to KHv1 group, while the behaviour of KH07 is consistent
246 with KH04.

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4.2 Tesserae

249 Trace element patterns allow a first well-defined separation of the analysed tesserae in two main
250 groups. R1, G/V3, Vsr4, V5, A6, Vc9 and Ga10, from now on referred to as KHt1, show lower
251 strontium, higher zirconium and a less depletion of REE when compared to G2, A7, A7bis, Vc8,
252 Am/Au11, G/V13 and Am14, from now on labelled KHt2 (Fig. 4c,d). KHt1 samples also display
253 higher titanium and iron oxides contents, respectively ranging from 0.27 to 0.51 wt% and from 0.94
254 to 1.78 wt%.

255 KHt1 tesserae show lower lime (2.75 - 4.53 wt%) and higher alumina contents (3.35 - 4.26 wt%)
256 when compared to KHt2 samples (lime ranging from 6.68 to 10.37 wt% and alumina ranging from
257 2.22 to 3.18 wt%); moreover, the two groups differ in terms of soda contents, KHt1 tesserae
258 containing higher soda (16.29 – 18.74 wt%) with respect to KHt2 (12.09 – 15.68 wt%). The above
259 differences are clearly displayed in CaO/Al₂O₃:Na₂O/SiO₂, TiO₂/Al₂O₃:Al₂O₃/SiO₂ and
260 FeO/TiO₂:FeO/Al₂O₃ bi-plots (Fig.5-7), also highlighting a strong separation of Am/Au11 from the
261 other KHt2 tesserae due to its lower CaO/Al₂O₃ and Na₂O/SiO₂ ratios.

262 Am12 and A15 translucent tesserae can be considered as outliers, since they show a less definite
263 behaviour that cannot allow unequivocally including them into neither the KHt1 nor the KHt2 group,
264 although they have some common features with KHt2 samples.

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5. Discussion

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5.1 KHv1 and KHt1: Egyptian vessels and tesserae

269 Vessels and tesserae belonging to groups KHv1 (KH01, KH02, KH03, KH05) and KHt1 (R1, G/V3,
270 Vsr4, V5, A6, Vc9, Ga10) have been manufactured by using sands richer in the heavy accessory
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271 minerals, characterised by relatively high contents of iron oxide, titanium oxide and zirconium, as
272 well as by a less depleted REE pattern (Fig. 4a-d). These values, as well as the high soda contents,
273 are typical of Egyptian glasses (Foy et al. 2003; Nenna 2014; Phelps et al. 2016).
274 However, even though they are linked by an Egyptian origin, KHv1 and KHt1 are separate glass
275 groups: KHv1 vessels are made of Egypt II glass, whilst KHt1 tesserae correspond to Egypt I
276 compositional category (Bimson and Freestone 1987).
277 Initially detected in a secondary workshop at El-Ashmunein (Middle Egypt) (Bimson and Freestone
278 1987), Egypt II glass was also identified by Gratuze and Barrandon (Gratuze and Barrandon 1990) in
279 a study concerning coin weights from Fustat (Egypt). Vessels dating back to the Abbasid period
280 (mid 8th to the end of 9th/beginning of 10th century), were also found belonging to Egypt II group,
281 referred to as Group 7 by Foy and co-workers (Foy et al. 2003). Egypt II compositional group was
282 also detected by Kato and co-workers at Raya (Sinai peninsula): more precisely, they label this group
283 as N2-b, with the majority of the analysed objects falling within it (Kato et al. 2009). The so-called
284 Upper Group, found at the monastery of St. Aaron on Jabal Hauran (near Petra, Jordan), also comprises
285 vessels belonging to Egyptian II category (Keller and Lindblom 2008; Greiff and Keller 2014);
286 interestingly, several vessels belonging to this Upper Group could indicate a certain degree of
287 recycling, in accordance with their compositional features (Greiff and Keller 2014). Group C
288 recognised by Freestone et al. (Freestone et al. 2015), including vessels, chunks and moils recovered
289 from an early Islamic secondary workshop at HaGolan Street (Khirbet al-Hadra, North-Eastern Tel
290 Aviv), is also equivalent to Egypt II compositional category. In a recently published paper, Phelps
291 and co-workers (Phelps et al. 2016) identified 57 samples made of Egypt II glass (Group N-3),
292 belonging to the period of the so-called Byzantine-Islamic transition (7th-9th centuries) and recovered
293 from several archaeological contexts in the Near East. **Lastly, some 6th-7th century Byzantine glass
294 weights from the British Museum and the Bibliothèque Nationale de France were also found matching
295 the Egypt II compositional category (Schibille et al. 2016).**
296 KHv1 vessels show high lime, low alumina, lower soda and a low Sr/CaO ratio (Fig. 5-8), suggesting
297 that lime is derived from a limestone source (Freestone et al. 2003; Phelps et al. 2016). The CaO/Sr
298 ratios reported in the literature for natron glass produced with limestone in Middle Egypt El-
299 Ashmunein (Freestone et al. 2003) are, indeed, of circa 616. CaO/Sr ratios measured for raw materials
300 were reported by Wedepohl and co-workers (Wedepohl et al. 2011) and follow the same trend
301 observed for the glass: low ratios for the marine carbonates, like shells (CaO/Sr=212) and higher
302 ratios for limestone (CaO/Sr=870). CaO/Sr ratios measured for KHv1 samples range from 450 to
303 690, compatible with the use of an inland sand source.
304 **A comparison between compositional features and chrono-typological study of the analysed vessels
305 needs to be addressed. Concerning KHv1 vessels, it should be noted that KH02 and KH03 are two
306 wall fragments of weak green glass, showing a decorative motif with trails of the same colour of the
307 body, frequently attested from Roman to Umayyad period; the weak green loop handle with pinched
308 thumb-rest (KH01) and the weak turquoise small neck with infolded rim (KH05) show precise
309 comparisons with some published materials and can be attributed to vessel types datable to the
310 Umayyad period and, more precisely, to the 8th century (see materials section). Analyses have
311 demonstrated that these vessels are made of Egypt II glass, perfectly consistent with the majority of
312 produced and consumed glass vessels of 8th century falling within this compositional category in the
313 Near East as attested in the literature (Kato et al. 2009; Greiff and Keller 2014; Freestone et al. 2015;
314 Phelps et al. 2016).**
315 **The tesserae belonging to KHt1 group are made of Egypt I glass as they show lower lime, higher
316 alumina and higher soda when compared to KHv1 vessels (Fig. 5-7). Contrarily from what observed**

317 for the KHv1 vessels, CaO/Sr ratios found for KHt1 tesserae have, on average, a value of 150. This
318 value is consistent with the use of a shell-containing coastal sand, as recently also stated by Phelps
319 and co-workers with regard to early Islamic Egypt I glasses (Phelps et al. 2016). Data of major and
320 minor oxides and trace elements here reported indicate the use of different sands for the production
321 of vessels and tesserae of Egyptian manufacture, in particular **with reference** to the distribution of
322 REE: even though the two sample sets show the same **relative** patterns, a higher depletion of REE is
323 observed for the KHv1 vessels, indicating the use of a purer sand.

324 **To date, evidence for the production of Egypt I glass has been only covered for the Roman period, as**
325 **exhaustive research on the primary workshops located at Wadi Natrun and in the Mareotid area, near**
326 **Alexandria, have demonstrated (Nenna 2014, 2015). Nevertheless, several studies witness the**
327 **consumption of Egypt I glass in the late Byzantine/early Islamic period, also stating its rare**
328 **occurrence.** Groups 8 and 9 identified by Foy and colleagues (Foy et al. 2003) include glass vessels
329 dating to the Umayyad period (mid 7th-mid 8th centuries), the location of whose primary glass
330 workshops is still unknown. Group 8, characterised by higher levels of iron, alumina and titanium,
331 corresponds to Gratuze and Barrandon's 1B group, whilst Group 9, which may pre-date Group 8,
332 corresponds to Gratuze and Barrandon's 1A group (Gratuze and Barrandon 1990). Glass belonging
333 to 1A and 1B groups has also been labelled Egypt I by Freestone et al. (Freestone et al. 2000). By
334 analysing a conspicuous assemblage of glass finds excavated from two well-dated archaeological
335 layers (from the 8th and the 9th centuries) at Raya (Sinai), Kato and co-workers identified the N2-a2
336 type, a low lime – high alumina glass comparable to Egypt I compositional category (Kato et al. 2009;
337 Kato et al. 2010). **A recently published study on late antique vessels and window glass from Cyprus**
338 **(Ceglia et al. 2015) also outlines the presence of some few samples matching the Egypt I**
339 **compositional category.** Finally, among 133 analysed vessels, well-contextualised from selected
340 excavations in the Near East and ascribable to the 7-12th centuries, Phelps and co-workers (Phelps et
341 al. 2016) only found two samples corresponding to Egypt I group (Group N4).

342 **CaO/Al₂O₃:Na₂O/SiO₂ and TiO₂/Al₂O₃:Al₂O₃/SiO₂ bi-plots (Fig. 5-6) unambiguously show that**
343 **KHt1 tesserae match Egypt I compositional category and, even more precisely, late antique/early**
344 **Islamic Egypt I. Reference data reported in the scatter plots highlight, indeed, a strong differentiation**
345 **between late antique/early Islamic Egypt I (Gratuze and Barrandon 1990; Foy et al. 2003; Kato et al.**
346 **2009; Phelps et al. 2016) and earlier Egypt I (Picon et al. 2008), clearly revisable in the compositional**
347 **features. Late antique/early Islamic Egypt I glass show lower soda, higher silica, higher alumina and**
348 **slightly higher lime compared to earlier Egypt I. These characteristics imply the use of different batch**
349 **recipes and, presumably, different sands. LA-ICP-MS data from this study also support the hypothesis**
350 **recently proposed by Phelps and colleagues (Phelps et al. 2016) about the use of an Egyptian shell-**
351 **containing coastal sand in the manufacture of early Islamic Egypt I glass (Fig. 4,8).**

352 Whilst the production and consumption of Egypt II glass has been frequently documented in the 8th
353 century Umayyad glass industry, having found an assemblage of Egypt I type (low lime – high
354 alumina) represents quite a **significant** finding. To date, research has underpinned indication of Egypt
355 I compositional category only playing a marginal role in glass production and consumption in the
356 Umayyad period: for instance, within more than 500 glassware fragments analysed from Raya (Kato
357 et al. 2009), less than 5% accounts for N2-a2 type; another example is represented by the small
358 number of Umayyad lamps and vessels remains from the monastery of St Aaron on Jabal Harun (near
359 Petra, Jordan), datable to the mid 7th to the mid 8th centuries, corresponding to the Egypt I group
360 (Greiff and Keller 2014).

361 Nevertheless, what makes this finding absolutely remarkable is the fact that we are discussing glass
362 tesserae and not vessels: it is the first time that evidence is provided of the existence of an Egyptian

363 manufacture for Umayyad glass tesserae.

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365 **5.2 KHv2 and KHt2: Levantine vessels and tesserae**

366 Vessels and tesserae belonging to groups KHv2 (KH04, KH06, KH07) and KHt2 (G2, A7, A7bis,
367 Vc8, Am/Au11, G/V13, Am14) have been manufactured by using sands low in the heavy accessory
368 minerals, with small contents of iron oxide, titanium oxide and zirconium, and showing a **greater** REE
369 depletion (Fig. 4a-d). In addition, the relatively high alumina suggests the use of a mature sand, and
370 the positive correlation between high lime and high strontium indicates a coastal sand containing
371 shells (Fig. 5, 8) (Freestone et al. 2003; Phelps et al. 2016).

372 As in the case of the Egyptian samples, even if they show a common Levantine origin, KHv2 and
373 KHt2 are distinct glass groups.

374 The term *Levantine* has been generally used to describe two main compositional categories
375 manufactured on the Syro-Palestinian coast, **first** identified by Freestone and co-workers (Freestone
376 et al. 2000; Freestone et al. 2002). The first group, named Levantine I, includes 6th to 7th century glass
377 from Apollonia-Arsuf, Bet She'an and Dor (Freestone et al. 2000; Freestone et al. 2008). Evidence
378 suggests that the sand from the Belus delta in the Bay of Haifa (or similar coastal sands containing
379 calcareous fragments) was used for the production of Levantine I glass (Freestone et al. 2003). This
380 type of glass is similar to the **Roman glass type** (e.g. Foster and Jackson 2009), but differs in being
381 slightly higher in lime (CaO around 8–9 wt%, as compared to 6.5–7.5 wt% in Roman glass) and
382 alumina (Al₂O₃ of about 2.5–3 wt%, as compared to 2–2.5 wt%) (Freestone et al. 2000). The second
383 group, named Levantine II, is associated with the primary furnaces found at Bet Eli'ezer, near Hadera
384 (Israel), probably active between the 6th and the early 8th centuries (Freestone et al. 2002; Freestone
385 et al. 2003). Levantine II glass is distinct from Levantine I and Roman glass for its lower lime and
386 sodium and higher silica contents, indicating a different silica source than the one utilized for
387 Levantine I glass, but still some local coastal sand (Freestone et al. 2002; Freestone et al. 2003).

388 Concerning the vessels, patterns **elucidated** on the basis of LA-ICP-MS data markedly distinguish
389 KH04 and KH06 samples from the Egyptian set (Fig. 4a,b). The former are, indeed, characterised by
390 very high strontium together with relatively lower zirconium, as well as by a higher depletion of REE
391 (particularly light REE). Furthermore, KH04 and KH06 samples show a CaO/Sr ratio of 270 and 217,
392 respectively; these values are comparable with those found by Freestone and co-workers (Freestone
393 et al. 2003) for Bet Eli'Ezer and Bet She'an glasses and compatible with the use of a Levantine coastal
394 sand. Glass of Levantine origin is, indeed, generally made by using pure sand, as confirmed by the
395 low levels of all the analysed trace elements and by the strongly depleted REE patterns. Major **oxides**
396 demonstrate that samples KH04 and KH07 seem to better **correspond** to Apollonia-type (Levantine
397 I) glass, being characterised by high lime (7.70 – 8.71 wt%), high soda (14.29 – 15.06 wt%) and low
398 silica (71.17 – 72.27 wt%) contents (Fig. 5-7). Whilst KH07 lacks of a precise typological
399 identification, the light olive green fragment KH04 is referable to a straight rim with wall folded
400 towards the outside, belonged to a small bottle probably similar to the n. 126 of the Bet Shean's
401 catalogue, dated to the Umayyad period (Hadad 2005). Sample KH06 has lower lime (6.63 wt%),
402 lower soda (12.89 wt%) and higher silica (75.44 wt%) contents, consistent with an attribution to Bet
403 Eli'ezer-type (Levantine II) group (Fig. 4 and 7); this hypothesis is further enhanced by the chrono-
404 typological data, since this fragment of a flat bottom, probably belonged to a globular bottle, is similar
405 to some types documented in the catalogue of the glass findings from Al-Hadir (northern Syria) (Foy
406 2012), dated from the 8th century AD onwards, therefore of a slightly later time.

407 Concerning KHt2 tesserae, trace element patterns are consistent with their attribution to a Syro-
408 Palestinian production, being characterized by high strontium and low zirconium contents: all these

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409 Levantine samples exhibit a CaO/Sr ratio around 270 (with the only exception of Vc8, showing a
410 slightly lower ratio); a strongly depleted REE pattern is also noticeable in comparison to the tesserae
411 of Egyptian production (Fig. 4c,d). Major oxides soda, silica, lime and alumina (Fig. 5, 6) demonstrate
412 that the majority of samples (opaque G2, A7, A7bis, Vc8 and translucent G/V13, Am14) show a close
413 match with Apollonia-type glass. The only exception is represented by Am/Au11tessera, showing
414 compositional features more similar to the ones of Bet Eli'ezer-type glass, being characterised by
415 higher silica (74.32 wt%), lower soda (12.09 wt%), lower lime (6.68 wt%) and higher alumina (3.17
416 wt%) contents.

417 With regard to the Umayyad period (mid 7th – mid 8th century), several studies have attested the use
418 of Levantine glass in the manufacture of vessels. Among the material from the site of Raya (Sinai),
419 Kato and colleagues (Kato et al. 2009; Kato et al. 2010) have identified the so-called N1 type,
420 corresponding to Levantine I and/or Levantine II, accounting for about 30% of the whole assemblage.
421 In their study concerning glass vessels, chunks and moils from the early Islamic secondary workshop
422 at HaGolan Street (Khirbet al-Hadra, Tel Aviv), Freestone and co-workers (Freestone et al. 2015)
423 recognised two groups comparable with Levantine glass: Group B, more closely matching Bet
424 Eli'ezer-type, and Group A, supposed being a different type of Levantine glass, previously unknown.
425 Greiff and Keller (Greiff and Keller 2014) also highlighted the presence of Umayyad glassware in
426 the monastery of St. Aaron belonging to both Apollonia- and Bet eli'ezer-type; additionally, authors
427 emphasise the predominance of Bet eli'ezer-type glass in the Umayyad period compared to the small
428 number of Egypt I finds. Concerning Umayyad Levantine glass, in a recently published paper Phelps
429 and co-workers (Phelps et al., 2016) made quite an important assertion: while in the 7th century,
430 Apollonia-type almost entirely dominated the production, from the early 8th the Bet Eli'Ezer-type
431 started being mainly used, with the quantities of Apollonia-type glass falling dramatically.

432 Within the Levantine vessel fragments from Khirbet al-Mafjar, two samples (KH04 and KH07) are
433 made of Apollonia-type glass and one sample (KH06) corresponds to Bet Eli'ezer-type. In accordance
434 with data reported in the literature, both compositional categories are attested in the Umayyad period,
435 and, more precisely, in the first half of the 8th century.

436 Concerning the mosaic tesserae, glass tesserae of a Levantine manufacture have been attested by
437 several studies in a number of monuments dated from the 6th century onward, often together with
438 other compositional categories. These include: the late antique church at Kilise Tepe, Turkey (Neri
439 et al. 2017), the basilica of Hagia Sophia in Constantinople, Turkey (Moropoulou et al. 2016); a
440 number of basilicas in Ravenna, Italy, such as St Severo (Classe), St Apollinare in Classe, St Vitale
441 and the Neonian Baptistery (Vandini et al. 2006; Verità 2010; Fiori 2015); the church of Hagios
442 Polyuktos at Saraçhane in Constantinople, Turkey (Schibille and McKenzie 2014); the chapel of St.
443 Prosdocius, inside the basilica of St Giustina in Padova, Italy (Silvestri et al. 2014); the Cross
444 Church in Jerash, Jordan (Arinat et al. 2014) and the Petra Church, Jordan (Marii and Rehren 2009).
445 Therefore, it would seem possible to link the use of a Levantine glass in the production of tesserae
446 used in the decoration of Byzantine monuments.

447 If, to date, little is known about the manufacture of Byzantine mosaics (how raw materials were
448 obtained by mosaicists? How was the supply of tesserae organised?), our knowledge of the Umayyad
449 mosaics is even more restricted, especially in terms of materials and techniques. The presence of
450 Levantine natron-based glass has been recently attested by Neri and co-workers (Neri et al. 2016) by
451 analysing a set of 8th century gold leaf tesserae from the Great Mosque of Damascus and the Baths of
452 Qusayr Amra.

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453 Among the tesserae from the *qasr* of Khirbet al-Mafjar, six samples were found matching the
454 Levantine I (Apollonia-type) compositional category and one is consistent with the Levantine II (Bet
455 Eli'ezer group).

456 Having found some Levantine manufactured glass tesserae in an Umayyad mosaic could be
457 interpreted as evidence of a kind of continuity with the Byzantine tradition and the gathering of
458 materials from abandoned monuments cannot be excluded. On the other hand, the finds from Khirbet
459 al-Mafjar include Egypt I tesserae too: since it is the first time this compositional category is attested
460 for the manufacture of mosaic tesserae, from where should these glass come from?
461

462 6. Conclusions

463 The results from analysing glass from Khirbet al-Mafjar displayed remarkable outcomes regarding
464 both the naturally coloured vessels and the tesserae. The obtained results enhanced the knowledge of
465 glass provenance, manufacture and consumption in the Umayyad period (where currently very little
466 is known), shedding, in particular, an entirely new light on the mosaic tesserae. Equally important
467 compositional data can be framed in the broader view to improve the knowledge of the compositional
468 categories identified in the literature, with particular reference to Egyptian manufacture in the late
469 Byzantine/early Islamic period.

470 A captivating picture emerged for both vessels and tesserae as, in both cases, it was possible to
471 distinguish between an Egyptian and a Levantine production.

472 Concerning the vessels, the presence of both an Egyptian and a Levantine manufacture with
473 distinctive Umayyad features within an assemblage of samples confidently ascribable to the first half
474 of the 8th century, perfectly matches that scenario of remarkable changes in the glass supply
475 distinctive of the first half of the 8th century in Palestine clearly outlined by Phelps and colleagues
476 (Phelps et al. 2016). The presence of Egyptian and Levantine glass, attested, to date, at both
477 production (the secondary workshop at Tel Aviv quoted in Freestone et al. 2015) and consumption
478 sites can be interpreted as a distinctive feature of the Umayyad period. The precise reasons of this
479 occurrence are still an open question: are they linked to technological reasons as, for instance, the
480 better working properties of Egypt II glass? Should this choice rather have been influenced by
481 economic factors? Answers to these questions still need to be provided and further research is needed.
482 However, the most outstanding results of this study stem from the tesserae. For the first time a set of
483 glass tesserae from an Umayyad mosaic has been investigated through an archaeometric approach,
484 revealing highly significant new information. Within the analysed tesserae, both Egypt I and
485 Levantine base glass have been, indeed, identified. Firstly, these data provide evidence of a double
486 supply of raw glass from Egypt and the Syro-Palestinian coast occurring not only for glassware, but
487 also for tesserae. In addition to that, it is the first time that the use of Egypt I compositional category
488 is documented for mosaic glass tesserae. The comparison between early Islamic Egypt I and earlier
489 Egypt I from Wadi Natrun seems, moreover, to show that these categories have dissimilar
490 compositional features and, therefore, they could be interpreted as different groups.

491 Results from one set of tesserae cannot ultimately address the issue of understanding the actual
492 relationship between early Islamic and Byzantine mosaic manufacture and technology. Nonetheless,
493 data provide quite a thought-provoking starting point for further research, giving the first material
494 evidence of a non-exclusive gathering of materials from Byzantium in the manufacture of early
495 Islamic mosaics.
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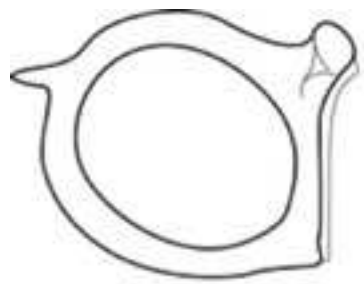
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Figure 1a

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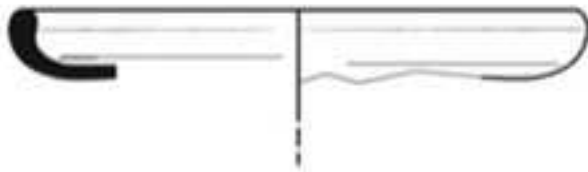
KH01



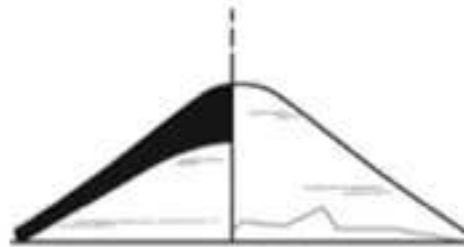
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KH06



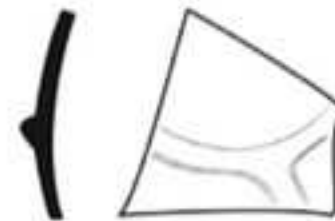
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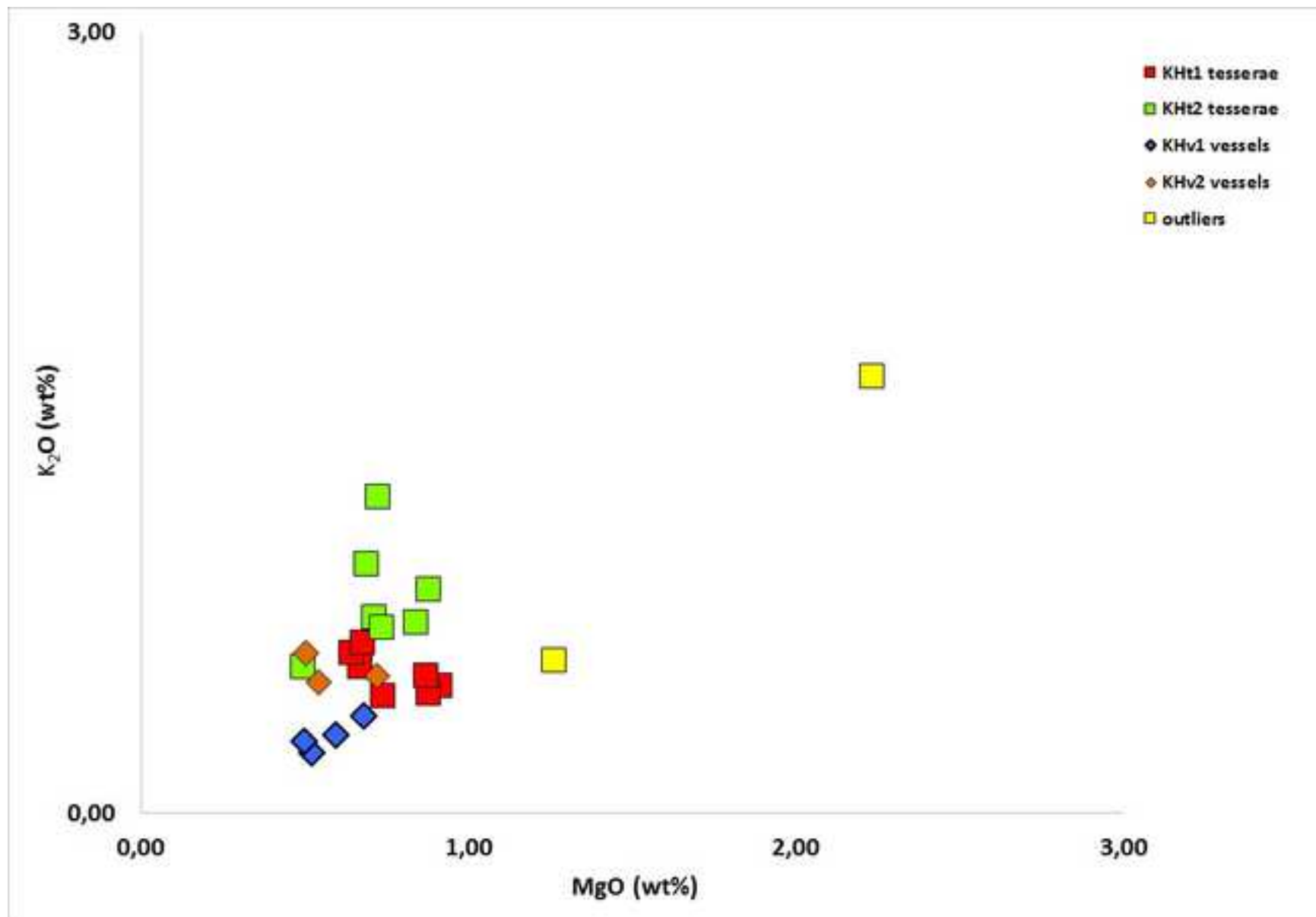


KH03



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Figure 3



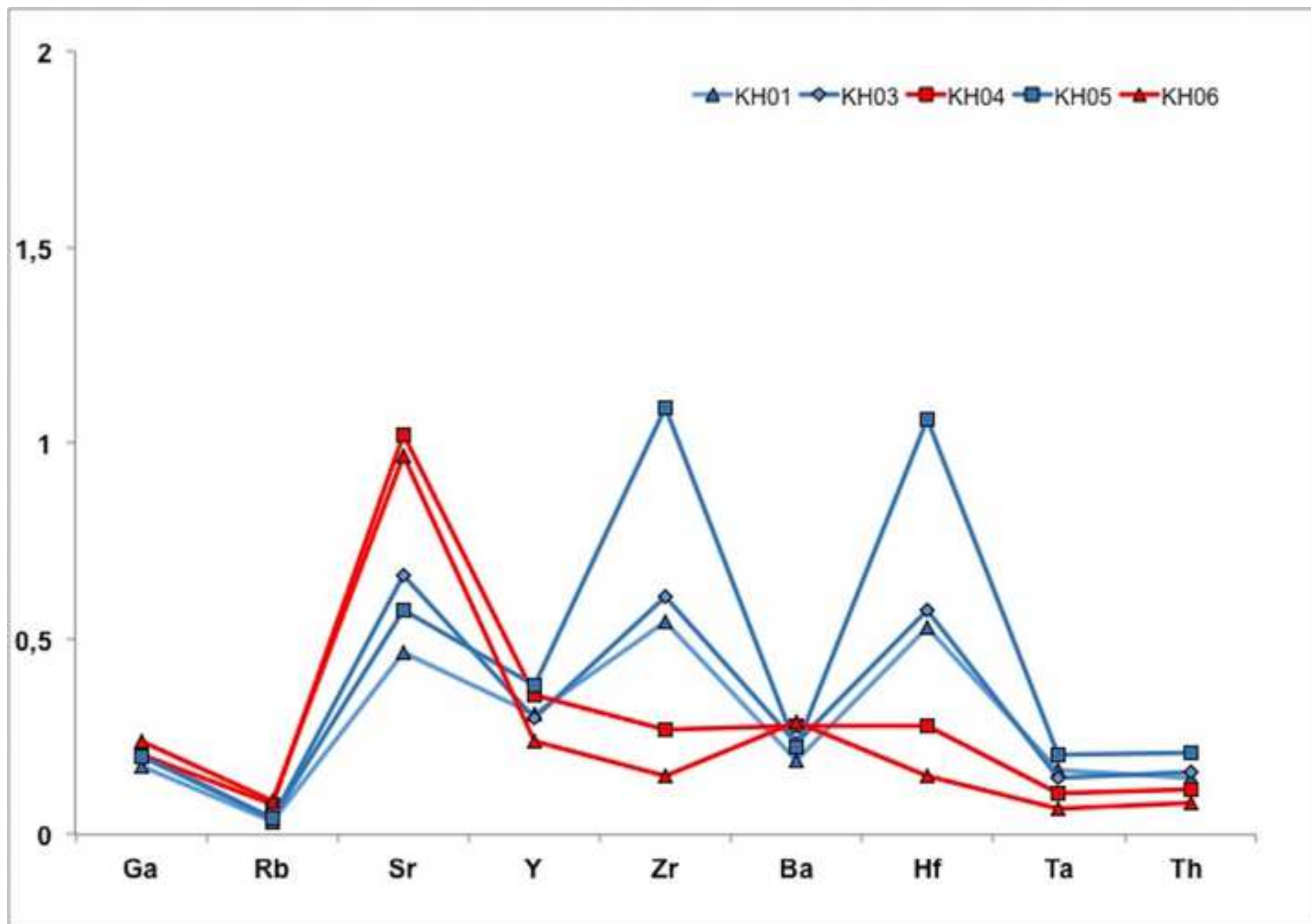
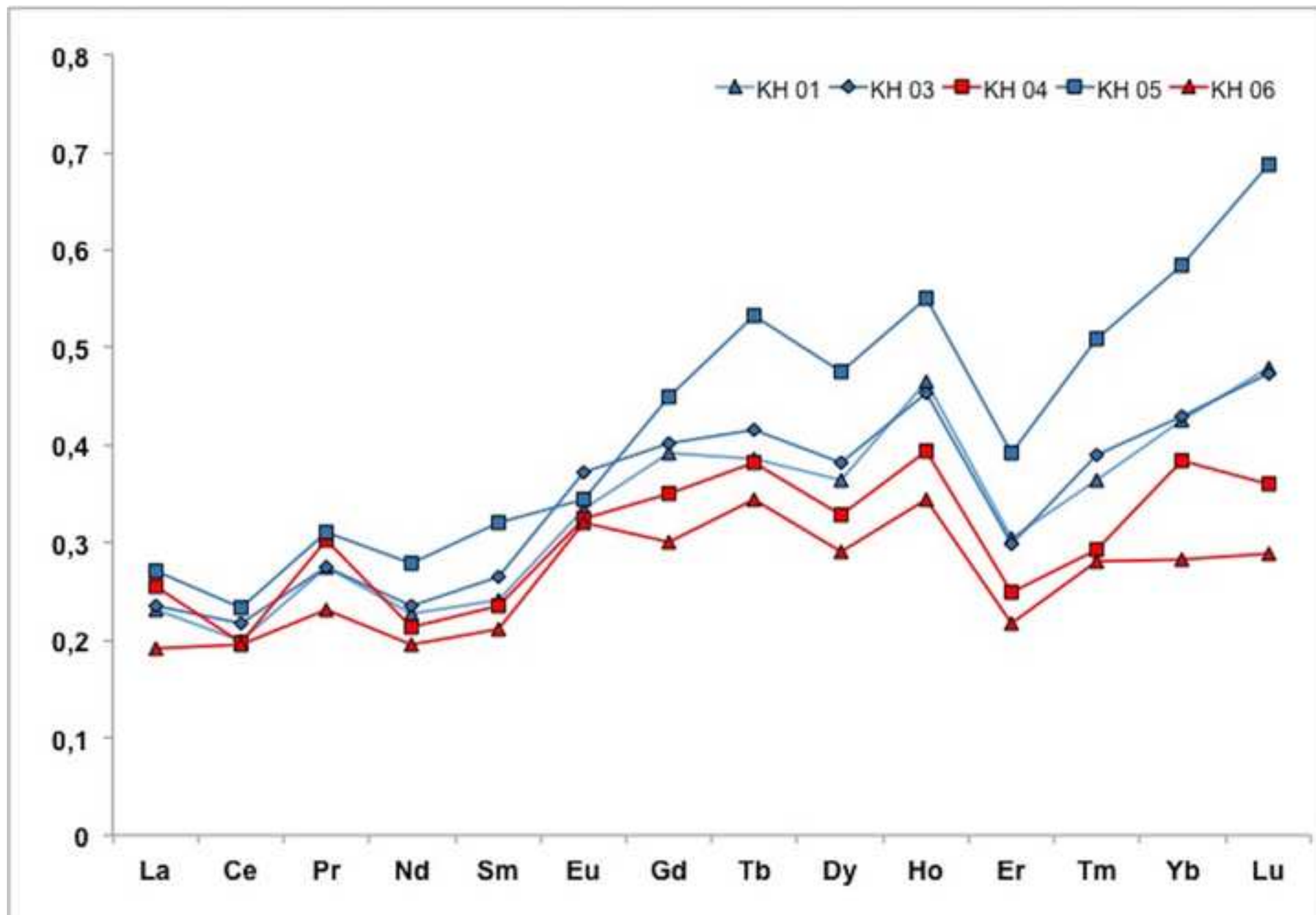
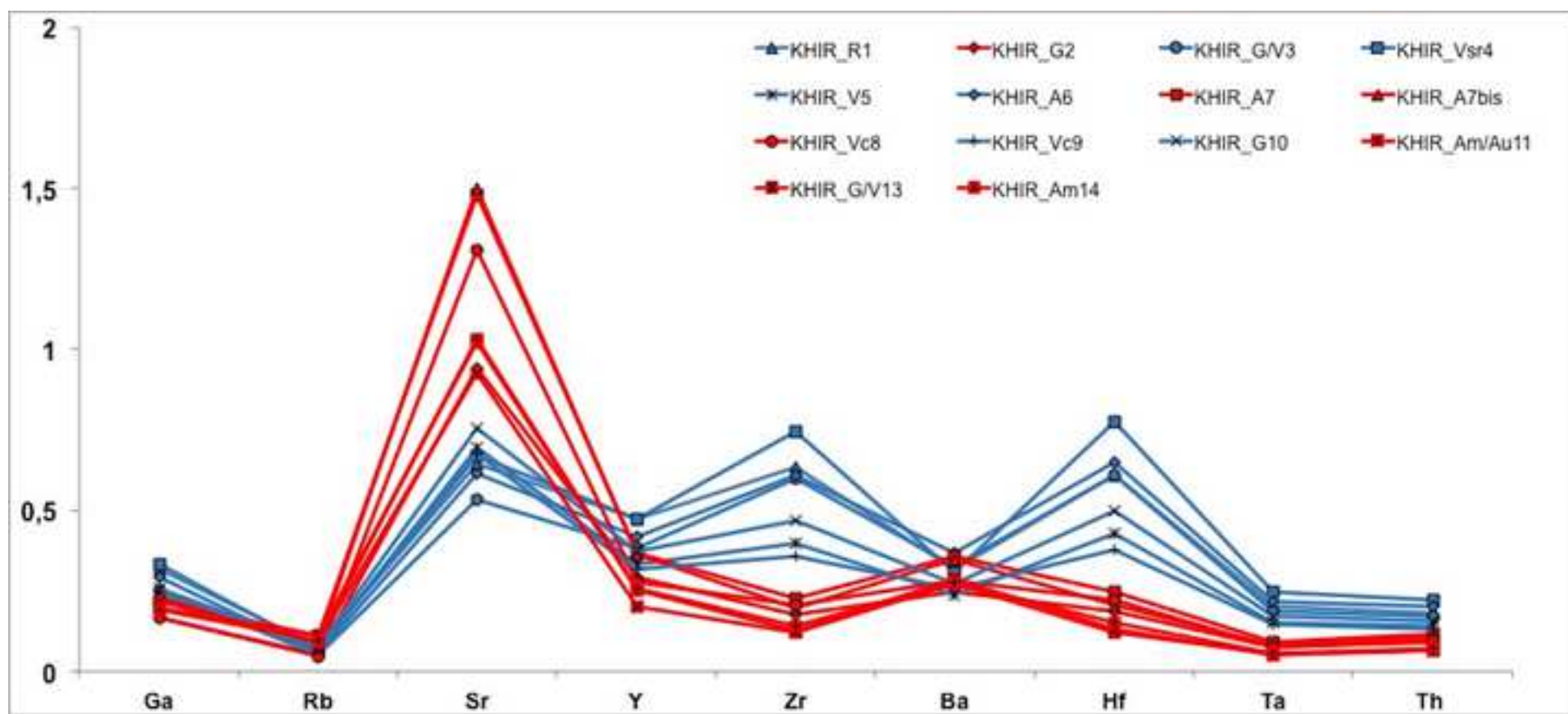


Figure 4b





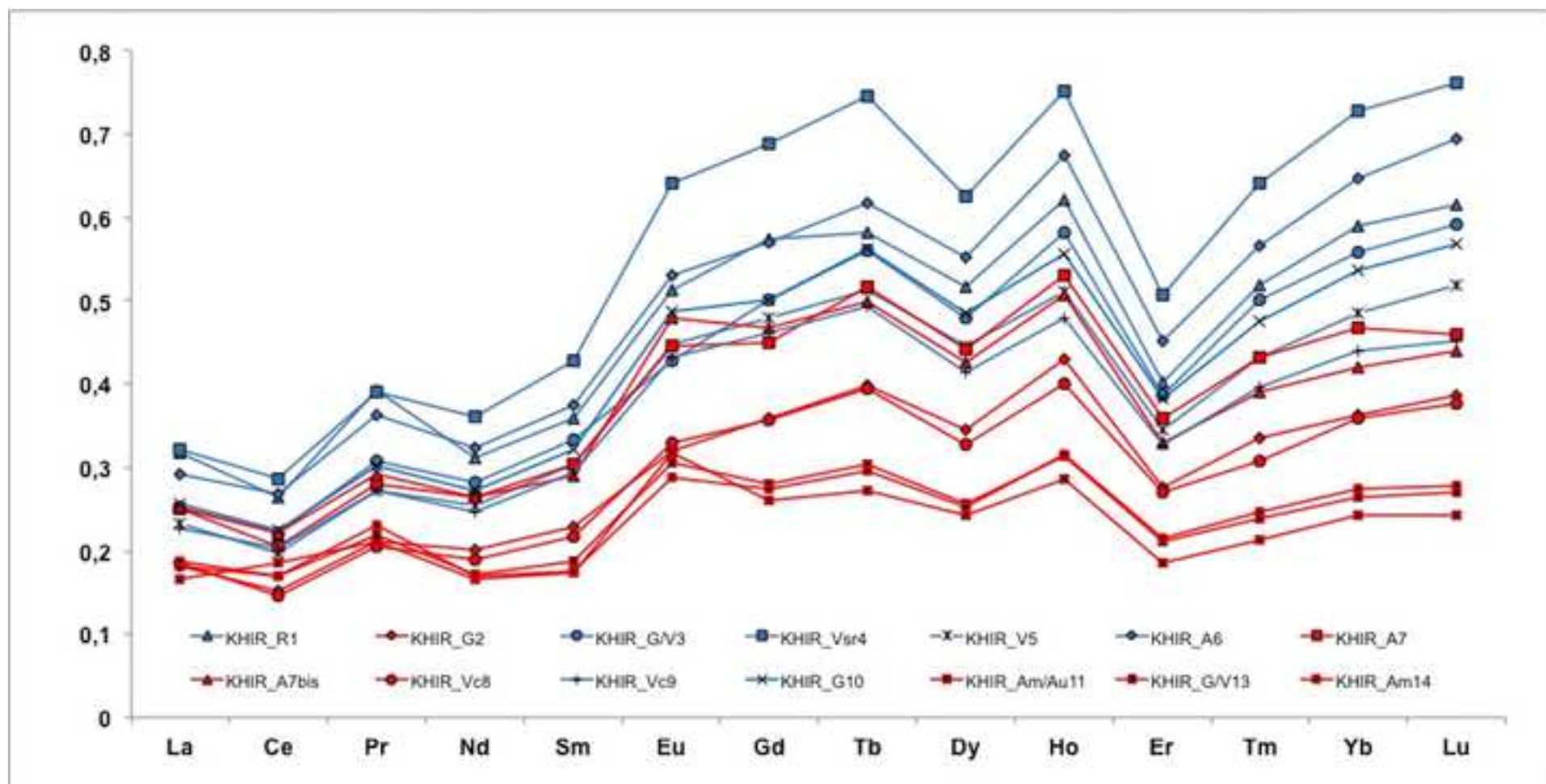


Figure 5

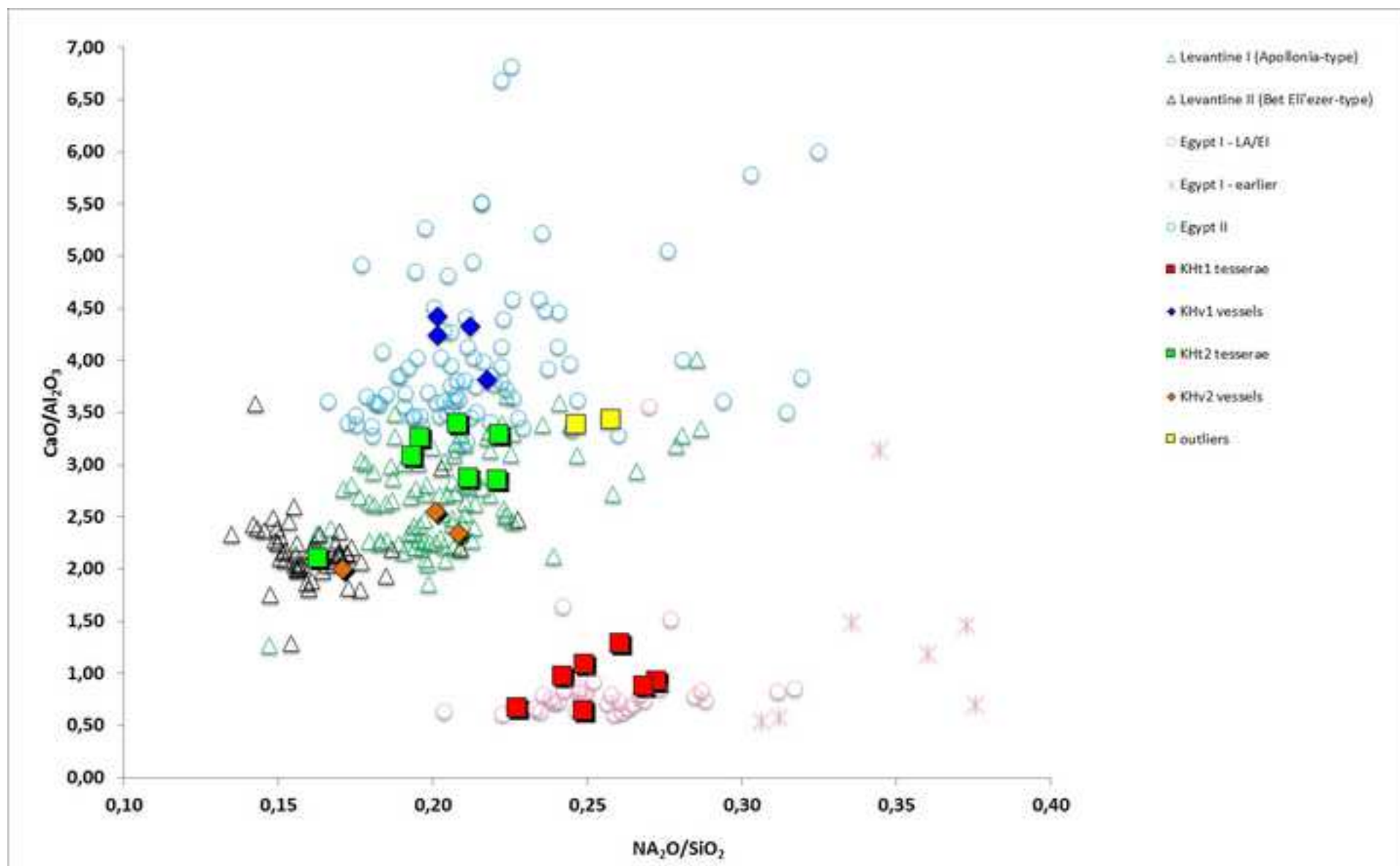


Figure 6

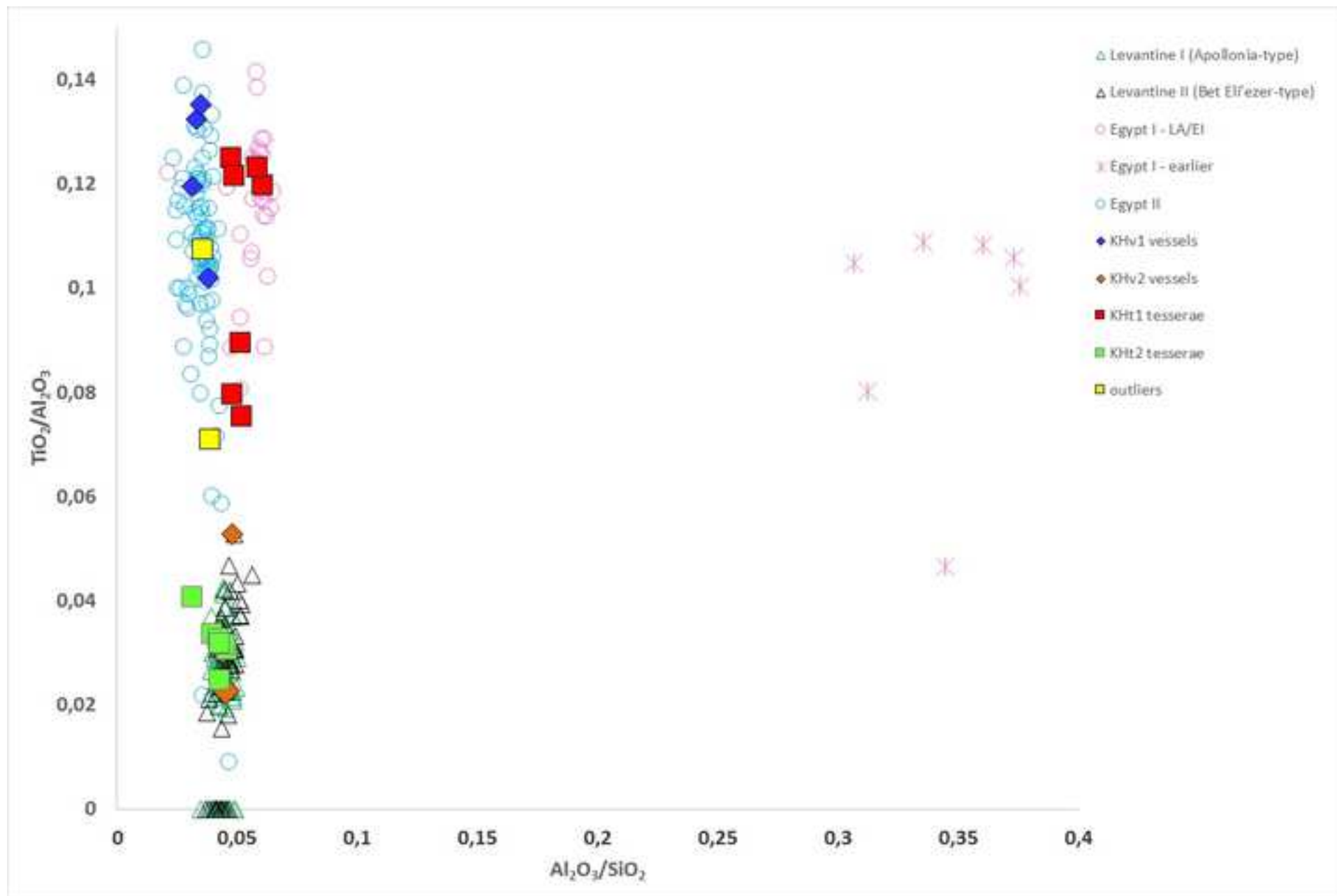


Figure 7

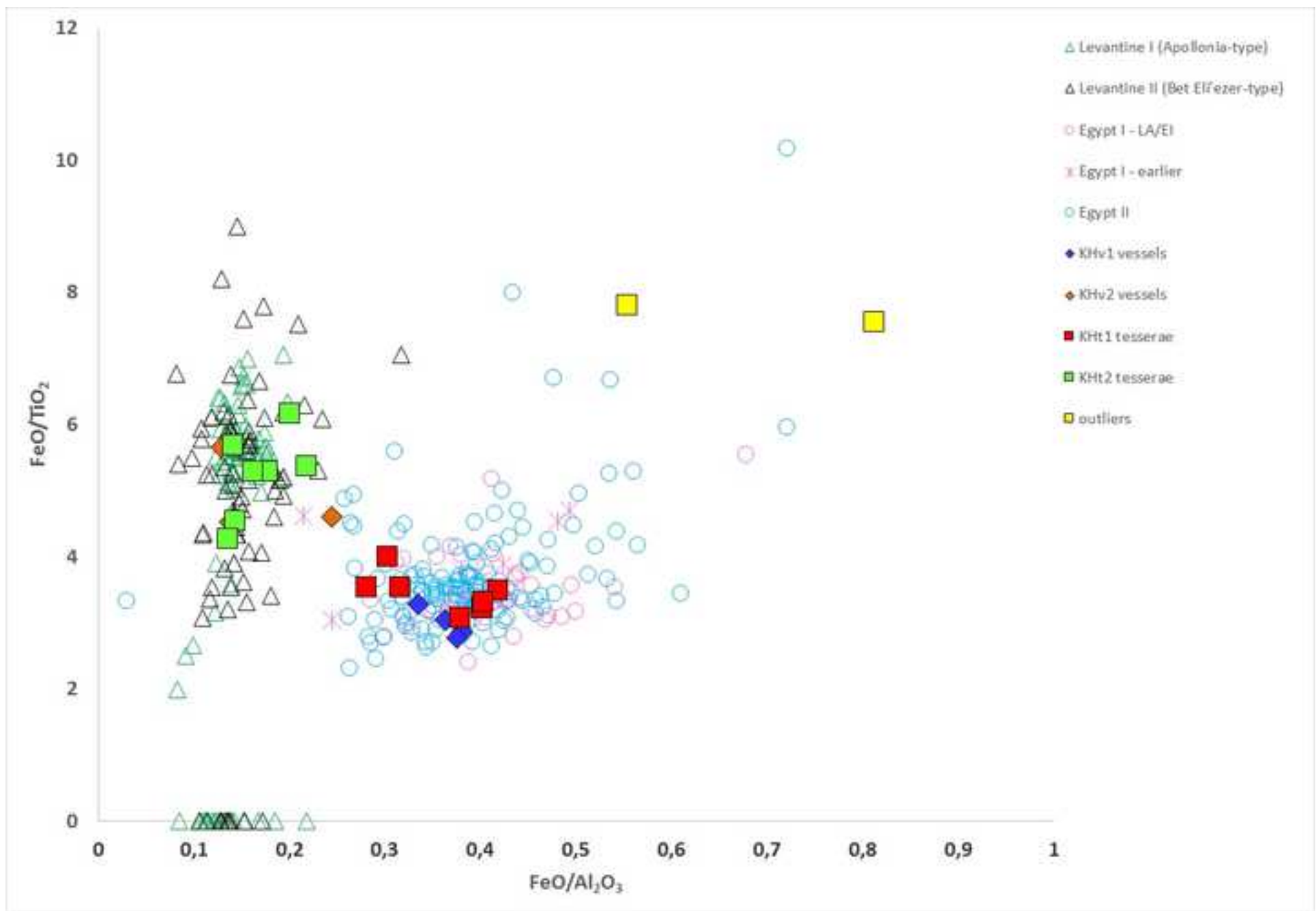


Figure 8

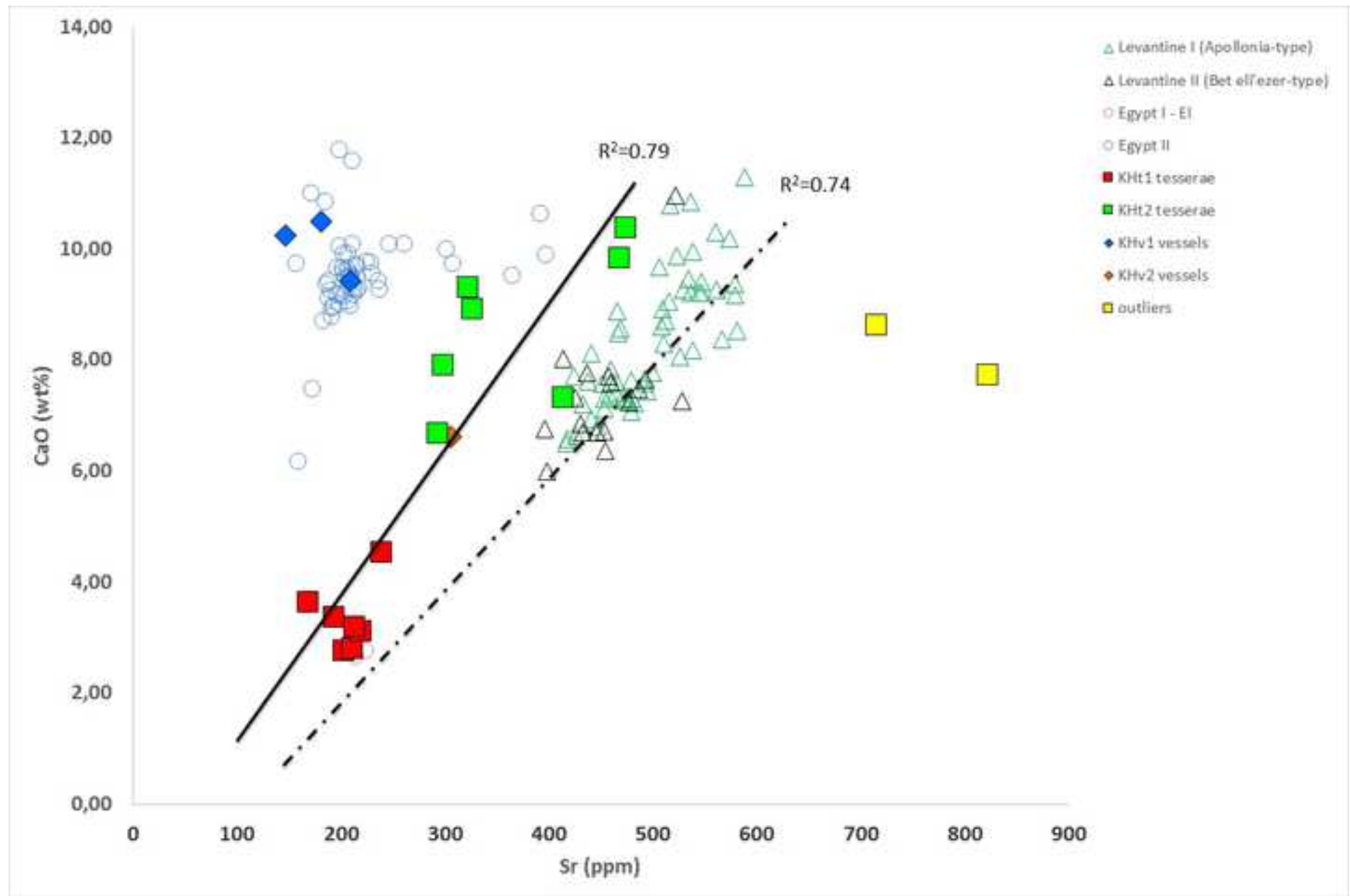

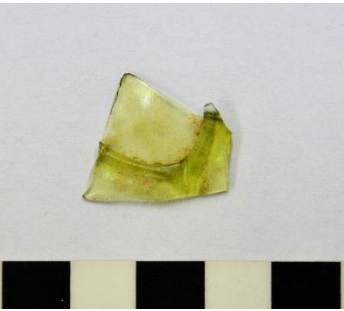
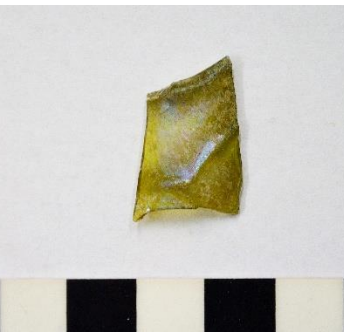


Table 1.a

Sample	Object	Photo	Typology	Datig (by form)	References
KH01	Loop handle with pinched thumb-rest		Cup or cup-shaped oil lamp	end 7 th - 8 th century	Hadad 2005, pl. 21, n. 398 (first half of 8 th century); Gorin-Rosen and Katsnelson 2005, p. 112, n. 40 (8 th century); Gorin-Rosen 2007, p. 49, n. 9 (Abassid/Fatimid period); Gorin-Rosen 2008, p.124, n. 16 (Late Byzantine/ Umayyad period); Gorin-Rosen 2010, p. 252, pl. 10.11, n. 4 (without thumb-rest) (Abassid/Fatimid period)
KH02	Wall with trails		Unidentified vessel with bifurcated ribs decoration?	3 rd – 8 th century	Harden 1936, pl. XVIII, n. 593 (2 nd -3 rd century); Crowfoot 1957, fig. 94, n. 12 (3 rd century); Clairmont 1963, pl. V, n. 189 (2 nd -3 rd century); Barag 1978, p. 24, fig. 12.50 (late 3 rd -4 th century); Weinberg and Goldstein 1988, p. 81, fig. 4-39 (2 nd -4 th century); Dussart 1998, BX.3211c, n. 11 (end 3 rd -4 th century); Gorin-Rosen 2006, p. 52, n. 27 (late Byzantine-Umayyad period); Gorin-Rosen 2007, p. 107, fig. 15.1 (late Roman-Early Byzantine period); Antonaras 2010, fig. 3 (last on the second row) (mid 3 rd -4 th century)
KH03	Wall with trails		Unidentified vessel with bifurcated ribs decoration?	3 rd – 8 th century	Harden 1936, pl. XVIII, n. 593 (2 nd -3 rd century); Crowfoot 1957, p. 410, n. 94.12 (4 th century); Clairmont 1963, pl. V, n. 189 (2 nd -3 rd century); Barag 1978, p. 24, fig. 12.50 (late 3 rd -4 th century); Weinberg and Goldstein 1988, p. 81, fig. 4-39 (2 nd -4 th century); Dussart 1998, BX.3211c, n. 11 (end 3 rd -4 th century); Gorin-Rosen 2006, p. 52, n. 27 (late Byzantine-Umayyad period); Gorin-Rosen 2007, p. 107, fig. 15.1 (late Roman-Early Byzantine period); Antonaras 2010, fig. 3 (last on the second row) (mid 3 rd -4 th century)




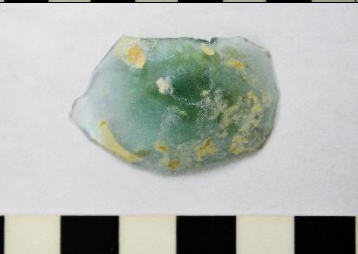

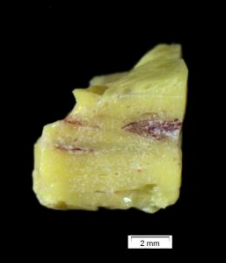
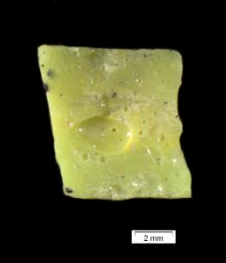





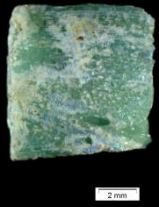


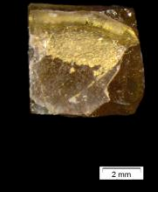
KH04	Straight rim with wall folded toward inside		Small bottle	Second half 4 th – first half 8 th century	Dussard 1998, BX.3244, n. 29 (second half 4 th -6 th century); Hadad 2005, pl. 7, n. 126 (first half 8 th century)
KH05	Small infolded rim		Small bottle	7 th – 8 th century	Katsnelson 1999, p. 72, fig. 3, n. 3 (late Byzantine); Dussard 1998, BXIII.1931bI, n. 19 (first half 8 th century); Gorin-Rosen 2010, p.234, pl. 10.6, n. 3 (Umayyad period)
KH06	Slightly concave bottom		Globular bottle	5 th – 8 th century	Katsnelson 1999, p. 72, fig. 3, n. 14 (5 th -6 th century); Foy 2012, pl. 18, n. 36 (8 th century)
KH07	Central fragment of bottom		Unidentified vessel	Undated	Hadad 2005, pl. 11, n. 208 (Umayyad period)?

Table 1.b

Sample	Visible colour	NCS	OM photo
R1	Red	S 5040-Y80R	
G2	Yellow with red strips	S 2040-G90Y	
G/V3	Greenish yellow	S 2040-G80Y	
Vsr4	Green with red strips	S 5030-G30Y	

V5	Green	S 4030-G30Y	 2 mm
A6	Turquoise	S 5040-B80G	 2 mm
A7	Turquoise	S 4040-B20G	 2 mm
A7bis	Turquoise	S 4055-B40G	 2 mm

Vc8	Light green	S 3040-G	
Vc9	Light Green	S 3065-G40Y	
Ga10	Greyish weak turquoise	S 1510-G	
Am/Au11	Amber with golden leaf	S 4050-Y10R	

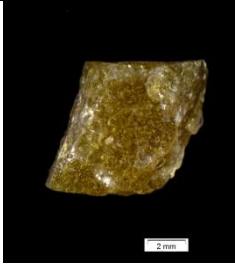
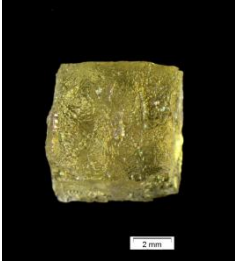

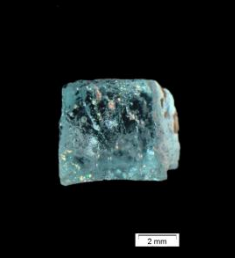
Am12	Amber	S 6030-Y20R	 <p>A photograph of an amber specimen, S 6030-Y20R, showing a yellowish-brown, irregularly shaped piece with a slightly textured surface. A 2 mm scale bar is visible at the bottom right of the image.</p>
G/V13	Greenish yellow	S 2050-Y	 <p>A photograph of a greenish yellow specimen, S 2050-Y, showing a roughly square, translucent piece with a slightly textured surface. A 2 mm scale bar is visible at the bottom right of the image.</p>
Am14	Amber	S 2060-Y	 <p>A photograph of an amber specimen, S 2060-Y, showing a roughly square, translucent piece with a yellowish-brown color and some internal inclusions. A 2 mm scale bar is visible at the bottom right of the image.</p>
A15	Weak turquoise	S 0515-B20G	 <p>A photograph of a weak turquoise specimen, S 0515-B20G, showing a roughly square, translucent piece with a light blue-green color and some internal inclusions. A 2 mm scale bar is visible at the bottom right of the image.</p>

Table 2a

Sample	Typology	Colour	Opacity	Compositional category	Group	Value	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	Cr ₂ O ₃	MnO	FeO	CoO	CuO	SnO ₂	Sb ₂ O ₃	PbO	Total
KH01	Vessel	Weak green	Translucent	Egypt II	KHv1	Mean	14.19	0.52	2.32	70.35	0.09	0.1	1.53	0.23	10.25	0.31	0.01	0.02	0.88	nd	0.01	0.01	nd	0.05	100.86
						StDev	0.50	0.02	0.13	0.31	0.02	0.04	0.02	0.13	0.05	0.02	0.01	0.03	0.04	-	0.01	0.01	-	0.02	
KH02	Vessel	Weak green	Translucent	Egypt II	KHv1	Mean	15.09	0.68	2.63	69.42	0.1	0.06	1.32	0.37	10.01	0.27	0.01	0.07	0.88	nd	nd	0.02	nd	0.08	101.01
						StDev	0.30	0.02	0.09	0.37	0.032	0.02	0.02	0.05	0.11	0.01	0.01	0.01	0.04	-	-	0.01	-	0.07	
KH03	Vessel	Weak green	Translucent	Egypt II	KHv1	Mean	14.36	0.5	2.22	71.26	0.08	0.19	1.37	0.28	9.43	0.27	0.01	0.02	0.81	nd	0.01	0.03	nd	0.04	100.87
						StDev	0.37	0.02	0.15	0.42	0.02	0.03	0.03	0.04	0.11	0.03	0.01	0.01	0.01	-	0.01	0.03	-	0.05	
KH04	Vessel	Weak olive green	Translucent	Levantine I Apollonia-type	KHv2	Mean	14.29	0.72	3.41	71.17	0.12	0.07	0.95	0.53	8.71	0.18	nd	0.04	0.83	0.01	0.01	nd	nd	0.05	101.09
						StDev	0.31	0.02	0.18	0.43	0.02	0.03	0.04	0.05	0.11	0.01	-	0.01	0.04	0.01	0.01	-	-	0.04	
KH05	Vessel	Weak turquoise	Translucent	Egypt II	KHv1	Mean	14.84	0.6	2.43	69.95	0.07	0.13	1.58	0.3	10.5	0.33	0.02	0.03	0.91	0.01	0.01	0.01	nd	0.04	101.76
						StDev	0.34	0.01	0.09	0.43	0.01	0.02	0.04	0.06	0.11	0.02	0.01	0.01	0.03	0.01	0.01	0.01	-	0.04	
KH06	Vessel	Weak turquoise	Translucent	Levantine II Bet Eli'ezer-type	KHv2	Mean	12.89	0.54	3.32	75.44	0.07	0.04	1.05	0.5	6.63	0.1	0.02	0.02	0.46	0.01	0.01	0.01	0.01	0.03	101.15
						StDev	0.18	0.01	0.16	0.35	0.02	0.03	0.02	0.03	0.07	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.03
KH07	Vessel	Weak turquoise	Translucent	Levantine I Apollonia-type	KHv2	Mean	15.06	0.5	3.28	72.27	0.06	0.11	1.27	0.62	7.7	0.07	0.01	0.02	0.42	0.01	0.01	nd	nd	0.04	101.46
						StDev	0.31	0.02	0.11	0.54	0.02	0.02	0.02	0.08	0.05	0.01	0.01	0.01	0.03	0.01	0.01	-	-	0.04	
R1	Tessera	Red	Opaque	Egypt I	KHt1	Mean	16.86	0.88	4.11	67.83	0.08	0.04	1.29	0.47	2.66	0.49	0.02	0.04	1.72	0.01	2.58	0.37	nd	0.85	100.3
						StDev	0.40	0.03	0.19	1.56	0.02	0.02	0.04	0.05	0.05	0.02	0.01	0.01	0.33	0.01	0.29	0.25	-	0.26	
G2	Tessera	Yellow	Opaque	Levantine I Apollonia-type	KHt2	Mean	11.1	0.61	1.98	50.24	0.06	0.05	0.8	0.53	5.65	0.07	0.01	0.03	0.35	0.01	0.39	2.3	nd	24.87	99.03
						StDev	0.25	0.03	0.09	0.91	0.02	0.03	0.04	0.09	0.08	0.01	0.02	0.01	0.02	0.01	0.02	0.27	-	0.93	
G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	Mean	13.84	0.7	2.64	55.61	0.09	0.06	1.17	0.37	2.86	0.33	0.01	0.72	1.06	nd	0.01	1.99	nd	17.94	99.41

Vsr4	Tessera	Green	Opaque	Egypt I	KHt1	StDev	0.44	0.03	0.12	1.54	0.02	0.01	0.04	0.05	0.11	0.02	0.01	0.06	0.04	-	0.01	0.40	-	1.77	
						Mean	14.47	0.77	3.71	63.67	0.08	0.05	1.21	0.47	2.48	0.46	0.02	0.11	1.41	nd	1.82	1.16	nd	8.63	100.51
						StDev	0.34	0.01	0.18	0.93	0.01	0.03	0.04	0.06	0.07	0.02	0.02	0.01	0.04	-	0.07	0.08	-	0.61	
V5	Tessera	Green	Opaque	Egypt I	KHt1	Mean	16.36	0.58	2.87	60.05	0.09	0.1	1.28	0.49	2.67	0.23	0.01	0.04	0.81	0.01	1.47	0.82	0.04	10.89	98.8
						StDev	0.28	0.02	0.14	0.85	0.02	0.03	0.03	0.05	0.04	0.01	0.01	0.01	0.01	0.01	0.04	0.06	0.01	0.25	
A6	Tessera	Weak turquoise	Opaque	Egypt I	KHt1	Mean	16.73	0.72	3.36	69.13	0.58	0.07	1.48	0.44	3.28	0.41	0.01	0.56	1.35	0.01	2.42	0.16	nd	0.53	101.23
						StDev	0.41	0.02	0.16	1.15	0.12	0.02	0.04	0.07	0.09	0.02	0.01	0.02	0.03	0.02	0.05	0.05	-	0.07	
A7	Tessera	Weak turquoise	Opaque	Levantine I Apollonia-type	KHt2	Mean	13.97	0.71	2.82	67.19	0.35	0.07	0.99	1.19	9.59	0.09	0.01	0.34	0.57	0.03	1.77	0.1	nd	0.4	100.16
						StDev	0.63	0.05	0.15	0.52	0.03	0.02	0.04	0.13	0.18	0.01	0.01	0.02	0.01	0.04	0.06	0.03	-	0.07	
A7bis	Tessera	Weak turquoise	Opaque	Levantine I Apollonia-type	KHt2	Mean	13.26	0.7	3.11	67.78	0.2	0.13	1.1	0.74	10.14	0.1	0.01	0.05	0.5	0.05	1.7	0.12	nd	0.26	99.9
						StDev	0.38	0.01	0.08	0.52	0.01	0.05	0.03	0.06	0.08	0.01	0.01	0.01	0.02	0.06	0.10	0.02	-	0.06	
Sample	Typology	Colour	Opacity	Compositional category	Group	Value	Na₂O	MgO	Al₂O₃	SiO₂	P₂O₅	SO₃	Cl	K₂O	CaO	TiO₂	Cr₂O₃	MnO	FeO	CoO	CuO	SnO₂	Sb₂O₃	PbO	Total
Vc8	Tessera	Green	Opaque	Levantine I Apollonia-type	KHt2	Mean	12.88	0.73	1.83	58.18	0.24	0.12	0.95	0.71	6.00	0.07	nd	0.37	0.4	0.07	0.7	1.47	nd	14.56	99.23
						StDev	0.21	0.02	0.10	0.46	0.02	0.04	0.04	0.07	0.05	0.01	-	0.02	0.02	0.08	0.03	0.09	-	0.42	
Vc9	Tessera	Green	Opaque	Egypt I	KHt1	Mean	16.27	0.56	3.15	60.66	0.14	0.14	1.41	0.53	2.77	0.24	0.01	0.04	0.95	0.09	1.12	0.81	nd	11.53	100.34
						StDev	0.32	0.02	0.12	0.44	0.01	0.03	0.03	0.06	0.05	0.02	0.01	0.01	0.01	0.10	0.04	0.07	-	0.41	
Ga10	Tessera	Greyish-weak turquoise	Opaque	Egypt I	KHt1	Mean	18.18	0.68	3.58	69.81	0.9	0.15	1.59	0.66	4.6	0.32	0.01	0.04	1.13	0.11	0.01	0.01	0.01	0.04	101.71
						StDev	0.37	0.02	0.13	0.91	0.45	0.02	0.05	0.06	0.33	0.02	0.01	0.01	0.03	0.12	0.01	0.01	0.01	0.04	
Am/Au1 1	Tessera	Weak brown (traces of gold leaf)	Translucent	Levantine II Bet Eli'ezer-type	KHt2	Mean	12.09	0.49	3.17	74.32	0.05	0.11	0.95	0.56	6.68	0.1	0.01	1.87	0.43	0.13	0.01	0.01	nd	0.03	100.9
						StDev	0.60	0.02	0.08	0.32	0.02	0.02	0.02	0.05	0.06	0.01	0.01	0.01	0.02	0.14	0.01	0.01	-	0.03	
Am12	Tessera	Weak brown	Translucent		outlier	Mean	16.28	1.26	2.55	66.07	0.1	0.28	1.13	0.59	8.63	0.18	nd	0.1	1.41	0.15	nd	0.01	0.01	0.04	98.65

Am12	Tessera	Weak brown	Translucent		outlier	StDev	0.32	0.02	0.12	0.83	0.02	0.03	0.04	0.04	0.08	0.01	-	0.03	0.04	0.16	-	0.01	0.01	0.04	
G/V13	Tessera	Greenish yellow	Translucent	Levantine I Apollonia-type	KHt2	Mean	13.71	0.69	3.01	71.01	0.17	0.06	1.18	0.96	9.3	0.07	0.01	0.02	0.42	0.17	0.02	nd	nd	0.05	100.69
						StDev	0.53	0.01	0.18	0.52	0.02	0.02	0.03	0.08	0.08	0.01	0.01	0.01	0.01	0.01	0.18	0.01	-	-	0.04
Am14	Tessera	Weak brown	Translucent	Levantine I Apollonia-type	KHt2	Mean	14.62	0.74	3.11	69.1	0.08	0.19	1.06	0.72	8.93	0.1	0.01	2.58	0.45	0.19	nd	0.02	0.01	0.02	101.72
						StDev	0.46	0.02	0.08	0.42	0.02	0.03	0.02	0.04	0.08	0.02	0.01	0.01	0.02	0.20	-	0.02	0.01	0.03	
A15	Tessera	Weak turquoise	Translucent		outlier	Mean	16.28	2.23	2.26	63.17	0.37	0.31	0.7	1.68	7.74	0.24	0.01	nd	1.83	0.21	0.01	0.01	nd	0.02	96.85
						StDev	0.50	0.02	0.13	0.31	0.02	0.04	0.02	0.13	0.05	0.02	0.01	-	0.04	0.22	0.01	0.01	-	0.02	

Table 2.b

Sample	Typology	Colour	Opacity	Compositional category	Group	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	Cr ₂ O ₃	FeO	CoO	Sb ₂ O ₃
R1	Tessera	Red	Opaque	Egypt I	KHt1	17.48	0.91	4.26	70.32	0.09	0.04	1.34	0.49	2.75	0.51	0.02	1.78	0.01	-
G2	Tessera	Yellow	Opaque	Levantine I Apollonia-type	KHt2	15.53	0.85	2.77	70.32	0.08	0.07	1.12	0.74	7.91	0.09	0.02	0.49	0.01	-
G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	17.58	0.89	3.35	70.63	0.12	0.07	1.49	0.47	3.63	0.42	0.01	1.35	-	-
Vsr4	Tessera	Green	Opaque	Egypt I	KHt1	16.29	0.87	4.18	71.71	0.09	0.05	1.36	0.52	2.80	0.51	0.02	1.58	-	-
V5	Tessera	Green	Opaque	Egypt I	KHt1	19.12	0.68	3.35	70.17	0.10	0.11	1.49	0.57	3.12	0.27	0.01	0.94	0.02	0.04
A6	Tessera	Weak turquoise	Opaque	Egypt I	KHt1	17.15	0.74	3.44	70.85	0.59	0.08	1.52	0.45	3.36	0.42	0.01	1.39	-	-
A7	Tessera	Weak turquoise	Opaque	Levantine I Apollonia-type	KHt2	14.32	0.73	2.89	68.88	0.36	0.07	1.02	1.22	9.83	0.09	0.01	0.58	0.01	-
A7bis	Tessera	Weak turquoise	Opaque	Levantine I Apollonia-type	KHt2	13.56	0.71	3.18	69.33	0.21	0.13	1.12	0.75	10.37	0.10	0.01	0.52	0.01	-
Vc8	Tessera	Green	Opaque	Levantine I Apollonia-type	KHt2	15.68	0.89	2.22	70.84	0.29	0.14	1.16	0.87	7.31	0.09	-	0.49	0.02	-
Vc9	Tessera	Green	Opaque	Egypt I	KHt1	18.74	0.64	3.63	69.86	0.16	0.16	1.63	0.61	3.19	0.27	0.01	1.10	0.01	-
Ga10	Tessera	Greyish-weak turquoise	Opaque	Egypt I	KHt1	17.89	0.67	3.52	68.70	0.89	0.15	1.56	0.65	4.53	0.31	0.01	1.11	-	0.01

Table 3

Sample	Typology	Colour	Opacity	Compositional category	Group	Sc	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Sn	Sb	Ba	La
KH01	Vessel	Weak green	Translucent	Egypt II	KHv1	5.59	1405.00	17.22	18.21	2.46	5.44	2.41	17.09	2.41	3.64	146.85	6.31	129.05	3.21	0.37	0.09	124.48	7.45
KH02	Vessel	Weak green	Translucent	Egypt II	KHv1																		
KH03	Vessel	Weak green	Translucent	Egypt II	KHv1	6.09	1271.25	17.40	23.51	5.12	7.11	33.95	28.33	2.85	4.55	209.20	6.16	143.98	2.97	10.83	1.55	154.20	7.58
KH04	Vessel	Weak green	Translucent	Levantine I Apollonia type	KHv2	6.54	939.33	16.82	17.01	2.39	6.05	36.65	21.01	2.88	8.46	321.93	7.34	63.95	2.22	4.32	1.56	186.25	8.25
KH05	Vessel	Weak turquoise	Translucent	Egypt II	KHv1	6.47	1665.50	21.09	27.23	2.67	6.48	2.86	15.96	2.77	4.38	180.73	7.92	258.40	4.01	0.43	0.08	150.02	8.74
KH06	Vessel	Weak turquoise	Translucent	Levantine II Bet Eli'ezer-type	KHv2	5.62	470.08	9.18	13.72	1.43	4.19	2.75	7.40	3.31	9.43	305.47	4.95	35.30	1.53	0.60	0.04	193.52	6.16
KH07	Vessel	Weak turquoise	Translucent	Levantine I Apollonia type	KHv2																		
R1	Tessera	Red	Opaque	Egypt I	KHt1	9.92	2716.20	38.10	52.15	7.57	32.19	12178.00	1528.20	4.45	8.40	203.02	9.80	150.50	4.26	1002.86	23.40	213.18	10.24
G2	Tessera	Yellow	Opaque	Levantine I Apollonia type	KHt2	4.59	400.63	6.83	9.84	1.90	8.20	2355.67	154.18	2.31	5.78	298.18	6.04	41.85	1.27	16715.00	194.38	163.83	5.87
G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	7.58	1872.33	26.13	36.94	4.71	10.19	192.32	56.87	3.53	5.69	168.15	7.93	141.52	3.40	17000.00	82.03	217.53	8.09
Vsr4	Tessera	Green	Opaque	Egypt I	KHt1	9.14	2482.17	34.62	53.91	6.56	24.67	11116.67	877.35	4.63	7.42	211.58	9.81	176.40	4.47	7881.00	57.85	206.17	10.41
V5	Tessera	Green	Opaque	Egypt I	KHt1	8.64	1387.67	21.53	33.89	5.55	17.45	8308.17	1003.12	3.30	7.26	219.28	6.91	94.06	2.72	5049.17	68.00	157.40	7.49
A6	Tessera	Weak turquoise	Opaque	Egypt I	KHt1	8.42	2253.83	29.82	45.27	6.96	28.69	14640.00	996.22	4.12	6.17	193.52	8.62	144.47	4.20	1034.63	21.54	245.62	9.41
A7	Tessera	Weak turquoise	Opaque	Levantine I Apollonia type	KHt2	6.00	525.60	13.26	17.21	10.57	20.81	9692.00	37.63	3.00	12.04	467.55	7.65	54.06	1.73	606.50	22.43	238.93	8.06
A7bis	Tessera	Weak turquoise	Opaque	Levantine I Apollonia type	KHt2	6.73	480.70	9.72	12.54	18.07	39.50	8780.83	47.77	3.16	10.27	474.43	7.55	47.01	1.61	662.00	7.15	231.73	8.17
Vc8	Tessera	Green	Opaque	Levantine I Apollonia type	KHt2	5.66	434.85	11.92	12.54	8.74	14.08	4226.33	364.68	2.31	5.30	413.30	5.77	49.47	1.34	10906.50	188.50	188.37	6.00
Vc9	Tessera	Green	Opaque	Egypt I	KHt1	7.20	1363.83	22.23	32.44	5.49	16.42	6778.50	658.53	3.53	7.53	213.03	6.57	85.21	2.75	5776.50	95.68	173.15	7.32
Ga10	Tessera	Greyish-weak	Opaque	Egypt I	KHt1	7.95	1649.33	24.87	37.92	3.59	7.19	14.61	27.59	3.59	8.36	238.93	7.71	111.60	3.18	2.30	0.09	182.58	8.28
Am/Au11	Tessera	Weak brown (traces of gold leaf)	Translucent	Levantine II Bet Eli'ezer-type	KHt2	9.79	398.00	8.23	14.28	1.31	4.05	2.75	9.42	3.05	10.04	293.05	4.20	28.33	1.28	0.61	0.03	180.72	5.36
Am12	Tessera	Weak brown	Translucent		outlier	9.70	852.80	39.11	15.00	11.94	15.85	56.85	31.07	3.29	6.21	715.30	9.93	86.55	2.73	5.90	142.27	394.50	11.96
G/V13	Tessera	Greenish yellow	Translucent	Levantine I Apollonia type	KHt2	8.15	372.84	9.33	12.32	5.95	4.70	39.21	18.91	2.76	12.19	322.72	5.20	29.77	1.06	7.89	5.14	192.86	5.87
Am14	Tessera	Weak brown	Translucent	Levantine I Apollonia type	KHt2	8.08	427.57	10.10	10.70	1.33	3.53	4.53	9.57	2.71	10.75	326.13	5.35	34.07	1.15	0.71	0.24	186.73	6.06
A15	Tessera	Weak turquoise	Translucent		outlier	9.16	1273.33	46.53	22.85	26.96	50.57	59.55	68.50	3.58	7.82	822.28	11.02	120.83	3.27	1.63	15.68	410.35	14.56

Sample	Typology	Colour	Opacity	Compositional category	Group	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	Au	Pb	Th
KH01	Vessel	Weak green	Translucent	Egypt II	KHv1	13.09	1.73	5.86	1.14	0.32	1.10	0.19	1.06	0.29	0.64	0.11	0.64	0.13	3.05	0.24	0.00	3.37	1.48
KH02	Vessel	Weak green	Translucent	Egypt II	KHv1																		
KH03	Vessel	Weak green	Translucent	Egypt II	KHv1	14.28	1.73	6.08	1.25	0.35	1.13	0.21	1.11	0.28	0.63	0.12	0.65	0.13	3.31	0.22	0.01	320.00	1.62
KH04	Vessel	Weak green	Translucent	Levantine I Apollonia type	KHv2	12.94	1.90	5.52	1.10	0.31	0.98	0.19	0.95	0.24	0.52	0.09	0.58	0.10	1.60	0.15	0.00	128.32	1.17
KH05	Vessel	Weak turquoise	Translucent	Egypt II	KHv1	15.32	1.95	7.24	1.51	0.33	1.26	0.27	1.38	0.34	0.82	0.15	0.88	0.19	6.15	0.30	0.00	4.18	2.15

KH06	Vessel	Weak turquoise	Translucent	Levantine II Bet Eli'ezer-type	KHv2	12.88	1.46	5.04	1.00	0.31	0.84	0.17	0.84	0.21	0.46	0.08	0.42	0.08	0.88	0.10	0.00	6.20	0.81
KH07	Vessel	Weak turquoise	Translucent	Levantine I Apollonia type	KHv2																		
R1	Tessera	Red	Opaque	Egypt I	KHt1	17.36	2.47	8.08	1.68	0.49	1.61	0.29	1.50	0.39	0.84	0.16	0.88	0.17	3.54	0.30	0.03	4306.40	1.87
G2	Tessera	Yellow	Opaque	Levantine I Apollonia type	KHt2	9.96	1.33	5.21	1.08	0.30	1.01	0.20	1.00	0.27	0.58	0.10	0.54	0.10	1.08	0.11	0.08	188216.6 7	0.91
G/V3	Tessera	Greenish yellow	Opaque	Egypt I	KHt1	14.53	1.94	7.29	1.57	0.41	1.40	0.28	1.39	0.36	0.81	0.15	0.84	0.16	3.54	0.28	0.06	165866.6 7	1.77
Vsr4	Tessera	Green	Opaque	Egypt I	KHt1	18.83	2.46	9.37	2.01	0.61	1.93	0.37	1.81	0.47	1.07	0.19	1.09	0.21	4.51	0.37	0.65	69925.00	2.30
V5	Tessera	Green	Opaque	Egypt I	KHt1	12.88	1.72	6.61	1.43	0.43	1.34	0.26	1.29	0.32	0.73	0.13	0.73	0.14	2.50	0.22	0.43	104133.3 3	1.43
A6	Tessera	Weak turquoise	Opaque	Egypt I	KHt1	17.61	2.28	8.35	1.76	0.50	1.59	0.31	1.60	0.42	0.95	0.17	0.97	0.19	3.77	0.32	0.78	4667.00	2.07
A7	Tessera	Weak turquoise	Opaque	Levantine I Apollonia type	KHt2	13.44	1.76	6.84	1.43	0.42	1.26	0.26	1.28	0.33	0.75	0.13	0.70	0.12	1.44	0.14	0.37	3065.00	1.21
A7bis	Tessera	Weak turquoise	Opaque	Levantine I Apollonia type	KHt2	14.55	1.84	6.82	1.36	0.45	1.31	0.25	1.24	0.31	0.69	0.12	0.63	0.12	1.20	0.12	0.20	2235.33	1.08
Vc8	Tessera	Green	Opaque	Levantine I Apollonia type	KHt2	9.54	1.30	4.91	1.02	0.31	1.00	0.20	0.95	0.25	0.57	0.09	0.54	0.10	1.29	0.11	0.66	139966.6 7	1.01
Vc9	Tessera	Green	Opaque	Egypt I	KHt1	13.28	1.71	6.39	1.38	0.41	1.29	0.25	1.20	0.30	0.69	0.12	0.66	0.12	2.19	0.22	0.39	102541.6 7	1.36
Ga10	Tessera	Greyish-weak turquoise	Opaque	Egypt I	KHt1	14.76	1.90	7.03	1.51	0.46	1.40	0.28	1.40	0.35	0.81	0.14	0.81	0.15	2.90	0.26	0.00	30.47	1.64
Am/Au11	Tessera	Weak brown (traces of gold leaf)	Translucent	Levantine II Bet Eli'ezer-type	KHt2	12.14	1.32	4.29	0.82	0.30	0.73	0.14	0.70	0.18	0.39	0.06	0.36	0.07	0.70	0.08	0.00	6.91	0.68
Am12	Tessera	Weak brown	Translucent		outlier	16.19	2.55	9.09	1.85	0.55	1.77	0.34	1.68	0.44	1.01	0.17	0.92	0.17	2.12	0.20	0.00	91.99	1.60
G/V13	Tessera	Greenish yellow	Translucent	Levantine I Apollonia type	KHt2	11.14	1.38	4.41	0.88	0.29	0.78	0.15	0.74	0.19	0.44	0.07	0.40	0.07	0.75	0.08	0.00	113.60	0.66
Am14	Tessera	Weak brown	Translucent	Levantine I Apollonia type	KHt2	11.14	1.45	4.37	0.82	0.27	0.77	0.15	0.73	0.20	0.45	0.07	0.41	0.08	0.87	0.08	0.00	11.48	0.71
A15	Tessera	Weak turquoise	Translucent		outlier	17.38	2.94	10.72	2.22	0.57	2.12	0.40	2.03	0.52	1.21	0.21	1.16	0.21	2.85	0.25	0.00	26.14	1.96

Captions

Figures

Fig. 1.a) Location of the *qasr* of Khirbat al-Mafjar; b) area of the *qasr* where the glass findings were unearthed.

Fig. 2. Drawings of the analysed vessel fragments.

Fig. 3. K₂O versus MgO bi-plot (for the opaque tesserae the reduced wt% contents are used). Samples belonging to the same group (see paragraph 5.Discussion) are shown by using the same shape and colour.

Fig. 4. a) Trace elements patterns and b) REE patterns of the vessels analysed by LA-ICP-MS. A blue line is used KHv1 vessels, whilst a red line identifies the KHv2 ones. KH02 and KH07 are not reported as LA-ICP-MS analyses did not provide proper results for these samples; c) trace elements patterns and d) REE patterns of the tesserae analysed by LA-ICP-MS. The blue lines identify the samples belonging to KHt1 group, while the red ones are used to distinguish the KHt2 group.

Fig. 5. CaO/Al₂O₃ versus Na₂O/SiO₂ bi-plot (for the opaque tesserae the reduced wt% contents are used).

Apollonia-type references: Freestone et al. 2000; Tal et al. 2004; Freestone et al. 2008; Phelps et al. 2016; Bet Eli'ezer-type: Freestone et al. 2000; Freestone et al. 2015; Phelps et al. 2016; Egypt I late antique/early Islamic references: Gratuze and Barrandon 1990; Foy et al. 2003; Ceglia et al. 2015; Phelps et al. 2016; earlier Egypt I references: Picon et al. 2008; Egypt II references: Bimson and Freestone 1985; Gratuze and Barrandon 1990; Foy et al. 2003; Freestone et al. 2015; Phelps et al. 2016.

Fig. 6. TiO₂/Al₂O₃ versus Al₂O₃/SiO₂ bi-plot (for the opaque tesserae the reduced wt% contents are used).

Apollonia-type references: Freestone et al. 2000; Tal et al. 2004; Freestone et al. 2008; Phelps et al. 2016; Bet Eli'ezer-type: Freestone et al. 2000; Freestone et al. 2015; Phelps et al. 2016; Egypt I late antique/early Islamic references: Gratuze and Barrandon 1990; Foy et al. 2003; Ceglia et al. 2015; Phelps et al. 2016; earlier Egypt I references: Picon et al. 2008; Egypt II references: Bimson and Freestone 1985; Gratuze and Barrandon 1990; Foy et al. 2003; Freestone et al. 2015; Phelps et al. 2016.

Fig. 7. FeO/TiO₂ versus FeO/Al₂O₃ bi-plot (for the opaque tesserae the reduced wt% contents are used).

Apollonia-type references: Freestone et al. 2000; Tal et al. 2004; Freestone et al. 2008; Phelps et al. 2016; Bet Eli'ezer-type: Freestone et al. 2000; Kato et al. 2009; Freestone et al. 2015; Phelps et al. 2016; Egypt I late antique/early Islamic references: Gratuze and Barrandon 1990; Foy et al. 2003; Kato et al. 2009; Ceglia et al. 2015; Phelps et al. 2016; earlier Egypt I references: Picon et al. 2008; Egypt II references: Bimson and Freestone 1985; Gratuze and Barrandon 1990; Foy et al. 2003; Freestone et al. 2015; Phelps et al. 2016; Kato et al. 2009.

Fig. 8. CaO (wt%) versus Sr (ppm) bi-plot (for the opaque tesserae the reduced wt% contents are used). Solid and dotted line show positive correlation between CaO and Sr contents for samples from this study and from the literature, respectively (Phelps et al. 2016).

Tables

Table 1a. Summary and documentation of the vessel samples selected for the analyses.

Table 1b. Summary and documentation of the analysed tesserae. NCS references are also reported.

Table 2a. Chemical compositions of glassy matrix of vessels and tesserae obtained by EMPA. All data are expressed as percentage concentrations of element oxides (nd is for not detected).

Table 2b. Reduced percentage concentrations of element oxides detected by EMPA, calculated for the opaque tesserae. CuO, SnO₂ and PbO were subtracted, whilst Sb₂O₃ and CoO were not detracted due to their scarce concentration (between 0.00 and 0.01 wt%).

Table 3. Trace element composition of the analysed samples obtained by LA-ICP-MS. All data are expressed in ppm.