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Abstract: ABSTRACT
In the Late Roman period, the city of Butrint (SW Albania) was one of the most important seaports of the eastern Mediterranean due to its very favorable position and an extended presence of human settlements (from the 5th century BC to the modern age). The city seems to have particularly flourished after being declared a Roman colony under Augustus in 31 BC, but even after the Roman period, Butrint remained a central node in eastern trade routes.
During the archaeological campaign of 2011 directed by David Hernandez (University of Notre Dame - US), aimed at identifying the eastern border of the Butrint Roman Forum, several glass artifacts were recovered and dated to the late antique and early medieval period.
In this study 33 fragments of glass (32 transparent, 1 opaque) were analyzed from different objects (drinking glasses, bowls, etc) mostly dated from the 5th to the 6th centuries AD.
The aims of this work are: i) understanding the raw materials, the manufacturing techniques employed for glass production, and their evolution through the time; ii) correctly classifying items of uncertain date; iii) interpreting the economic development and trade models of the area.
Chemical analyses were performed by electron microprobe (EMPA) for major and minor elements and by ICP mass spectroscopy (LA-ICP-MS) for trace elements.
The chemical results indicate that the samples were produced with natron as fluxing agent. They can be divided, on the basis of the concentrations of Fe, Ti, and Mn, between the two main compositional groups widespread in the Mediterranean from the 4th century onward: HIMT (23 samples), and Levantine I (10 samples). Among the HIMT samples, both "weak" HIMT (13 samples), and "strong" HIMT (10 samples) were identified. This variety of compositions indicates that in Butrint, between the end of the 4th and the end of the 6th century, the glass materials were probably imported from different suppliers.

***Highlights (for review)**

- Chrono-typological and chemical classification of glass from Butrint are reported.
- Comparison of glass varieties with the coeval production in the Mediterranean.
- Correspondence of chemical and typological/chronological groups is shown.
- Levantine I and HIMT are distinguished on chronological basis and product quality.
- Compositional grouping aids chronological definition of finds and site stratigraphy.

***Revision Notes**

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Dear Editor,
please find enclosed the revised version of manuscript **BUTRINT (ALBANIA) BETWEEN EASTERN AND WESTERN MEDITERRANEAN GLASS PRODUCTION: EMPA AND LAICP-MS OF LATE ANTIQUE AND EARLY MEDIEVAL FINDS.** by Sonia Conte, Tania Chinni, Rossella Arletti, Mariangela Vandini.
All the minor changes suggested by the editor have been done (correction in the text, in the tables and figure 7).

Best regards

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Butrint (Albania) between Eastern and Western Mediterranean glass production: EMPA and LA-ICP-MS of Late Antique and Early Medieval finds.

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ABSTRACT

In the Late Roman period, the city of Butrint (SW Albania) was one of the most important seaports of the eastern Mediterranean due to its very favorable position and an extended presence of human settlements (from the 5th century BC to the modern age). The city seems to have particularly flourished after being declared a Roman colony under Augustus in 31 BC, but even after the Roman period, Butrint remained a central node in eastern trade routes.

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The aims of this work are: i) understanding the raw materials, the manufacturing techniques employed for glass production, and their evolution through the time; ii) correctly classifying items of uncertain date; iii) interpreting the economic development and trade models of the area.

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Keywords: late antique glass, trace elements, LA-ICP-MS, HIMT, Levantine.

1. Introduction

Set on a small hill, facing the Vivari Channel, between the Butrint swampland and the Mediterranean Sea, the ancient *Buthrotum* was one of the strongholds of the main Hellenistic and Roman trade routes.

The origins of the site are not easily traceable, but the finding of some lithic tools has led to the hypothesis of a Neanderthal settlement (Hodges and Hansen, 2007). The few data traceable to the Hellenistic period seem to indicate a first nucleus dated to the 8th-7th century BC, linked to the presence of some Trojan exiles (as testified by Virgil). The construction of an important temple dedicated to Asclepius is possibly dated to the 3rd century BC, a period in which Butrint assumed a significant administrative role in the *koinon* of the Praesebes tribe (Hodges and Hansen, 2007).

In 44 BC, Julius Caesar proposed transforming Butrint into a colony (Hodges and Hansen, 2007; Hernandez and Çondi, 2008), but only in 31 BC Augustus decreed this status. From that time onwards, Butrint flourished progressively and several infrastructures were realized, including an imposing aqueduct (Ugolini, 1937; Hodges and Hansen, 2007; Hernandez and Çondi, 2008). The town entered a crisis starting from the end of the 4th to the beginning of the 5th century AD, when the ancient Roman buildings started to be ransacked and the area of the forum was occupied by common houses (Hodges and Hansen, 2007). After that, the history of Butrint is again uncertain with the archaeological stratifications providing little information for the 6th century AD, and even less for the period between the 7th and the 9th century AD (Hodges et al., 2000).

The following centuries were characterized by Byzantine dominion over the area, with Butrint being recognized as a strategic geographical position of primary importance for the control of the Aegean sea. Subsequent rapid changes of dominion confirm the great instability of the area in medieval times. (Hodges et al., 2000) and in the 16th century AD, the city of Butrint was definitively abandoned.

Butrint was rediscovered by an Italian archaeologist, Luigi Maria Ugolini, who excavated the ancient town in the years 1928-1936. Italian teams (until 1940), the Albanian Archaeological Insitute and the Butrint Foundation (from 1993) gave continuity to the archaeological investigations in the area (Ugolini, 1937; Hodges et al., 1997; Hodges and Hansen, 2007; Hernandez and Çondi, 2008).

In 2004 a new research project was started with the aim of redefining Butrint's historical phases, directed by Richard Hodges (The American University of Rome), David Hernandez (University of Notre Dame du Lac, Indian- USA), and Dhimitër Çondi (Albanian Archaeological Institute), and co-sponsored by the American Philosophical Society. The archaeologists managed to locate the north-eastern boundary of the Roman forum (dated at the 2nd half of the 1st century AD), built with remarkably large limestone slabs, with estimated dimensions of 20 x 70 m, much wider than expected (Hernandez, 2011). During the 4th century AD, possibly after a violent earthquake, the forum floor was covered with a raised layer (Hernandez, 2007). Around the 5th - 6th century AD, new buildings were erected in the area providing evidence of the endurance of the site until at least the end of the 6th century AD. During the 7th century, erosion layers from the adjacent acropolis accumulated on the forum area and some necropolises were constructed. The area was again occupied between the 10th and the 16th century, with new buildings and a cemeterial area, possibly connected to a Byzantine settlement (Hernandez, 2007).

The excavation campaign in 2011 in the area of the Roman Forum (Hernandez, 2011), substantiated the chronological stratification of the area and the persistence of commercial activity. Among the various materials (coins, ceramics, etc.), several glass finds were recovered and analysed.

Typological studies of the glass material dated around 800 AD ca. from Butrint (tower 1 and 2 of the Western defence) were conducted by Jennings (Jennings, 2010 and Jennings and Stark, 2013). In these studies, the large group of objects is represented by wine glasses classidicable as: a) short stem, b) long stem and c) hollow stem. A previous study by Schibille (2011) represents the first

attempt to investigate the chemical complexity of the glass types found in Butrint. Schibille presents data for different types of glass artifacts (tesserae, windows, vessels, debris), variably dated and of different provenance within the Butrint area, leading to the confirmation of regional and temporal variations in glass composition, as is well attested in the Mediterranean area, indicating the existence of primary glass production groups. The marked complexity that emerged and subsequent difficulty in systematizing the range of glass production data is possibly due to the great variety of the finds (types, colours, chronology, provenance) considered.

In the present study the materials - mostly well dated (on the basis of precise archaeological data), and including different types of glass - were selected from a single provenance (the Roman Forum). Most of the material analysed in the present work is dated between the 5th and the 6th century, on the basis of archaeological and typological criteria. Obtaining chemical features of a number of selected diagnostic fragments (i.e. attributable to recognised forms) will allow to define compositional groups, to establish relation of each group to the form and/or chronology of the glass, and to compare the glass varieties from Butrint with the coeval scenario of glass production in the Mediterranean. In some cases, the chemical composition could also confirm or support an archaeological hypothesis. This is achieved by establishing the major and minor chemical component fingerprints for a certain type or chronology, but fundamental support is also provided by the analysis of trace elements, extremely helpful for identifying glass production types of the Mediterranean area in the first millennium CE (Arletti et al., 2010a,b; Freestone et al., 2002, Šmit et al., 2013).

2. Glass chemical composition of Late Roman period: the state of the art.

The Late Roman period is perceived to be a period of transition in many field, from the new political organisation of the Empire –which was formally divided into Eastern and Western in the

4th century AD- to the general social, cultural and economic changes, that are reflected in the material records. As observed by Foster and Jackson (2009), also the glass of the Late Roman period differs from that produced in the previous centuries: while the 1st-3rd the glass was commonly blue-green, in the 4th century it was characterised by a yellowish-green colour. This change in colour was coupled with a general decline in the quality of the glass, the later glass showing more bubbles and unaesthetic inclusions. A number of recent publications (Freestone et al., 2000, 2002; Foy et al., 2003) have suggested that at least two new glass compositions were introduced in the 4th century AD and continued to be produced until the 8th century AD: Levantine I glass and HIMT (High Iron Mangese Titanium). Freestone (1994) named HIMT a glass (previously identified by Sanderson et al., 1984) characterised by high level of iron, manganese and titanium, with a positive strong correlation between iron and titanium and a less strong positive correlation between iron and manganese. Subsequently (2005) he stressed also the positive correlation between iron and alumina. Moreover, Foster and Jackson (2009) observed for this glass the presence of higher soda (Na_2O ~18-19%), magnesia (usually MgO ≥0.8%), and lower lime (CaO ~6%) with respect to that normally found in the earlier Roman glass. Glass of the same compostion was recongnised also by Foy et al. (2003) in Late Roman glass from France (Group 1 and 2). The other glass type introduced in the 4th century - called Levantine I by Freestone et al. (2000) and matching the 'Group 3' identified by Foy et al.'s (2003) - contains lower soda (Na_2O ~15%), higher lime (CaO ~9%), and often lower levels of iron (FeO ~0.4%) than HIMT glass (Foster and Jackson, 2009).

These chemical features have been recognised in many other studies, relative to the Levantine I (e.g. Freestone et al., 2002; Foster and Jackson, 2009; Schibille et al, 2008) and to the HIMT glass (e.g. Arletti et al., 2010a,b; Freestone et al., 2002; Foster and Jackson, 2009; Mirti et al., 1993, Šmit et al., 2013). Table 1 reports the minimum, maximum and the average of Al_2O_3, FeO, MgO, CaO, Na_2O, K_2O, TiO_2 and MnO, relative to the samples analysed in the aforementioned papers (and also

this work). Foy et al. (2003) observed a sub-division of HIMT glass into "strong" (Group 1) and "weak" (Group 2) on the basis of their Fe, Ti, and Mn concentrations. A similar subdivision was found by Foster and Jackson (2009), whose sub-group HIMT1 corresponds to Group 2 Foy et al., while the sub-group HIMT2 is characterized by the lowest concentration of the key oxides. The splitting of HIMT glass into two groups, on the basis of iron, titanium, and manganese (that is HIMT1 and 2 Foster and Jackson, 2009 Table 2) can be recognised also in other HIMT sample sets analysed by Arletti et al. (2010a, b), Freestone et al. (2002, 2005), Mirti et al. (1993) and Šmit et al. (2013) all around Europe.

3. Materials

During the 2011 excavation campaign numerous glass objects were recovered from the area of the Roman Forum, although not referable to the Roman phase but to later productions. Most of them are characterized by a high degree of fragmentation. After recovery, rapid water washing and mechanical cleaning were adopted to remove residues and deposits, avoiding an abrupt transition to dry conditions. A total of 157 glass fragments was divided morphologically and by functional subcategories: diagnostic elements of vessels (rims, bottoms and handles, which allow recognition of the original forms by comparison with known typologies); vessel walls (each fragment is attributable to a glass vessel, but without significant elements useful for identifying the original form); architectural glass (window glass and mosaic tesserae); cullets. When possible, the typological classification proposed by C. Isings (Isings, 1957) was applied, with further additions by comparisons with more recent catalogues (see Table 3). A number of samples (33 in total) was selected from the complete set representative of the various typologies and chromatic varieties. The description of the samples, selected on the basis of type and colour, their chronological indications (based both on stratigraphic and typological data) and relevant bibliographical refences are reported in Table 3.

Fragments of vessels

The chrono-typological study of the glass material shows a more concentrated chronological distribution between the 5th and 6th centuries AD. Among the diagnostic elements of vessels, the most common class is represented by beakers (25% of the total of the recognised forms), most of them with rounded rims and flat bottom. Due to the high degree of fragmentation, it was not always possible to identify the original form and therefore the possibility that some of the rims could be related to the more defined form of the stemmed beakers cannot be excluded. The stemmed beakers (representing the 13% of the total) are generally identified as form Isings 111 (Isings, 1957). This is one of the most common objects in the Mediterranean basin between 5th and 8th century AD (Sternini, 1995; Uboldi, 1999; Saguì, 2001; Stiaffini, 2004; Gallo et al., 2014) and represents "the watershed between Late Antiquity and the Middle Ages" (Saguì, 1993), although after the 8th century it disappeared, replaced by beakers with high hollow stems, or fully twisted stems (Silvestri and Marcante, 2011). The success of this form is also evident in the numerous variants recognized throughout the Mediterranean, which show different profiles of rim and stem (see for exemple Dussart, 1998 and Falcetti, 2001). This large variability in shapes and sizes has led some authors to assume that they are not a result of a chronological evolution of the form, but of different degrees of specialization of the workshops (Falcetti, 2001; Corti, 2012). The identification of the variants of the stemmed beakers is connected to the techniques of production of the stem. Three main types of stem - folded base, short stem and short solid stem – were firstly described by Isings (Isings, 1957, pp.139-140) and extensively recalled and redefined by many other authors (for example Jennings, 1997-1998, 2006 and 2010; Jennings and Stark, 2002; Falcetti, 2001; Stevenson, 2001; Foy, 2000 and 2003).

In this study, the dominant form of I.111 is the folded base type from which five samples were taken (BT 4, 7, 12, 17, 38). That of the stemmed beakers is the only form that could compare with the findings of Jennings (2010), since the production technique is probably the same even if, due to

differences in dimensions, foot inclination and type of stem, only one of the forms identified by Jennings can be considered to have similarities with the beakers of the present study. The conformation of the foot of our fragment from sample BT38 (Figure 1) shows close comparison with the stemmed beaker reported in Figure 5, 6 by Jennings (2010), but this latter have a hollow stem.

Among the class of drinking glasses, sample BT29 is likely to be attributed to a long stemmed beaker (Fünfschilling, 2010): it is a fragment of light green twisted glass, slightly longer than 10 cm, but the absence of the two ends does not allow a definite attribution.

Glass fragments connected to cups are also well represented in our set (12% of the total of the recognised forms) from which three samples were collected: one from a cup with thick filament applied under the rim (BT5 – Glençler, 2003; Jennings, 2004-2005) and two from cups raised on foot (BT16 and 32 - Sternini, 1995; Foy, 1995; Glençler, 2003).

From the category of bottles (11% of the total), sample BT39 from the body and 39a from the decoration are representative of a bottle with mid-dark blue glass thread under the rim. This kind of bottle is very common in the late Roman and Early Byzantine period (see for example Jennings, 1997-1998; Dussart, 1998; Foy, 2000; Jennings and Abdallah, 2002).

Sample BT15 comes from a fragment in green glass with circular stamps on the surface. Considering its slightly concave profile, it appears plausible to attribute the glass to the bottom of a bottle with circular stamps (similar, for example to the Isings 50/51 type, Isings, 1957). Unfortunately, this kind of marks are very common in the Mediterranean area since the Roman period and the profile of fragment doesn't allow a more precise definition.

Sample BT6 was taken from a hanging lamp (lamps represent the 9% of the total) with hollow stemmed bottom (Uboldi, 1995; Foy, 1995 and 2004). This kind of lamp was produced from the

late 5th century AD to the early 7th century AD, with a widespread distribution throughout the Mediterranean sea, from East to West (Uboldi, 1995).

One sample (BT45) is from the unguentaria or toilet bottles category (5% of the total) of dark blue glass. These small containers for perfumes or oils were made in the Roman period with good quality glass but, from the 6th century AD , their presence in urban sites seems substantially increased (Uboldi, 1995).

The remaining samples from vessels subject to analyses, identified as "walls", can not be attributed to a specific typology and were selected for the color of the glass.

Not identified glass and cullets

The two areas of excavation of the Roman Forum brought to light only five small objects identified as cullet and deformed "blocks", all of which were analysed: BT 2, 3, 10, 19, 35. These should not be indicative of the presence of a secondary production area in the Forum of Butrint and probably represent random moments of negligence.

4. Experimental methods

The good state of preservation of the samples permitted removal of small chips of only few hundreds μm^3. Scroupoulous attention was paid in sampling outside the recognizable profile of the diagnostic parts of vessel's fragments. Micro-sampling was performed on the body and different coloured decorations of each find in order to characterise the composition of the bulk and all the different coloured decorations.

4.1 Electron microprobe analysis

The chemical analyses of major and minor elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, S, Cl, Cr, Co, Cu, Sn, Sb, and Pb) were carried out using a Cameca SX 50 microprobe equipped with four scanning wavelength-dispersive spectrometers (WDS). The samples were embedded in epoxy resin and polished with diamond paste. The reference Smithsonian glass A standard (Jarosewich, 2002) was employed as primary reference sample. Details of analytical conditions, standards used and accuracy and precision of the measurement are reported in supplementary material S1 and S2. Ten points were analysed on each sample to test homogeneity and the mean value was calculated. The standard deviations among the analysed points resulted to be between 2-3 and 3-4% for major and minor constituents, respectively. The correction program is based on the PAP method (Pouchou and Pichoir, 1988) and was used to process the results for matrix effects. The results are reported in Table 4. The elements Ti, Cr, Co, Cu, Sn, Sb, and Pb were also analysed by LA-ICP-MS.

3.2 Laser-ablation inductively coupled plasma mass spectrometry

LA-ICP-MS was used to determine the concentration of 37 trace elements. The analyses were carried out with a Thermo Fisher X-Series^{II} quadrupole based ICP-MS coupled with a New Wave ablation system with a frequency quintupled (λ = 213 nm) Nd:YAG laser, at the Centro Grandi Strumenti of the University of Modena and Reggio Emilia. The laser repetition rate and laser energy density on the sample surface were fixed at 20 Hz and ~18 J/cm^2, respectively. The analyses were carried out using a laser spot diameter of 100 μm on the same polished fragments used for EMPA. External calibration was performed using NIST SRM 610 and 614 glass as external standard, and ^{29}Si, previously determined by EPMA, as internal standard, following the method proposed by Longerich et al. (1996). Standard Reference Material NIST612 (Pearce et al., 1997) was used as a secondary reference sample to check precision and accuracy, which are reported in supplementary material S3, while the results are reported in Table 5.

4. Results

The chemical analyses of the major and minor elements carried out by Electron Microprobe are reported in Table 4, and the trace elements composition obtained by LA-ICP-MS in Table 5.

4.1 Major components

All the analysed samples are silica glass, with SiO_2 values ranging from 63.33% to 71.91%. The data indicate that the samples were produced with natron as the source of flux, since the contents of K_2O *vs.* MgO, (Figure 2) never exceed 1.5 wt. % and since the Na_2O contents are quite high, ranging from 14.18 to 22.34 wt%.

The contents of Al_2O_3 and CaO - reflecting the feldspatic and carbonatic fractions present in the sand, respectively - give indications about the sand employed as vitrifying components. The samples show a relative homogeneity: they have Al_2O_3 ranging from 1.54% to 2.91% and more variable CaO from 4.55% to 8.90%. In Figure 3 (Na_2O *vs*. CaO) the samples are plotted along with other coeval samples from literature (HIMT: Freestone et al., 2002; Arletti et al., 2010a; 2010b; Mirti et al., 1993; Foster and Jackson, 2009; Šmit et al., 2013; and Levantine I: Freestone et al., 2002; Foster and Jackson, 2009; Schibille et al., 2008). From the plot it is possible to identify two groups, mainly distinguishable on the basis of Na_2O and CaO levels: i) Group 1 composed by 23 Butrint samples, with high Na_2O (between 16.89% and 22.34%) and rather low CaO (between 4.55% and 8.57%); ii) Group 2 (10 Butrint samples) with lower Na_2O (ranging from 14.18% to 17.13%) and higher CaO (ranging from 6.68% to 8.90%). The two groups also differ for their contents of MgO, FeO, TiO_2, MnO, and trace elements such as Zr, V, and Cr which are always higher in the Group 1 with the exception only of sample BT39 (Tables 4 and 5).

In agreement with literature data, these chemical differences allow the identification of two distinct glass compositions: Group 1 belonging to the so-called HIMT glass (with the exclusion of BT39), and Group 2 falling within the compositional field of Levantine I glass.

On the basis of the Fe, Ti, Mn, Zr, Ni and Cr levels, the Butrint HIMT glass can be further divided into: HIMT1, HIT (named after Rehren and Cholakova, 2010, see below) and HIMT2 (see Table 4, 5). The HIMT1 group (7 samples) contains, on average, higher contents of FeO, TiO_2, MnO, Zr, Ni and Cr with respect to the HIMT2 group (13 samples). Anyway the highest levels of Fe, Ti, Zr, Ni and Cr are found, on average, in the HIT (3 samples) group which, on the contrary, exhibits very low Mn. Two of the groups (HIMT1 and 2) have already been recognised in literature by Foy et al.(2003) and by Foster and Jackson,(2009) at several coeval sites in France and Britain, respectively. The mean values of iron, titanium, and manganese in HIMT1 and 2 observed in this work fit perfectly with those reported in Table 2 and show the typical correlation between FeO and TiO_2 (Figure 4). Conversely, HIT appears to exhibit different features, not well documented, anyway their very high concentration of the key oxides suggest that HIT could be a sub-group of the HIMT1. The HIT samples display the highest levels of iron and the lowest contents of MnO. It is important to take into account that the three samples (BT39a, BT41, BT45) are all blue. Glass with similar features have been recognised by Rehren and Cholakova (2010) in green samples from Dichin (Bulgaria), and called HIT for the absence on manganese; however the Dichin HIT show lower FeO (1.42%) than the Butrint's one (2.57%). HIMT glass with very high levels of iron (3.23±0.57%) are reported by Gallo et al. (2014) for Aquileia samples, neverthless they display also very high contents of MnO (1.78±0.27%). Considering our Butrint blue HIT we can observe that some elements result associated to iron, in particular cobalt and copper, indicating the use of the same colorant to obtain the desired nuance. Therefore, the higher contents of iron can be related to its unintentional introduction, as a component of the cobalt colorant raw materials, as suggested also by Foy et al. (2003).

The very high level of Ni in the HIT samples (84 ppm cf. 15ppm of HIMT1 and 12 ppm of HIMT2) can also be related to the source of Co (Gratuze et al., 1992). An explanation for the low level of MnO can be found in the final color of these HITglass. As known, the addition of manganese in

HIMT glass was aimed at preventing the glass turning black, and contributed to lend it a characteristic green-yellow coloration (Freestone, 2006). In this case, the blue glass varieties were intentionally coloured by adding some cobalt colorant, thus decoloration was unnecessary. These data seem to suggest that the chemical differences between HIMT1 and HIT are mainly related to the introduction of a cobalt colorant, while only in one case (sample BT41) to the use of different sands. Considering the remarkable chemical similarity of the BT39a and BT45 samples we can suppose that they came from the same batch, while BT41 sample exhibiting lower silica and higher lime, was probably produced with different raw materials.

The Levantine I glass of the Butrint assemblage exhibits a very homogeneous composition, the main differences involve the deep blue coloured sample BT36a which has high iron content (as shown in Figure 4). The Levantine I group of samples can be divided into two sub-groups distinguished on the basis of the MnO content: high MnO (BT10, 27, 39, 43) and low MnO (BT3, 5, 14, 16, 36, 36a), if considering 0.5% the threshold value discriminating the intentional addition of the element (Jackson, 2005). In the high MnO group the introduction of manganese had a decoloration purpose in the colourless samples BT39, BT43 and possibly in the yellowish BT27 glass, while it could be the effect of recycling or contamination in sample BT10, a glass scrap. The separation in two groups, with respect of MnO content, of Levantine I glasses has already been reported in studies by Foster and Jackson (2009) and Brill (1988), the latter showing high levels of the oxide both in cullet and vessels glass.

4.2 Colorants

Butrint glass comes in a wide selection of colours. Colourless samples (BT36, BT39, BT43) uniquely belong to the Levantine I group and were decoloured by the addition of manganese to the batch (BT39: 0.77% MnO, BT43: 1.71% MnO), with the exclusion of BT36 which has excessively low MnO 0.01% and was probably decoloured by acting on the furnace atmosphere. The single brown glass (the HIMT2 BT19) and the yellow samples (BT11, BT22-HIMT2, BT42-HIMT1;

BT27-Levantine I) owe their colours to the presence of FeO and MnO. Overall, the amounts of FeO in the Levantine I green glass samples (BT3, BT5, BT10, BT14, BT16) are quite low (≤0.50%), but enough to provide the coloration. The coloration of the HIMT green samples (BT2, BT4, BT6, BT7, BT12, BT15, BT17, BT21, BT28, BT29, BT32, BT34, BT35, BT38, BT40) is a consequence of the FeO and MnO levels. On average, in the blue glass of both the Levantine I (BT36a) and HIMT groups (BT30, BT39a, BT41, BT45), coloration is provided by cobalt (0.07-0.25%), often associated with high FeO and Cu_2O.

It is generally assumed that the presence of repeated recycling can be reflected in the amounts of certain additives (e.g. Co, Cu, Zn, Sb, Pb). When these are present at levels above those associated with the occurrence of natural impurities (100 ppm), but below levels that suggest their intentional addition (~1000 ppm), it is assumed they derive from the recycling of earlier glass (Foster and Jackson, 2009). It is important to take into account that the non-detectable presence of Co, Cu, Zn, Sb, Pb could only demonstrate that no earlier glass with high contents of those elements was recycled. In addition, for the HIMT glass, copper, lead and antimony occurring at mean concentrations <89 ppm, ≤200 ppm, ≤100 ppm respectively, have been taken as an indication of natural impurities in unrecycled HIMT glass by Foy et al. (2003). Therefore after the exclusion of the more deeply colored samples (BT6, BT36a, BT39a, BT41, BT45), we can observed that the HIMT samples show levels of these elements in the range of the natural impurities (except the BT21 sample), hence they probably derived from newly manufactured "fresh" glass, in contrast with the literature data regarding HIMT glass (Foster and Jackson, 2009). Some of the Levantine I samples conversely exhibit slightly high levels of antimony (BT3, BT10, BT14 which shows a slight degree of opacity), indicating the possibility of some recycle or contamination, expecially in the case of BT3 and 10 that were taken from glass cullets, the latter also showing a high content of manganese.

4.3 Trace elements

A trace element study was conducted on all the samples, with the exclusion of BT28 and BT29 due to their limited dimensions. The averaged values were normalised to the concentration of the upper continental crust (Wedepohl, 1995). As can be seen in Figure 5, the average composition of the Butrint samples is depleted for most of the trace elements, with the exception of strontium. This is probably due to the presence of aragonite in the coastal sand used as the vitrifying raw material (Freestone et al., 2003, Freestone, 2006). Aragonite is the polymorph of calcite that forms seashells, in which Sr can substitute Ca. The three chemical groups (HIMT1(+HIT), HIMT2 and Levantine I) differ in trace element composition: firstly, HIMT glass exhibits a higher absolute concentration of Zr and REE compared to Levantine I. The high level of zirconium in HIMT glass is probably related to the presence of zircon in the sand. Differences on elements concentration are present also in the HIMT groups, being the strongest values in most of the cases related to HIMT1 and HIT glass - see for example the amount of zirconium (on average 146 ppm HIMT1, 188 ppm HIT cf. to 61 ppm HIMT2), vanadium (on average 31 ppm HIMT1, 32 ppm HIT cf. to 25 ppm HIMT2), yttrium (on average 8 ppm HIMT1, 9 ppm HIT cf. to 6 ppm HIMT2), hafnium (on average 4 ppm HIMT1, 5 ppm HIT, 2 ppm HIMT2). An important exception is Ba. HIT exhibits a negative anomaly for Ba, which might be related to the very low levels of MnO observed in these glass varieties. It has been suggested firstly by Silvestri (2008) and then by Arletti et al. (2010a) that, as an alternative to the well-known use of the mineral pyrolusite to introduce MnO into the batch, the mineral psilomelane [(Ba, H_2O)MnO_5O_{10}] could also have been used for this purpose. This phase is documented in manganese oxides/hydroxides deposits (Peacor, 1978). Therefore the use of psilomelane involves the presence of quite a high level of barium in the final glass and a positive correlation between MnO and Ba. In this case HIMT1 and 2 exhibit this behaviour (high MnO-high Ba, with positive correlation), while in contrast, the low contents of barium in HIT can be explained by the lack manganese introduction into the batch.

The REE patterns (Figure 6) are very similar for all the analysed samples, which are depleted in REE, with a stronger depletion for light REE. The main difference within the groups lies in the relative abundance of REE, which is higher, as already observed for the other trace elements, in HIMT glass. This probably indicates the use of an impure sand rich in heavy minerals as monazite, zircon, rutile, and iron oxides, as also suggested by the large amount of Zr, Y, V, FeO, and TiO_2. It is again noted that the highest values are related to HIMT1 and HIT.

5. Discussion

The Butrint assemblage (33 samples) is composed by natron glass. The samples can be subdivided into HIMT glass and Levantine I glass on the basis of their contents of soda and lime, and for their levels of MgO, FeO, TiO_2, MnO, and trace elements such as Zr, V and Cr, always higher in HIMT. The HIMT typology, first recognized by Sanderson et al. (1984) and named by Freestone in a study about a raw chunks from Carthage (Freestone, 1994), represents a type widespread in the western Mediterranean, particularly during the 4^{th} century. It is characterized by relatively low lime, high soda, and high contents of iron, manganese and titanium, compared to Levantine I glass, which is the typical Syro-Palestinian production between the 4^{th} and the 9^{th} century AD. In the graph of Figure 7 the data for the natron Butrint glass and available literature data for HIMT and Levantine I glass varieties are plotted. Relevant data to HIMT are reported from Maroni Petrera, Cyprus (Freestone et al., 2002), Ganzirri, Italy (Arletti et al., 2010a), Galeata, Italy (Arletti et al., 2010b), Augusta Praetoria, Italy (Mirti et al., 1993), Tonovcov, Slovenia (Šmit et al., 2013), and several sites in Britain (Foster and Jackson, 2009). As regards Levantine I data from Maroni Petrera (Freestone et al., 2002) and several sites in Britain (Foster and Jackson, 2009) are also plotted with the addition of samples from Petra (Schibille et al., 2008).

The comparison of the chemical data of this study with glass from Butrint previously studied by Schibille (2011) shows that the chemical groups identified in this study are substantially different. In her study on vessel and window glass, Schibille isolated two main groups divided in subgroups:

"WD" (with the subgroups WD1 and WD2) constituted by samples from the Western defences (6^{th} – 8^{th} century AD) and "Misc" group of miscellaneous vessels and window glass with the subgroups Misc1, Misc2 and Misc-HIMT (1^{st} – 5^{th} century AD). The first group, chronologically closer to our samples, includes a first subgroup (WD1) recognized as "Egypt II type", which shows important differences when compared with the sample here analysed. In fact, respect to the HIMT glass of our study, they show lower alkalis, higher lime and scarce manganese; moreover they don't exhibit the HIMT typical iron-alumina and iron-titanium correlation. With respect to our Levantine I glass they differ for the content of lime and soda. The second subgroup WD2 is quite controversial since it lies in a mid-way between HIMT and Levantine I types. In fact, even if the contents of lime and alumina would be compatible with Levantine I they show too high iron, titanium and manganese. In the group of miscellaneous glass Schibille isolated the Misc2 type, a Roman antimony decolorised type, not present in our set. The subgroup Misc1, tentatively post-dated (4th century or later) with respect to the Misc2 type on the basis of the use of manganese as a decolorizer, shows quite close resemblances with the Levantine I type glass found in our study, even if our set shows samples with slightly lower lime. Finally – and surprisingly – only two samples were recognized by Schibille as HIMT type: the Misc-HIMT group presents similarities with our HIMT1 type, although our samples are characterized by lower alumina.

As previously noted in the results, the natron glass of the present study fits perfectly with the HIMT category (23 samples) and Levantine I category (9 samples) with the exception of BT39, which exhibits some peculiarities: the typical chemical traits of Levantine I (i.e. high Ca, low Mg, low Ti, low trace elements, etc.) are contrasted by high levels of soda that prevents a precise grouping. In addition, sample BT39 has a very low alumina content, (1.54% Al_2O_3). This sample, even if dated to the 5^{th} - 6^{th} century AD, has the peculiarity of being composed of an archaeologically non classifiable colorless base glass, decorated with a rim in blue glass which, in contrast, belongs to the HIT type, making this object a peculiarity in the glass production panorama.

A more detailed subdivision can be made among the Butrint HIMT samples, distinct in three sub-groups on the basis of the contents of titanium, iron, manganese, zirconium, nichel and chromium. As can be seen in Figure 8, seven Butrint HIMT samples (cross) belong to the so-called HIMT1-strong (diamond), and thirteen (circle) to the HIMT2-weak (square) groups (Foy et al., 2003; Foster and Jackson, 2009). The remaining three glass samples (HIT-triangle) show higher levels of iron and cobalt and lower manganese (see Table 4 and 5) as a consequence of their blue color.

The generally low levels of trace elements is a typical trend observed in many ancient glass (Arletti et al., 2010a, Arletti et al., 2011, Freestone et al., 2000) and suggests the use of a mineralogically mature sand, rich in quartz and poor in clay and heavy minerals. This is confirmed by the fact that the higher depletion is, on average, related to the samples richer in SiO_2. In addition, the levels of strontium suggest the use of a coastal sand as vitrifying raw material in all the Butrint samples. It has also been noted that, even if trace elements are depleted in all the samples, the HIMT glass samples (in particular HIMT1 and HIT) exhibit the highest concentrations. Since iron, titanium, zirconium, and REE are related to the heavy mineral and/or mafic fraction of the sand (e.g., zircon, rutile, ilmenite, monazite, and iron oxides), the chemical composition of the HIMT indicates the use of an less pure sand source (Foster and Jackson, 2009). As shown in Figures 9 and 10, these data are consistent with literature data for coeval samples.

An important observation can be made by considering the type, chronology, and form of the glass objects, and their subdivision in compositional groups. The first relevant point is that all the closed forms (stemmed beakers – I.111 and lamps) belong to the HIMT2 type, a medium grade glass (better quality than HIMT1 since it contains less impurities, but worse than Levantine glass). This is the evidence of a different selection of raw glass for the production of these objects (particularly of I.111), starting from the same supply of primary glass. This production is chronologically placed in a period between the 5^{th} and 6^{th} century, as can be deduced from archaeological data (matrix data and typologies – see Table 3). Conversely, a precisely recognizable form cannot be identified for

the HIMT1 type, except the bowl BT32, dated to the 5th – 6th century for its shape, and we can consider this chemical group as belonging to a later production on the basis of archaeological data, assigning this set to the second half of the 6th century. The earlier spread of HIMT2 has already been observed by Foster and Jackson (2009), on the basis of the relatively high presence of recycling indicators (such as Cu, Pb, Sb). In contrast with these examples, the Butrint HIMT2 samples have no recycling indicators that suggest their dilution with other glass, and are instead freshly made glass. An obvious difference is the lower quality (colour heterogeneity, presence of bubbles) of the glass belonging to the HIMT1 group compared to the other natron type groups. Higher quality is recognizable in the Levantine set: only two glass samples (BT5 and BT16) are attributable to known forms of bowls, but the value of these vessels is certainly higher than the "common" form of beakers of type HIMT2. Therefore, the Levantine type, whose chronology overlaps the HIMT 1 and 2 types, can be distinguished for superior product quality, also corroborated by high glass quality.

Five cullets (BT2, BT3, BT10, BT19 and BT35) fit perfectly into the three main chemical categories: BT35-HIMT1, BT2 and BT19-HIMT2, BT3 and BT10-Levantine I. For some samples (in particular BT17, 32, and 36 but also 19, 21, and 34), the lack or doubt of chronological location from archaeological data can be overcome by the definition of the object chrono-type and/or using chemical data to locate the sample in a recognized compositional group: the earliest find is sample 17, a stemmed beaker of the HIMT2 type (5th – 6th cen AD); samples 21 and 32 are of the HIMT1 type of lower quality and later chronology (second half of the 6th century) and samples 19, 34, 36, belong to Levantine I type, whose production is attested in the 4th to 7th century AD production.

6. Conclusions

The very interesting result of this work, which gives particular importance to considering type, chronology, and form of glass objects, is the correspondence of chemical and typological/chronological groups, all the more impressive considering the brief time span involved. In some interesting cases compositional grouping helped the chronological definition of the site stratigraphy. The production of the three natron types identified in this work can be distinguished on a chronological basis (HIMT1 later than HIMT2) and product quality criteria (Levantine I better than HIMT2, which in turn is better than HIMT1). This indicates that in Butrint, between the end of the 4th and the end of the 6th centuries glass materials were imported (at present, no signs of primary or secondary production are attested) either from (a) different suppliers evaluating the cost and the quality of glass, or from (b) the same supplier who consciously selected the type of primary glass for more costly or cheaper items (compare Levantine with HIMT2 and later with HIMT1).

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Table captions

Table 1: Minimum, maximum and avegare values of Al_2O_3, FeO, MgO, CaO, Na_2O, K_2O, TiO_2 and MnO, relative to the HIMT and Levantine I samples analysed here and reported in literature. Literature data are taken from: Maroni Petrera, Cyprus (Freestone et al., 2002), Ganzirri, Italy (Arletti et al., 2010a), sites in Britain (Foster and Jackson, 2009), Galeata, Italy (Arletti et al., 2010b), Augusta Praetoria, Italy (Mirti et al., 1993), Tonovcov, Slovenia (Šmit et al., 2013) and Petra, Jordan (Schibille et al., 2008).

Table 2: Minimum, maximum and avegare values of FeO, TiO_2 and MnO, relative to the HIMT 1 and 2 reported by Foster and Jackson, 2009.

Table 3: Summary table of the analyzed samples: description, chrono-typological definition (when applicable), chronology (on the basis of the form and/or archaeological matrix data).

Table 4: Chemical data for major and minor elements obtained by EMPA (oxide weight %). n.d.= not detected.

Table 5: Chemical data for trace elements obtained by LA-ICP-MS (ppm). n.d.= not detected.

Figure captions

Figure 1. Drawings of I.111 stemmed beakers: BT38.

Figure 2. K_2O vs. MgO (weight %) for the analysed samples.

Figure 3. Na_2O vs. CaO (weight %) for the analyzed samples and for literature data relative to HIMT glass-group 1 (Maroni Petrera-Cyprus, Freestone et al., 2002; Ganzirri-Italy, Arletti et al., 2010a; Galeata-Italy, Arletti et al., 2010b; Augusta Praetoria, Italy-Mirti et al., 1993; Britain, Foster and Jackson, 2009; Tonovcov-Slovenia, Šmit et al., 2013), and Levantine I glass-group 2 (Maroni Petrera-Cyprus, Freestone et al., 2002; Britain, Foster and Jackson, 2009; Petra- Jordan, Schibille et al., 2008). The sample BT39 shows high level of soda, unsual for the Levantine I glass, but all the other chemical features (i.e. high Ca, low Mg, low Ti, low trace elements, etc.), are typical of that type.

Figure 4. TiO_2 vs. FeO (weight %) for the analysed samples.

Figure 5. Average trace element composition for Butrint compositional glass group (with the exclusion of BT28, BT29) normalised to the composition of the upper continental crust (Wedepohl, 1995).

Figure 6. REE average composition for Butrint compositional glass group (with the exclusion of BT28, BT29), normalised to the composition of the upper continental crust (Wedepohl, 1995).

Figure 7. Al_2O_3 vs. FeO (weight %) for the analysed samples compared with literature data. HIMT data are taken form: Maroni Petrera, Cyprus (Freestone et al., 2002); Ganzirri, Italy (Arletti et al., 2010a); Galeata, Italy (Arletti et al., 2010b); Augusta Praetoria, Italy (Mirti et al., 1993); Tonovcov, Slovenia (Šmit et al., 2013); Britain (Foster and Jackson, 2009). Levantine I are taken from Maroni

Petrera, Cyprus (Freestone et al., 2002), Britain (Foster and Jackson, 2009), and Petra, Jordan (Schibille et al., 2008).

Figure 8. TiO_2 vs. FeO (weight %) for the analysed samples compared with literature data. Literature data are the same as for Table 1.

Figure 9. Average trace element composition for Butrint compositional glass group (with the exclusion of BT28, BT29) normalised to the composition of the upper continental crust (Wedepohl, 1995) compared with literature data from Maroni Petrera, Cyprus (Freestone et al., 2002) Ganzirri, Italy (Arletti et al., 2010a), Apollonia, Israel (Freestone et al., 2000).

Figure 10. REE average composition for Butrint HIMT (with the exclusion of BT28, BT29) normalised to the composition of the upper continental crust (Wedepohl, 1995) compared with literature data from Ganzirri, Italy (Arletti et al., 2010a), and Tonovcov, Slovenia (Šmit et al., 2013).

Supplementary captions.

Table S1: EMPA analytical conditions.

Table S2: Comparison of "known" values and data from EMPA for Smithsonian Glass A (Jarosewich, 2002). The standars deviation, the accuracy and the detection limits are also shown.

Table S3: Comparison of "known" values and data from LA-ICP-MS for NIST612. The standars deviation and the accuracy are also shown. "Known" values are given according to recommended composition (Pearce et al., 1997).

Table1

			Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
HIMT	BUTRINT, this study	min	1.73	0.51	0.55	4.55	16.89	0.30	0.07	0.07
		MAX	2.72	2.76	1.43	8.57	22.34	0.88	0.59	3.24
		average	2.32	1.10	1.00	6.82	19.07	0.52	0.23	1.15
	MARONI-PETRERA (Freestone et al., 2002)	min	2.12	0.83	0.94	5.20	19.50	0.34	0.10	0.20
		MAX	2.80	1.58	1.45	8.70	20.50	0.67	0.54	2.22
		average	2.39	1.20	1.13	6.86	20.00	0.50	0.24	1.11
	GANZIRRI (Arletti et al., 2010a)	min	3.10	1.69	1.07	5.67	15.90	0.41	0.49	1.77
		MAX	3.87	3.69	1.41	6.70	18.60	0.78	0.59	2.36
		average	3.47	2.25	1.26	6.12	17.40	0.63	0.54	2.03
	BRITAIN (Foster and Jackson, 2009)	min	1.53	0.47	0.42	3.89	15.56	0.28	0.09	0.55
		MAX	3.42	2.28	1.53	7.96	22.87	0.91	0.72	3.04
		average	2.34	0.95	0.84	6.03	19.46	0.55	0.19	1.24
	GALEATA (Arletti et al., 2010b)	min	1.99	0.35	0.96	6.61	16.68	0.39	0.06	0.14
		MAX	2.63	1.08	1.58	7.54	22.65	0.75	0.15	2.15
		average	2.37	0.77	1.30	7.03	19.96	0.50	0.12	1.29
	AUGUSTA PRAETORIA (Mirti et al., 1993)	min	2.18	0.40	0.81	5.21	16.27	0.67	0.39	1.81
		MAX	3.28	2.29	1.27	6.38	20.47	1.92	0.79	2.52
		average	2.55	1.51	1.02	5.67	17.44	0.94	0.56	2.09
	SLOVENIA (Šmit et al., 2013)	min	2.42	1.38	0.92	5.75	17.00	0.48	0.46	1.76
		MAX	2.91	1.58	1.23	6.27	18.70	0.67	0.52	2.12
		average	2.68	1.48	1.08	6.09	17.80	0.58	0.49	1.98
			Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
LEVANTINE I	BUTRINT, this study	min	1.54	0.30	0.43	6.68	14.18	0.31	0.05	0.02
		MAX	2.91	1.28	0.66	8.90	20.74	1.03	0.08	1.71
		average	2.52	0.46	0.55	7.85	16.46	0.67	0.07	0.56
	PETRA (Schibille et al., 2008)	min	2.25	0.39	0.38	7.52	13.40	0.58	0.07	0.11
		MAX	3.06	0.64	4.45	10.98	19.98	1.78	0.11	0.80
		average	2.85	0.49	0.70	9.13	15.24	0.96	0.09	0.28
	MARONI-PETRERA (Freestone et al., 2002)	min	2.65	0.32	0.63	6.30	15.10	0.36	0.10	0.10
		MAX	3.23	0.61	1.08	11.00	19.90	0.79	0.21	1.13
		average	2.97	0.46	0.81	8.54	16.69	0.60	0.12	0.17
	BRITAIN (Foster and Jackson, 2009)	min	2.30	0.29	0.36	7.12	12.94	0.43	0.05	0.02
		MAX	3.42	0.64	0.95	9.59	16.79	0.92	0.10	2.10
		average	2.85	0.39	0.55	8.48	15.22	0.64	0.06	0.85

Table2

	HIMT1			HIMT2		
	Foster and Jackson, 2009			Foster and Jackson, 2009		
	min	max	average	min	max	average
FeO%	0.90	2.28	1.36	0.47	1.02	0.72
TiO_2%	0.11	0.72	0.33	0.09	0.22	0.12
MnO%	0.81	3.04	1.71	0.55	1.47	0.98

Table3

Sample	Area	Description	Typology	Form dating	Matrix dating	References
BT2	16	Cullet			5th – 6th century AD	
BT3	16	Cullet			4th century AD	
BT4	16	Bottom of stemmed beaker	Goblet Isings 111	From the 5th century AD onwards	5th century AD	Isings,1957, form 111; Stevenson, 2001, p. 236, fig. 7:66
BT5	16	Rim of bowl with a thick thread of the same colour	Bowl Jennings, 2004-2005, fig. 5.20, n.7	5th century AD	5th century AD	Glençler, 2003, pag. 719, fig. 35.18 (3rd century); Jennings, 2004-2005, fig. 5.20, n.7 (5th century)
BT6	16	Bottom of hanging lamp with hollow stem	Hanging lamp Uboldi, 1995, IV.2	end of 5th – 6th century AD	5th – 6th century AD	Tabaczynska, 1977, fig. 113, n.23 (context dated at 4th century); Saguì, 1993, fig. 9, n.84 (6th century); Uboldi, 1995, type IV.2; Price, 1997, fig. 93, nn. 146-149 (5th century onwards); Glençler, 2003, p. 735, tav. 51 (5th – 6th century AD); Corti, 2012, fig. 6, n. 11 (end 5th – early 6th century)
BT7	16	Bottom of stemmed beaker	Goblet Isings 111	6th century AD	10th – 11th century AD with pottery from 4th – 5th century AD and glass from 6th – 7th century AD	Isings 1957, form 111; Foy, 1998, p.131, fig.97, n.190; Falcetti 2001, p. 419, tav. 49, n. 99 (6th century – 7th century)
BT10	17	Cullet			mid-6th century AD	
BT11	17	Rim of beaker or goblet	Beaker or goblet	6th century AD	mid-6th century AD	Falcetti, 2001, p. 429, fig. 53, n. 264 (identified as rim of goblet); Foy, 2004, p. 322, fig. 188, n. 24 (end 6th – 7th century AD); Sternini, 2013, p. 638, fig. 15.4, n. 75 (7th century AD – identified as rim of beaker Is. 106/109)
BT12	17	Bottom of stemmed beaker	Goblet Isings 111	5th - 6th century AD	end of the 6th century AD	Isings, 1957, form 111; Foy, 1995, forme 14, pl. 10, n. 95 (5th century); Dussart, 1998, BIX.1 suite n. 75 (end of 6th century)
BT14	17	Wall in light green glass			mid-6th century AD	
BT15	17	Bottom of bottle with stamp (possible)	Probably bottle		mid-6th century AD	Fadić-Štefanac 2012, fig. 2, n. 17 (similar stamp but more ancient).
BT16	17	Bottom of bowl raised on long foot	Bowl Sternini 1995, fig. 15, n. 203	4th – 5th century AD	4th century AD	Sternini, 1995, p. 283, fig.15, n. 203 (5th century AD); Glençler, 2003, p. 722, tav. 38, n. 65 (Late Antique period)
BT17	17	Bottom of stemmed beaker	Goblet Isings 111	from the 6th century AD		Isings, 1957, form 111; Foy, 1998, p. 130, fig. 86, n.183 (6th century AD); Dussart. 1998, BIX.1 suite n. 3 (with byzantine pottery)

BT19	16	Cullet				
BT21	16	Wall in green glass				
BT22	16	Wall in amber glass			5th – 6th century AD	
BT27	16	Wall in yellowish glass			4th century AD	
BT28	17	Wall in water green glass			mid-4th century AD	
BT29	17	Probably long twisted stem of goblet	Probably goblet	From the 7th century AD onwards?	mid-6th century AD	Fünfschilling, 2010, fig. 8, pag. 222 (7th century).
BT30	17	Wall in dark blue glass			mid-6th century AD	
BT32	19	Bottom of bowl raised on a long foot	Bowl Foy, 1995, form 10	5th – 6th century AD		Sternini, 1995, p. 283, fig.15, n.205; Foy, 1995, p. 225, pl.7, n. 46 (second half of the 5th century AD)
BT34	16	Wall in light green glass				
BT35	16	Cullet			5th century AD	
BT36 (a)	16	Wall in colourless glass with light blue thread				
BT38	16	Bottom of knobbed goblet	Goblet Isings 111	5th – 7th century AD	end of 6th century AD	Isings 1957, form 111; Falcetti 2001, p. 421, fig. 50, n. 123; Glençler 2003, p. 733, tav. 49 (without knob; 5th – 7th century AD); Gürler-Lafli, p. 134, fig. 10, n. 67 (7th century)
BT39 (a)	17	Rim of bottle with blue thread	Bottle with blue thread	from the 5th century AD onwards	mid-6th century AD	Jennings, 1997-1998, pp. 142-143; Jennings-Abdallah, 2002 p. 7, n. 13
BT40	17	Wall in light green glass			mid-6th century AD	
BT41	17	Wall in blue glass			end of 6th century AD	
BT42	17	Wall in amber glass			mid-6th century AD	
BT43	17	Wall in colourless glass			mid-6th century AD	
BT45	17	Refolded rim of unguentarium	Unguentarium	4th – 6th century AD	mid-6th century AD	Foy, 2010, pag. 480, n. 780 (3rd – 4th century AD)

Table4

Samples	Color	Chemical-typology	SiO_2	Al_2O_3	TiO_2	MnO	FeO	MgO	CaO	Na_2O	K_2O	SO_3	Cl	P_2O_5	Cr_2O_3	CoO	Cu_2O	SnO_2	Sb_2O_3	PbO	Total
BT15	green	**HIMT1**	68.7	2.68	0.41	1.40	1.18	1.05	4.55	18.8	0.45	0.20	1.64	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	101.1
BT21	green		65.5	2.52	0.17	1.02	1.33	1.18	7.44	18.7	0.88	0.37	1.04	0.12	n.d.	n.d.	0.02	n.d.	0.02	0.05	100.3
BT29	green		67.2	2.36	0.23	1.47	0.88	1.31	5.56	19.5	0.31	0.28	1.65	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	100.8
BT32	green		66.9	2.37	0.24	1.50	0.90	1.32	5.60	19.8	0.33	0.25	1.66	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	100.9
BT35	green		65.4	2.23	0.31	2.12	0.98	1.41	6.18	20.0	0.40	0.39	1.52	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	101.0
BT40	green		66.9	2.30	0.27	1.35	0.94	0.98	7.26	18.9	0.55	0.29	1.59	0.02	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	101.3
BT42	amber		66.2	2.71	0.59	3.24	1.82	1.16	6.65	16.9	0.45	0.28	1.17	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	101.2
BT39a	blue	**HIT**	66.9	2.69	0.49	0.08	2.76	1.07	5.84	18.8	0.30	0.37	1.35	n.d.	n.d.	0.25	0.34	n.d.	n.d.	0.33	101.6
BT41	blue		63.3	2.72	0.36	0.49	2.21	1.43	8.57	19.1	0.58	0.56	1.11	0.09	n.d.	0.14	0.21	n.d.	n.d.	0.11	101.0
BT45	blue		67.3	2.62	0.49	0.07	2.74	1.02	5.78	18.1	0.38	0.37	1.31	n.d.	n.d.	0.25	0.32	n.d.	n.d.	0.30	101.1
BT2	green	**HIMT2**	63.3	2.14	0.14	1.38	0.70	1.06	8.48	19.7	0.74	0.45	1.34	0.07	n.d.	n.d.	n.d.	0.02	n.d.	0.02	99.6
BT4	green		68.0	1.90	0.12	1.07	0.56	0.73	6.33	20.0	0.44	0.43	1.30	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	101.0
BT6	green		66.2	2.06	0.13	0.73	0.87	0.74	7.11	19.8	0.56	0.37	1.42	0.08	n.d.	0.05	0.06	n.d.	n.d.	0.08	100.3
BT7	green		66.1	2.10	0.14	1.13	0.66	0.83	7.78	19.1	0.58	0.43	1.19	0.07	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	100.2
BT11	yellow		66.4	2.07	0.11	0.95	0.63	0.62	6.76	21.2	0.46	0.41	1.62	0.04	n.d.	n.d.	0.02	n.d.	n.d.	n.d.	101.2
BT12	green		69.2	2.25	0.13	0.77	0.79	0.86	6.58	18.0	0.54	0.30	1.25	0.06	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	100.7
BT17	green		69.3	1.91	0.11	0.89	0.52	0.83	5.89	19.2	0.35	0.20	1.81	0.02	n.d.	n.d.	n.d.	0.02	n.d.	0.03	101.1
BT19	brown		66.6	2.20	0.15	1.40	0.71	0.95	7.26	18.4	0.61	0.32	1.31	0.05	n.d.	n.d.	0.02	n.d.	n.d.	n.d.	99.9
BT22	amber		64.4	1.73	0.10	1.36	0.51	0.74	6.78	22.3	0.45	0.48	1.43	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	100.4
BT28	green		67.4	2.52	0.16	0.80	0.75	0.97	7.77	17.6	0.61	0.42	1.12	0.07	n.d.	n.d.	n.d.	n.d.	0.02	0.02	100.2
BT30	blue		68.5	2.47	0.07	0.54	0.93	0.55	7.52	17.7	0.77	0.28	1.14	0.10	n.d.	0.07	0.08	n.d.	n.d.	0.03	100.7
BT34	green		65.4	2.38	0.16	1.31	0.90	1.18	7.81	18.9	0.67	0.38	1.22	0.14	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	100.4
BT38	green		66.8	2.40	0.14	1.33	0.97	1.11	7.38	18.2	0.63	0.37	1.26	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100.6
BT3	green	**Levantine I**	69.6	2.57	0.07	0.16	0.31	0.46	7.54	17.1	0.86	0.19	1.19	0.07	n.d.	n.d.	n.d.	0.03	n.d.	0.06	100.2
BT5	green		70.8	2.86	0.07	0.02	0.30	0.62	8.81	15.0	1.03	0.04	1.42	0.07	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	101.1
BT10	green		71.9	2.53	0.07	1.37	0.36	0.43	7.32	14.2	0.58	0.09	1.29	0.10	n.d.	n.d.	0.02	n.d.	0.02	0.03	100.3
BT14	green		70.2	2.58	0.06	0.29	0.30	0.54	7.85	16.6	0.77	0.19	1.45	0.09	n.d.	n.d.	n.d.	n.d.	n.d.	0.02	100.9
BT16	green		70.0	2.45	0.06	0.39	0.33	0.53	7.84	16.8	0.57	0.19	1.49	0.09	n.d.	n.d.	n.d.	n.d.	0.04	0.02	100.8
BT27	yellow		71.2	2.32	0.06	0.80	0.30	0.46	6.68	16.3	0.59	0.09	1.47	0.11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100.4
BT36	colorless		71.9	2.83	0.06	0.02	0.34	0.54	7.68	15.4	0.66	0.12	1.29	0.08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	101.0
BT36a	blue		69.3	2.87	0.08	0.06	1.28	0.59	7.80	14.8	0.74	0.10	1.25	0.09	n.d.	0.05	0.24	0.04	n.d.	1.09	100.3
BT39	colorless		67.8	1.54	0.08	0.77	0.40	0.54	7.29	20.7	0.31	0.42	1.61	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	101.5
BT43	colorless		69.5	2.91	0.07	1.71	0.35	0.65	8.90	14.9	0.57	0.15	1.29	0.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	101.1

Table5

Sample	Classification	Sc	Ti	V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Sn	Sb	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	Au	Pb	Th	U
BT15	HIMT1	4.9	2382	30	45	8.5	15	31	23	4.1	5.0	432	8.0	190	3.7	5.5	0.8	292	8.8	16	2.0	8.7	1.8	0.5	1.6	0.3	1.5	0.3	0.9	0.1	1.0	0.1	4.2	0.2	n.d.	53	1.5	1.0
BT21		3.7	895	35	19	16	25	81	39	3.6	9.1	731	8.3	73	2.2	62	120	320	10.0	14	2.1	9.3	1.9	0.5	1.8	0.3	1.7	0.4	1.0	0.1	1.0	0.1	2.2	0.2	0.08	773	1.3	1.1
BT32		3.3	1250	28	23	7.8	14	16	23	3.5	4.8	539	6.7	91	2.4	1.0	0.7	456	7.8	13	1.7	7.7	1.6	0.4	1.5	0.2	1.4	0.3	0.8	0.1	0.8	0.1	2.8	0.2	n.d.	9.0	1.2	1.2
BT35		6.4	1493	28	30	6.9	12	20	25	6.3	4.3	446	7.0	129	2.8	2.7	0.3	312	7.9	13	1.7	7.2	1.5	0.4	1.4	0.2	1.4	0.3	0.8	0.1	0.8	0.1	3.3	0.2	n.d.	8.0	1.3	1.1
BT40		8.4	1312	25	29	5.5	10	38	17	6.2	7.4	472	7.9	118	2.6	2.4	19	235	8.6	13	1.8	7.4	1.5	0.5	1.4	0.2	1.5	0.3	0.9	0.1	0.9	0.1	3.0	0.2	n.d.	52	1.2	0.9
BT42		9.7	3044	39	66	14	11	42	23	7.7	5.7	491	12	275	5.5	9.1	2.7	297	13.0	33	2.9	12	2.5	0.6	2.3	0.4	2.3	0.5	1.3	0.2	1.4	0.2	6.7	0.4	0.01	50	2.3	1.4
BT39a	HIT	9.9	2498	32	56	1 617	81	1 985	67	9.8	5.2	375	8.5	204	4.3	51	2.3	126	8.8	15	1.9	8.1	1.7	0.5	1.5	0.3	1.6	0.3	1.0	0.1	1.0	0.2	5.2	0.3	0.01	2 886	1.7	1.4
BT41		8.3	1779	32	37	875	91	1 351	43	11	7.0	650	8.4	154	3.8	30	34	199	9.1	16	2.0	8.0	1.7	0.5	1.5	0.3	1.6	0.3	0.9	0.1	1.0	0.1	3.9	0.2	0.01	929	1.7	1.5
BT45		9.0	2563	33	57	1 631	81	1 911	69	9.9	5.6	391	8.7	206	4.4	53	2.4	129	8.8	16	2.0	8.1	1.7	0.5	1.5	0.3	1.6	0.3	1.0	0.1	1.0	0.2	5.2	0.3	n.d.	2 772	1.7	1.4
BT2	HIMT2	3.9	712	30	13	7.2	8.8	37	16	2.8	5.1	716	6.4	56	1.7	12	53	367	6.9	11	1.5	6.6	1.4	0.4	1.3	0.2	1.2	0.3	0.7	0.1	0.7	0.1	1.6	0.1	0.01	66	0.9	0.9
BT4		3.7	583	20	12	4.2	8.1	22	11	2.7	5.4	503	5.5	53	1.5	0.9	5.6	284	5.9	9.7	1.3	5.7	1.2	0.3	1.1	0.2	1.0	0.2	0.6	0.1	0.6	0.1	1.5	0.1	n.d.	18	0.8	1.0
BT6		3.7	797	21	17	491	25	622	32	4.2	5.8	563	6.1	68	1.8	12	2.3	235	6.4	11	1.4	6.2	1.3	0.3	1.2	0.2	1.1	0.2	0.6	0.1	0.7	0.1	1.9	0.1	n.d.	647	1.0	0.9
BT7		3.6	660	23	12	5.5	8.3	46	16	2.9	6.2	648	6.3	57	1.8	9.0	54	302	6.9	11	1.5	6.7	1.4	0.3	1.2	0.2	1.2	0.2	0.7	0.08	0.7	0.08	1.6	0.1	n.d.	43	0.9	1.0
BT11		3.3	582	24	12	6.4	9.2	28	16	2.9	6.1	547	6.1	52	1.5	4.8	2.8	294	6.6	11	1.4	6.3	1.3	0.4	1.2	0.2	1.1	0.2	0.6	0.1	0.7	0.1	1.4	0.1	n.d.	39	0.8	1.0
BT12		3.7	677	25	13	7.1	13	34	18	3.3	8.0	598	6.8	58	1.8	3.7	73	305	7.7	12	1.7	7.3	1.5	0.4	1.4	0.2	1.3	0.3	0.7	0.1	0.7	0.1	1.6	0.1	n.d.	98	1.0	0.7
BT17		3.2	738	23	15	6.1	9.3	53	26	3.0	6.7	691	6.3	61	1.8	13	34	273	7.0	11	1.5	6.6	1.4	0.4	1.2	0.2	1.1	0.3	0.6	0.09	0.6	0.1	1.6	0.1	0.01	139	0.9	0.8
BT19		3.8	767	23	15	6.0	10	40	19	3.2	6.9	660	6.2	63	1.9	4.0	105	341	6.9	11	1.5	6.5	1.4	0.4	1.2	0.2	1.2	0.3	0.7	0.09	0.7	0.1	1.8	0.1	0.01	48	1.0	0.9
BT22		2.8	510	18	9.8	4.4	6.8	25	14	2.4	4.8	590	5.9	46	1.3	0.8	9.1	294	6.3	10	1.4	6.0	1.2	0.3	1.2	0.2	1.2	0.2	0.6	0.09	0.6	0.1	1.4	0.1	n.d.	7.0	0.8	1.1
BT30		3.4	1262	28	24	8.0	14	16	23	3.5	4.8	548	6.6	91	2.5	1.0	0.8	471	8.0	14	1.8	7.7	1.6	0.4	1.5	0.2	1.4	0.3	0.8	0.1	0.8	0.1	2.8	0.2	n.d.	9.0	1.3	1.2
BT34		6.5	782	27	16	9.7	14	64	31	6.0	9.4	583	6.3	64	2.4	10	68	266	7.8	13	1.6	6.8	1.4	0.4	1.2	0.2	1.2	0.2	0.7	0.1	0.7	0.1	1.7	0.1	0.01	118	1.4	0.9
BT38		5.8	706	32	14	9.5	16	45	22	6.9	8.4	604	7.3	61	2.0	4.3	117	366	8.4	13	1.8	7.5	1.6	0.4	1.4	0.2	1.4	0.3	0.8	0.1	0.8	0.1	1.6	0.1	0.01	68	1.1	0.8
BT3	Levantine I	3.4	353	5.9	11	1.9	3.2	14	6.2	2.8	13	419	5.5	31	0.9	74	1.5	220	5.5	10	1.2	5.5	1.1	0.4	1.1	0.2	1.0	0.2	0.5	0.08	0.5	0.08	0.9	0.06	n.d.	207	0.6	0.4
BT5		3.3	296	5.7	13	1.1	3.4	5.0	38	3.3	14	393	4.3	22	0.9	1.1	0.3	190	4.7	10	1.1	4.7	0.9	0.3	0.9	0.1	0.8	0.2	0.4	0.06	0.4	0.06	0.6	0.06	n.d.	11	0.5	0.5
BT10		3.2	385	49	11	8.1	13	10	15	3.2	5.7	464	5.9	33	1.1	2.2	216	440	5.8	9.8	1.3	5.7	1.2	0.3	1.1	0.2	1.0	0.2	0.6	0.08	0.6	0.08	0.9	0.07	n.d.	15	0.7	0.6
BT14		2.8	352	11	11	4.2	7.1	7.1	12	3.1	7.4	498	6.2	32	1.1	2.4	239	256	6.3	11	1.4	6.2	1.3	0.4	1.2	0.2	1.1	0.2	0.6	0.09	0.6	0.09	0.9	0.06	n.d.	45	0.7	0.7
BT16		3.1	566	13	12	5.5	9.0	21	14	2.8	4.9	517	5.3	44	1.4	1.7	2.3	256	6.0	10	1.3	5.8	1.2	0.3	1.1	0.2	1.0	0.2	0.5	0.08	0.6	0.08	1.2	0.09	0.01	16	0.7	0.7
BT27		2.4	357	19	11	8.8	14	11	20	2.8	7.0	490	5.8	33	1.0	1.0	12	277	6.1	9.9	1.3	5.9	1.3	0.4	1.2	0.2	1.1	0.2	0.6	0.09	0.6	0.1	1.1	0.08	n.d.	7.0	0.8	0.7
BT36		5.1	289	7	11	1.0	3.3	3.4	7.9	5.1	9.5	342	4.0	22	0.9	0.5	0.1	209	4.6	9.8	1.1	4.3	0.9	0.3	0.7	0.1	0.7	0.1	0.4	0.06	0.4	0.05	0.6	0.05	n.d.	5.0	0.5	0.5
BT36a		5.3	355	8.8	11	293	103	1 431	28	7.8	9.9	392	5.5	30	1.1	199	18	231	5.7	10	1.3	5.4	1.1	0.3	1.0	0.2	1.0	0.2	0.5	0.08	0.5	0.08	0.8	0.07	0.01	7 689	0.7	0.6
BT39		6.8	358	17	8.5	3.6	5.4	12	11	4.1	4.8	482	5.8	39	1.1	5.2	0.3	170	6.0	9.3	1.3	5.3	1.1	0.3	1.0	0.2	1.1	0.2	0.6	0.09	0.6	0.09	1.0	0.07	n.d.	27	0.7	0.8
BT43		6.4	386	38	11	7.9	6.3	5.9	11	7.4	7.5	502	7.0	35	1.2	0.4	0.3	326	7.1	12	1.5	6.4	1.3	0.4	1.2	0.2	1.3	0.3	0.7	0.1	0.7	0.1	0.9	0.09	n.d.	4.0	0.8	0.9

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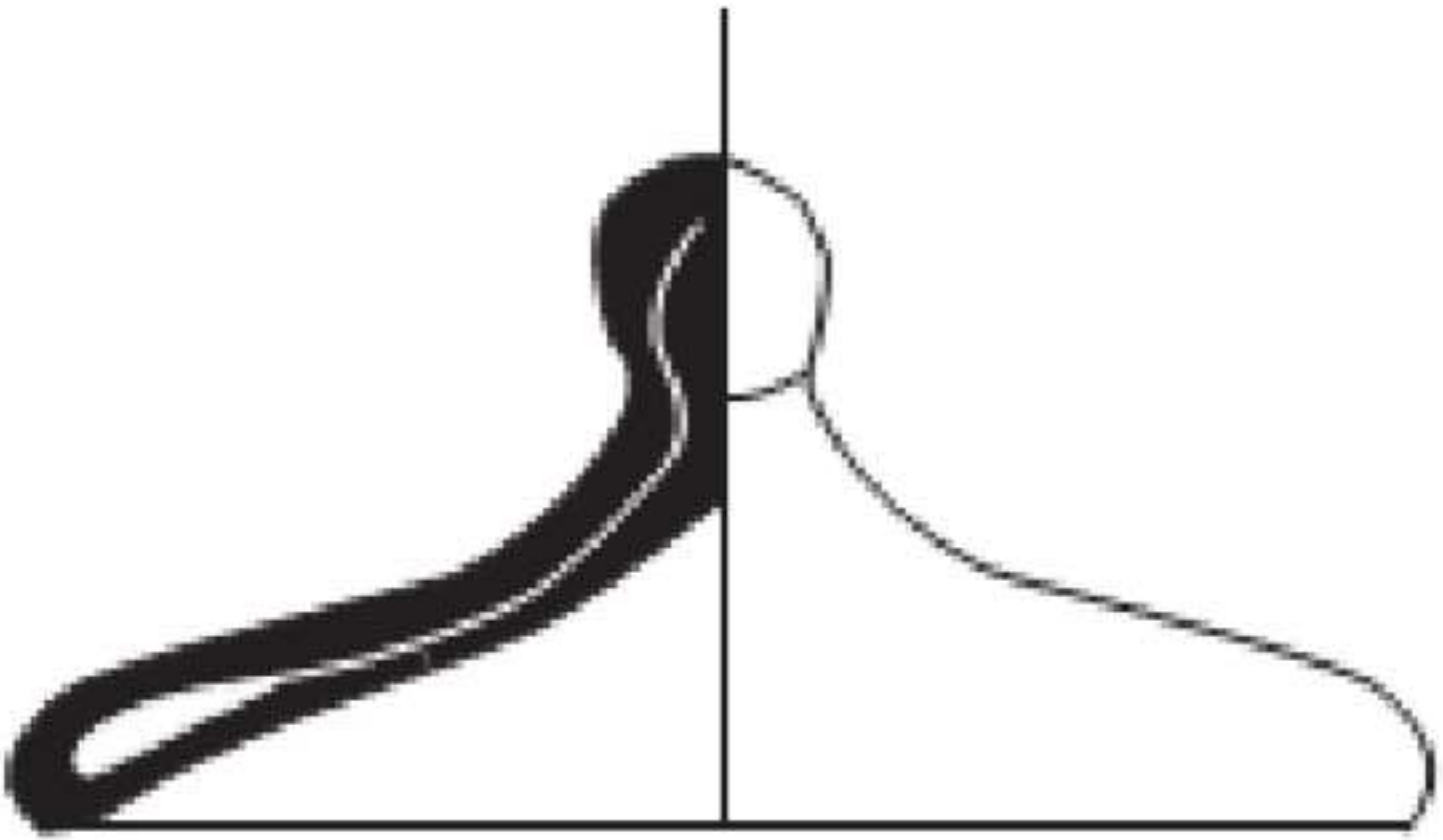

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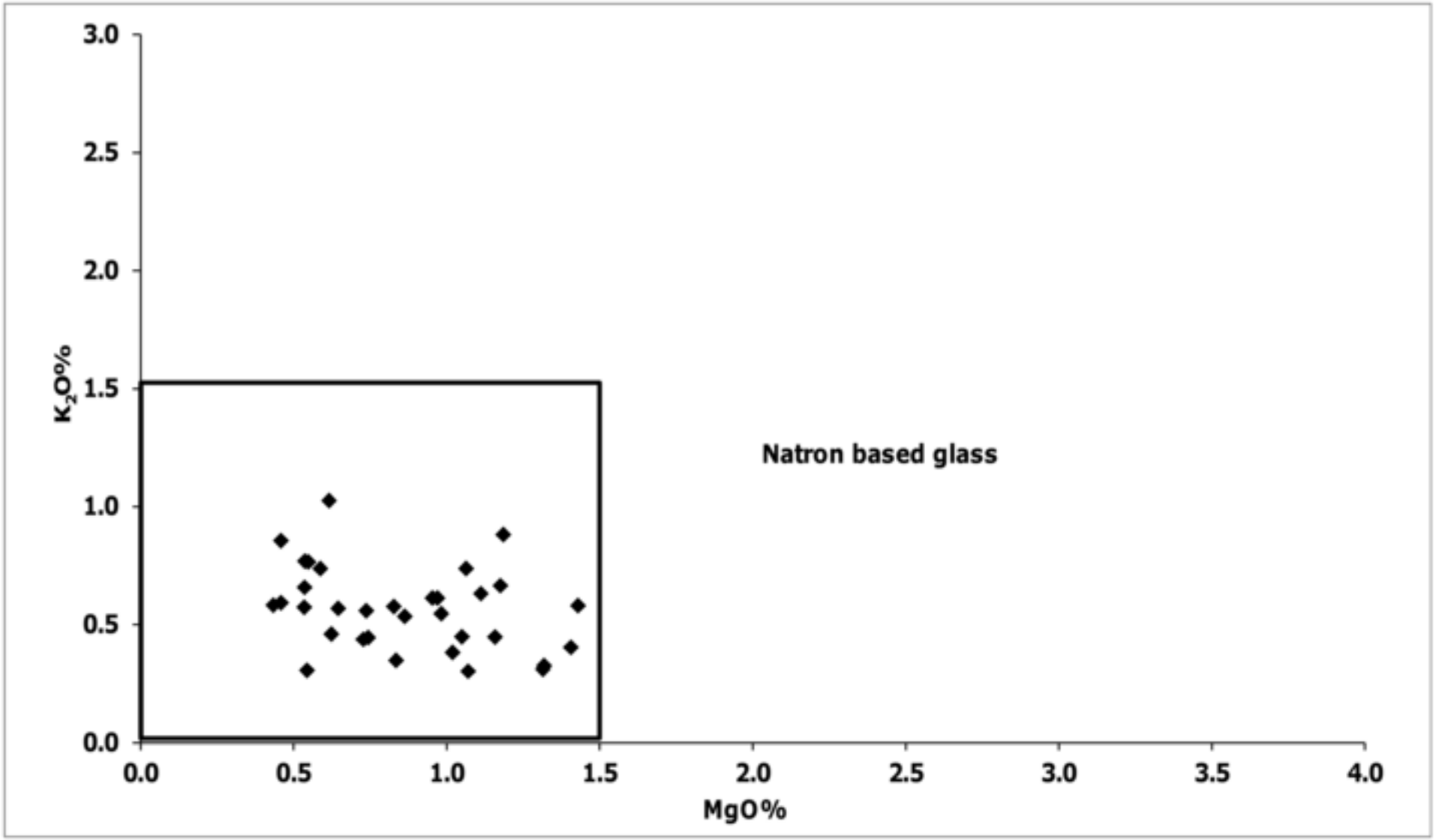

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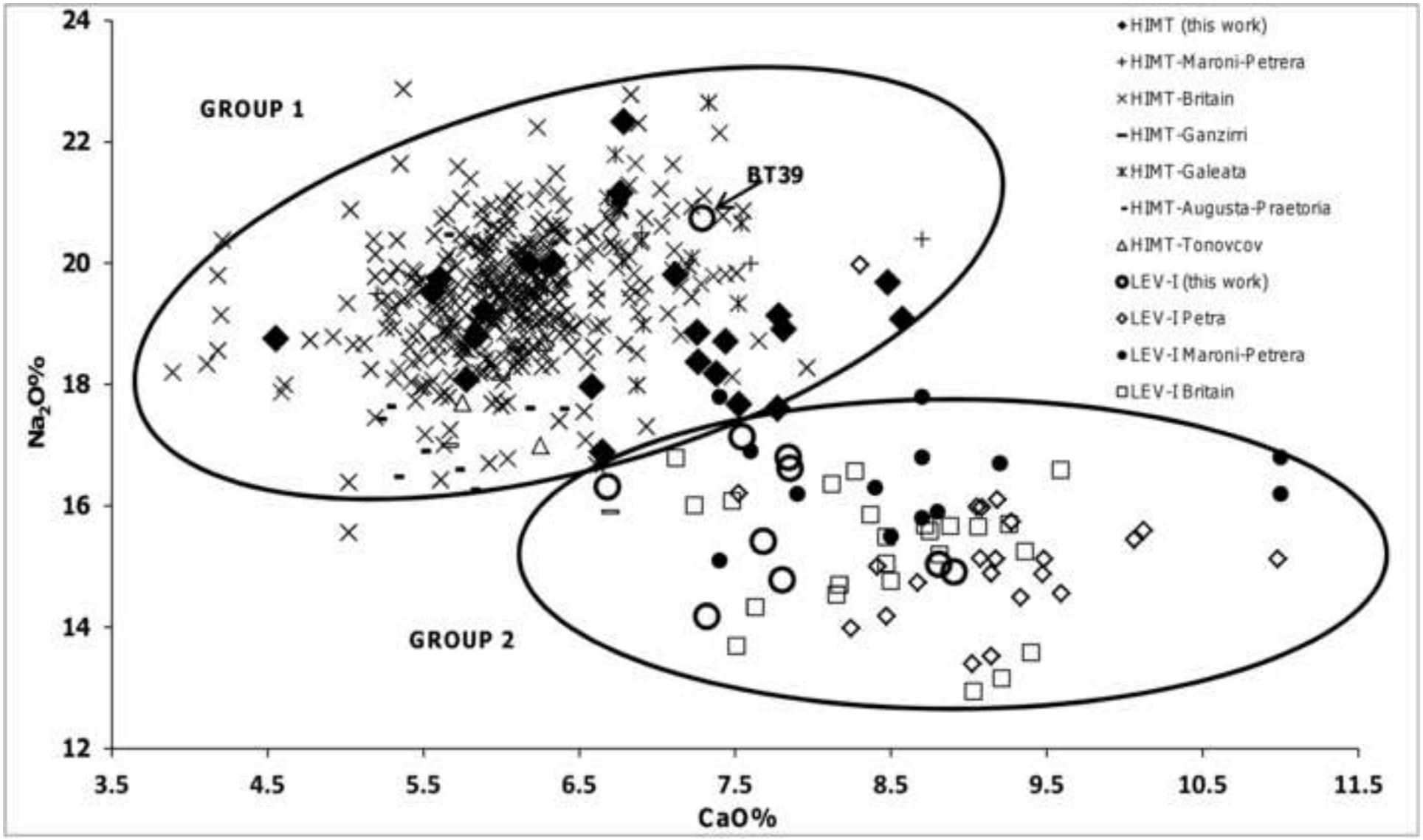

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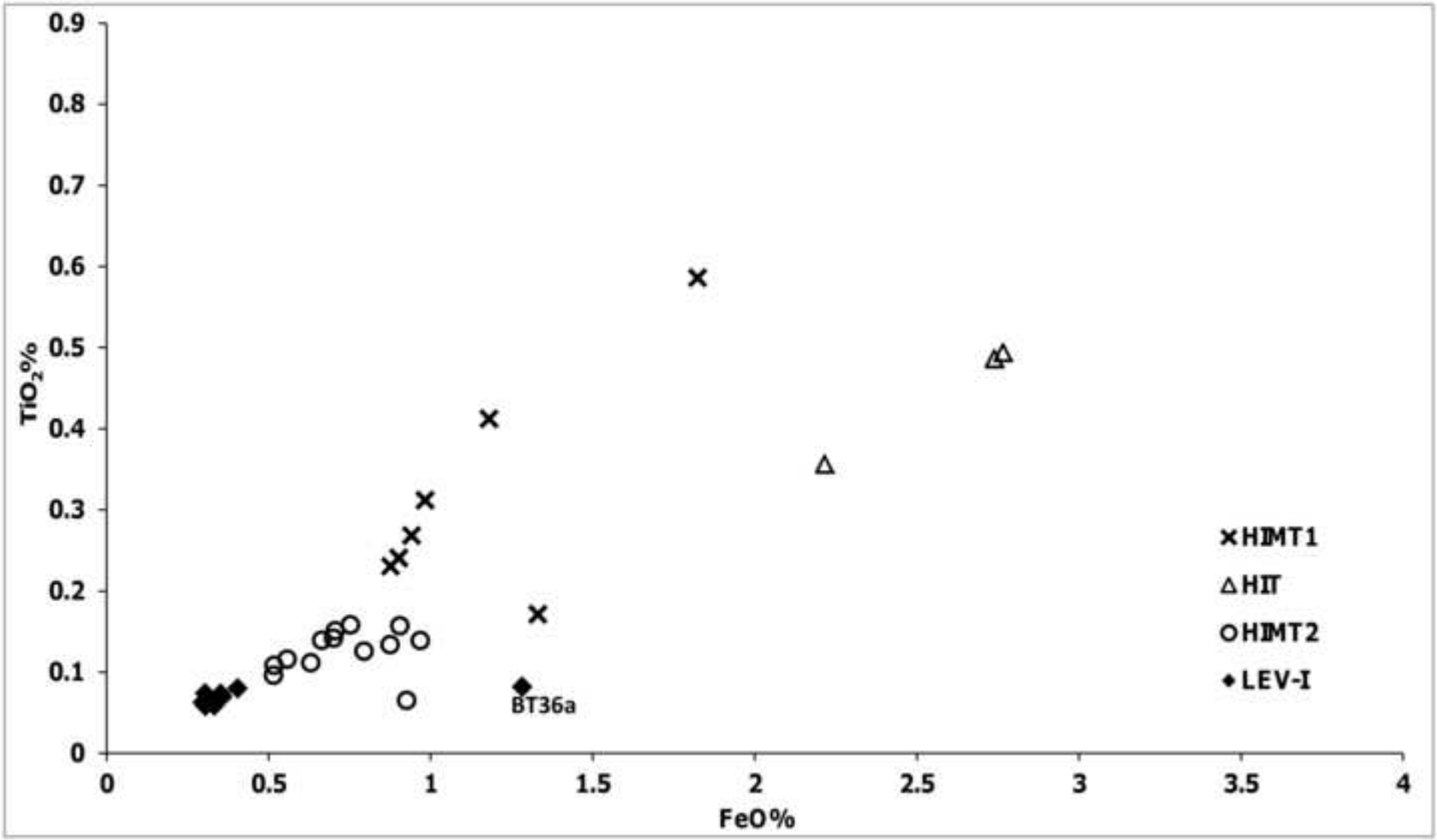

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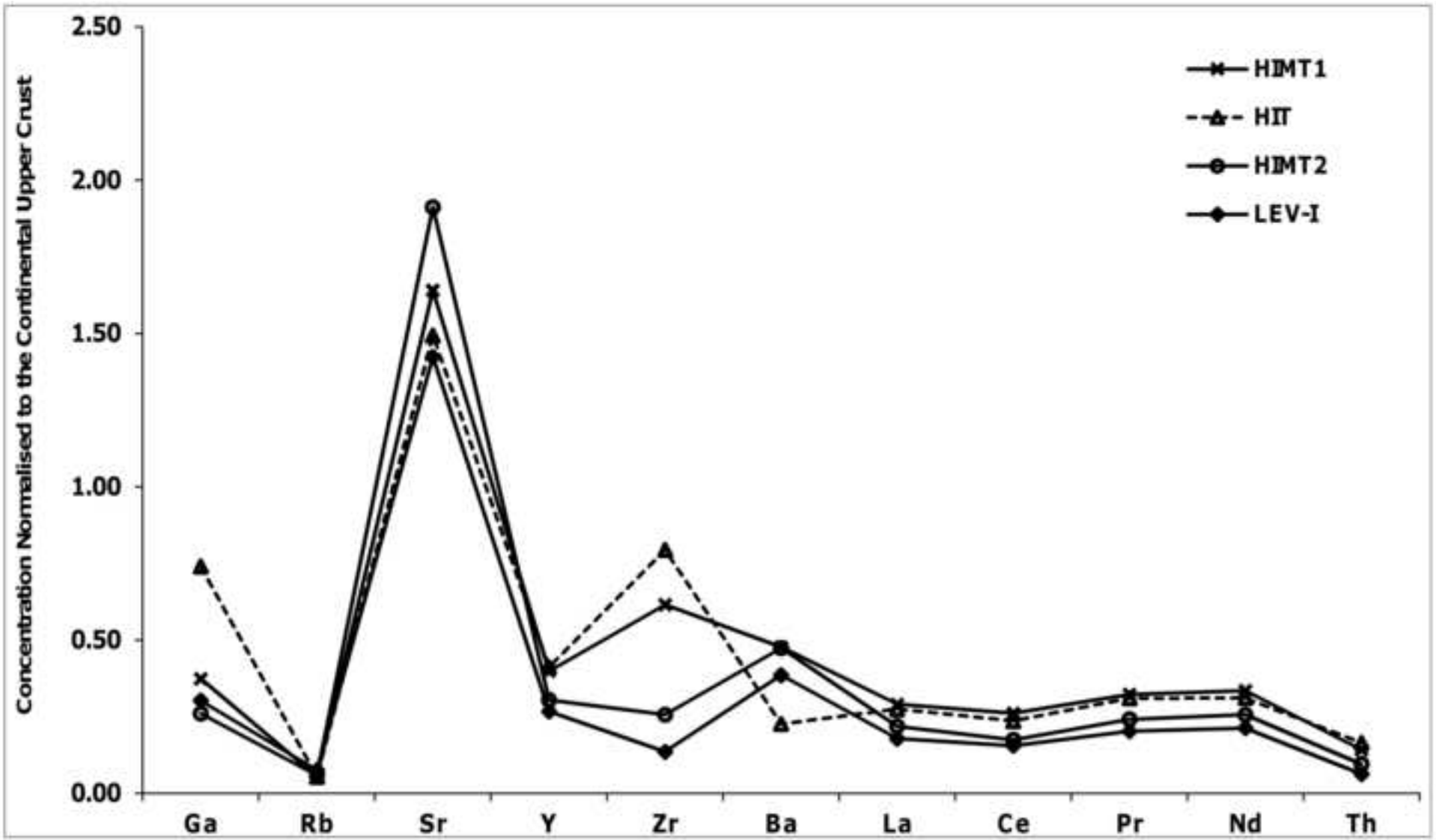

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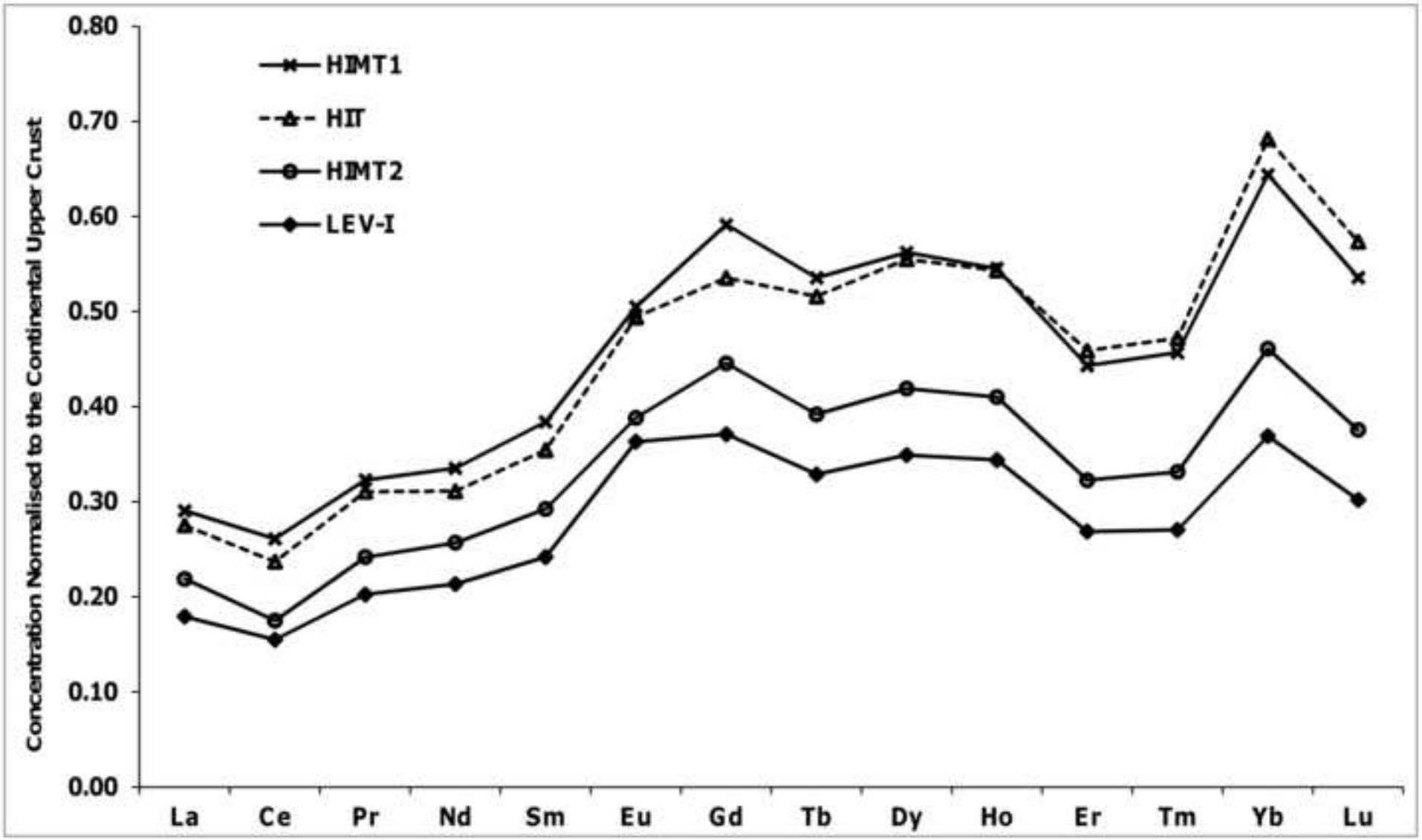

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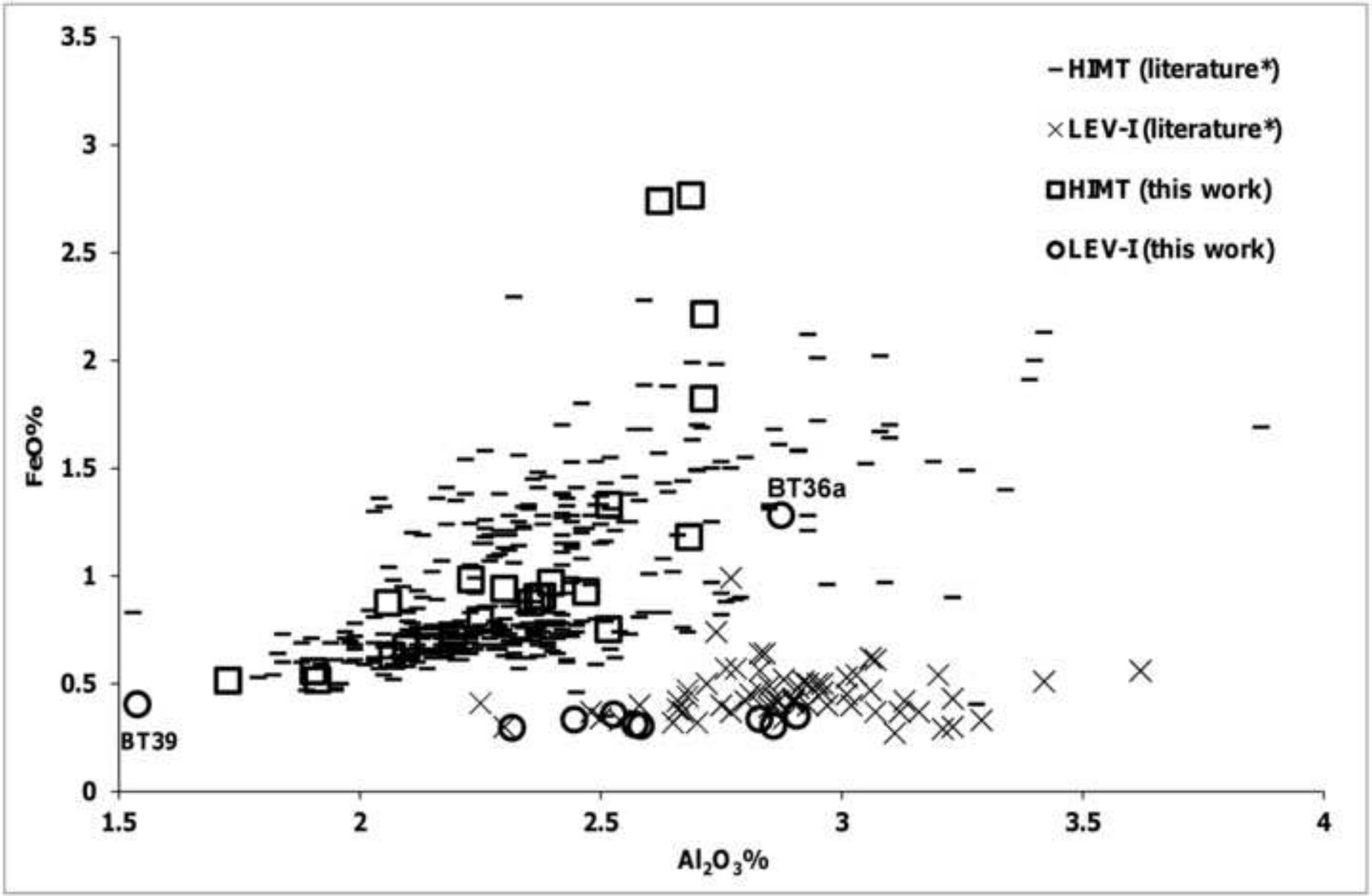

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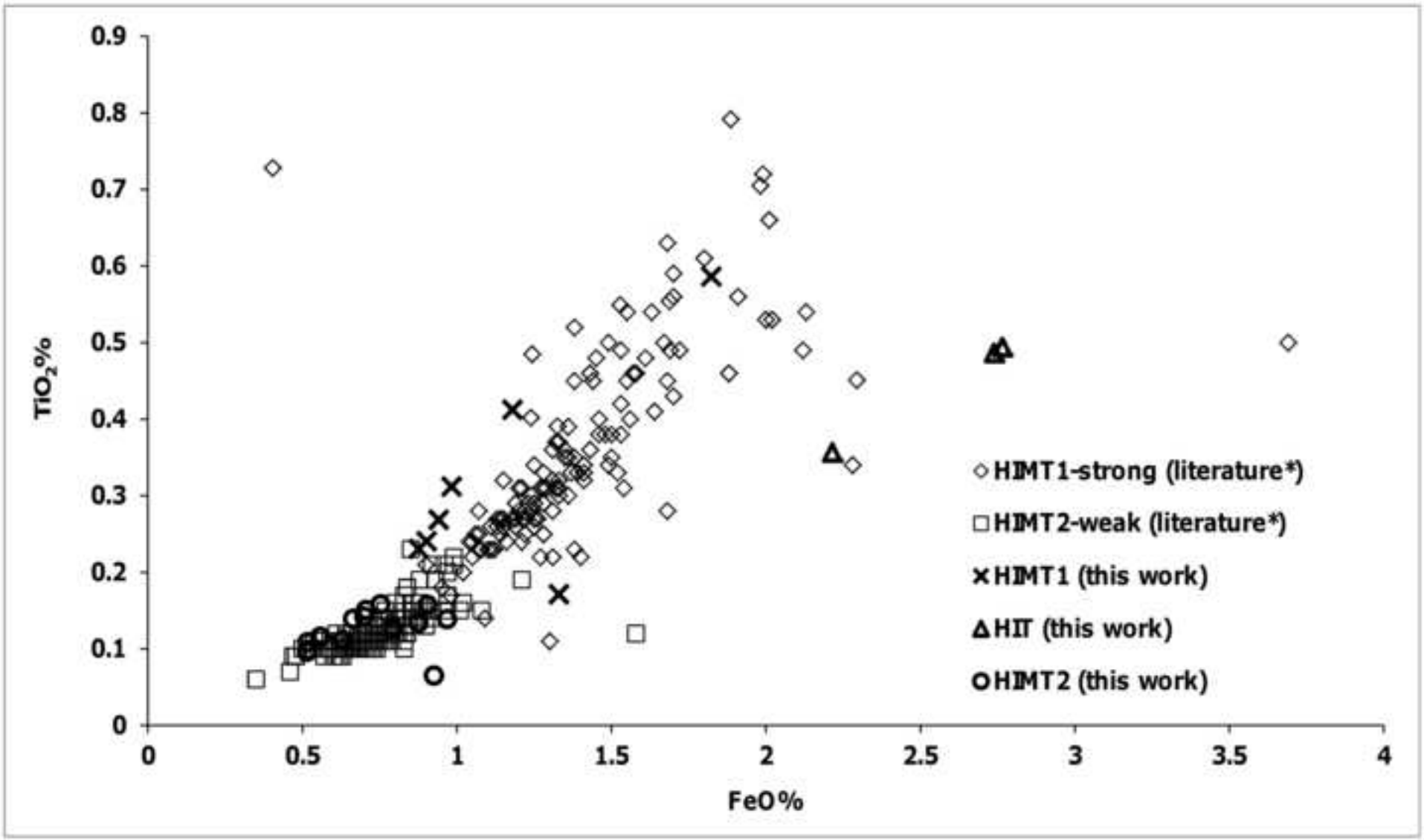

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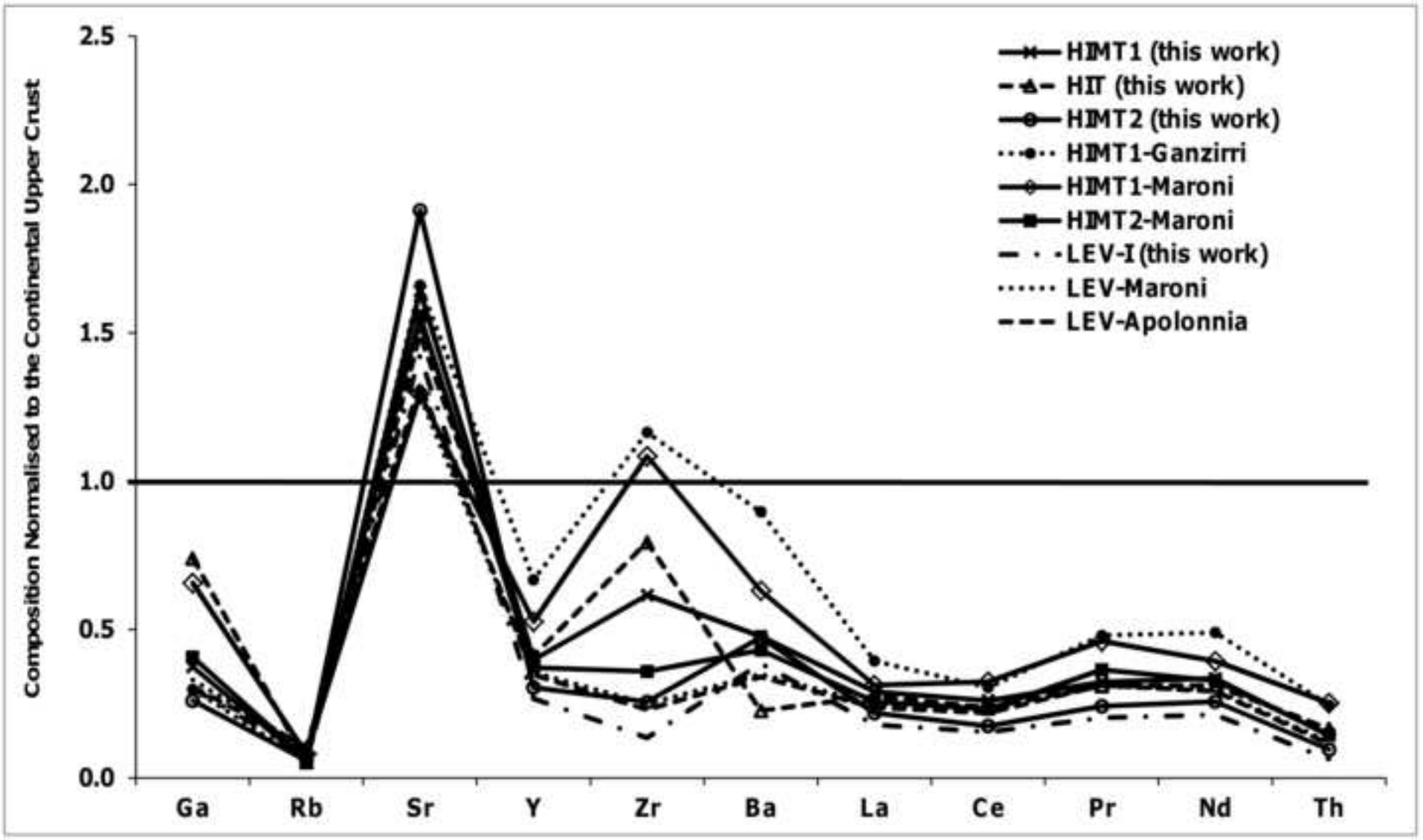

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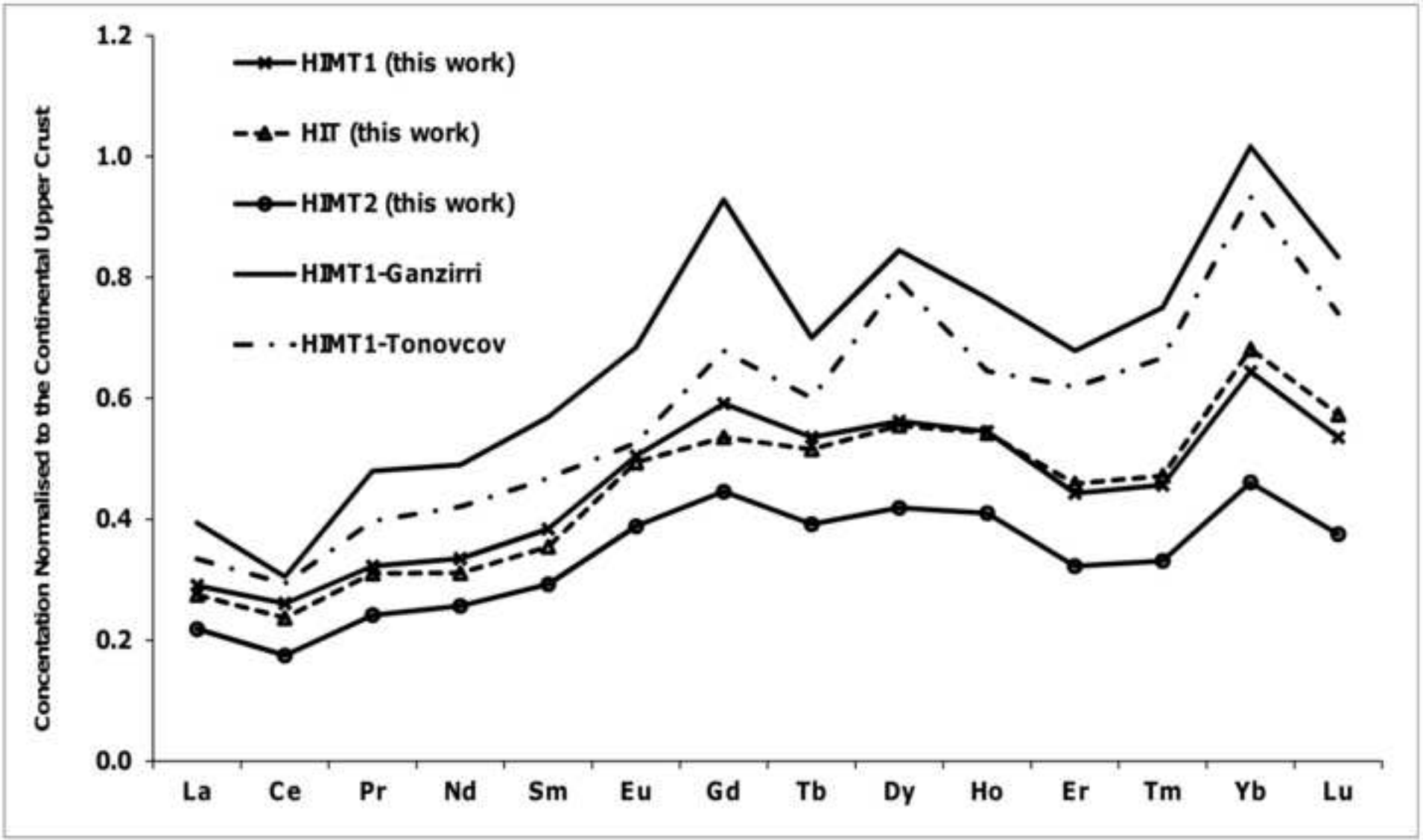

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