

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Pre-Roman Glass from Mozia (Sicily-Italy): the first archaeometrical data

This is the author's manuscript

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/118779> since 2017-11-03T11:51:34Z

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

Manuscript Number:

Title: PRE-ROMAN GLASS FROM MOZIA (SICILY-ITALY): THE FIRST ARCHAEOMETRICAL DATA

Article Type: Full Length Article

Keywords: Iron Age, glass, Phoenician-Punic, Mediterranean Group EMPA, XRD

Corresponding Author: Dr Rossella Arletti,

Corresponding Author's Institution: University of Turin

First Author: Rossella Arletti

Order of Authors: Rossella Arletti; Daniela Ferrari; Giovanna Vezzalini

Manuscript Region of Origin: ITALY

Abstract: This study presents the results of an archaeometrical investigation performed on a series of opaque pre-roman glass (vessels and ornaments) dated from the 6th to 4th century BC coming from Sicily. Sixteen core formed vessels, twelve beads, three pendants and one spindle-whorl recovered in the Phoenician-Punic Mozia and Birgi's sites were analyzed through a micro destructive approach. The complete chemical analyses and X-Ray diffraction analyses were performed on small fragments of glass. The aims of this work are: 1) to obtain a chemical characterization of these samples in order to understand the raw materials employed for their production; 2) to obtain information regarding the opacifying phases dispersed in the glass; 3) to make a comparison with the results recently obtained on coeval and similar finds recovered in other cultural contexts, in particular in Northern Italian Etruscan contexts in order to understand whether they could belong to the same Greek-Eastern production. The chemical data of these samples confirm they are silica soda lime glass produced with natron. The opaque decorations of the samples were realized by using Sb based opacifiers. The major and minor analyses of the majority of the samples seem to suggest a common origin with the coeval material found in Northern Italian context. On the contrary, for some artifacts, in particular the pendants, a Phoenician-Punic origin is supposed.

Suggested Reviewers: Natalie Venclovà
venclova@arup.cas.cz

Bernard GRATUZE
bechmalubati@orange.fr

Maria Pia Riccardi
mariapia.riccardi@unipv.it

Alberta Silvestri
alberta.silvestri@unipd.it

Marie Dominique Nenna

marie-dominique.nenna@mom.fr

	Università degli Studi di Torino Dipartimento Scienze Mineralogiche e Petrologiche
	Dr. Rossella Arletti

Torino 16/11/11

Dear Sirs,

here enclosed you can find the documentation of the manuscript “Pre-Roman Glass from Mozia (Sicily-Italy): the first archaeometrical data” for publication on the Journal of Archaeological Science.

Sincerely yours

Rossella Arletti

Referees suggestions:

Maria Pia Riccardi, Dipartimento di Geoscienze, Università degli Studi di Pavia
mariapia.riccardi@unipv.it

Bernard GRATUZE, Institut de Recherche sur les ArchéoMATériaux, UMR 5060 du CNRS
bechmalubati@orange.fr

Natalie Venclovà
Institute of Archaeology, Czech Academy of Sciences, Prague, Czech Republic,
venclova@arup.cas.cz

Marie Dominique Nenna
marie-dominique.nenna@mom.fr

Alberta Silvestri University of Padova
alberta.silvestri@unipd.it

Research Highlight

PRE-ROMAN GLASS FROM MOZIA (SICILY-ITALY): THE FIRST ARCHAEOMETRICAL DATA by Arletti et al.

- Mozia samples are silica soda lime glass
- The chemistry of Mozia glass resemble that of Northern Italy coeval samples
- The opacifiers used for the vessels are lead antimonates for yellow decorations and calcium antimonates for white and light blue decorations.
- The major difference found in the samples are linked to the “pendant” probably of Phoenician origin

Pre-Roman Glass from Mozia (Sicily-Italy): the first archaeometrical data

Rossella Arletti¹, Daniela Ferrari², Giovanna Vezzalini¹

¹Dipartimento di Scienze Mineralogiche e Petrologiche, Università degli Studi di Torino, Via
Valperga Caluso 35, Torino I-10125, Italy

³Dipartimento di Storia e Metodi per la Conservazione dei Beni Culturali Università di Bologna (sede di
Ravenna), Via degli Ariani 1, Ravenna I-48110, Italy

² Dipartimento di Scienze della Terra, Università degli Studi di Modena e Reggio Emilia, Modena
I-41100, Italy.

*Fax: +390116705128, e-mail: rossella.arletti@unito.it

ABSTRACT

This study present the results of an archaeometrical investigation performed on a series of opaque pre-roman glass (vessels and ornaments) dated from the 6th to 4th century BC coming from Sicily. Sixteen core formed vessels, twelve beads, three pendant and one spindle -whorl recovered in the Phoenician-Punic Mozia and Birgi's sites were analyzed thought a micro destructive approach. The complete chemical analyses and X-Ray diffraction analyses were performed on small fragments of glass. The aims of this work are: 1) to obtain a chemical characterization of these samples in order to understand the raw materials employed for their production; 2) to obtain information regarding the opacifying phases dispersed in the glass; 3) to make a comparison with the results recently obtained on coeval and similar finds recovered in other cultural context, in particular in Northern Italian Etruscan contexts in order to understand whether they could belong to the same Greek-Eastern production.

The chemical data of these samples confirm they are silica soda lime glass produced with natron. The opaque decorations of the samples were realized by using Sb based opacifiers.

1 The major and minor analyses of the majority of the samples seem to suggest a common
2 origin with the coeval material found in Northern Italian context. On the contrary, for some
3 artifacts, in particular the pendants, a Phoenician-Punic origin is supposed .
4
5
6
7
8

9 Key words: Iron Age, glass, Phoenician-Punic, Mediterranean Group EMPA, XRD.
10
11
12
13
14
15

16 INTRODUCTION 17

18 The recent publication of three catalogues on Pre-Roman glass artefacts recovered in Sicily
19 allowed the compilation of exhaustive documentation, previously unavailable for these
20 materials (Spanò Giammellaro, 2004; 2008a; 2008b). In the first catalogue (Spanò
21 Giammellaro 2004), a large set of glass samples from sites of Phoenician-Punic, Greek and
22 Sicilian contexts is studied. The second catalogue, dedicated to glass of the Whitaker
23 Museum in Mozia (Spanò Giammellaro, 2008a), treats a series of glass varieties from: i)
24 archaic necropoleis of Mozia Island (end 8th cen. - first half 6th cen. BC); ii) Birgi
25 necropoleis (second half 7th cen. – 4th cen. BC); iii) Lilibeo necropoleis (3rd cen. BC-2nd
26 cen. AD). The third catalogue includes all glass coming from Phoenician-Punic contexts in
27 Sicily (Spanò Giammellaro, 2008b).
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42

43 Three categories of glass were found: i) polychrome vessels realized using the core forming
44 technique (n. 132); ii) polychrome pendants (human head-shaped or animal-shaped) realized
45 using the rod-forming technique, generally assigned to Phoenician-Punic handicraft
46 production (n. 33); iii) polychrome beads, realized using the core forming technique.
47
48
49
50
51
52

53 The majority of the vessels belong to the so-called Mediterranean Group I, dated from the
54 second half of the 6th century to the first half of the 4th century BC. The site of provenance of
55 these glass artefacts is thought to be the island of Rhodes. This conclusion was reached on
56 the basis of: i) the large number of vessels recovered on that island; ii) the presence at this
57
58
59
60
61
62
63
64
65

1 site of glass scraps dated to the 5th century BC, and iii) the recovery of glass working
2 furnaces in the following centuries (Triantafyllidis, 2003). However, it is not possible to
3
4 exclude production sites for these artefacts in the Siro-Palestinian or Ionic area (Spanò
5
6 Giammellaro, 2008a,b). Conversely, a Phoenician-Punic origin is presumed for the pendants
7
8
9 (Spanò Giammellaro, 2004).
10

11 In this work a first suite of glass samples from Mozia island (Sicily) are analysed, including:
12
13 vessels of Mediterranean group I (n.13), vessels of Mediterranean group II (n.3), beads
14
15 (n.12), spindle whorls (n.1), and pendants (n.3) (see Table 1). . The decision to analyse glass
16
17 from Mozia arose out of the existing project involving the University of Bologna, the
18
19 Soprintendenza per i Beni Culturali di Trapani, and the Fondazione Whitaker, aiming to
20
21 study the role of Mozia in the Mediterranean area (Acquaro and Savio, 2004).
22
23
24

25
26 Mozia is a small Island (45 hectares) facing the city of Marsala and represented an ideal
27
28 goods storage depot for the Phoenicians (Tucidide, Storie, VI, 2,6).
29
30

31 This work is part of a wider archaeometrical study aiming to characterize Pre-Roman glass
32
33 from different Italian sites. A large number of Mediterranean vessels and beads from the
34
35 Etruscan context of Northern Italy (Spina (Ferrara) and Bologna) have already been analysed
36
37 and the results published (Arletti et al., 2010). In their paper Arletti et al. (2010) showed that
38
39 almost all the analysed samples from the Etruscan contexts of Northern Italy exhibit an
40
41 extremely homogenous composition. All these glass samples present the characteristic traits
42
43 of the silica soda lime glass produced using a calcareous siliceous sand and natron as flux, as
44
45 already noted by Gratuze and Billaud (2003) in a series of coeval glass beads recovered at
46
47 various French sites.
48
49
50
51

52
53 The aim of this work is to compare the results with those obtained for coeval artifacts from
54
55 different cultural contexts - the Etruscan sites of Spina (Ferrara) and Bologna (Arletti et al.,
56
57 2010) - in order to understand whether or not the artifacts of these two regions were
58
59 produced at the same manufacturing site. In fact, while the Spina and Bologna sites, without
60
61
62
63
64
65

doubt, represent a connection between the Etruscan and Greek worlds across the Adriatic Sea, Mozia's position is more complex and the co-presence of Phoenician-Punic and Greek cultures on the Island make the interpretation of the provenance of the glass less straightforward.

EXPERIMENTAL

The good state of preservation of most of the samples meant that only small chips of a few hundred μm^3 could be removed. For each find, when possible, sampling was performed on the body of the item and on all the decorations of different colours present on the surface. Chemical analyses and X-ray diffraction experiments were carried out on the same glass chip samples.

X-Ray Powder Diffraction (XRPD)

X-ray diffraction experiments were performed on a selection of opaque samples of different colours to identify crystalline phases dispersed in the glass matrix. Due to the small quantity of material available, the samples were mounted on a goniometric head of a 4-circle single crystal diffractometer, Bruker X8-Apex with $\text{MoK}\alpha$ radiation, equipped with an area detector. The diffraction patterns were collected with a detector-sample distance of 60 mm and a time exposure variable between 60 and 120 seconds, depending on the amount of crystalline phases present in the glass. The diffraction rings were integrated using the Fit2d software programme (from 5° to 30° 2θ degrees) and the patterns were then interpreted using the JCPDF database (McLune, 1989).

WDS-Electron Microprobe Analysis (EMPA)

The chemical analyses were carried out with an ARL-SEMQ electron microprobe equipped with four scanning wavelength spectrometers. The samples were embedded in an epoxy resin

and polished with diamond paste. The elements analysed were: Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Co, Cu, Sn, Sb, Pb. Natural and synthetic standards were employed for calibration. The analyses were performed operating at 15 kV, 20 nA, using counting times of 5, 10, 5 sec. on background-peak-background, respectively. To prevent the known migration phenomenon of alkalis under the electron beam, a 30 µm defocused electron beam was used. Several points were analysed on each sample to test the homogeneity, and the mean value of all the measurements was calculated. The results were processed for matrix effects using the PHI(ρZ) absorption correction of the Probe programme (Donovan and Rivers, 1990). The measured accuracy for the analysed elements was better than 3%, while precision was between 1-2% and 2-3% for major and minor constituents, respectively. The results of the chemical analyses are reported in Table 2

RESULTS

Various glass chips were removed from each vessel/bead/spindle whorl/pendant in order to characterize the composition of all the different colored decorations, and consequently the number of analyzed samples is higher than the number of items considered. The chemical analyses are reported in Table 2.

The results of the chemical analyses show that all the analysed samples are silica soda lime glass with values of Na₂O ranging from 12 to 18.5%, with the exclusion of the yellow portion of three samples (MZ-09 and MZ-18) which exhibit slightly lower levels. Conversely, as reported in Figure 1, the levels of MgO and K₂O are very low, and for almost all the samples they never exceed 1%; only the blue portion of the beads MZ-20 and MZ-32 show, respectively, levels of magnesium and potassium oxides slightly higher than 1%. This data clearly indicates that all these items, independently of their typology were produced using natron as source of flux. This assessment is consistent with the percentages of SO₃

(from 0.10 to 0.49%), Cl (from 0.54 to 1.60%), and P_2O_5 (<0.12%) found in the samples. The plot reported in Figure 2 shows that the content of lime is relatively constant in the sample set, ranging from about 4 to 10%, with the exclusion of two samples (the yellow portion of pendant MZ-18 and the blue portion of sample MZ-20), while the levels of Al_2O_3 are more variable. In fact, along with a large group of samples showing levels of Al_2O_3 from 1.5% to 2.5%, the figure evidences some samples with very low aluminium contents - two samples from two pendants (MZ-18y and MZ-19b) and two portions of vessels (MZ-06y and MZ-09b) - and some others with rather high levels of this oxide - MZ-20b and MZ-32b. Manganese is present at trace levels in almost all the analyzed samples, only samples MZ-07b, MZ-09y, and MZ-20b show $MnO > 0.1\%$. Titanium levels are very low in all the sample set, but on average the values are higher than those found for MnO , ranging from 0.05 to 0.43%. The amounts of all the other oxides are mainly linked to the color and the opacity of the samples. The levels of iron show the widest range of variations: the blue portions of the pendants MZ-18 and MZ-19 FeO reach levels of 8.50 and 6.09%, respectively, indicating the clear intentional addition of this element. In all the other blue samples iron oxides are lower, but in most cases high enough to be considered as intentionally added, or at least not introduced as an impurity in the sands. In twelve of the remaining eighteen blue samples FeO percentages are higher than 1%. Iron oxide is also relatively high in almost all the yellow samples and in two turquoise decorations (MZ-02t and MZ-22t). Conversely, it is unexpectedly low in the green glass, where FeO levels never exceed 1%. Even if in general the green color is due to the presence of iron ions dispersed in the matrix, for one of these samples it is possible to hypothesize that the origin of the color is the result of high levels of other transition elements (Cu for sample MZ-34g, which is dark green in color). The other two green samples do not contain additional transition elements, so it is possible to hypothesize that the color derives from low quantities of strongly reduced iron. Copper oxide is present in high levels, often exceeding 2%, in almost all the turquoise

1 samples. Only three of these, MZ-02t, MZ-22t, and MZ-29t, contain Cu_2O at levels below
2 0.5%: these samples seem to owe their color to a combination of copper and cobalt ions.
3
4 Finally, and predictably, the highest levels of CoO are from the blue samples: even if cobalt
5 oxide in these samples is at levels of about 0.1%, this is sufficient to impart a deep blue
6
7 color, due to the high absorbance coefficient of this transition element. It is worth noting that
8
9 in the high-Fe blue portions of the two pendants MZ-18 and MZ-19, Co was not detected.
10
11

12 The presence of Sb and Pb in the analyzed samples is strictly related to the color and,
13 especially, to the opacity of the glass. In Figure 3 the levels of PbO and Sb_2O_3 are reported
14 for all the samples. From the plot it is clear that the yellow portions of all the items,
15 independently of typology, contain high levels of lead oxide and relatively high levels of
16 Sb_2O_3 . The highest levels of Sb are observed, conversely, for the turquoise samples, which, in
17 turn, do not contain Pb. Only two turquoise samples (MZ-27t and MZ-31t) contain low levels
18 of Sb_2O_3 . In addition to the turquoise decorations, the two blue samples MZ-22b and MZ-32b
19 (the latter already cited as an exception in Figures 1 and 2) also contain quite high levels of
20 antimony. High levels of antimony are also found in the single white sample analyzed (MZ-
21 02w).
22
23

24 The data for PbO and Sb_2O_3 are consistent with the results obtained in XRD experiments.
25
26 The X-ray diffraction patterns collected from turquoise samples show, in most cases, the
27 presence of crystals of CaSb_2O_6 and $\text{Ca}_2\text{Sb}_2\text{O}_7$. The low intensity of the diffraction peaks in
28 most cases suggests the presence of few and/or very small dispersed crystals. Unfortunately,
29 it was not possible to perform X-ray diffraction analyses on the single white sample or on the
30 two Sb bearing blue glass samples to confirm the presence of these phases. The X-Ray
31 analyses on the yellow samples revealed, as expected, the presence of crystals of $\text{Pb}_2\text{Sb}_2\text{O}_7$.
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

61 DISCUSSION

62
63
64
65

1 The alkali composition of the analysed samples allows them to be classified as silica soda
2 lime glass produced with natron as flux (Fig. 1). The majority of the glass samples contain
3 alumina between 1.5 and 2.5% and calcium oxide between 4 and 9%. It is reasonable to
4 suppose that the samples were produced starting from a silicatic sand containing feldspars
5 and carbonates (Sayre and Smith, 1961, 1967).
6

7 In Figures 4 and 5 a comparison is provided between the chemical analyses of the samples
8 from Mozia considered in this work, and those of the coeval samples from the Etruscan
9 context in Northern Italy (Arletti et al., 2010). It is clear in both diagrams that - excluding the
10 outlier samples (in particular the pendants) - the chemical composition of the two sample
11 sets is extremely similar, as regards both the sand and flux components.
12

13 These data are also consistent with the studies reported by Shortland and Schroeder (2009)
14 on Iron Age unguentaria of the Mediterranean Group I originating from Pichvnari in Georgia
15 showing a very homogenous composition as regards aluminium, calcium, titanium and
16 manganese. This leads to the hypothesis that almost all the glass were produced starting from
17 the same type of sand. All these glass could derive from coastal sand from the Levant or
18 from a similar source of sand. Similar results were obtained by Gratuze (2009) and by
19 Gratuze and Picon (2006) and Gratuze and Billaud (2003) for Iron Age beads.
20

21 It is, however, interesting to note some differences found some glass of the sample set, since
22 they represent exceptions and exhibit some peculiar traits. The major differences are found
23 among the pendants. Some of them show a particular composition regarding both major
24 components and coloring elements. Sample MZ-19b and MZ-18y, for example, have the
25 lowest levels of aluminum when compared with the other items.
26

27 Another peculiarity found in the pendants regards the transition elements employed for
28 coloration: two of the three blue samples, MZ-18b and MZ-19b, owe their hue to the
29 presence of high levels of iron. This is quite unusual, since in all the other samples the dark
30 blue color is essentially due to the presence of hundreds of ppm of cobalt, which is not
31

1 detected in these samples. This indicates that along with the use of different raw materials
2 employed for the production of the base glass, also different techniques for the glass coloring
3 were employed for the production of these samples. However the number of analyses is too
4 low to do reliable hypotheses regarding their origin.
5
6
7

8 All the opaque glass have been produced employing Sb based opacifiers, consistently with
9 their chronology: Ca-antimoniates for turquoise, blue and, possibly for white samples, and Pb
10 antimoniates for yellow samples. It is well known that calcium antimoniates were used from
11 the 2nd millennium BC as opacifiers for blue and white glass. The calcium antimoniates are
12 neo-formation phases produced by adding antimony (probably as oxide) to a lime-rich glass
13 batch or to raw glass (Shortland, 2002; Arletti et al., 2006a; 2006b).
14
15
16

17 Lead antimoniate, was employed almost from the beginning of glass production (1500 BC)
18 until the 4th century AD (Turner and Rooksby, 1959; Tite et al., 2007) to produce opaque
19 yellow glass.
20
21
22

23 The most reliable hypothesis regarding the technique employed for the production of
24 this glass suggests that $Pb_2Sb_2O_7$ was produced by adding a combination of roasted lead and
25 antimony ore minerals to the glass batch - thus producing oxides - with a lead excess
26 (Shortland, 2002; Rehren, 2002).
27
28
29
30

31 CONCLUSIONS

32 It could be hypothesized that the vessels and most of the beads found on Mozia and those
33 recovered at the Northern Italian sites, for which a Greek origin was already presumed,
34 derive from the same production site. Different origin, probably a Phoenician-Punic origin,
35 can be supposed for the pendants, even if the low number of items do not allow a precise
36 hypothesis to be formulated and this issue require further analyses.
37
38
39
40
41
42

43 The chemical and archaeometrical studies, even if providing important information, do not
44 answer all the questions raised regarding trade, traders, and final users of the items. For the
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

vessels of the Mediterranean I Group it is well known that they were traded along with Attic ceramic artifacts. While it is known that Spina was an Etruscan goods depot for Greek and Mediterranean trade, in Sicily the situation is more complex, since the dominant Greek presence makes interpretation of the trade of glass items less straightforward.

From the 7th century BC the island of Mozia was, probably, on the connecting route between the Tyrrhenian Sea and Eastern Mediterranean regions, but it is also worth noting that some documents seem to indicate a possible presence of Rhodian people among the Phoenician traders (Spanò Giammellaro, 2008a). Furthermore, from the 5th century BC the documented trade between Athens and Carthage allowed a spread of Attic ceramic artifacts into the Phoenician area under the control of Carthage (Acquaro, 2003).

The presence of Greek culture and probably a Greek community is documented on Mozia island from the 6th century BC: Diodoro Siculo, in his writings, relates that on Mozia a Greek community, worshipping their idols in meeting houses, was present (Biblioteca Storica, XIV, 53,2). Several items recalling Greek cults are documented in various Phoenician colonies. It is, however, not easy to establish if these cults were linked to the presence of an “original” Greek ethnic group on the island, or to Phoenician, Punic or Carthaginian families coming from Carthage or Eastern cities where the Greek culture was already established (Acquaro and De Vita, 2004-2005; De Vita, 2009). It is clear that only analysis of the archaeological context will further help resolve these questions.

Acknowledgements

Professor Enrico Acquaro (Università di Bologna), Dr. Rossella Giglio (Soprintendenza ai Beni Archeologici di Trapani), Fondazione Giuseppe Whitaker (Palermo), Dr. Maria Pamela Toti (Museo Whitaker) are acknowledged for providing the samples.

REFERENCES

- Acquaro, E., 2003. Per un portolano fenicio. In: *Archeologia del Mediterraneo. Studi in onore di Ernesto De Miro*. Bibliotheca Archaeologica 35, Roma, pp. 21-36.
- Acquaro, E., De Vita, P., 2004-2005. Note iconografiche: su alcune arule di Mozia. *Byrsa*, 1-4, 93-123.
- Acquaro, E., Savio, G. 2004. 'Scavi e ricerche a Mozia – I. Agorà Edizioni, Sarzara.
- Arletti, R., Ciarallo, A., Quartieri, S., Sabatino, G., Vezzalini, G., 2006a. Archaeometrical analyses of game counters from Pompeii. In: Maggetti, M., Messiga, B. (Eds.), *Geomaterial in Cultural Heritage*. Geological Society Special Publication 257. Geological Society of London, London, pp. 175-186.
- Arletti, R., Quartieri, S., Vezzalini, G., 2006b. Glass mosaic tesserae from Pompeii: an archaeometrical investigation. *Periodico di Mineralogia* 76, 25-38.
- Arletti R., Maiorano C., Ferrari D., Vezzalini G., Quartieri S., 2010. The first archaeometric data on polychrome Iron Age glass from sites located in Northern Italy. *Journal of Archaeological Science* 37, 703-712.
- De Vita, P. 2009. Dioniso a Mozia: culti pubblici e privati. www.fenici.unibo.it.

1 Donovan, J.J., Rivers, M.L., 1990. PRSUPR da PC-based automation and analysis software
2 package for wavelength-dispersive electron-beam microanalysis. In: Michael, J.R., Ingram, P.
3 (Eds.), Microbeam Analysis 1990. San Francisco Press, San Francisco, pp. 66-68.
4
5
6
7
8

9 Gratuze, B., Billaud, Y., 2003. La circulation des perles en verre dans le Bassin Méditerranéen,
10 de l'Age du Bronze moyen jusqu'au Hallstatt. In : Foy, D. and Nenna, M.D. (Eds.), Echanges et
11 commerce du verre dans le monde antique. Actes colloque AFAV, Aix-en-Provence et Marseille
12 2001. Mergoïl Editor., Montagnac, pp. 11-15.
13
14
15
16
17
18
19
20

21 Gratuze, B., 2009. Les premier Verres au Natron retrouvés en Europe Occidentale:
22 composition chimique et chrono-typologie. In: Antwerp, Janssens, K.,
23 Degryse, P., Cosyns, P., Caen, J., Van't dack, L. (Eds.), Annales du 17eme Congres
24 de l'Association Internationale pour l'Histoire du Verre, pp. 8-14.
25
26
27
28
29
30
31
32
33

34 Gratuze, B., Picon, M., 2006. Utilisation par l'industrie verrière des sels d'aluns des
35 oasis égyptiennes au début du premier millénaire avant notre ère. In: Brun, J.-P.
36 (Ed.), L'Alun de Mediterranie. Institut Français de Naples, pp. 269-276.
37
38
39
40
41
42

43 McLune, W. F., 1989. Powder Diffraction File: Inorganic Phases; JCPDS International Centre
44 for Diffraction Data: Swarthmore, PA.
45
46
47
48
49
50

51 Rehren, Th, 2002. Comment I on Mass, J.L., Wypysky, M.T. Stone R.E., 2002, Malkata and
52 Lisht glassmaking technologies: toward a specific link between second millennium BC metallurgist
53 and glassmaker. Archaeometry 44, 67-82.
54
55
56
57
58
59

60 Sayre, E.V., Smith, R.W., 1961. Compositional categories of ancient glass. Science 133,
61
62
63
64
65

1824-1826.

Sayre, E.V., Smith, R.W., 1967. Some materials of glass manufacturing in antiquity.

In: Levey, M. (Ed.), *Archaeological Chemistry: A Symposium*. University of Pennsylvania Press, Philadelphia, PA, pp. 279-311.

Shortland, A.J., 2002. The use of antimonate colorants in Early Egyptian Glass. *Archaeometry* 44, 517-530.

Shortland, A., Schroeder, H., 2009. Analysis of first millennium BC glass vessels and beads from the Pichvnari necropolis, Georgia. *Archaeometry* 51, 947-965.

Spanò Giammellaro, A., 2004. Il vetro preromano della Sicilia nella prospettiva mediterranea. In: Basile, B., Carreras Rossell, T. Greco, C. Spanò Giammellaro, A. (Eds.), *Glassway. Il vetro: fragilità attraverso il tempo*, Filippo Angelica Editore, Ragusa, pp. 25-40.

Spanò Giammellaro, A. 2008a. I vetri preromani. In: De Simone, R., Toti, M.P. (Eds.), *La collezione Whitaker*, I, Fondazione Whitaker, Palermo, pp. 89-145.

Spanò Giammellaro, A. 2008b. I vetri della Sicilia punica. *Corpus delle antichità fenicie puniche*, Bonsignori Editore, Roma.

Tite, M., Pradell, T., Shortland, A., 2007. Discovery, production and use of tin-based opacifiers in glasses, enamels and glazes from the late Iron Age onwards: a reassessment. *Archaeometry* 50, 67-84.

1 Triantafyllidis, P., 2003. Classical and Hellenistic workshop from Rhodes. In: Foy, D., Nenna,
2 M.D. (Eds.), *Echanges et commerce du verre dans le monde antique*. Actes du colloque AFV, Aix-
3 en-Provence et Marseille 2001. Mergoil Editor, Montagnac, pp. 131-138.
4
5
6
7

8
9
10 Turner, W. E. S., and Rooksby, H. P., 1959. A study of opalising agents in ancient opal glasses
11 throughout three thousand four hundred years. *Glastechnische Berichte* 32K, VII, 17-28.
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Table 1: Summary of the analysed samples (Abbreviations: t=turquoise; b=blue; y=yellow, w=white; g=green, Masc.=masculine; Anim.= animal shaped).

Table 2: Chemical analyses (oxides wt%) obtained by EMPA. The labels are the same reported in Table 1. (n.d. = not detected)

Figure. 1. K₂O vs. MgO contents of all the analysed samples. Outsider samples are labelled.

Figure 2: CaO vs. Al₂O₃ contents of all the analysed samples. Outsider samples are labelled.

Figure 3: PbO vs. Sb₂O₅ contents for the analysed samples grouped by colour.

Figure 4: CaO vs. Al₂O₃ contents for the samples analyzed here in comparison with those reported by Arletti et al (2010) for the Spina and Bologna sites.

Figure 5: K₂O vs. Na₂O contents for the samples analyzed here in comparison with those reported by Arletti et al (2010) for the Spina and Bologna sites.

Table 1

VESSELS					
Sample	Typology	Colors	N. ref	Analysed Portion	
				Label (Table 2)	color
MZ-02	Alabastron	Blue with turquoise and white decorations	803	MZ-02b	blue
				MZ-02w	white
				MZ-02t	turquoise
MZ-03	Amphoriskos	Blue with yellow decorations	805	MZ-03y	yellow
MZ-04	Aryballos	Blue with turquoise and yellow decorations	807	MZ-04b	blue
				MZ-04y	yellow
MZ-05	Aryballos	Light blue with turquoise and yellow decorations	809	MZ-05y	yellow
MZ-06	Oinochoe	Blue with white and yellow decorations	812	MZ-06b	blue
				MZ-06y	yellow
MZ-07	Oinochoe	Blue with yellow decorations	813	MZ-07b	blue
MZ-08	Oinochoe	Blue with white and yellow decorations	814	MZ-08b	blue
MZ-09	Unguentarium	Blue with yellow decorations	817	MZ-09b	blue
				MZ-09y	yellow
MZ-10	Aryballos	Blue with turquoise and yellow decorations	819	MZ-10b	blue
				MZ-10t	turquoise
MZ-11	Oinochoe	Blue with turquoise and yellow decorations	824	MZ-11b	blue
				MZ-11y	yellow
MZ-12	Amphoriskos	Blue with white and yellow decorations	826	MZ-12b	blue
MZ-13	Aryballos	Light blue Blue with turquoise and yellow decorations	829	MZ-13b	blue
MZ-14	Amphoriskos	Blue with yellow decorations	830	MZ-14b	blue
				MZ-14y	yellow
MZ-15	Amphoriskos	Blue with yellow decorations	831	MZ-15y	yellow
MZ-16	Aryballos	Blue with turquoise and yellow decorations	833	MZ-16b	blue
				MZ-16y	yellow
				MZ-16t	turquoise
MZ-17	Amphoriskos?	Blue with turquoise decorations	834	MZ-17b	blue
				MZ-17t	turquoise
BEADS AND PENDANTS					
MZ-18	Masc. Pendant	Blue and yellow	1832	MZ-18b	blue
				MZ-18y	yellow
MZ-19	Anim. Pendant	Blue and white	1833	MZ-19b	blue
MZ-20	Bead	Blue with white and yellow decorations	906	MZ-20b	blue
MZ-21	Eyes bead	Turquoise with blue and white decorations	907	MZ-21t	turquoise
				MZ-21b	blue
MZ-22	Bead	Turquoise with blue and white decorations	910(1)	MZ-22t	turquoise
				MZ-22b	blue
MZ-23	Melon shape bead	Green	6062	MZ-23g	green
MZ-24	Eyes bead	Turquoise with blue and yellow decorations	882	MZ-24b	blue
MZ-26	Bead	Turquoise	909(1)	MZ-26t	turquoise
MZ-27	Eyes bead	Turquoise with blue and white decorations	909(2)	MZ-27t	turquoise
MZ-29	Eyes bead	Turquoise with blue and white decorations	910(3)	MZ-29t	turquoise
MZ-31	Eyes bead	Turquoise with blue decorations	912(1)	MZ-31t	turquoise
MZ-32	Bead	Dark blue	912(2)	MZ-32b	blue
MZ-33	Spindle whorl	Green transparent	912(3)	MZ-33g	gree
MZ-34	Bead	Dark green transparent	912(4)	MZ-34g	dark green
MZ-35	Masc. Pendant	Blue with yellow decorations	1834	MZ-35b	blue
MZ-37	Eyes bead	Turquoise with blue and white decorations	2262	MZ-37t	turquoise

Table 2

LINE	SiO ₂	Al ₂ O ₃	TiO ₂	MnO	MgO	FeO	CaO	Na ₂ O	K ₂ O	Sb ₂ O ₃	Cu ₂ O	PbO	SnO ₂	CoO	SO ₃	Cl	Cr ₂ O ₃	P ₂ O ₅	Totals
MZ-02b	67.94	2.25	0.05	n.d.	0.42	1.08	6.39	17.51	0.28	0.90	0.15	0.04	n.d.	0.07	0.10	1.26	n.d.	0.04	98.50
MZ-02t	69.37	2.33	0.07	0.02	0.45	1.10	6.95	17.32	0.34	0.77	0.12	0.10	n.d.	0.09	0.10	1.34	n.d.	0.05	100.53
MZ-02w	66.70	2.18	0.07	n.d.	0.42	1.03	6.73	17.32	0.30	0.87	0.10	0.07	n.d.	0.13	0.11	1.22	n.d.	0.04	97.30
MZ-03y	57.69	1.85	0.06	0.03	0.28	1.01	5.09	13.17	0.31	1.79	0.07	18.48	n.d.	0.02	0.24	1.27	n.d.	0.05	101.42
MZ-04b	66.53	2.31	0.06	0.09	0.34	2.20	7.05	17.50	0.58	0.70	0.40	1.28	n.d.	0.07	0.28	0.76	n.d.	0.07	100.21
MZ-04y	56.00	1.82	0.06	n.d.	0.25	1.05	5.44	15.27	0.43	1.56	0.06	16.26	n.d.	0.01	0.27	0.71	0.02	0.03	99.27
MZ-05y	54.81	1.91	0.05	n.d.	0.30	1.07	6.79	11.96	0.64	1.93	0.04	18.07	n.d.	0.01	0.19	0.89	n.d.	0.06	98.71
MZ-06b	69.68	1.97	0.43	0.08	0.71	1.66	7.81	15.62	0.49	0.17	0.27	0.27	n.d.	0.15	0.28	1.00	n.d.	0.10	100.69
MZ-06y	58.05	1.23	0.13	n.d.	0.40	1.90	4.99	13.35	0.27	1.69	n.d.	16.95	n.d.	0.01	0.25	0.60	0.02	0.04	99.90
MZ-07b	68.34	2.37	0.06	0.63	0.43	0.68	7.46	18.46	0.60	0.02	0.20	0.03	n.d.	0.04	0.36	1.10	n.d.	0.05	100.81
MZ-08b	70.29	1.82	0.18	0.06	0.63	1.62	7.30	16.21	0.43	0.03	0.19	0.14	n.d.	0.16	0.21	1.33	n.d.	0.05	100.64
MZ-09y	52.40	1.76	0.06	0.25	0.36	1.54	4.33	11.00	0.56	1.92	0.15	26.56	0.05	0.01	0.30	0.63	n.d.	0.04	101.91
MZ-09b	74.10	1.02	0.15	0.03	0.55	0.60	6.17	18.06	0.29	0.02	0.03	0.09	n.d.	0.02	0.19	1.47	0.02	0.06	102.86
MZ-10b	67.09	2.36	0.09	n.d.	0.89	1.72	8.19	18.33	0.49	0.08	0.53	0.13	n.d.	0.20	0.49	0.92	n.d.	0.05	101.57
MZ-10t	64.21	2.05	0.06	0.02	0.84	0.76	7.94	16.73	0.43	1.91	2.07	0.44	0.13	0.02	0.35	0.61	0.02	0.03	98.60
MZ-11b	71.62	2.14	0.04	n.d.	0.43	0.88	5.91	16.16	0.74	0.12	0.17	0.06	n.d.	0.07	0.10	0.81	n.d.	0.02	99.29
MZ-11y	57.62	1.83	0.07	n.d.	0.30	1.44	5.37	13.56	0.53	2.32	0.14	15.51	n.d.	0.01	0.18	0.92	n.d.	0.05	99.88
MZ-12b	70.25	2.12	0.06	0.02	0.47	1.95	6.76	14.78	0.56	0.04	0.35	0.08	0.02	0.10	0.29	0.53	n.d.	0.07	98.44
MZ-13b	67.09	2.33	0.07	0.02	1.00	1.81	8.74	18.48	0.48	0.04	0.25	0.09	n.d.	0.13	0.43	0.64	n.d.	0.05	101.66
MZ-14y	58.92	1.86	0.04	0.02	0.31	0.80	4.06	14.56	0.33	1.46	0.05	16.17	n.d.	0.04	0.18	0.74	0.04	0.04	99.64
MZ-14b	69.72	2.22	0.07	0.03	0.57	1.08	7.74	15.82	0.53	0.04	0.14	0.06	n.d.	0.15	0.18	0.98	n.d.	0.05	99.39
MZ-15y	55.91	1.88	0.05	0.02	0.46	0.89	5.48	14.62	0.44	1.50	0.10	16.09	n.d.	0.01	0.32	0.59	n.d.	0.03	98.39
MZ-16b	65.69	2.35	0.08	0.02	0.96	2.53	8.13	17.67	0.53	0.04	0.41	0.13	n.d.	0.14	0.42	0.67	n.d.	0.05	99.84
MZ-16y	58.28	1.95	0.06	0.04	0.37	1.32	7.92	12.75	0.35	1.41	0.12	14.98	n.d.	0.00	0.12	1.14	0.04	0.06	100.93
MZ-16t	63.33	2.27	0.08	n.d.	0.59	0.40	9.49	14.66	0.46	4.07	2.75	0.11	0.04	0.01	0.40	0.86	n.d.	0.03	99.56
MZ-17b	68.06	1.90	0.05	0.02	0.34	1.50	6.44	18.41	0.38	0.32	0.35	0.09	n.d.	0.24	0.18	1.28	n.d.	0.02	99.58
MZ-17t	64.73	1.88	0.07	n.d.	0.43	0.34	6.61	18.03	0.31	2.73	3.28	0.20	n.d.	0.02	0.23	0.98	n.d.	n.d.	99.89
MZ-18b	61.89	1.52	0.12	0.07	0.51	8.50	8.75	16.42	0.34	0.07	0.09	0.54	n.d.	0.00	0.34	0.99	n.d.	0.12	100.28
MZ-18y	45.71	0.70	0.09	n.d.	0.23	1.82	2.43	10.86	0.28	2.16	0.07	35.60	n.d.	0.01	0.20	0.54	n.d.	0.04	100.75
MZ-19b	66.06	0.70	0.17	0.02	0.56	6.09	6.80	16.38	0.23	0.08	0.07	0.03	n.d.	0.00	0.37	1.33	0.02	0.10	99.02
MZ-20b	66.28	2.67	0.26	1.11	1.56	2.09	3.89	17.50	0.91	0.09	0.22	0.03	0.02	0.20	0.19	1.12	n.d.	0.07	98.21
MZ-21b	62.99	2.40	0.07	0.04	0.54	1.97	9.74	15.99	0.80	3.53	0.49	0.61	n.d.	0.62	0.33	0.87	0.02	0.05	101.06

Figure 1
[Click here to download high resolution image](#)

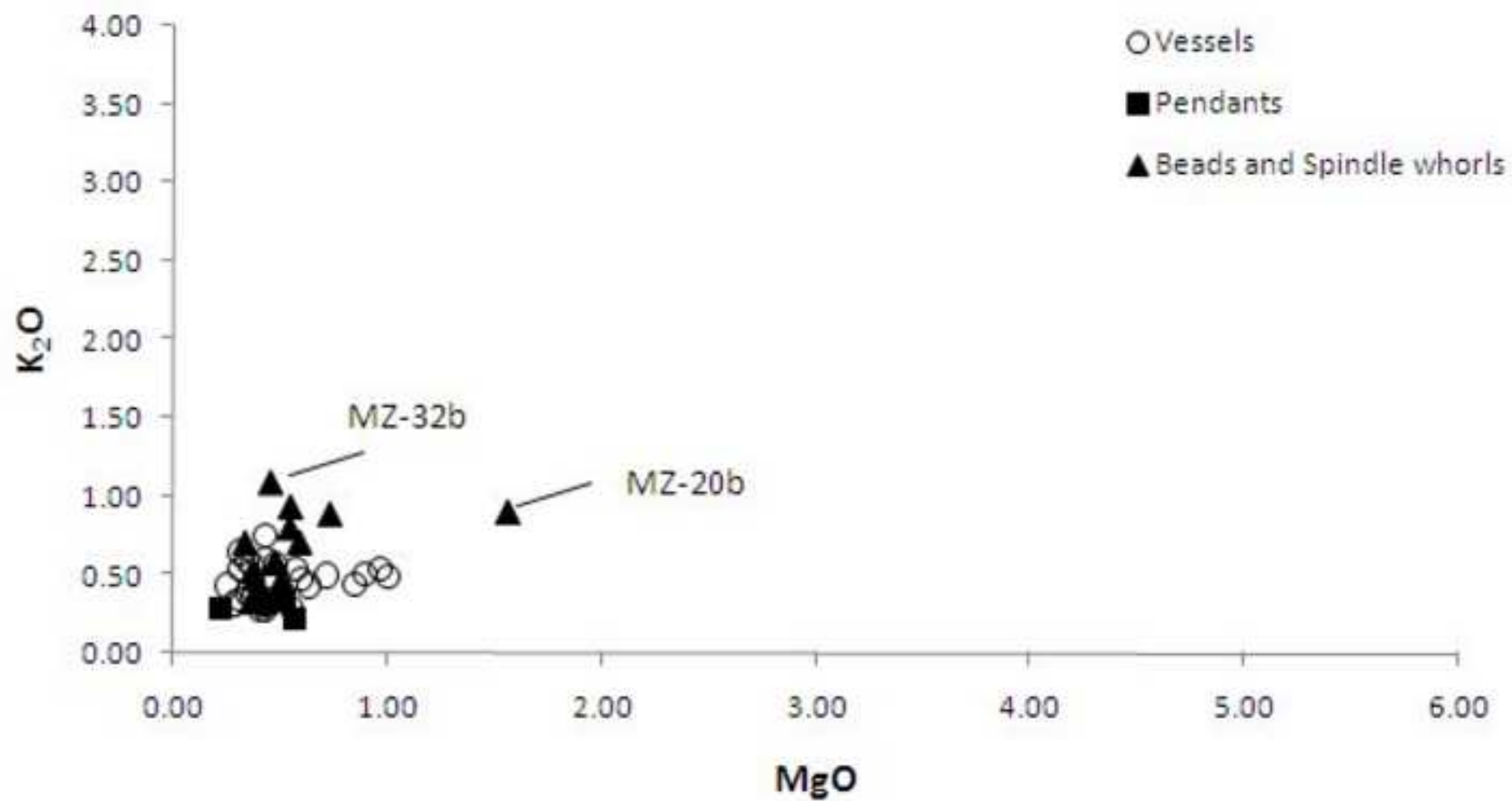


Figure 2
[Click here to download high resolution image](#)

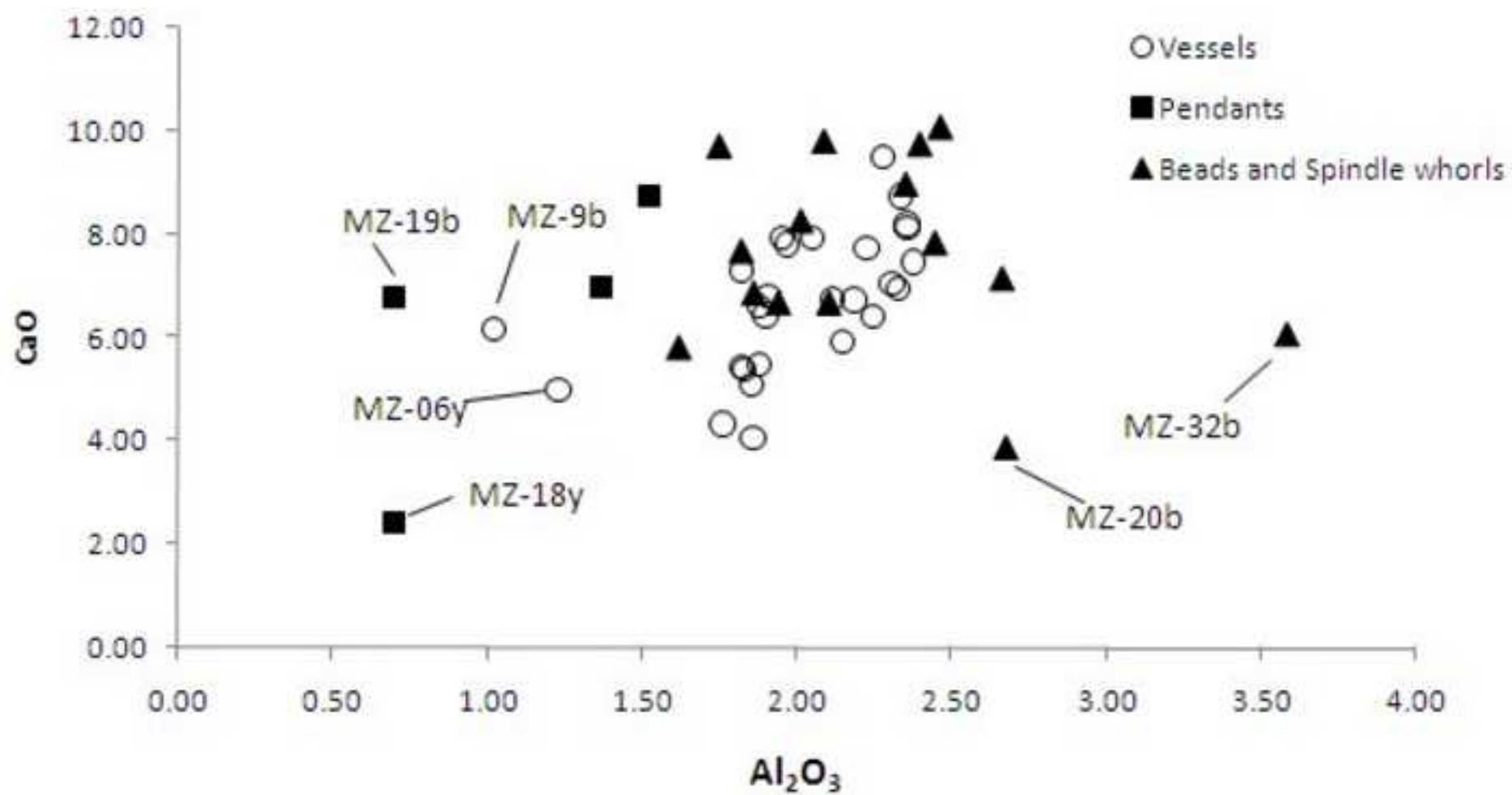


Figure 3
[Click here to download high resolution image](#)

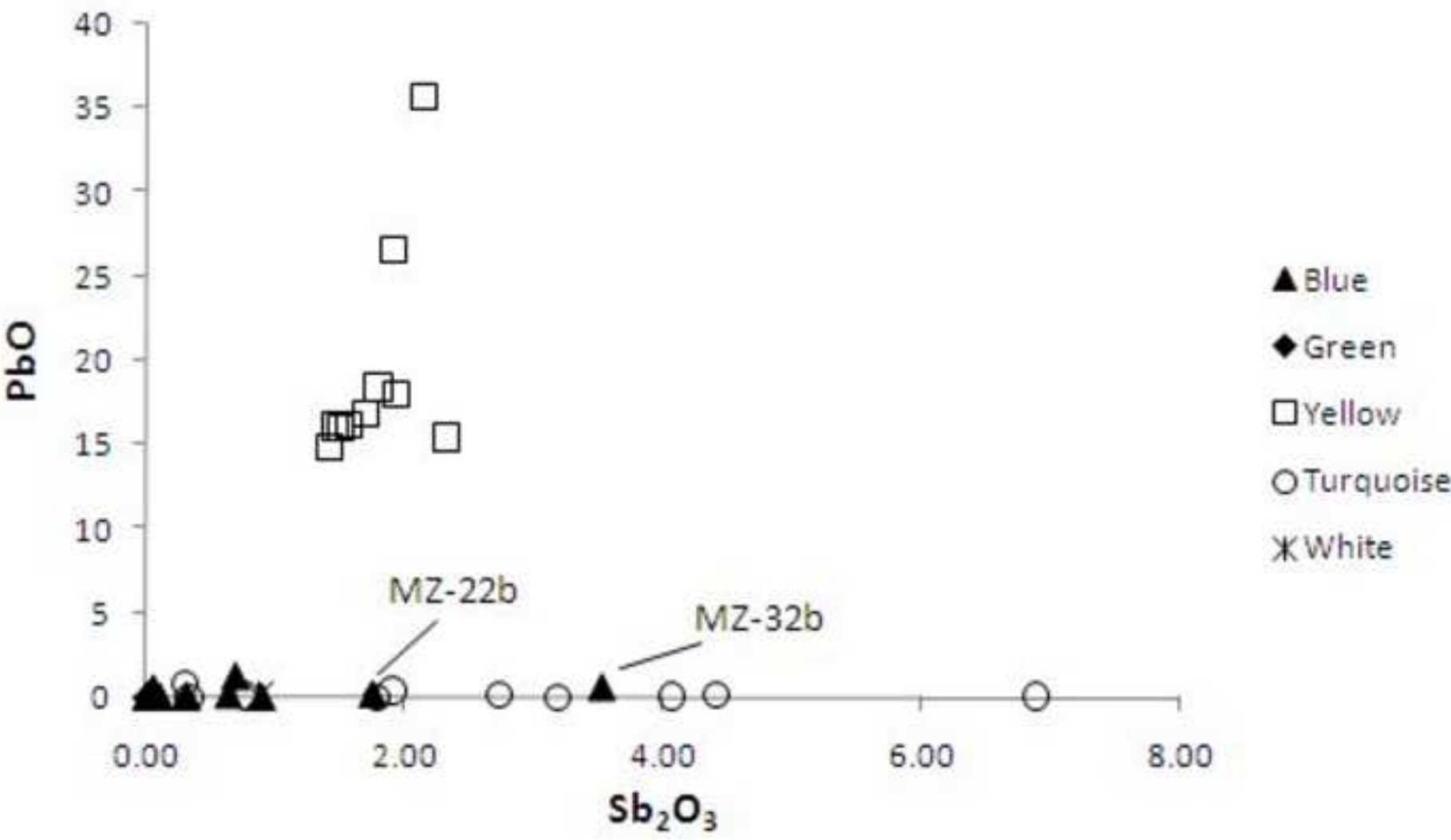


Figure 4

[Click here to download high resolution image](#)

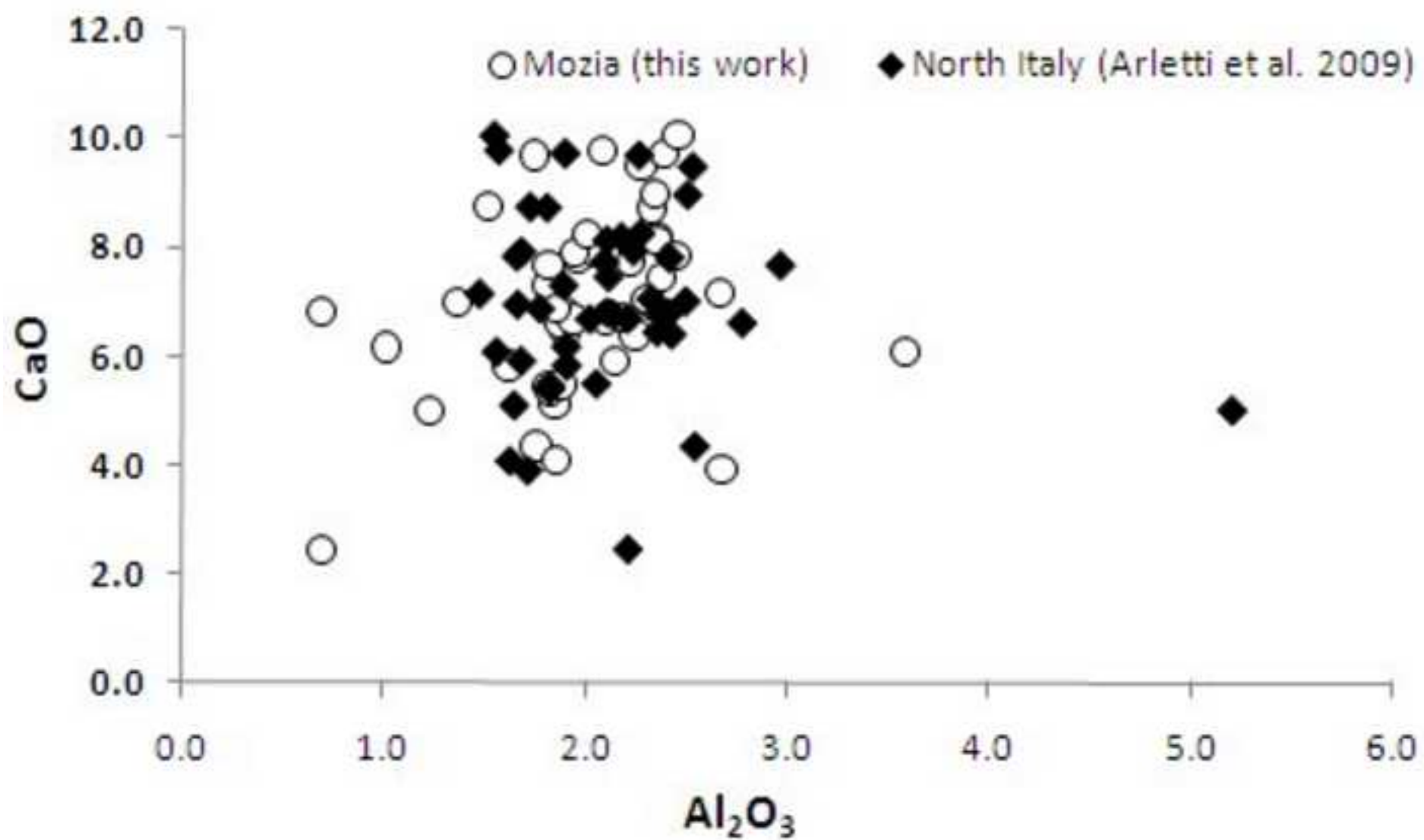


Figure 5

[Click here to download high resolution image](#)

