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

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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 .

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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

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*Highlights

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

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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.

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 .

Key words: Iron Age, glass, Phoenician-Punic, Mediterranean Group EMPA, XRD.

INTRODUCTION

The recent publication of three catalogues on Pre-Roman glass artefacts recovered in Sicily allowed the compilation of exhaustive documentation, previously unavailable for these materials (Spanò Giammellaro, 2004; 2008a; 2008b). In the first catalogue (Spanò Giammellaro 2004), a large set of glass samples from sites of Phoenician-Punic, Greek and Sicilian contexts is studied. The second catalogue, dedicated to glass of the Whitaker Museum in Mozia (Spanò Giammellaro, 2008a), treats a series of glass varieties from: i) archaic necropoleis of Mozia Island (end 8^{th} cen. - first half 6^{th} cen. BC); ii) Birgi necropoleis (second half 7^{th} cen. – 4^{th} cen. BC); iii) Lilibeo necropoleis (3^{rd} cen. BC-2^{nd} cen. AD). The third catalogue includes all glass coming from Phoenician-Punic contexts in Sicily (Spanò Giammellaro, 2008b).

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

The majority of the vessels belong to the so-called Mediterranean Group I, dated from the second half of the 6^{th} century to the first half of the 4^{th} century BC. The site of provenance of these glass artefacts is thought to be the island of Rhodes. This conclusion was reached on the basis of: i) the large number of vessels recovered on that island; ii) the presence at this site of glass scraps dated to the 5th century BC, and iii) the recovery of glass working furnaces in the following centuries (Triantafyllidis, 2003). However, it is not possible to exclude production sites for these artefacts in the Siro-Palestinian or Ionic area (Spanò Giammellaro, 2008a,b). Conversely, a Phoenician-Punic origin is presumed for the pendants (Spanò Giammellaro, 2004).

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

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

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

The aim of this work is to compare the results with those obtained for coeval artifacts from different cultural contexts - the Etruscan sites of Spina (Ferrara) and Bologna (Arletti et al., 2010) - in order to understand whether or not the artifacts of these two regions were produced at the same manufacturing site. In fact, while the Spina and Bologna sites, without 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 MoKα 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 Na_2O 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 K_2O 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 SO_3

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

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

The data for PbO and Sb_2O_3 are consistent with the results obtained in XRD experiments. The X-ray diffraction patterns collected from turquoise samples show, in most cases, the presence of crystals of $CaSb_2O_6$ and $Ca_2Sb_2O_7$. The low intensity of the diffraction peaks in most cases suggests the presence of few and/or very small dispersed crystals. Unfortunately, it was not possible to perform X-ray diffraction analyses on the single white sample or on the two Sb bearing blue glass samples to confirm the presence of these phases. The X-Ray analyses on the yellow samples revealed, as expected, the presence of crystals of $Pb_2Sb_2O_7$.

DISCUSSION

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

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

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

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

Another peculiarity found in the pendants regards the transition elements employed for coloration: two of the three blue samples, MZ-18b and MZ-19b, owe their hue to the presence of high levels of iron. This is quite unusual, since in all the other samples the dark blue color is essentially due to the presence of hundreds of ppm of cobalt, which is not detected in these samples. This indicates that along with the use of different raw materials employed for the production of the base glass, also different techniques for the glass coloring were employed for the production of these samples. However the number of analyses is too low to do reliable hypotheses regarding their origin.

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

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

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

CONCLUSIONS

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

The chemical and archaeometrical studies, even if providing important information, do not answer all the questions raised regarding trade, traders, and final users of the items. For the 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 Cartage 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, worshiping 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.

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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 Archaological Science 37, 703-712.

De Vita, P. 2009. Dioniso a Mozia: culti pubblici e privati. www.fenici.unibo.it.

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

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

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

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

McLune, W. F., 1989. Powder Diffraction File: Inorganic Phases; JCPDS International Centre for Diffraction Data: Swarthmore, PA.

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

Sayre, E.V., Smith, R.W., 1961. Compositional categories of ancient glass. Science 133, 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.

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

Turner, W. E. S., and Rooksby, H. P., 1959. A study of opalising agents in ancient opal glasses throughout three thousand four hundred years. Glastechnische Berichte 32K, VII, 17-28.

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. K_2O vs. MgO contents of all the analysed samples. Outsider samples are labelled.

Figure 2: CaO vs. Al_2O_3 contents of all the analysed samples. Outsider samples are labelled.

Figure 3: PbO vs. Sb_2O_5 contents for the analysed samples grouped by colour.

Figure 4: CaO vs. Al_2O_3 contents for the samples analyzed here in comparison with those reported by Arletti et al (2010) for the Spina and Bologna sites.

Figure 5: K_2O vs. Na_2O 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 bea*	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_2O_3	TiO_2	MnO	MgO	FeO	CaO	Na_2O	K_2O	Sb_2O_3	Cu_2O	PbO	SnO_2	CoO	SO_3	Cl	Cr_2O_3	P_2O_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
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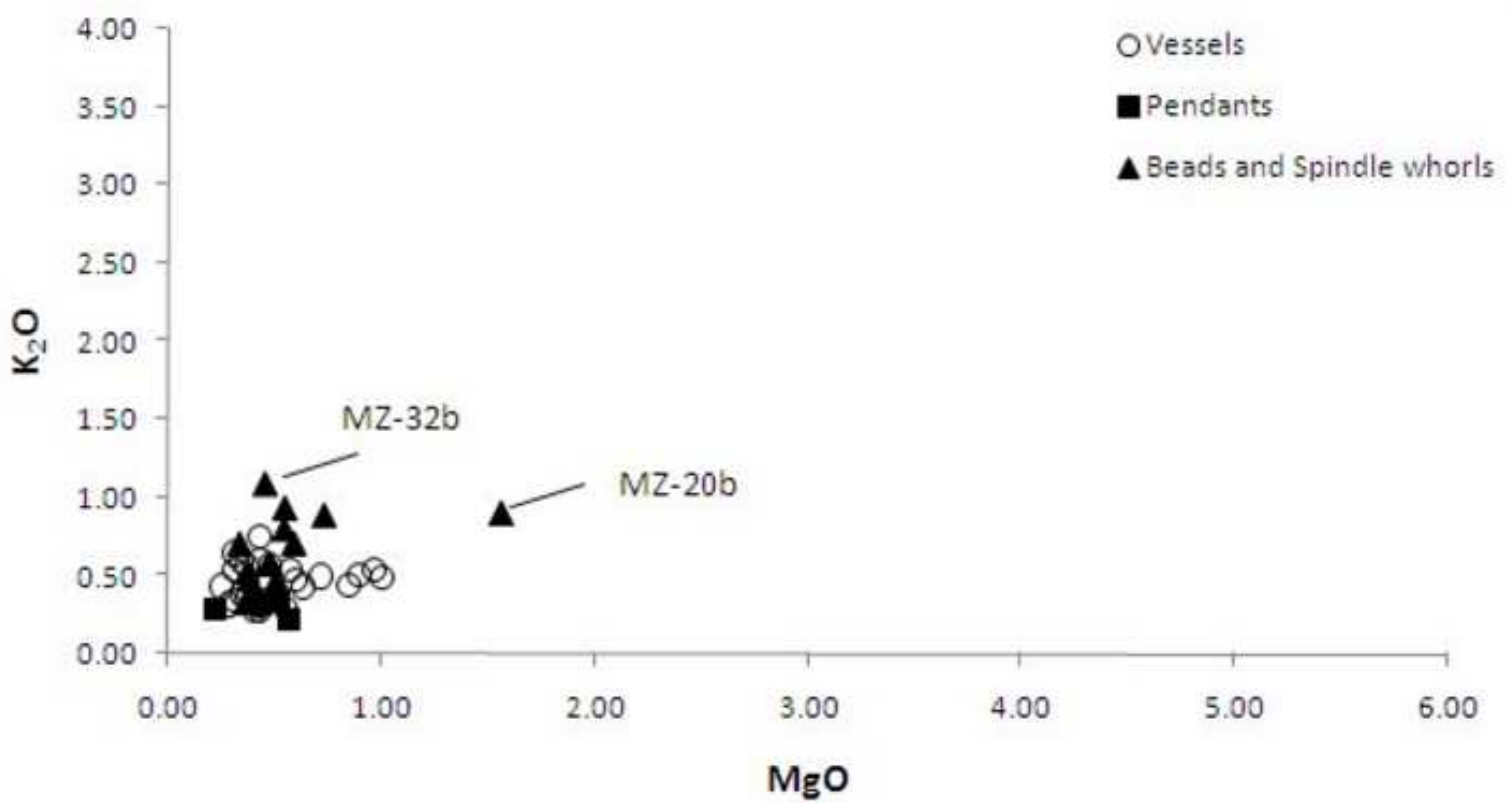

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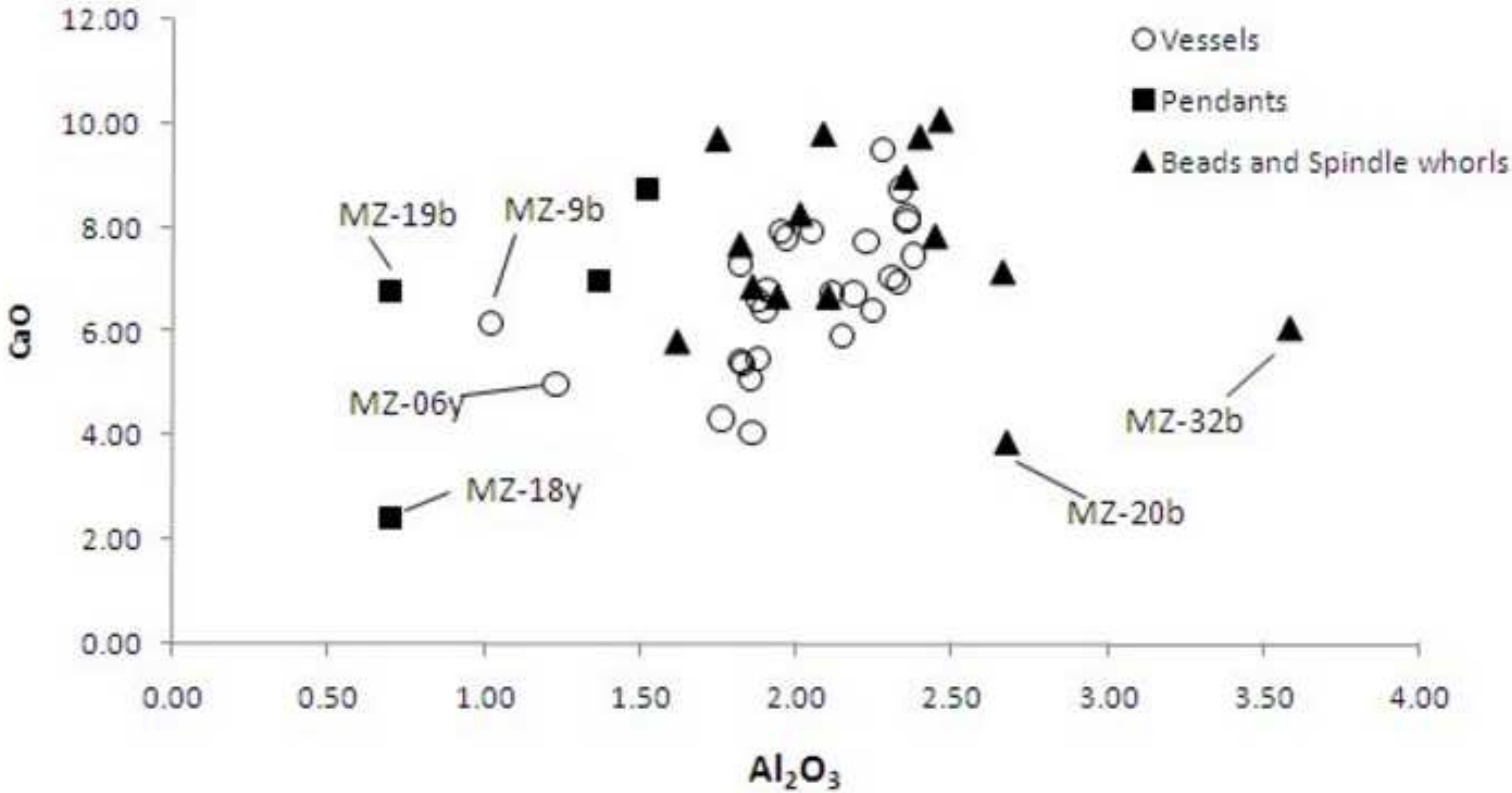

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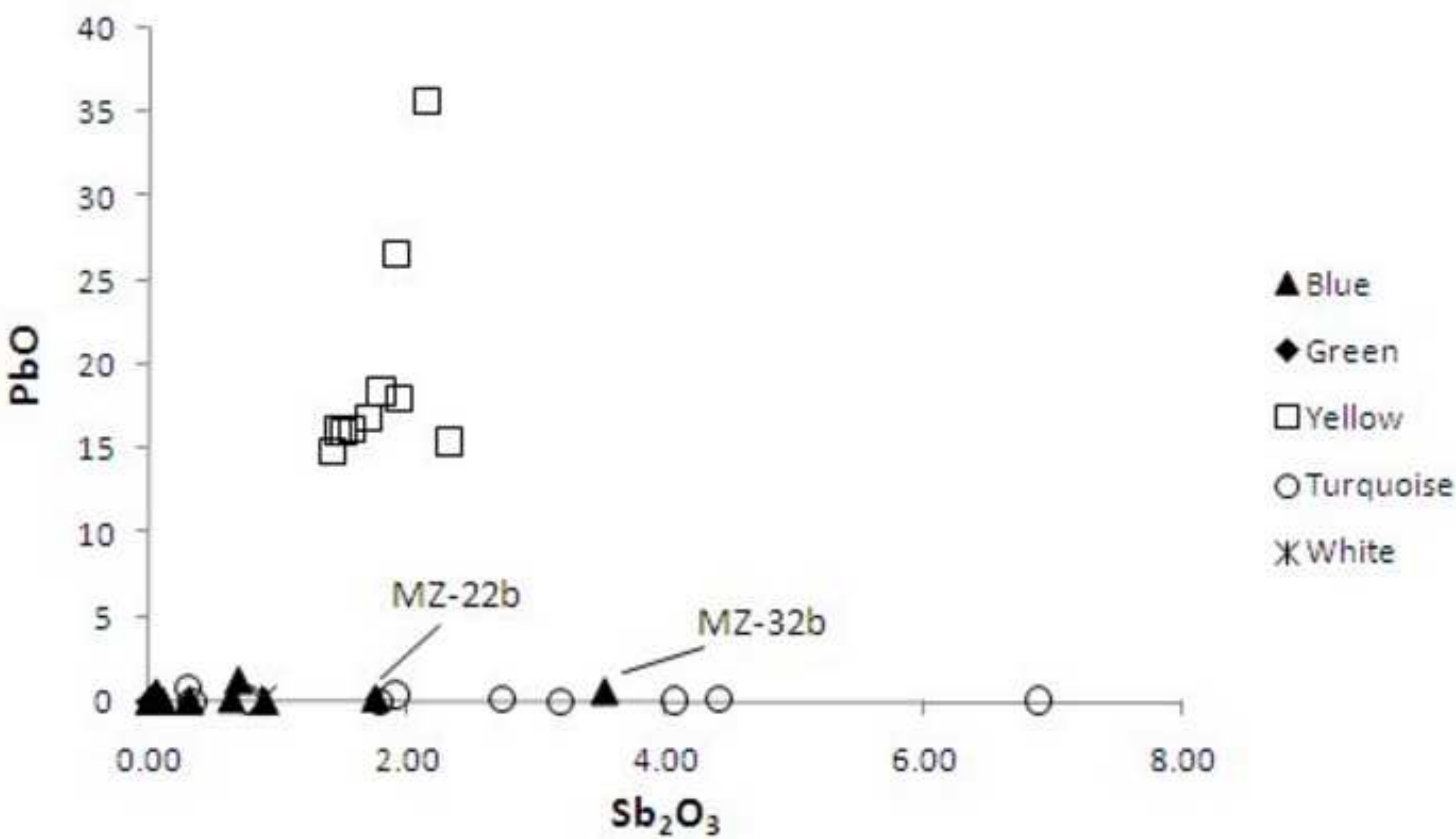

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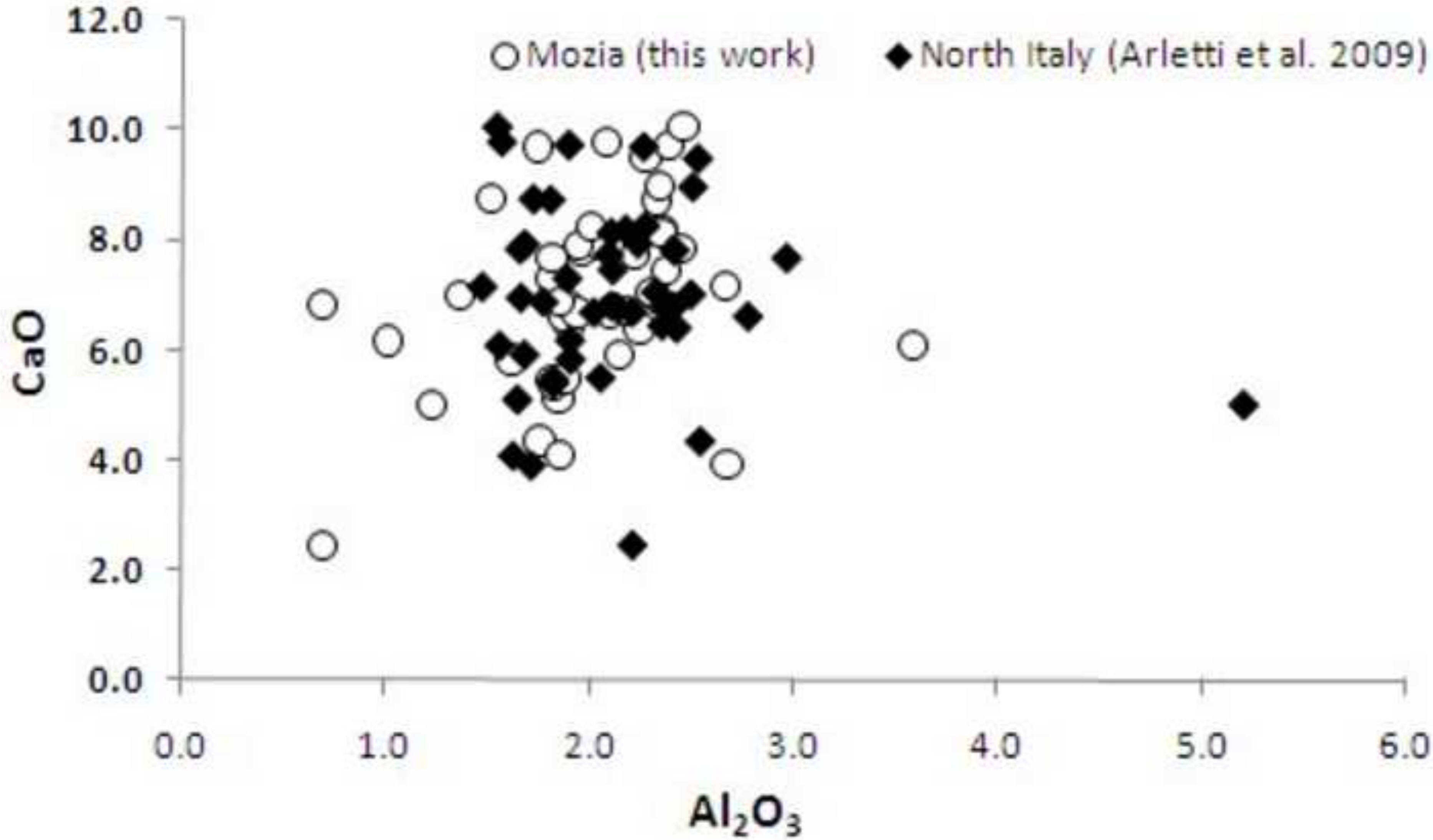

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