

LOMBARDIC GLASSWORKING IN TUSCANY

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Abstract

The excavations carried out since 2005 at Aiano-Torraccia di Chiusi, near San Gimignano (Siena) in Tuscany, by the team of the *Université catholique de Louvain*, directed by Prof Marco Cavalieri, have unearthed the remains of a Roman villa, dated between the 3rd and the end of the 5th c. or the beginning of the 6th c. AD. The complex, abandoned in the 6th c., was occupied by Lombardic (Langobard) artisans in the period between the 6th and the 7th c. AD. The artisans installed various kinds of workshops in the rooms of the representative part of the villa. The workshops were connected one to another and were provided with water from a complex system of channels, probably fed by a higher positioned reservoir. They include a ceramic workshop with a kiln and other spaces for different working stages, a large and well organized iron smithy, three rooms in which Roman glass *tesserae* and glass fragments were recycled and reworked, and apparently also a workshop for the production of copper-based items. The latter can only be hypothesized because of the remains recovered from some not yet fully excavated areas, behind the North/North-East wall, in which the waste from the workshops was dumped. Other remains suggest that in one or more rooms of the Roman architectural structure gold was also worked. Well organized and efficient Lombardic workshops for so many different productions, connected to each other and competently provided with water and possibly fuel for their various needs, dated to this period have never been identified and thoroughly studied before. This paper presents the analysis data of the materials from the excavation, which allows the reconstruction of the different glass working processes carried out on this site.

Introduction

The *Université catholique de Louvain* has been carrying out excavations in Tuscany at Aiano-Torraccia di Chiusi, near San Gimignano (Siena) since 2005, under the direction of Prof Marco Cavalieri (1, 2) . The ongoing campaigns have brought to light architectural structures belonging to a Roman villa, dated between the 3rd and the end of the 5th c. or the beginning of the 6th c. AD, in particular a representative room with 6 *exedrae* and a mosaic floor. Around this central structure there was an *ambulatio* (i.e. a circular passage) closed by curved walls forming 6 lobes (Fig.1).

The villa was situated in the Foci river valley in a strategic position. The river Foci was a tributary of the Elsa river and its valley represented an important connection to the *via Clodia* - which went from Rome to Lucca, over the Apennines and to the *Gallia Cisalpina* -, to the *via Francigena* (the pilgrimage route from Canterbury to Rome), and to the nearby town of Volterra and the sea (3, 4).

Based on a series of geodiagnostic surveys the villa was found to extend over an area of 1 hectare (5). The buildings were abandoned in the 6th c., but shortly after, between the 6th and the 7th c. AD the complex was occupied by a group of people who installed workshops of different kinds in the *ambulatio* and adjoining rooms. Finds such as belt- buckles and -fittings suggest that the artisans were the Langobards who invaded Italy in this period (4, 6).

Experimental

For this research, samples of remains of various nature, such as lead pieces, glass fragments and droplets, beads and differently coloured mosaic *tesserae* were collected. For the first explorative analysis of a group of *tesserae* only samples without traces of weathering and /or alteration due to burning were selected. A group of five to eight pieces was selected for each colour. The individual *tesserae* were first inspected visually and then compared with the specimens of the same group for the determination of the colour. The final determination was carried out by examining the samples under the microscope, to see if the *tesserae* belonging to the same group also showed the same features, such as inclusions, bubbles, striations or crystalline structures, spread through the glass

matrix. The optical observations confirmed the homogeneity of the differently coloured groups of *tesserae*. The chemical composition was determined by XRF. Unaltered and smooth *tesserae* surfaces were chosen for analysis. Special attention was given to the composition and manufacture of the various parts of the gold *tesserae*.

Transparent light and dark blue, greenish, red and yellowish Roman glass samples from Rome and Northern Italy, analyzed in the past by ICP-OES were employed as standards for XRF. For ICP analysis the glass fragments had been ground to fine powder and dissolved in hydrochloric (30 wt%), nitric (65 wt %) and hydrofluoric (40 wt%) acid, and diluted with distilled water, to prepare an ICP-OES solution, as described in the literature. (7, 8). The calculated relative error of the XRF measurements was around 10 % in the case of samples in good condition, but it increased to around 25 % in the case of altered pieces, such as the burnt *tesserae* (results not given in the table) and to a lesser degree some of the necklace beads. Each piece was analyzed at a minimum of three different spots. In the case of unclear results the analysis was repeated several times to obtain more reliable data. Differently coloured areas were analyzed three times each for a better determination of the colouring agents. The results are expressed as percentage concentrations of element oxides for major and minor elements. Trace elements are indicated as “*tr*” only. The composition results obtained by XRF at trace levels can only be indicative, but it gives important qualitative information on the type of glass, the colouring components and the production techniques employed for the production of *tesserae* and beads. Important indications were achieved also through the analyses of burnt *tesserae*, lead samples and heterogeneous samples from the excavations. More detailed analyses and publication of details are planned for the future. Aim of this paper is the reconstruction of the processes carried out in the glass workshop and in the adjoining rooms.

The workshops

The spaces inside the *ambulatio*, subdivided and readapted into rooms according to the necessities of the individual workshops, were provided with water from a system of channels, probably fed by

a higher positioned reservoir. During the excavation campaign 2007 areas for the production of ceramics with a cistern for clay purification, places for working and drying the artifacts were discovered, and a room with a large kiln (3, 4). The waste from the workshops was dumped behind the North/North-East wall and the remains indicate that somewhere in this area, besides iron in the already excavated smithy, copper-based alloys and gold were also worked.

In the 2008 campaign a glass furnace was excavated in the vestibule of the room with three absides and the mosaic floor, and this allowed the identification of the adjacent room A as the place for the recycling of the glass of mosaic *tesserae* (i.e. mosaic stones). In this room a pit containing around 6000 glass *tesserae* mixed with charcoal was found, and a water pit to wash them.

The glass furnace is not of the kind used in antiquity for the production of freshly made glass, but the classical kind of smaller furnace for melting down and working raw glass and cullet, in the production of glass objects. Even if the glass furnace was relatively small the objects produced here could also be of large size, depending on the skill of the glassmaker.

It is well known that in Roman times broken glass was collected and re-used. Both Iuvenalis (Sat., V, 46-48) and Martialis (Epigr., I, 41, 4; X, 3, 4) – the latter in two different passages - mention in their works that glass sherds were exchanged for sulphur matches by peddlers.

The habit of glass peddlers of collecting broken glass fragments and exchanging them for finished small glass objects or other merchandise is well documented for all the Middle Ages and until the 18th c. AD. An excellent example for this is a print, dated 1753, which shows a Venetian peddler selling glass bottles from Murano (the island in the lagoon of Venice, famous for its glass manufacture) and, as the text in old Venetian dialect clearly underlines, also collects broken glass for remelting (*Mi porto da Muran e tazze e goti, Bozze, ampolete e veri d'ogni sorte E togo anca in barato i veri roti - I bring from Murano cups and beakers, bottles and small flasks, and glass of all kinds, and I also take broken glass in exchange.* Translation by A.Giumlia-Mair). The woman on the right of the illustration is bringing down the stairs a container full of broken glass objects to be

bartered for some new bottles (Fig. 2).



Fig.2: Print, dated 1753 showing a Venetian peddler selling glass bottles from Murano and collecting broken glass. The woman is bringing broken glass to be bartered for new bottles. (from Stiaffini D., 1999, *Il vetro nel Medio Evo*, Fratelli Palombi Editori, Roma, 34)

Nevertheless, in the period to which the workshop of Aiano-Torraccia di Chiusi is dated, i.e. in the 6th and the 7th c. AD, the reuse of mosaic *tesserae* represents a very special kind of recycling.

After the 4th c. AD, there had been a general and progressive decay in technology in general and in particular in the production of glass. One of the symptoms of the loss of skill in the production of glass is the greenish colour of the glass artifacts manufactured after the end of the 4th c. AD, which seems to suggest that the practice of adding manganese and antimony oxides as decolouring agents to the molten glass had been forgotten or that the atmosphere and the temperature inside the glass furnace were not as carefully controlled as in the past. This loss of know-how has a parallel in the decrease of skills in the metallurgy and the mining techniques of the time and seems to be a rather common phenomenon all over Europe (9). And even if the techniques had not been completely

forgotten and greenish or yellowish and bubbly glass was produced for economic reasons - i.e. because less costly materials were used or the refining processes were shortened and insufficient as the market did not require better quality glassware - this fact still reflects the technology crisis of this time.

Many skills, recipes, technological tricks and abilities were doubtlessly lost in the time of the decline and fall of the Roman Empire. One of the pieces of knowledge lost was that of the production of opaque glass.

From Theophilus Presbyter, a monk who lived in Germany at the beginning of the 12th c. AD and wrote the “Treatise on Divers Arts” in Latin, we know that in Northern Europe, in Germany and France, the glass artisans were not able to produce opaque coloured glass and that they used Roman mosaic *tesserae*.

In Book 2, chapter 12, under the title “Various colours of non-translucent glass” he writes:

Different kinds of glass, namely white, black, green, yellow, blue, red and purple, are found in mosaic work of ancient pagan buildings. They are not transparent, but dense like marble, almost like little square stones, and out of this is made enamel on gold, silver and copper (alloys) and of this we will speak enough in the proper place. Also various small vessels are found of the same colours, which the Franks - who are very skilled in this work - collect, and they melt down a certain blue glass in their furnaces and add to this a small amount of clear and white glass and then produce precious blue glass sheets and very useful in windows. They also make the same out of purple and green glass (translation by A.Giumlia-Mair).

In the next chapter (2, 13) Theophilus describes the goblets made of blue glass, produced by melting mosaic *tesserae* by “Greeks”, i.e. in the Byzantine Empire.

These passages are very important for the understanding of the processes carried out in the villa of

Aiano-Torraccia di Chiusi, as the finds and the working remains indicate that already in the 6th -7th c. AD mosaic *tesserae* were collected from Roman buildings and used in the manufacture of glass objects, as described by Theophilus four or five centuries later.

It is also quite important to note that Theophilus' description even seems to suggest that glass *tesserae* might have been exported to countries over the Alps, where there were perhaps less mosaics in abandoned Roman villas than on the Italian territory.

The Langobards (or Lombards) were originally from the area between the river Elbe and the territory of the Germanic tribe of the Cheruscii along the Weser, but believed to be descendants of a tribe from the island Scadanan (Schonen) in Southern Sweden. They left their territory in the north of Germany and moved to the South, occupying the region *Pannonia* (the Hungarian Plain) and *Noricum* (part of today's Austria) first, and later invaded Italy. However Lombardic groups also remained in the areas they had previously occupied, for example in the Pannonian Plain, where they were subjugated first by the Huns and then by the Avars (10).

The group of people who settled in the area of Aiano-Torraccia di Chiusi and installed the workshops in the ruins of the Roman villa might have been some of the earliest artisans who employed *tesserae* to produce glass objects and perhaps even sold them as raw glass.

The glass workshop

The small glass furnace (Fig.3, L.65cm, W.46cm, H.55cm approx.) identified in the vestibule of the building wing with the absides is very similar, for size and type of construction, to the simple furnace for firing glass, described by Theophilus (Fig.4) around four centuries later. They are similar to common hearths and their size was relatively small, because in this way the temperature could be better controlled.

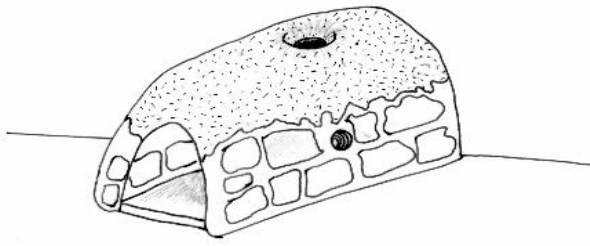


Fig. 3: Reconstruction of the glass furnace of Aiano/Torraccia, 7th c. AD. The walls are made of bricks, stones and tile fragments. The dome is made of clay mixed with snail-shell fragments.

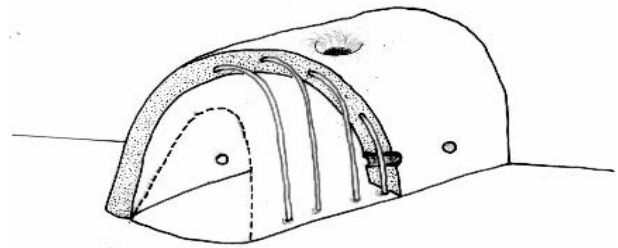


Fig.4: The furnace described by Theophilus in the 12th c. AD. The walls and dome are made of clay mixed with dung. The shape and size are similar to that of the furnace of Aiano/Torraccia. (Drawings AGM Archeoanalisi)

Theophilus Presbyter, II, XXII, On the furnace in which glass is fired.

Take flexible canes and stick them evenly with both ends, like a bow, in the earth in a corner of the house. The bows should have a height of one and a half feet, with a similar width, but (it should have) a length of a little more than two feet. Then you will knead the clay with water and horse dung, so that three parts are clay and the fourth is dung. After kneading very well, you will mix in dried grass and then make elongated cakes. (With these) you will cover the cane bows inside and outside to the thickness of a fist. On top, in the centre, leave a round hole through which you can reach with your hand. Make yourself three iron rods a finger thick and so long that you can cross the width of the furnace. You will make three holes on the walls, on both sides, so that you can push them through and take them out whenever you wish. Then put fire and wood into the furnace until it is dried out (translation by A.Giumlia-Mair).

The base of the furnace at Aiano-Torraccia is a Roman tile, far larger than the ones which have as yet been found in any of the excavated parts of the villa. The walls of the furnace consist of stones and tile fragments, while the dome was made of clay mixed with snail shells (instead of dung and hay as in Theophilus), so that it remained porous and more resistant to heat. A number of snail

shells, obviously collected for this purpose, were found in a corner of the same room.

Prolonged exposure to the heat led to the deterioration of the wall supporting the furnace. Several portions of the walls in this room show similar damage. This indicates that the furnace was reconstructed several times in different positions and possibly there was more than one furnace in use at the same time. In antiquity no refractories existed, so furnaces of this type did not last for a long time and often had to be completely rebuilt.

In the room with the glass furnace there are also two pits for water one (diam.71cm, depth 40cm) of which is connected to the external water system by a channel(L.3000cm, max.W. 36cm). The water flow could be regulated by a piece of Roman tile, which could be opened or closed.

Not far from the furnace, in a corner of the room, the fragments of a brazier for glass were found (Fig. 5). The artisans worked their glass, heated their tools and elaborated their artifacts on the charcoal contained in this perforated vessel. Similar braziers are known from pictures of Medieval and early modern times glass workshops (Fig. 6).

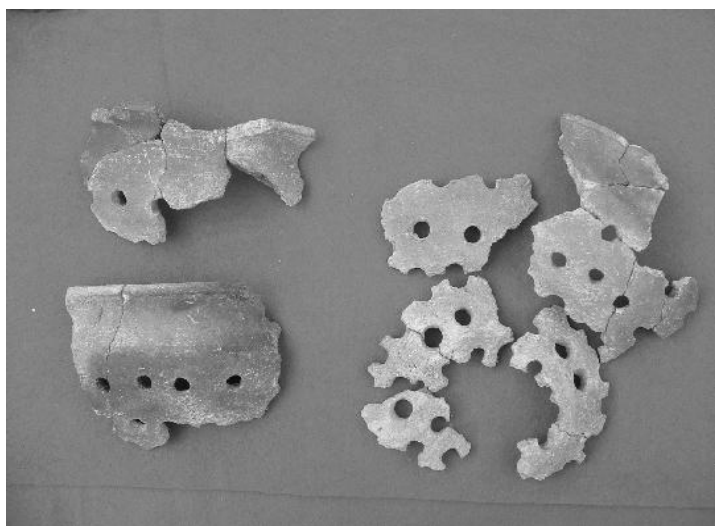


Fig.5: Brazier fragments found at Torraccia.



Fig.6: Renaissance glass workshop from H. Sachsen, Eygentliche Beschreibung aller Stände auff Erden, 1568. A brazier similar to that found on excavation is visible on the left.

This particular kind of brazier allowed the regulation of air through bellows. The artisan was able to maintain reducing or oxidizing conditions, as required by the material which was being worked. Fragments of glass objects and *tesserae* were found in the vicinity of the furnace, whereas solidified glass rivulets, drips and trails, and necklace beads of various size and colour were recovered from several areas. The glass working residues and solidified rivulets of glass seem to come from the various phases of glass working, during recycling of the *tesserae*. The finds include cement lumps still containing glass *tesserae*, amorphous blobs of opaque glass of uncertain colour, brightly coloured glass lumps and fragments, and glass trails and droplets. Some of the latter seem to be unsuccessful attempts at making beads.

A very similar glass workshop arrangement was found in a further Lombardic town, i.e. in the Roman *Tridentum* (today's Trento), on the foothills of the Alps in the upper Adige valley, where Euin, one of the most important Lombardic chiefs, founded the Duchy of Tridentum (574-584), after the assassination of king Alboin. In the 7th c. AD the Duchy of *Tridentum* was united with the Duchy of Brescia and, after the collapse of the Lombardic kingdom in 773-774, the town was occupied by the Franks and became one of the strongholds which controlled the important passage to the North of the Alps.

The excavations carried out in the nineties in the centre of the town brought to light the remains of glass furnaces and a water channel (Fig. 7). Next to these structures a large number of fragments of glass vessels and glass working remains was found. The finds, which are dated to the 5th - 6th century AD, suggest that also in this workshop broken glass objects and cullet were recycled. It is quite interesting to note the similar structures and arrangements in the two broadly contemporary Lombardic workshops.

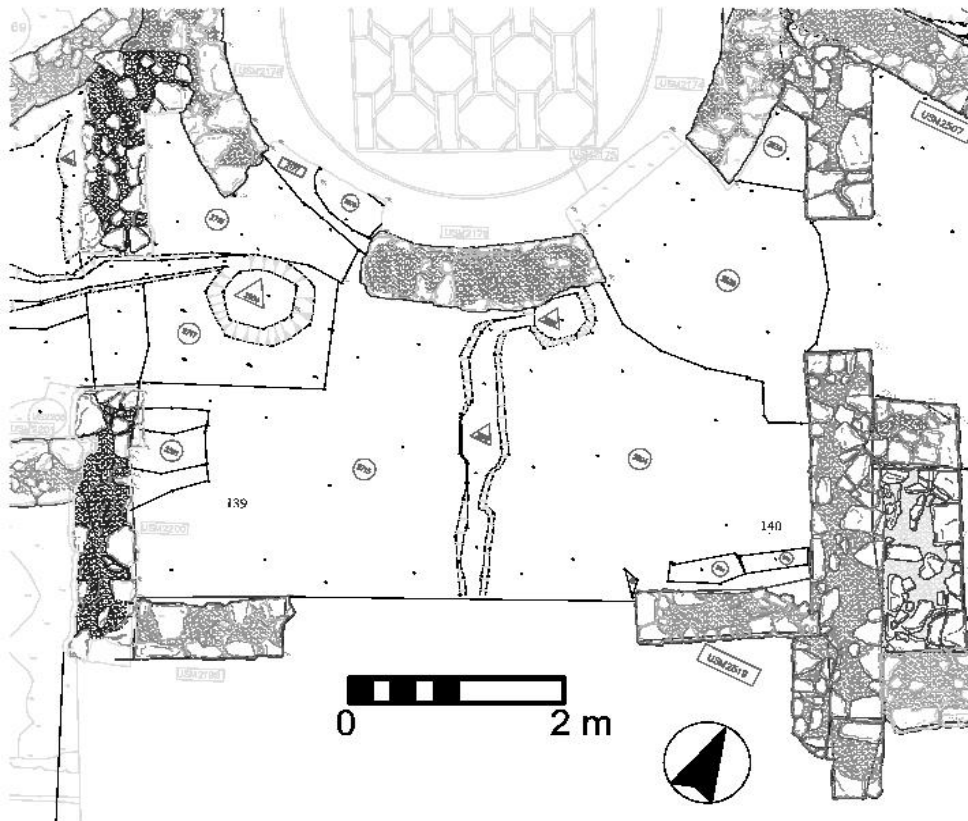


Fig. 7a: The glass workshop at Aiano/Torraccia with the furnace on the right and water channels and pits.

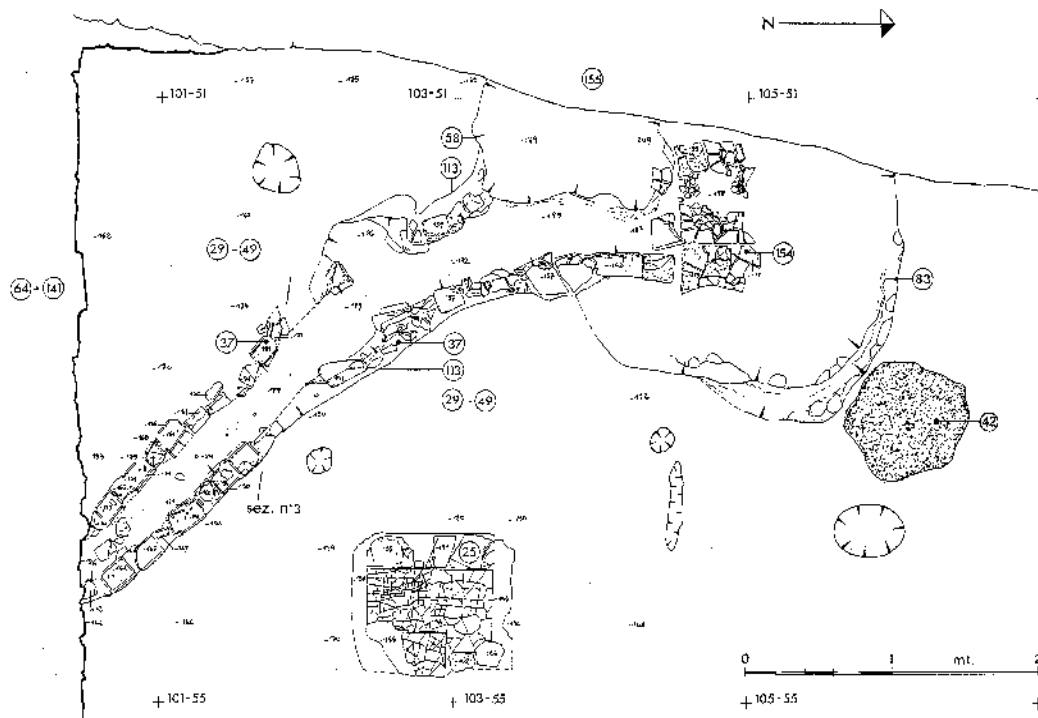


Fig. 7: Glass workshop excavated in the Lombardic town *Tridentum* (Trento) dated to the 5th - 6th century AD. The arrangement is very similar to that of the broadly contemporary workshop in Tuscany. (From Cavada E. Endrizzi L, 1998, *Produrre vetro a Trento*. In: *Il vetro dall'antichità all'età contemporanea: aspetti tecnologici, funzionali e commerciali*, 173-179.)

Roman glass *tesserae* and glass remains

The glass *tesserae*, glass beads, thin glass plates, apparently from a former *opus sectile* decoration, and the glass fragments found on excavation have been analyzed by a surface method such as XRF, but elements like Si, Al, Na, S and P did not produce reliable results. Therefore they are not given in the table. This research focused mainly on the colouring agents. The results were calculated as oxides. Minimum detection level for Mg was 0,5%, for Fe 0,005%.

The qualitative and only indicative data for Na and the results for K and Ca, seem to indicate that all analyzed objects were made of silica-soda-lime glass with low magnesium and potassium, i.e. of the most common kind of glass, produced in Roman times. None of the pieces analyzed gives any indication that the glassworkers knew how to produce woodash glass or mixed alkali glass. Glasses of these compositions are known in Northern Europe from later times, i.e. from the 8th or 9th century AD. The people of Germanic origin who were active in the workshop of Aiano-Torraccia di San Gimignano in the 7th c. AD do not seem to have known these recipes. As the discovery of the small glass furnace suggests, no freshly made raw glass was produced in the Roman villa, but Roman glass *tesserae* and glass fragments were collected and remelted.

Most of the mosaic *tesserae* are made of opaque glass. The exception is some dark blue and black *tesserae* and transparent *tesserae* with gold leaf. In Roman times opaque glass was produced by introducing antimony salts to the molten glass to form calcium antimonate crystals by precipitation in the glass matrix (7). If no colourant was added the glass colour was opaque white. Among the analyzed glass samples the highest antimony content was identified in opaque white *tesserae* and in a white *opus sectile* plate. However, relatively high antimony was also determined in other opaque glass examples. It is quite interesting to note that measurable tin amounts were determined in two samples of white *tesserae* and that in Roman Empire this element was also added to glass as an opacifier. Even if the determined tin is rather low (0,2 and 0,3 % respectively) it might have been added to the melt to obtain a glass with higher opacity. This element also acts as glass decolourant as it oxidizes the iron present in the melt, and removes dissolved gases from the molten mass.

Analyses Aiano-Torraccia di Chiusi																
	object	inv. nr.	K ₂ O	CaO	MgO	TiO ₂	Fe ₂ O ₃	MnO	Sb ₂ O ₃	CuO	PbO	SnO ₂	CoO	ZnO	NiO	As ₂ O ₃
1	o. white t.	TCC06 1089	0.4	9.1	-	tr	0.4	0.8	1.3	-	5.3	0.2	-	-	-	tr
2	o. white t.	TCC06 1089b	0.3	8.8	0.5	tr	0.6	0.9	1.1	-	3.6	0.3	-	-	-	0.1
3	o. blue t.	TCC06 1089	0.3	5.4	1.1	tr	0.6	0.2	0.8	3.2	1.8	-	tr	0.2	-	-
4	t. blue t.	TCC06 1089	0.3	1.5	-	0.1	1.2	-	tr	1.1	0.1	-	0.1	tr	tr	-
5	o. blue/green t.	TCC06 1089	tr	4.2	-	tr	0.7	0.5	tr	1.1	0.2	-	-	-	-	-
6	o. yellow t.	TCC06 1089	0.4	5.8	-	-	1.1	0.4	1.7	-	5.2	tr	-	-	-	tr
7	o. green t.	TCC06 1089	2.6	6.6	tr	tr	1.2	0.5	tr	1.3	8.1	-	-	0.4	-	-
8	o. green t.	TCC06 1089	0.3	4.3	-	tr	1.5	0.4	0.7	2.2	7.6	-	-	0.3	-	-
9	o. turquoise t.	TCC06 1089	0.4	6.5	-	tr	1.4	1.2	tr	2.5	5.4	-	-	-	-	-
10	o. pink/orange t.	TCC06 1095	tr	1.2	0.5	tr	1.8	-	-	4.3	5.3	-	-	-	-	-
11	transl. black t.	TCC06 1095	tr	7.1	0.6	0.3	4.5	2.2	tr	tr	tr	-	0.3	-	tr	-
12	o. red t.	TCC06 1095	tr	4.5	tr	tr	2.8	0.6	-	2.4	4.8	-	-	-	-	-
13	o. red t.	TCC06 1095	0.5	4.4	tr	tr	2.7	0.7	-	2.2	0.7	-	-	-	-	-
14	o. red t.	TCC06 1089	0.3	4.3	tr	0.2	2.8	0.9	-	1.7	1.4	-	-	-	-	-
15	o. red t. dark	TCC06 1089/2	0.6	5.1	tr	tr	2.8	1.1	-	3.5	0.9	-	-	-	tr	-
16	o. red t.	TCC06 1089	0.3	4.4	1.2	tr	2.9	0.9	-	1.8	0.7	-	-	-	-	-
17	o. red t. dark	TCC06 1089/3	0.3	4.2	0.7	tr	2.3	1.3	-	2.5	1.3	-	-	-	-	-
18	emerald green t.	TCC07 2000	0.4	6.7	-	tr	0.3	1	tr	3.2	9.9	tr	-	0.2	tr	tr
19	t. blue droplet	TCC07 2001	0.4	6.3	-	tr	1.7	0.8	tr	1.6	tr	tr	tr	-	-	-
20	t. blue frg.	TCC07 2001	tr	7.1	tr	0.3	1.8	0.2	tr	2.5	7.8	-	-	0.1	-	-
21	red bead thread	TCC07 2024	0.4	5.6	-	-	1.9	0.9	0.7	2.2	1.5	-	-	-	-	-
22	red bead bead	TCC07 2024	0.2	4.9	-	-	3.1	0.7	-	2.2	2.8	0.1	-	-	-	-
23	o. green bead	TCC07 2041	0.3	4	-	tr	0.6	0.6	0.3	1.9	3.2	-	-	-	-	-
24	blue white b. white	TCC07 2078	0.6	7.5	-	tr	0.5	tr	0.8	tr	12.3	-	-	-	-	-
25	blue white b. blue	TCC07 2078	0.5	6.2	-	tr	0.7	0.2	1.2	2.7	10.5	-	-	-	-	-
26	t. yellow green b.	TCC07 2083	1.2	7.6	tr	0.2	1.3	1.3	0.5	-	-	-	-	-	-	-
27	yellow green frg.	TCC08 2593	0.9	7.2	2.3	0.1	1.2	1.1	0.3	-	-	-	-	-	-	-
28	o. green bead	TCC07 room A	0.4	5.2	0.6	tr	1.1	-	tr	4.8	4.6	-	-	-	-	-
29	o. red plate	TCC08 2000	2.3	7.3	-	0.1	0.9	0.2	tr	3.3	8.7	-	-	-	-	-
30	o. white plate	TCC08 2559	0.6	6.8	-	tr	0.4	0.2	2.6	-	0.8	-	-	-	-	-
31	o. red plate	TCC mus.	0.8	8.2	-	tr	0.8	0.3	tr	2.2	11.5	-	-	-	-	-
32	purple plate white	TCC mus.	0.5	5.9	-	0.2	0.5	1.2	tr	-	15.3	tr	-	-	-	tr
33	purple plate, purple	TCC mus.	0.6	4.8	-	tr	0.8	2.6	tr	tr	11.8	-	-	-	-	-
34	t. blue frg. large	TCC mus.	3.8	8.7	-	tr	0.6	0.6	-	tr	tr	-	-	-	-	-
35	gold t. support	TCC B	0.6	6.5	tr	tr	0.7	0.9	-	tr	tr	-	-	-	-	-
36	gold t. sheet	TCC B	6.2	9.8	tr	tr	0.6	0.3	0.5	tr	-	-	-	-	-	-
37	gold t. support	TCC F	0.6	4.7	tr	0.3	0.8	0.7	-	1.2	1.4	-	-	-	-	-
38	gold t. sheet	TCC F	0.4	5.9	0.6	0.1	0.7	0.8	tr	tr	tr	-	-	-	-	-
39	gold t. support	TCC B	0.5	6.2	0.5	0.1	0.6	0.6	-	-	tr	-	-	-	-	-
40	o. red t.	TCC mus.	0.4	3.1	-	tr	0.5	0.7	tr	2.2	1.4	-	-	-	-	-

Antimony, in form of stibnite – antimony sulphide Sb₂S₃ -or perhaps of bindeheimite – a complex mineral containing lead, antimony and sometimes bismuth Pb₂Sb₂O₆(O.OH)- was apparently employed as a decolourant until the end of the 3rd century AD. In the following century colourless glass was increasingly produced by employing manganese as a decolourant (11).

Manganese was found in measurable amounts in most samples; however its presence is not always to be explained by its role as decolouring agent. It is well known that high manganese concentrations were used to produce purple and violet glass. The highest Mn concentration in this group of samples was determined in the purple glass of a purple/white *opus sectile* plate, in which it doubtless had the function of colouring agent. A rather high Mn percentage (2,2 % Mn) was also determined in a translucent black mosaic *tessera* which also shows a high Fe content (4,5% Fe) and

the highest cobalt result (0,3%) determined in the whole group of glass samples. The metal salts were employed as the darkest colouring agents at hand to produce black *tesserae*. Looking at them against a light source the colour is a very dark blue.

As pointed out by Jackson (11) manganese can enter the glass also as an impurity in the raw materials, or be added with the purpose of oxidizing the sulphur present in the ingredients and therefore to prevent the glass from going black. His studies on colourless glass have shown that in glasses for which antimony was used as decolouring agent iron and alumina are rather low, while glasses with high iron and alumina either contain both antimony and manganese or they were mostly decoloured with manganese. Glasses decoloured with antimony are truly colourless and of better quality, while the glasses which contain manganese are slightly greenish, in particular on the cut edge. In the group of analyzed samples the transparent glass used for the thick support of the gold *tesserae* contains manganese and looks rather greenish, but the thin glass sheet used as protection on the gold leaf is of better quality and contains some antimony.

Blue and green glass of different nuances have been coloured with copper in oxidizing conditions, while in the darker emerald green also very high Pb, manifestly added to darken the colour, was determined. A very high lead content was also determined in both the white and the blue glass (12 and 10 % respectively) of a large blue/white bead found on the excavation (Fig.).



Fig.8: Different kinds of glass beads found on excavation at Aiano/Torraccia. The picture shows oval, flattened green beads (left), a large red bead with thread decoration (centre above), a large blue and white bead (right) and a small transparent bead of greenish glass (centre below).

The small and flattened oval beads of opaque green glass have the same composition of the light green *tesserae* and seem to have been produced by melting and casting the opaque glass of the recovered *tesserae*.

Red glass *tesserae* were found to contain copper, manganese, copper and iron. Cuprite and elemental copper colour glass red and also act as opacifier. Apparently in Roman times heated copper scrap was employed as colouring agent for red glass. Iron was added to the melt to prevent oxidation (7), while an addition of manganese turned the colour to a darker, more purplish red. The red *tesserae* analyzed in this study show darker layering and the XRF analyses demonstrated that the darker veins are richer in manganese than the lighter areas visible on the surface of the *tesserae*.

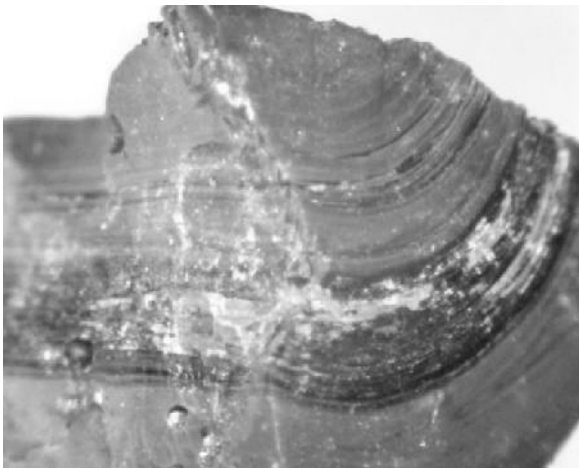


Fig.9: Red *tessera* at the microscope showing darker veins rich in Mn and Pb.



Fig.:10: Red bead with transparent blue thread decoration. At the microscope the red glass is veined like the *tesserae*.

The composition of the darker veined red bead, decorated with a transparent blue thread, found on the excavation is slightly different from that of the red *tesserae*, with a lower copper content, a relatively high lead content and some measurable tin (which might come from bronze scrap). The lead content is comparable to that of the Merovingian beads from multiple burials along the river Rhein in Germany, and from the cemetery of Schleithem in Switzerland, analyzed by Heck and Hoffmann (12) and dated to the 5th-7th century AD. The addition of lead oxide lowers the temperature and this represented an advantage during the production process and the decoration of the beads. This technique was often employed also in Roman times. Analyses of Romano-British vessel glass have for example shown that lead was added to the molten glass for the production of

some particular shapes of vessels (13).

However it has to be noted that one of the red *tesserae* from Aiano-Torraccia in the museum of San Gimignano showed, for example, a slightly higher lead and a lower iron content than the other red *tesserae* analyzed, while the two different *opus sectile* plates of the same colour contain much higher lead percentages (up to ca. 12 %). The colour of the red *tesserae* looks the same, but the composition, in particular the lead content, can differ in a noticeable way, most probably because, in many cases, the glass is not homogeneous.

Up to now not many glass plates from *opus sectile* architectural ornaments have been analyzed, with the notable exception of the fragments from a Roman villa in Faragola (Foggia, Italy), dated to the 4th - 6th century AD (14). The colours of the plates are red, orange and yellow, therefore only the red ones can be directly compared with the specimens from Aiano-Torraccia. The main difference is the lead content, which in the Faragola example is noticeably lower than in the examples from Aiano-Torraccia. On the contrary the lead content of the orange plates (there are no orange examples at Aiano-Torraccia) is very high and demonstrates that the addition was deliberate and the technique known. The yellow plates from Faragola are coloured with Pb antimonates like the yellow *tesserae* from Aiano-Torraccia (see below), however more detailed comparisons cannot be drawn, because of the different analytical techniques employed.

Opaque yellow *tesserae* contain relatively high lead and antimony, and suggest the use of bindheimite which in Roman times might have been found for example in Hüttenberg in the Austrian region of Styria. As mentioned above, this mineral, added to molten glass, can act as decolourant, but can also produce a yellow and opaque colour by precipitation of lead pyroantimonates. Traces of tin have also been determined, but in this case the content seems to be too low for the tin to be a deliberately added colouring agent. A fragment of transparent yellowish glass was found in the outer clay of the furnace wall. The analyses have shown that its composition is identical to that of a small yellowish bead found on the excavation.

Gold *tesserae*

Numerous gold *tesserae* have been found all over the workshop area. As in other known cases (15, 16), they are made of transparent glass covered by a thin glass sheet on which gold leaf was applied. As pointed out above, the analyses of the glass support showed that this material was common transparent glass of a greenish colour, due to the presence of iron impurities in the glass. The glass sheet was blown into a large bubble which was then taken from the blow pipe, cut open and laid flat (probably on a layer of ash) on a flat surface. The sheet had to be annealed to relieve the internal stress, before applying the gold leaf. The analyses of the glass sheet identified a high manganese percentage and traces of antimony. As discussed above, these elements, which can also be employed as glass colourants to produce purple and bright yellow glass respectively, but also other colours, if in combination with other salts - act as decolouring agents (in the case of manganese, when the molten glass is heated to over 1200°C). To bring out the colour of the gold the protective glass sheets are significantly clearer and more transparent than the glass of the support. The common molten glass was poured onto the gilt glass sheet. Finally the three layers were cut into *tesserae*.

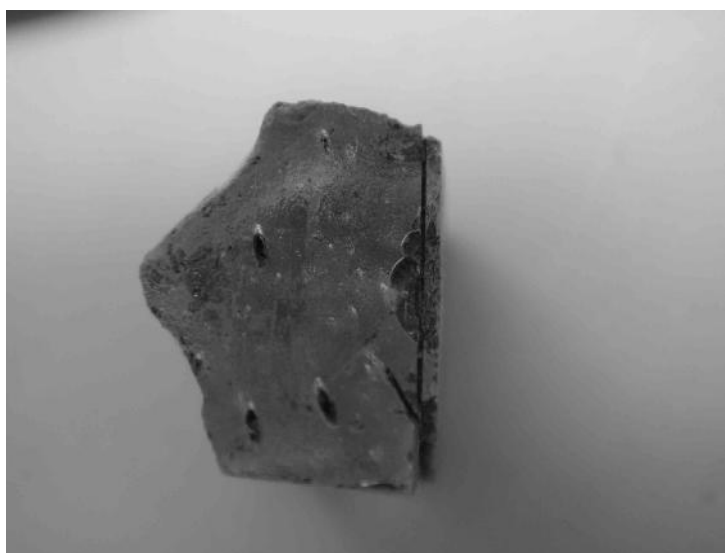


Fig.9: Gold mosaic *tesserae* are made of transparent glass covered by a thin glass sheet on which gold leaf was applied. To bring out the colour of the gold the protective glass sheets contain more Sb and Mn and are significantly clearer and more transparent than the glass of the support. (Photo A.Giumlia-Mair)

The gold leaf used for the *tesserae* was produced by hammering out thin gold sheets inserted between the pages of a parchment “book” (17). This book was continuously turned around under the broad wooden hammer to obtain a regular thickness of a few microns. With this method the

thickness of the gold sheet was gradually reduced, until a few centimeters of the gold were visible at the edges of the book and could be cut off for reuse. This process was repeated several times until the required thickness was obtained (often as thin as 0,4 micron). Modern methods do not easily achieve the same results. The parchment leaves were covered with a layer of talcum or chalk powder to prevent the gold from sticking to the parchment. Gold is so malleable that the leaf of gold can stick to metals just by pressing it with wood-, bone- or ivory tools. Metal tools cannot be used because they would damage the soft gold. The gold leaf was previously applied to the thin blown glass sheet using an organic adhesive such as tragacanth gum.

The recovery of gold from the *tesserae*

The remains of burnt glass *tesserae*, obviously discarded, without the gilt glass sheet suggest that the artisans recovered the gold from the mosaic *tesserae*. This hypothesis seems to be confirmed by a strange lead “ingot” found on the excavation. This lead object is different from any other known lead ingots and has a hole for carrying purposes. The analyses identified low, but measurable (2,3%) gold amounts in the lead, while in other lead pieces found on the excavation no gold was discovered, with the exception of a smallish lead casting residue.



Fig.10: The analyses identified 2,3% Au in the lead of this strange “ingot”. No gold was determined in other lead pieces found on the excavation. This suggests that this particular batch of lead was used to recover the gold of the *tesserae*.

A process which foresaw the use of lead in the extraction of gold from some particular kinds of deposits has been known since ancient times (18) and it was also employed for the purification of gold and to collect and recover gold applied to glass, but also other kinds of materials. The amount of lead to be used was four times the amount of gold to be recovered. The gilded glass sheets were ground and added to the molten lead. By increasing the temperature the intermetallic compound Pb_3Au was formed, which could then be cupelled. Cupellation was also used in the extraction of silver from argentiferous galena (i.e. silver rich lead sulphide, the most common silver ore used in antiquity) (19). To separate the precious metals from the lead and all impurities the mixture was heated to approximately 1000°C in a furnace with strong oxidizing conditions, i.e. with an abundant supply of air. The lead oxidized and turned into litharge (lead oxide), and absorbed the impurities present in the metal, the glass silicates and part of the silicates of the crucible. The non-oxidizing precious metals separated during the process, floated to the surface of the litharge and could be recovered in form of a button. This process was employed in the extraction of silver until the late medieval times, but it was in use also in modern times to recover the gold from old embroideries or from gilded wood or leather. In this case the organic material was first burnt and the ashes were added to the molten lead.

Conclusions

This study has shown that in some of the rooms of the Roman villa of Aiano-Torraccia di San Gimignano, occupied by Langobards who installed different workshops here in the 7th century AD, glass fragments and glass mosaic *tesserae*, recovered from some not yet excavated part of the villa, were collected, washed and recycled for glass working.

The colouring agents employed for the manufacture of the Roman *tesserae* do not differ much from that of other similar contemporary finds. Gold *tesserae* were made by using two glasses of different quality, with the protective sheet made with the more clear and transparent glass. The gold samples analyzed are quite homogeneous and contain around 5% silver and 1-2% copper.

The analyses have demonstrated that some of the glass beads found on excavation, in particular the green and the yellow beads, have the same composition of the glass mosaic *tesserae* and fragments. The more elaborated beads – the red bead with thread decoration and the blue/white bead – show a composition which is slightly different from that of the mosaic *tesserae*. This might be due to the addition of some further ingredient such as lead for the manufacture of the artifacts.

The remains of gold *tesserae* and the traces of gold identified in two particular lead finds suggest that the gold *tesserae* were collected, crushed, reduced to fine powder and mixed with lead for cupellation with the aim of recovering the gold. Some finds and remains in the workshops seem to indicate that in the workshops area gold was also worked.

The most important data recovered through this study is not the special nature of the glass working identified *in situ*, but the amazing organization and efficiency of the different, but correlated workshops installed under one single roof, so as to make use of the complex water system, the fuel supply and the need for similar materials (for example sand and clay). Without doubt the tools needed by the different productions, such as for example tongs, hammers, shears of different size and shape, and other more specialized instruments for glass, gold and copper working, were also produced in the smithy. Diverse clay vessels, crucibles and the clay mixtures, necessary for the various furnaces and the smithy structures, must have been produced in the ceramic workshop. The villa was employed like a “mine”, as a raw materials source. The recycling of glass and the correlated recovery of gold from the mosaics has, to our knowledge, never been as clearly documented before. In the next years the excavation will most probably come up more surprises.

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