Received: 2024-05-14 | Accepted: 2024-11-06 | Published: 2025-02-28

The "Treasure of Como" and the Production of *Solidi* During the Late Roman Empire

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Keywords
Gold, coinage, Late Antiquity, minting technology, archaeometry, XRF, SEM, EDS

Abstract

The Como Treasure, discovered in 2018 during archaeological excavations in the Roman town of *Novum Comum*, consists of 1,000 *solidi* and a few other gold artifacts – three rings, a small piece of an ingot and incomplete and unfinished gold jewelry. It is the most important hoard of Roman gold coins discovered in Central/Western Europe in recent decades. The examination of the *solidi* allowed for the study of the traces of workmanship and the reconstruction of the operative chain used in Late Antiquity mints. The gold was melted under oxidizing conditions, purified by cupellation and cementation and then assayed. In order to obtain the blanks, foils were made, cut in round plates with iron shears. Then the edges and the weight were adjusted *al pezzo* with iron files. As some of the impurities visible to the naked eye show on some coins, iron filings from files accidentally got into the filings or gold waste used for melting. Coins were obtained by minting using dies engraved according to a well determined sequence: after a subdivision of the die's surface with compasses, the figures and finally the inscriptions were engraved. The production process was concluded by checking the weight of the coins. In times of intensive production mints could shorten their production times by recoining old coins. In this case, the purity of the gold was checked by taking a sample from the center of the coins before their recoinage.

These different stages required specialized staff and ateliers with different features placed in a building that guaranteed high levels of security and that was well connected to the road network to allow supplies. These characteristics seem to be found in a building unearthed in old excavations in Milan and already interpreted as a bath. On the basis of the information currently available, however, the possibility of it being the mint of the *comitatus* cannot be ruled out.

Como Treasure and gold coin production in Late Antiquity

Facchinetti

Como Treasure was discovered on September the 5th 2018 during archaeological investigations by Soprintendenza Archeologia Belle Arti e Paesaggio of the provinces of Como, Lecco, Monza and Brianza, Pavia, Sondrio and Varese – Ministry of Culture (Figure 1). They were rescue excavations prior the construction of a building in the centre of Como, this is the area of the Roman town of *Novum Comum*.

This Treasure is formed of 1.000 *solidi* (Table 1), jewellery (a pair of earrings, a possible pendant of an earring, three rings), the fragment of an ingot and some semi-finished gold objects (one golden drop, one small and bent gold bar, five small fragments of golden thread)[1]. They were inside a truncated-cone soapstone jug with a lid (E. Sedini in Facchinetti, 2022, pp.65-76, Fig.2). This jug was hidden in a pit dug under the floor, in the corner of a room of what possibly was a public building (Grassi and Facchinetti, 2019; Grassi and Garatti in Facchinetti, 2022, pp.14-40). The concealment of the treasure is likely to have occurred between the end of the year 472 and the beginning of 473 AD, in a period of great political uncertainty spanning the death of Olybrius and the designation of Glycerius as Emperor of the West (Facchinetti, 2022, pp.303-304).

All these coins are in exceptional condition. The majority seems to have not circulated at all or just for a very short time, this has allowed for the study of their manufacturing traces and faults. In its turn this has given us new information about the methods of production, from the engraving of the coin dies to the production of the blanks for the coinage of the *solidi*.

The *solidi* are gold coins with a weight of 1/72 of a Roman libra (about 4.54 gr; Carlà, 2009, pp.42-43). The

DOI:10.46586/metalla.v28.2024.i2.135-160

Table 1. The coins of the Treasure of Como divided by issuing authority and mint.

	Constantinopolis	Thessalonica	Roma	Ravenna	Arelate	Mediolanum	Imitations	
Arcadius			1			1		**2**
Honorius	2			26		4		**32**
Teodosius II	34					1		**35**
Pulcheria	1							**1**
Valentinian III	2		66	49		29	16	**162**
Placidia			1	3				**4**
Honoria				1				**1**
Licinia Eudoxia				1				**1**
Marcian	15					3		**18**
Petronius Maximus			4					**4**
Avitus						14		**14**
Leo I	34	8	5	3		93		**143**
Majorian				4	2	62	2	**70**
Libius Severus			31	8		221		**260**
Anthemius			31	11		201		**243**
Olyibrius						10		**10**
	88	**8**	**139**	**106**	**2**	**639**	**18**	**1000**

reforms of Constantine introduced them in 310, they were made of pure gold and their value was the same as their intrinsic value. In other words, they were worth the quantity of precious metal of which they were made and, as the study of ancient sources shows, their value was subject to variations according to market demand, as for any other good (Carlà, 2009, pp.36-41, 48, 78-79). One should also remember that various sources clearly refer to the trade of *solidi* (Carlà, 2009, pp.94-95).

Because of their high value, the *solidi* were not used by all the social classes and their use was limited to a few instances when payment of large sums was requested. The State used them in order to pay for supplies and rewards, mainly for the army. While private citizens used them for substantial payments, e.g. for important commercial transactions (Facchinetti, 2022, pp.87-90). Moreover, late Roman legislation envisaged the use of gold for the payment of taxes.

The gold coinage had been controlled directly by the emperor himself since the times of Augustus. With the reforms of Valentian I and Valens in 366-367, gold coinage was under the control of the *comitatus* composed of the emperor's closest civil and military collaborators who held the highest positions in their respective hierarchies and in particular of the *comes sacrarum largitionum* (Kent, 1956, pp.199-200; Hendy, 1972, p.125). This is shown by the initials COM on the exergo of the reverse.

Since the *comitatus* was always with the emperor, this meant that gold coinage in the various mints was intermittent and normally connected to the emperor's presence in the various hosting towns, although in the West, during the second half of the 5th century, it cannot be excluded that *solidi* were produced even if the emperor was not present.

It must therefore be assumed that the gold coin production staff travelled with the *comitatus* and that the local workers and the facilities of the local mints were also used to mint the gold coins. The marks and the faults on the blanks or on the coinage on some of these coins have been particularly revealing (Facchinetti, 2022, pp.175-180; Cucini in Facchinetti, 2022, pp.241-275; Facchinetti and Cucini, in print).

The coinage faults with writing and figures not correctly impressed allow us to suggest a minor degree of accuracy from the second half of the 5th century AD (Facchinetti, 2022, pp.177-180). The reconstruction of the sequence of the engraving of the dies can be reconstructed on the basis of some of the marks impressed on the dies.

Figure 1. The discovery of the Treasure of Como. Photo: SAP società archeologica srl. © MiC - SABAP-CO-LC.

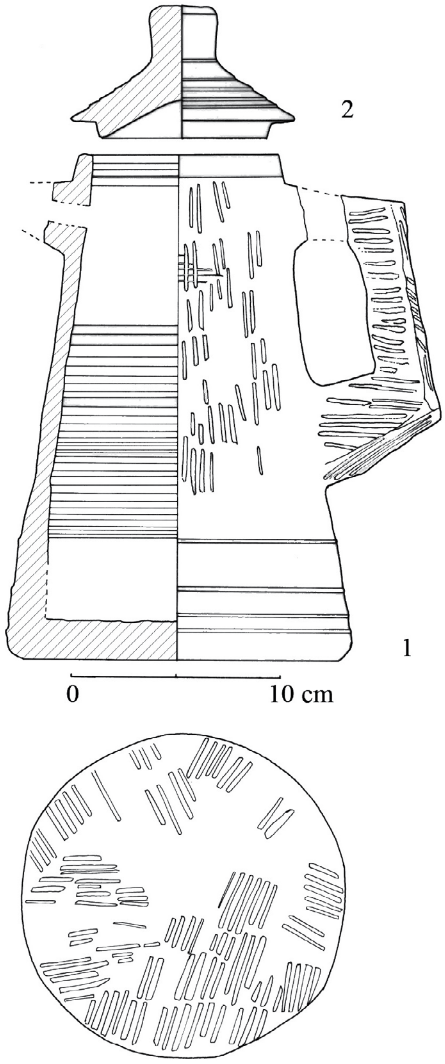

Figure 2. The soap stone container of the Treasure of Como. Drawing: E. Sedini.

The faults of the blanks (their irregular shape, the inclusions of iron fragments) have been meaningful in the reconstruction of the different minting procedures. The iron fragments appear as a powdery blackish deposit within the grooves of the coin's surface, they show an irregular pattern and circular or sub-circular cross sections. Their composition was determined by SEM-EDS thanks to CNR-IGAG and to the Department of Earth Sciences "Ardito Desio", Milan University (F. S. Aghib, et al. in Facchinetti, 2022, pp.233-240). The presence of this kind of inclusions in coins of different mints dating from the early until the late 5th century shows that production methods were left unchanged at least during the first three quarters of the 5th century (Facchinetti, 2022, pp.175-177).

The Treasure of Como has given us the unique opportunity for an interdisciplinary study with the partnership of scholars from Turin University (Angelo Agostino, Maria Labate, Benedetta Vitale), Pavia University (Maria Pia Riccardi, Maya Musa), Elettra-Sincrotrone Trieste (Ilaria Carlomagno, Giuliana Aquilanti) and the authors of the present paper. The previous and ongoing analyses of the chemical composition of the coins, which have already been published (A. Agostino, M. Labate and M. Aceto in Facchinetti, 2022, pp.221-231), have shown the need for further research. The topic of this paper is the investigation of the technological aspect of the production of *solidi*. The paper mainly deals with the description of the technological aspects of production, based on observations made with an optical microscope. The additional trace element analyses of the gold were carried out on a limited number of coins by XRF (A. Agostino, M. Labate and M. Aceto in Facchinetti, 2022, pp.221-231).

From the ore to the production of blanks: metallurgic practices and operating chain in the Late Imperial mints

Cucini

Origin of the gold used for coinage

The Como Treasure provided the occasion for reconsidering the metallurgic techniques used in Late Roman mints and the making of the blanks used for coins. The blanks were often thought of as made by casting the metal in various kinds of moulds. But this method was time consuming, chaotic, inaccurate and wasted resources. It was completely unfit for the large number of issues of the Roman Empire (C. Cucini in Facchinetti, 2022, p.252). It was then necessary to reconsider the whole system of blank making. The idea arose from the observation that about 62 coins of the Treasure showed iron filings visible to the naked eye (Figures 3, 4). The shape, size and distribution of these tiny iron fragments varied greatly, often being a few millimetres long. Their analysis by SEM/EDS (F. S. Aghib, et al. in Facchinetti, 2022, pp.233-240) has shown that they are formed from iron hydroxides. The iron filings are not only found on the surface of some coins, but are also contained in the body of the blanks and visible on one or both surfaces of the coin. Sometimes they are completely oxidized and have left more or less deep grooves filled with a blackish powder. As these iron fragments have increased their volume through oxidation, they have caused tiny cracks in the surrounding gold, leaving clearly visible marks on the surface of the coins. It quickly became apparent that they were already on the metal before it was minted, but that they had nothing to do with the actual alloy of the coins.

It is easy to work gold, it has a rather low melting point, 1.064° C. When smelted in oxidizing conditions it does not oxidize, while the other elements which are associated with it do. It is easy to separate it from its gangue and other impurities. It has a high specific weight – 19.25 g/cm^3 – and during its smelting its impurities float on the liquid metal and can be removed. It is very ductile (hardness about 18 HB), because of this it must be alloyed with small percentages of other metals such as copper and silver. Therefore, after it was purified and alloyed the next minting operations were relatively simple and they did not change much over the centuries (Eissler, 1896; Maryon, 1998).

As most of the gold that arrived at the late Roman imperial mints came from taxes and levies, it was processed into coins as it already had a high degree of purity. A smaller quantity of gold came from other sources, it was mined from hard rock and gold placers.

Native gold cannot be used as it comes from the mine: is not pure being a solid solution of gold and silver (electrum) (Morrisson, et al., 1985, 1985, p.189: "… Rappelons qu'El = electrum est utilisé par les numismates pour designer tout "or blanc" natif ou artificiel d'un titre compris entre 70 et 10 % Au environ …".; with copper and iron: Raub, 1995, pp.244-245; Berger, et al., 2021).

The "new" gold was probably the so-called *balluca*, a gold sand that comes both from placers and from the crushing and washing of gold-bearing quartz, as was still being done in the 17th century in the gold mines of Monte Rosa in Piedmont (Italy) (Tizzoni, 1990, p.140). The *balluca* (Greek χρυσάμμος, literally "gold sand"), mentioned by *Plinius the Elder* (Nat. Hist. XXXIII, 77

Figure 3. Solidus of Leo I (*Mediolanum*, 461; Facchinetti, 2022, cat. no. 124). Photo: L. Caldera. © MiC - SABAP-CO-LC.

Figure 4. Solidus of Olybrius (*Mediolanum*, 472; Facchinetti, 2022, cat. no. 996). Photo: L. Caldera. © MiC - SABAP-CO-LC.

balux) and *Martial* (12, 57, 9 *balux*), must therefore have been a very impure gold at the time. It seems that no new gold mines were opened in the west after the 4th century (Morrisson, 1982, p.209). After the beginning of the 3rd century, large-scale exploitation of the gold deposits in north-west Spain strongly declined and during the Late Empire there was little mining activity in this area (Edmondson, 1989, p.89; Domergue, 1990, p.314). Anyhow it is possible that the exploitation of gold placers continued (Cucini, 2016, pp.194-198), in the Italian Alpine valley where there are gold deposits (Piana Agostinetti, et al., 1995).

It is possible that the mints used gold from scraps, broken jewels, semi-finished gold objects like those found in the Como Treasure with the 1.000 *solidi*. In order to be able to handle gold in various degrees of purity, and not just that of raw gold, it had to be smelted and then purified like gold from mines and placers, in various stages. The first was by smelting in oxidizing conditions in order to get rid of its main impurities. A further purification was necessary by cupellation (Craddock, 2000a, p.27; Blet-Lemarquand, et al., 2017; Berger, et al., 2021, pp.2-3, 23). During this process lead was added to the impure Au-Ag alloy in order to form litharge. The cupel was made with bone ash and then heated, in this way litharge and impurities were absorbed by the cupel's porous walls. At the end of the cupellation process a pure Au-Ag alloy remained at the bottom of the cupel. But gold cannot be separated from silver during the cupellation process, a further step is necessary to purify gold (Cucini in Facchinetti, 2022, pp.245). This last operation is called *parting* process (Craddock, 2000a; 2000c): in this way pure gold is separated from silver.

The purity of gold in the coins was of the utmost importance for the Roman State. Its monetary system was based on a very pure metal certified by the coin itself. Instead, ever since the mid-4th century AD the percentage of silver in the *solidus* increased up to 5 %. This damaged the state finances and debased the currency (Amandry, et al., 1982; Morrisson, 1982).

The reforms of Valentinian I and Valens, with the three *constitutiones* in 366 and 367 AD, provided the definitive solution (*CTh* XII, 6, 12; XII, 6, 13; XII, 7, 3; Carlà, 2009, pp.206-220). They established that all the gold from any source reaching the state coffers had to be melted and purified in order to have perfectly purified gold cast into ingots. This gold was called *massa obryzae* or *aurum obryzae* (from the Greek ὀβρυζα, Benveniste, 1953).

The gold collected in the provinces by tax collectors was stored in *thesauri* (*CTh* XII, 6, 17 and *CJ* X, 72, 7), these offices were subordinate to the *comes sacrarum*

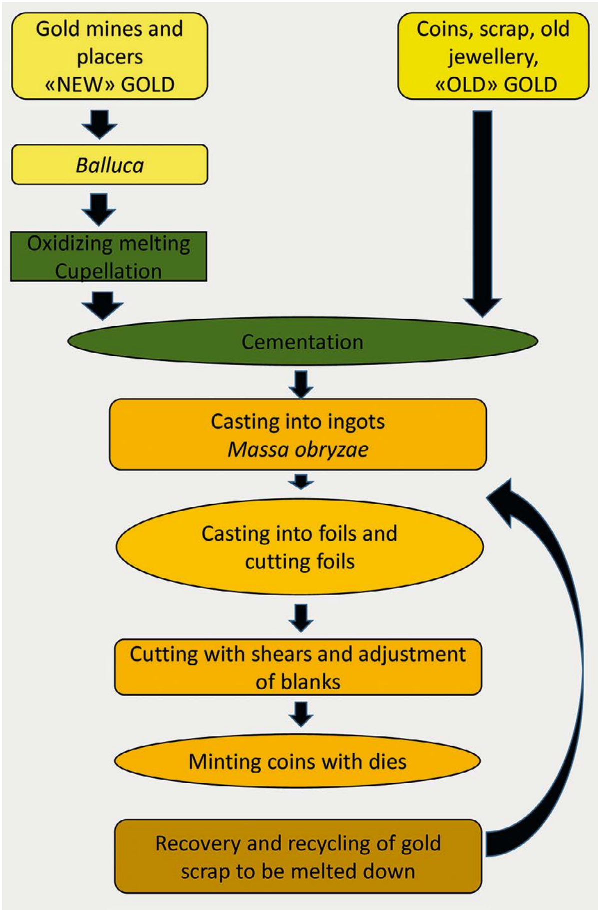

Figure 5. Outline of the late Roman gold coins production operative chain. Reconstruction and drawing: Costanza Cucini.

largitionum (Painter, 1991). The *Sacrae Largitiones* was an *officium* employed by the emperor for gifts and payment to the army. It had a very important role which involved tax collection, finance management and the control of the mines and the state mints. The *Notitia Dignitatum* (*Occ*. XI) informs us that there were four *thesauri* in the Western Empire: in Rome in *Italia Suburbicaria* and in Aquileia, Milan and *Augusta Vindelicorum* (Augsburg in Bavaria) in *Italia Annonaria*. In each *thesaurum* the metal was kept in the *scrinium aureae massae* (Carlà, 2009, pp.234-235), while a department called *scrinium auri ad responsum* perhaps had the duty to return the gold to the stores of the dioceses. There were many specialized workers in these departments: the goldsmiths or *aurifices specierum*, those who made blanks and minted gold coins or *aurifices solidorum* and the engravers of dies or *sculptores* and other unidentified artisans - *et ceteri artificies*. Since 374 (*CTh* X, 22, 1) in the laboratories connected to some mints there were also the *barbaricarii* (Glad, 2018), who embellished weapons and armours and the *argentarii*. During the late Empire workers in the mints, the *monetarii*, were free state workers. They were well paid, had a high social standing and formed a guild (Carlà, 2009, pp.189-195).

We can suppose that the *scrinium aureae massae* was in the same building as the mint, in well-guarded stores near the rooms where the minters worked (C. Cucini in Facchinetti, 2022, p.259).

We do not know if up to the 4th century gold refining and its casting into ingots were decentralised activities or who took care of them. Gold melting and purifying continued in the *Pars Orientis* at least until 409 (*CTh* XII, 8, 1), when Arcadius established that when new coins were minted, they had to be made in the seat of the *comitatus*. According to some sources it seems that it continued in the Western Empire; the extreme purity of the *solidi* of Como (Au > 99 wt.%), which show an extremely high partitioning and purification, seem to confirm it. Purification and melting of large quantities of gold was not so simple from a technological point of view and above all the organization of the operations since the quantity could vary from hundreds of kilos to tons according to the period. It is now clear that late Roman mints were almost industrial factories. The sequence of their minting operations was well organized, they were subdivided into departments capable to make their finished products independently. Here we shall try to reconstruct the different activities and operating sequence (Figure 5, Table 2).

Making pure gold: parting process, refining and assaying

Parting gold from silver was the preliminary compulsory phase needed to make the *massa obryzae*. Gold refining and cementation processes are ancient (Halleux, 1985), their earliest archaeological evidence was excavated at Sardis and belongs to the 6th century BC (Ramage and Craddock, 2000, pp.35-36). Possibly the process was described for the first time in the 2nd century BC by *Agatharchides of Cnidus*, cited by *Diodorus Siculus* III.12-14 (Craddock, 2000 a, pp.34-71, with the other ancient, medieval and post-medieval sources). Its main descriptions are in *Pliny the Elder* (*Nat. Hist.* XXXIII, 84 and XXXV, 183).

The techniques employed in the late Roman mints were the most up to date from a long series of practices, which had their origins in the Greek-Hellenistic alchemy developed at the school of *Zosimus of Panopolis* between the end of the 3rd- beginning of the 4th century AD. The most important technical treaties which are nearer to the period we are examining belong to the 4th century AD. They are the *Leyden Papyrus* dated to the period of Constantine (Halleux, 1981) and the slightly later *Mappae Clavicula* (Baroni, Pizzigoni and Travaglio, 2013).

The ancient sources have many recipes for gold purification. Generally, they are written in simple and plain language, but their interpretation is seldom easy and clear, mainly when dealing about the names of their ingredients and the nature of some operations (Craddock 2000a, p.35). Because of this, the Medieval commentaries to these texts are important[2] as are the chemical handbooks of the 16th - 18th centuries (such as Biringuccio, 1540; Brembato, 1663; Nicolis de Robilant, 1781-1801) and documents of the Milan State Archive (ASMi) concerning the 16th century mint of Gian Giacomo Trivulzio in the Grisons, Switzerland (Cucini Tizzoni, 2014) and those of the 18th century Austrian mint in Milan (Cucini Tizzoni, 2010), because the same techniques and metallurgic processes were used for a long time.

The easiest and most proficient method of partitioning gold from silver and from any other metal is by the salt cementation process (Ramage and Craddock, 2000; Berger, et al., 2021). It was a dry chemical attack: first gold was beaten into thin foils, covered with a mixture of common salt (sodium chloride NaCl), ochre (synopsis of the Black Sea or of Egypt) and/or *misy* (*Plinius the Elder*, *Nat. Hist*. XXXII, 60; XXXIII, 69, 84; XXXIV, 121; XXXV, 183; *P. Leyd*. 24 and 14. *Mapp. Clav*. II, XVIII, XXII). This mixture had to be lightly sprinkled with water or urine (e.g. *Teophilus*, 3.33). This mixture formed a "cement" used to cover the gold foils which were "thin as a nail" (*Mapp. Clav*. XVIII). It seems that at least since the 10th century early sources refer to the use of powdered fired clay (first cited in Al Hamdānī, Allan, 1979, pp.8-9; then *Theophilus*, pp.108-109; and *Parisinus Graecus* 2327). Its purpose was the absorption of the silver salts from which the metal could be recovered by cupellation and in this way, they were not lost on the furnace's walls. Thus, it is extremely possible that powdered fired clay was already used in antiquity (Craddock, 2000a, p.35; 2000c, p.202; Berger, et al., 2021). Recent cementation experiments have been made using fired clay with common salt and sulfurated compounds (Craddock, 2000b; Celauro, Loepp and Ferro, 2017; 2021; Berger, et al., 2021).

After this the "cemented" foils were arranged in various layers (Brembato, 1663, Cap.VI) within a crucible sealed with clay or lute "so to be airtight" and put on a mildly ventilated charcoal fire at a temperature of 500°-800° for a day and a night. The gases released in a damp and reducing atmosphere reacted with the silver and with the other metals reducing them in the solid state. The main reaction agent was gaseous chlorine and possibly ferric chloride ($FeCl_3$); water vapour had to be in the correct amount (Halleux, 1981, pp.31-32; Craddock, 2000b, pp.180-183; 2000c, p.202; Celauro, Loepp and Ferro, 2017; Berger, et al., 2021, p.13).

It is an endothermic process which needs a constant amount of heat and rather low but controlled temperatures. It was necessary to avoid overheating which would have caused the melting of the impure gold, on the other hand too low a temperature would not have allowed the formation of gases. According to our sources, this process was repeated three times and it required three days and three nights. Thus, a cement formed by salt and/or sulfur compounds (ferrous hydrated sulfates) leaves gold intact, but attacks silver and the other impurities (Halleux 1981, p.10; *P. Leyd.* V, 14, 16, 86, 24).

There is a long bibliography about *misy*. It was a mixture of corrosive sulfates mainly of ferric sulfate (Craddock, 2000a, pp.36, 37, nt.76). It is an ore connected to the weathering of iron sulfides and its formation is always followed by acid drainage (ARD): it can be found where iron sulfides are reached by percolating waters both on the surface and underground. According to Celauro, et al. (2021, pp.437-439, 441-443, referring to ancient sources), *misy* was found in Anatolia, Cilicia, Cyprus, Egypt, Rammelsberg (Germany), Massa Marittima (Italy) and Sweden. But it is possible that for the mint of Milano-*Mediolanum*, other closer sources may have been used. E.g. the following iron sulfide-rich deposits and mines in the Lombard Alps: Gaeta on Lake Como and in Valsassina (Lecco) at Pasturo – Ca' del Boëcc – or on Colle Balisio (Tizzoni, 1998, p.68; 2015, pp.119-120, Figs. 96-98; Vergani, 2022), in Val Seriana at Gromo and finally farther there are the deposits in Trentino such as Vetriolo. At the Gaeta mine, in 1842 the geologist Giulio Curioni observed the transition from pyrite into limonite with an intermediate stage of hydrated iron sulfates and sulfuric acid, something quite similar to *misy* (Fabrizio Vergani, pers. comm.).

This cement produces hydrochloric and/or sulfuric acid (Halleux, 1981, pp.31-32). It sems that there was not a single recipe for the "cement", but there were "mixed processes" implying the combined usage of sulfates and chloride. This makes our understanding of the process of gold refining harder.

After this treatment, crusts of chlorides and sulfates formed on the gold foils. In order to remove them they had to be washed carefully with plenty of water. The sources insist on the thinness of the gold foils. The solid-state reactions begin from the surface (Meeks, 2000; Berger, et al., 2021, p.2, 16, Figs.5, 17), because of this the old coins were hammered and thinned on small wooden anvils (reference to the sources in C. Cucini in Facchinetti, 2022, pp.248-249).

The use of small crucibles was the ideal solution for cementation. They have a relatively large surface (in proportion to the volume of the metal inside) lying directly on the ignited charcoal. A highly refractory clay was not necessary, common vessels could be used (*Plinius the Elder*, *Nat. Hist.* XXXIII, 84; Craddock, 2000a, p.39; Brembato, 1663, Cap.VI) since the temperatures had to be kept relatively low (Craddock, 2000c, pp.202-203). Partitioning crucibles have been found in various sites in Roman Britain, but it is not always easy to distinguish them from those used for cupellation or melting (Bayley, 1992, pp.314-315, 318). We can suggest vessels similar to the mass-produced olla used for brass production in Milan-*Mediolanum* during the 1st - 2nd century AD; in these instances, the pots were covered both inside and outside with a thick layer of clay (Ceresa Mori and Cucini, 2012), as was often done with the Roman metalworking crucibles (Gardner, et al., 2020). This extra layer of clay was not necessary in partitioning because of the low temperatures used. Moreover, the presence of organic matter within the clay of the coarse pottery provided a certain amount of porosity needed because of gas formation. Generally, most of the parting vessels were globular in shape, but in Roman Britain instead they were shallow and large (Craddock, 2000a, p.45).

Few archaeological finds and few ancient sources inform us about the use of square shaped parting furnaces. They were raised above the ground and built with stone and clay, inside there was the place for the olla or crucible used in the partition process (Craddock, 2000a, p.33; *Mapp. Clav.* 246; *Theophilus*, III, 33). Rarely the sources make reference to a set of a few not specific tools. The chemical reactions were slow and had to be repeated for days because the active principals were diluted (Halleux, 1981, pp.33-34).

There was a risk that very pure gold would lead to technical problems during minting due to its viscosity. However, the state specified the type of alloy (high-purity gold) without considering the practical implementation and the associated difficulties for the minters. X rays fluorescence analyses (XRF) of a group of 45 *solidi* of the Treasure of Como have shown that their gold percentage varies between 99.52 and 99.98 wt.%, they seem completely devoid of silver while two others which possibly were made in non-official ateliers have a silver content (Facchinetti, 2022, p.136, 138; A. Agostino, M. Labate, M. Aceto in Facchinetti, 2022, p.223). Instead, copper and iron are always present, but with minimal percentages.

Assaying the metal was necessary before its coinage. This assaying was made with utmost care by state expert employees called *probatores et signatores auri* and by the *aurifices*, who were beholden to the *comes sacrarum largitionum*. They punched each ingot with their own punch as a warranty of the metal purity (Carlà, 2009, pp.214-216, 374; Iliescu, 1988). Different methods were used for this check. That of the touchstone –βάσανος – still in use till today, was not very accurate (Moore and Oddy, 1985). The best method was fire assaying: a small quantity of metal was heated up to red in a κάμινος: if it returned to its original color after this treatment, it was pure. The *Codex Theodosianus* (*CTh* XII, 7, 3: *multumque flammae edacis examine in ea obryza detinetur;* C. Cucini in Facchinetti, 2022, pp.249-250, and nts. 100, 101 with sources and bibliography) seems to refer to this method.

All these operations were carried on in well-lit and well-ventilated rooms with many small furnaces arranged in batteries and with working benches for the hammering of foils.

Gold melting and its casting into foils

Once pure gold was attained, it was necessary to transform it into blanks having the correct measure and weight for the *solidus*. The first operation was melting and making it into thin foils.

The laboratories of this department of the mint must have been different from those of the partitioning workshops. The temperature of the metal was determined by sight and this was easier in a dark place. This reminds us of the "dwellings without sun" where the workers of the mint of the Great Imperial Palace of Constantinople worked, as described in 1201 by Nicolas Mésarites (Morrisson and Papadopoulou, 2013). Some of the ateliers of the mint were semi subterranean (Morrisson, 2001) not only as a security measure.

It is possible that the furnace, κάμινος (Halleux, 1981, pp.33-34; *P. Leyd*. 88 e 152) was a simple truncated cone with a central chimney and a place for the crucible, it had bellows and a working bench in front of it for the ingot mould. Our sources do not give information about this or about the tools used in the operating sequence. At *Virunum* on Magdalensberg, in *Noricum* a *fabrica auraria* of the 1st century AD was archaeologically investigated (Piccottini, 2001, pp.51-56, Figs.7-9, Plans 2 and 3). These furnaces had a maximum diameter of 30 cm, they were 40 cm tall and the opening of their chimney had a diameter of 15 cm. They were similar to those still in use at the end of the 19th century (Eissler, 1896, p.534, Fig.165).

These furnaces were filled with charcoal, the crucible was supported by a metal grill or by a refractory brick to keep it upright so avoiding spilling the metal (Figure 6).

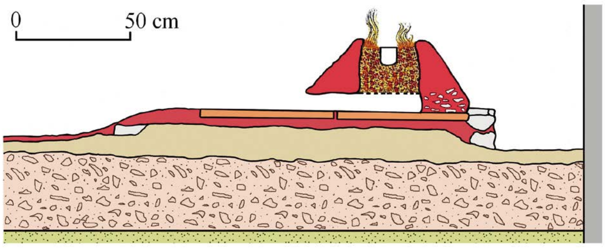

Figure 6. Hypothetical reconstruction of a gold smelting furnace according to the finds from Magdalensberg, redrawn from Piccottini (2001, p.54, Fig.8a). Graphics rendition: M. Tizzoni.

Gold pieces were put inside the crucible and as soon as it reached its melting temperature the worker seized the mouth of the crucible with a pair of tongs and poured the metal into the ingot mould. The metal had to be very hot and the ingot mould heated and greased to obtain smooth foils without bubbles (Biringuccio, 1540, p.133v-134r; Nicolis de Robilant, 1786-1801, p.59; Eissler, 1896, pp.533-534, 537; Maryon, 1998, p.238). About the mint at Constantinople Nicolas Mésaritès quotes τάς πυράγρας and τάς λαβίδας, they are smith tongs and pokers for the furnaces (Mésarites, 1907, p.9, in Morrisson and Papadopoulou, 2013).

Many furnaces were necessary in a late imperial mint in order to liquify the huge quantities of metal needed for the large number of coins. The furnaces had to be accessible from their rear and had a working bench in front of their opening, from here a small bellow was operated. We may suppose that within the department batteries of small furnaces were operated at the same time as was the case up to the beginning of the 20th century (Maryon, 1998, p.235). Technologically it was better to use small crucibles (Bayley, 1992, p.318) to avoid keeping them for a long time on the fire and to better control the operation (Bayley and Rehren, 2007, p.53; Cucini Tizzoni, 2010, p.279). If, as it seems plausible, it was an oxidizing melt the crucibles could be made of kaolinitic clay similar to those found in the *dark soil* layers of the Imperial palace in Milan (Cucini, Riccardi and Tizzoni, 2020).

About these late Roman mints, we may adopt Thilo Rehren's conclusions about brass making: a large-scale production achieved with the use of many small furnaces and possibly mass-produced crucibles all having the same small measurements and typology – "small size, large scale" (Rehren, 1999, pp.254-255). The large number of furnaces and crucibles compensated for the small size of each vessel.

The key for understanding the way blanks were made came from the observation of the few late Roman surviving ingots (C. Cucini in Facchinetti, 2022, pp.251). They belong mostly to the second half of the 4th century AD

(Carlà, 2009, pp.213-216). The most famous are those from Transylvania and were cast after Adrianopolis (378 AD) in the mint of a *comitatus* which was active first at *Sirmium* for the emperor Gratian and then itinerant across the Balkans following the army and the emperor Theodosius I as far as Thessaloniki (Iliescu, 1988, pp.67-71; Woytek, 2023, pp.334-335, Fig.20 shows one of these ingots, now at the Kunsthistorisches Museum Wien, inv. RÖ 37443). This mint had the equipment to cast gold into ingots and to mint coins with the name of the new emperor using a fast and proficient method even in difficult times. The ingots we have were cast into narrow and elongated moulds of a standard width - about 2 cm - which corresponds to the diameter of the *solidus* (diameter between 19.82 and 24.30 mm). These same ingot moulds could be used to cast gold foils with a thickness just above 1 mm and about 2 cm wide, which are the dimensions of the gold coins. This way to make the blanks was easier and more proficient. Of course, the mint and the *comitatus* could travel at least in part with readymade blanks. But the dimensions of the Transylvanian ingots show that they were made for the mint. They are quite different from those of the moulds for ingots discovered in the *Fabrica Auraria* in Magdalensberg (Piccottini, 1994, pp.467-471; Piccottini, 2001, pp.44-45), which are a lot larger. In the 16th and continuing into the 18th century the usage of iron ingot moulds with a small channel whose width could be adjusted according to the coin to be minted is cited. They allowed the casting of a strip of gold of the necessary width (Biringuccio, 1540, p.133; Nicolis de Robilant, 1786-1801, p.58). In the Sixties and Seventies of last century David Sellwood experimented with casting metal into flat bar moulds, flattening it and cutting the blanks with shears, for bronze and silver-plated Roman coins (Sellwood, 1973, p.66, 68, Fig.104).

The making and adjustment of blanks

In the Roman period blanks for coins were made with the same technique that would be used for a long time in European mints up to the end of the 18th century. The blanks for the *solidi* had to be made of the purest gold and have the weight specified by the state. An iconographic example showing the production sequence of blanks starting from narrow strips of metal which were first flattened then cut *al marco* in small squares and then adjusted with a pair of shears can be seen in the sculptures of the archivolt of the church gate at Santiago di Carrión de los Condes in Spain (end of the 12th century). They were copied in part from the portal of the nearby church of Arenillas de San Pelayo (Torres, 2007, mainly pp.309, 311-313, Fig.5, character no. 40. The *cortador*

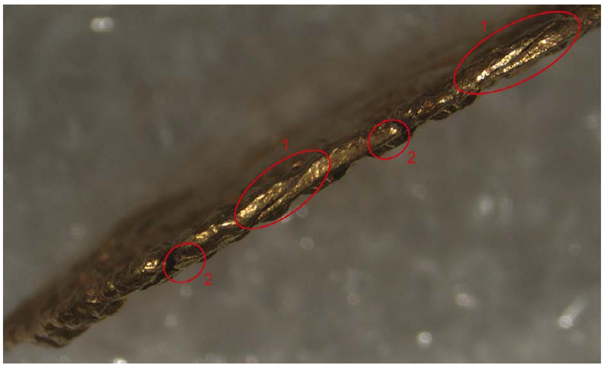

Figure 7. Solidus of Libius Severus (Rome, 462; Facchinetti, 2022, cat. no.519): it shows an almost helicoid fold raising from bottom to top due to the crushing of badly welded irregularities of the foil; the edge of the coin overflew under the strike of the die. Photo: G. Facchinetti. © MiC - SABAP-CO-LC.

is portrayed only at Carriòn). The thickness itself of the *solidus* is a proof of this being just above 1 mm. Cutting such a thin foil of pure gold was easy. After their casting the gold strips were hammered in order to conform their thickness with that of the coins to be minted. The resulting foil was not always homogeneous, often it had cavities and cracks, it was irregularly flattened, it had ill-compacted joints and visible bends at its edges (Figure 7). These metal foils were cut first into small squares and then into blanks using shears.

Procopius of Caesarea (*Procopius Caesariensis*, III, 28-32) confirms this: Justinianus had sent to Italy a certain Alexandros in the retinue of Belisarius. He was the official in charge of the control of the *solidi* paid to the state coffers. Since he was able to shear the gold coins cutting all around their edges but keeping their circular forms, he had the sobriquet of Ψαλίδιον, this is "small scissors" (Carlà, 2009, p.412, nt.627). This sort of cheating must have been common practice as shown by the *CTh* IX, 22 ("*… si quis solidi circulum exteriorem inciderit …*"). The cutting of the metal foils was made for the blanks of bronze coins, as shown by the marks on the coins discovered at *Serdica* (Sofia) in the 4th century mint and the cuttings made by shears discovered among the rejects of a mint in the Great Palace of Constantinople in the excavations near the Peristyle (Morrisson, 2001, pp.50, 52).

The following observations were made from our direct observations of the *solidi* of the Treasure of Como. After the gold for the *solidi* was cast in the form of a thin plate, the desired width was cut out with shears, as can still be clearly seen today on the edges of the solidi from Como (Biringuccio, 1540, p.133; Nicolis de Robilant, 1786-1801, p.55; Cucini Tizzoni, 2010, pp.284-286; 2014, pp.185-230). After having cut them out by shears,

Figure 8. Solidi of Libius Severus (*Mediolanum*, 461-465) details of their polygonal edges: a) Facchinetti, 2022, cat. no.607; b) Facchinetti 2022, cat. no.552. Photo: L. Caldera and G. Facchinetti. © MiC - SABAP-CO-LC.

it was necessary to adjust their edges. First the four corners were cut off in order to achieve an octagonal outline, then the blank was hammered with the aim to make a circular form by flattening it, after this it was cut all around its edges with a pair of shears. These blanks could not be hammered in groups as was done with those of silver and bronze (Biringuccio, 1540, p.133r; Millet and Téréygeol, 2011, pp.116-125), because the gold is too soft.

Late Iron Age and Roman shears were made of iron, they were formed by two parallel blades (possibly covered with steel on their surfaces), which were connected by a curved strip of iron acting as a spring. They worked like a pair of pincers. This type of shears can be found in Northern Italian graves from the middle La Tène period and continued, with little changes in the shape of their blades until the 19th century for shearing sheep (some examples of shears in Tizzoni, 1982, Fig.2c, Tabl. XXXV; Fig.3b, Tabl. XXXVI; Fig.6a, Tabl. XXXIX; Fig.7c, Tabl. XL; Fig.10, Tabl. XLIII; and Bolla, 2004, pp.204, 216, 227-228, Fig.3). Cutting a perfectly circular blank using them was not easy and the edges of the coins show the marks of the snips. The resulting blanks had shapes similar to that of irregular polygons with corners between the snips Figures 8-10. Moreover, the blades of the shears often twisted the side of the blank and did not cut the metal completely, then the worker had to bend the foil to detach the fragment. After the blanks were made, they were weighted *al pezzo* and in case a correction of their weight was necessary which had to be precise, *integri ponderis* (Carlà, 2009, pp.191-192, 443-444; Woytek, 2023, pp.334-335). *Trutinae* or balances of various types were in use, also hydrostatic ones (Bachmann, 1995; Oddy and Hugues, 1972), and *exagia*, the sample weights of the *solidus* (it was 1/72 of a *libra*, i.e. about 4.5 gr). Also, another *solidus* of proved weight could be used as a weight (Carlà, 2009, pp.99-114). To remove the irregularities of the shape, to round the corners and to achieve the correct weight they used files of wrought iron, which left slanting notches on the coins' edges Figure 11. Since these marks are seldom seen, the filed edges were then polished with burnishing stones. Not always were the *aurifices solidorum* able and capable mainly in the final years of Western Empire when working conditions and timings were rather hasty and unrestrained.

During the weight adjustment of the blanks the iron files were easily worn out and small fragment detached, the same happened to the blades of the shears.

Stannard has suggested manufacturing techniques for the blanks that are completely different from ours, he observed that the weight adjustment implied an increase in the cost of labour (Stannard, 2011, p.427, 429). Statistics of the weights of the *aurei* have been made with the aim to establish if the adjustment had been made *al pez-*

Figure 9. Solidus of Libius Severus (*Mediolanum*, 461-465; Facchinetti, 2022, cat. no.556): its edge is multifaceted due to the cutting of the foil with scissors. Photo by G. Facchinetti. © MiC - SABAP-CO-LC.

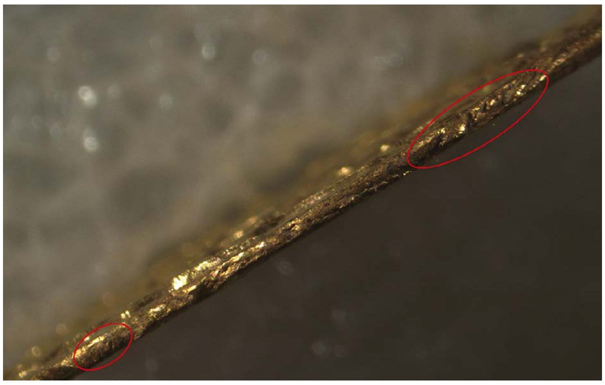

Figure 10. Solidus of Libius Severus (*Mediolanum*, 461-465; Facchinetti, 2022, cat. no.689): traces of filing on its edge. Photo: G. Facchinetti. © MiC - SABAP-CO-LC.

Figure 11. Solidus of Maiorianus (*Arelate*, 457-461; Facchinetti, 2022, cat. no.424): its irregularly polygonal edge shows that it was made cutting a foil. Photo by L. Caldera. © MiC - SABAP-CO-LC.

zo or *al marco* (Woytek, 2008). The rough method of adjustment of the flans weight by gouging used for the Republican silver *denarii* was not certainly used for the Late Imperial *solidi* (Stannard, 1998, p.8). The adjustment of the blanks was made *al pezzo*, using files for the *solidi* of the Treasure of Como as in general for this type of coins (Woytek, 2023, p.334). The adjustment of the weight of the coins only after their minting does not seem plausible (Grierson, 1960-1963, p.6).

The department where these operations were carried on must have been well-lit and must have had working benches both for the weight adjustment of blanks and for accounting. All this was made under an accurate control aimed to limit pilfering.

Cutting out of the blanks was a practical, fast and proficient technique perfectly suited for the large quantities of coins needed by the empire. Anyhow it is quite plausible that this technique was already in use by the 1st century BC. There are clear marks of shears on an *aureus* of *Hirtius* of 46 BC (Arslan, 2019, p.119, Fig.50). The following *aurii* are some further examples: an *aureus* of Caesar[3], an *aureus* of Vespasian[4], an *aureus* of Vespasian for Titus[5], an *aureus* of Antoninus Pius[6] and an aureus of Volusianus (251-253AD)[7]. Also, gold coins discovered in 1821 in the Treasure of Parma show cutting out of the blanks: an *aureus* of Plautilla (202-205 AD), an *aureus* of Alexander Severus (226 AD), an *aureus* of Philip the Arab (244-247 AD) and an *aureus* of Trajan Decius (249-250 AD) (Gelichi, 1994, pp.15-72, Figs. 24, b, d, f, g).

Scraps and cuts out: precious metal to be recovered, but with iron filings

In a late Roman mint making the blanks produced a large number of scraps of pure gold that had to be recovered and recycled. Since the techniques of handmade gold working had not change for centuries, we may assume that by this period working benches for the weight adjustment and filing of the blanks had a drawer, where using a hare's paw, the worker gathered the gold fragments and the gold powder which had to be melted down (Maryon, 1998, p.3). Metallic crusts, tiny drops and seepage remained in the crucibles and cupels, who were therefore crushed and ground in mortars. Then the powder was sieved and washed to recover the gold particles. These techniques used in the mints are described in treaties of the Renaissance and in archive documents (Biringuccio, 1540, p.72v; Cucini Tizzoni, 2014, p.221). But also, iron filings ended up with the gold scrap and it was not easy to discern them because they were white and shining. The largest could be removed using a pair of small tweezers but the smallest escaped (magnets used to remove them as it was done in 18th century mints were not yet invented, Nicolis de Robilant, 1781-1801, p.116). The gold scrap was melted in crucibles and cast again into foils. Iron fragments, being lighter than gold (specific weight 7.85 kg/dm^3), but with a far higher melting point (1.535° C), floated on the molten metal and must not have very evident when its temperature was raised to white heat. Possibly a part of the iron fragments was skimmed off, but some remained and were encased in the new foils for the blanks where they were unnoticed. With the passing of time iron oxidized and transformed itself into its hydroxide increasing its volume breaking and pushing aside the surrounding gold. Then the iron tiny filings became visible. This phaenomenon was observed by contemporary people such as John Cassian (about 360-435 AD), he advised the rejection of the coins corroded by rust, which must have been rather common: "… *sive illa, quorum pondus ac praetium aerugo vanitatis adrodens exagio seniorum non sinit adaequari, ut nomismata levia atque damnosa minusque pensantia recusemus* ..." (*Johannes Cassianus*, *Collationes* I, 22, 1).

This "flaw" is evident on some coins of the Treasure of Como, its earliest appearance in on the coins of Honorius (395-423 AD) and continues at far as Anicius Olibrius (472 AD), showing an increase with the kingdom of Antemius (467-472 AD). It is not a one off of a particular atelier; it can be observed in specimens minted in all the mints of the Western Empire. It was observed also on coins of the hoard of Sovana (Grosseto) (Facchinetti, 2022, p.177).

Similar defects have been observed on the surface of modern silver coins in the Austrian collection: they had inclusions of iron and "oxygen" (?). This contamination was attributed "… to occasional problems that occurred during the manufacture of the coin …" (Gusmano, et al., 2004). Recently, contamination of gold coins (Austro-Hungarian period, end of the 19th - beginning of the 20th century) with iron, and the consequent formation of "corrosion" has been investigated (Kučera, et al., 2021).

The technology employed both in the Western and Eastern Empire was the same. It was based on the availability of a large workforce and the enlargement and expansion of production sites in order to achieve mass production. The mints were large state mills set in towns where tax levies were concentrated and consequently precious metal stocks. When active, the mints gave origin to a remarkable number of satellite activities (C. Cucini in Facchinetti, 2022, p.258). Gold coin minting followed a standardized routine within the different phases of their production. This feature being similar to that for other metals or alloys in the Roman period, e.g. brass making in Milan-*Mediolanum* (Ceresa Mori and Cucini, 2012). This implies large areas with different lightening and ventilation features were available for the ateliers. Moreover, not only a large number of specialized workers was necessary, but also continuous supplies of wood, charcoal and clay. A "regional" network was necessary for the supply of basic materials.

Some analytical observations

The following observations are preliminary since the processing of the data from the synchrotron analyses is still underway, as also are the SEM/EDS analyses. The few analyses so far carried out are those of the iron hydroxides inclusions discussed above (F. S. Aghib, et al. in Facchinetti, 2022, pp.233-240).

So far, a few tens of coins have been analysed by X-ray fluorescence spectrometry (XRF). These coins, which had been carefully cleaned by conservators, did not show surface patinas (A. Agostino, M. Labate, M. Aceto in Facchinetti, 2022, pp.221-231). To avoid damaging the coins, laser ablation was not considered, only XRF analysis, which is a strictly non-destructive technique. Thus, only the surface of the object was analyzed, which only reaches a depth of a few tens of micrometers (Blet-Lemarquand, 2023, p.28). Its major drawback is if the object analysed has a patina caused for example by copper depletion and in such an instance "… the results are not representative of bulk composition of the object …". But since the "… *solidi* generally have a very high purity… and there is no appreciable difference between the surface and interior of the gold coins…", so the compositions of their surfaces are representative of the bulk composition of the coins (see Green, 2023, pp.490-491).

The elements detected in the *solidi* of Como are Au, Ag, Cu, Sn and Fe. Therefore, at present we cannot make observations on the trace elements.

The XRF analyses of 45 *solidi*, made by different mints, have shown a gold content between 99.52 and 99.98 wt.%. Copper is present in all of them with percentages between 0.02 and 0.37 wt.% while iron is between 0.05 and 0.89 wt.% (A. Agostino, M. Labate, M. Aceto in Facchinetti, 2022, p.223). There is no silver, but its presence as traces cannot be ruled out, since it can be below the detection level (LOD) of the XRF, which is usually of about 100 ppm (A. Agostino, M. Labate, M. Aceto in Facchinetti, 2022, p.224). Inclusions or metals of the PGE group were not observed under the optical microscope and in the few SEM-EDS analyses carried out. This could indicate that the metal has undergone cupellation (Craddock, 2000a, pp.33, 238-240; Blet-Lemarquand, et al., 2017; Berger, et al., 2021, p.17; Blet-Lemarquand, 2023, p.49) or that this monetary gold contains no visible PGE inclusions.

Concerning the sources of the ore for the coins minted in Milan, a general framework of the gold-bearing primary and secondary deposits in the Italian Alps has been outlined (Piana Agostinetti, et al., 1995). According to classical sources, gold was extracted on a large scale in the area lying between the Alps and the River Po from the 2nd century BC. The greatest concentrations of gold ore were found in the Western Alps in Northern Piedmont and to a lesser extent in the Central Western Pre-alps (Lombardy and Canton Ticino, CH). In the Apennines, most gold ore was found in Liguria and Southern Piedmont.

The Romans, intervening in 143 BC on the pretext of resolving a quarrel between miners and farmers concerning the rights of use of the water from the *Duria* river, in Piedmont, took control of the rich gold mines - χρυσεῖα - of the *Salassi* (*Strabo*, IV, 6.7). The waters of the *Duria* (a name common to many water courses in this area) were employed in the washing of the ore, with facilities - χρυσοπλύσια – consisting of a network of sluices, constructed so as to capture all the waters from the streams. Perhaps this large gold placer can be identified with the site of La Bessa near Biella, in Northern Piedmont, or better still with the gold rich sands of the surrounding streams. Ancient sluices, temporary workers settlements and old quarries have been archaeologically investigated at La Bessa. After 143-140 BC the *Salassi* were excluded from gold exploitation – χρυσουργείων – and from their own country, the gold mines continued to be used by the Romans, who sub-contracted them to *publicani*.

With the foundation of *Eporedia* (Ivrea) in 100 BC, all the lands of the *Ictimuli* came under the control of this colony. The famous *aurifodinae* of the *Ictimuli* are described by *Plinius the Elder* (*Nat. Hist.* XXXIII, 78): the *Lex censoria* limited the work force used by the *publicani* to 5.000 men. Possibly they were indigenous "*dediticii*", this is people subjugated during the wars between the Romans and the *Salassi*. This limit may mean that in certain periods the number of workers was larger. *Strabo* (V, 1, 12.15) and *Anonymus Ravennatis* (IV, 30) described *Victimulae*, a village close to Ivrea, possibly to be identified with the archaeological remains near Salussola.

During *Strabo's* times these mines were no longer exploited on a large scale as it was done earlier, because those of Transalpine Gaul and Iberia were richer, but it is possible that the placers of North-West Italy were still being exploited on a smaller scale in the following centuries (as in other areas, Edmondson, 1989, p.85, 95). Unfortunately, these Italian gold sources have been overlooked by most scholars.

Analytical definition of the geochemical region and chemical signature of the possible ore deposits are still missing, they would be necessary to understand the behaviour of the trace elements in the minted coins (Blet-Lemarquand, Nieto-Pelletier and Sarah, 2014, pp.133-134; Guerra, 2014, p.163; Blet-Lemarquand, 2023, pp.41-42). There are no analyses of the gold from primary deposits or from placers in this area. It is possible that gold placers were still exploited in the confused period at the end of the Western Empire, as it happened during the Roman Principate and the early Medieval periods (Piana Agostinetti, et al., 1995, pp.210-213, with ancient sources and archive documents concerning the Italian Alps; C. Cucini in Facchinetti, 2022, p.275, nt.157). Moreover, the practice of recycling old coins makes it hard to draw any conclusions (Belt-Lemarquand, Nieto-Pelletier and Sarah, 2014, p.134; Guerra, 2014, pp.162-163; Baron, 2024).

XRF analyses of 45 *solidi* have shown that only 4 have tin (0.17 - 0.36 wt.%) and they are all from the mint of Milan (cat. no. 125 Leo I 461 AD; cat. no. 892 Anthemius 467-472 AD; cat. nos. 999 and 1000 Olybrius 472 AD). These *solidi* belong to the last period of activity of the imperial mint, this could suggest an origin of their gold from placers (Guerra, 2014, p.164, 166) or from alloyed gold to be refined (Blet-Lemarquand, 2023, p.50). Because of the homogeneous historic and archaeological context, they could come from the same "stock" of precious metal (about the concept of "stock", Blet-Lemarquand, 2023, p.42). But gold from the Alpine deposits is not associated with cassiterite, which has never been observed in primary gold deposits and it is a very rare mineral in the Southern Alps (Fabrizio Vergani, pers. com.). This gold with tin must have come from other geological regions (e.g. non-Italian alluvial deposits). It should be noted that the absence of tin is characteristic of the alpine gold deposits. We would like to emphasise that cassiterite has a high melting point (1.720 °C) and a low density (6.2/7.1) as such it is not affected by gold melting.

XRF analyses have shown that there is iron in all the analysed coins, in varying percentages (0.05 - 0.62 % and up to 0.89 wt.%). This is a rather high percentage. Iron cannot be alloyed with gold as it does not enter into solid solution with gold. This iron has nothing to do with iron filings which accidentally ended up with the gold to be melted down and which are visible to the naked eye. This iron is imbedded in the gold alloy and could come from the original ore, or from some metallurgic processes used during its purification (Raub, 1995, p.245; Blet-Lemarquand, 2023, pp.50-51). In some hard rock Alpine deposits gold is as native gold in quartz, but mainly as nanoparticles in gold bearing arsenopyrite, bournonite and chalcopyrite. Likewise silver in argentiferous galena, this gold cannot be seen under a microscopy. It the above-mentioned sulfides are weathered gold specks can be seen in their weathered products.

The low values of the measured copper (< 0.5 wt.%) suggest that the copper could not have been added to the gold after its purification and separation by cementation, for example to influence the ductility of the gold. It could therefore not have been a controlled addition to simplify the minting process but, like iron, came from the original ore or from the use of gold scrap. In addition, recent studies have shown (Süss, et al., 2004, p.197) that a higher proportion of Cu is necessary to increase the hardness and strength of gold.

Copper at these low percentages did not require whitening the blanks and it did not affect the alloy in any way nor changed its color. This was quite important as the state guaranteed the purity of the gold.

To the analyses of the 45 *solidi* we should also add those of 2 *solidi* which have been attributed to the production of non-official ateliers (cat. nos.422 and 423). They have the mint punch mark RV (Ravenna), according to their style they are imitations (Facchinetti, 2022, p.136, 138, 159 with citation of the passage from the *Novella Maioriani* 7, par. 14 and bibliography). They show an abnormal composition: Au 94.53 and 92.83 wt.%, Ag 5.05 and 6.54 wt.%, Cu 0.37 and 0.52 wt.%, Sn 0.06 and 0.12 wt.% (A. Agostino, M. Labate, M. Aceto in Facchinetti, 2022, p.223). The so called "Gaulish" *solidi* have been discussed by Carlà (2009, pp.444-457). Because of their unusual composition these 2 *solidi* deserve new analyses in the future researches.

XRF analyses of the jewels, of the fragment of the ingot and of the gold scraps found in the Treasure of Como, and those of the 1.000 *solidi* have shown quite variable gold percentages (44.85 - 98.24 wt.%), but their composition is mostly less pure than that of the *solidi* (A. Agostino, M. Labate, M. Aceto in Facchinetti, 2022, p.224). Possibly their gold had not been cemented, as it has been observed in other contexts (Ramage and Craddock, 2000, p.31 and nt.33 with bibliography). They were made in different workshops.

A follow up of the analyses by increasing the number of specimens (*solidi*) and investigating their trace elements will allow us to compare the composition of the coins of Como with those discovered in the other hoards from the same period. It would be possible to see if they agree with analyses of other coins struck by the same emperors or if there are differences between those struck by the same emperor in the western and eastern mints, for example those struck by Leo I.

Table 2. The organisation into departments of a late imperial mint. From gold purification to the production of the blanks.

Department	Tools and materials	Workers	Features of the workshops
Gold purification by cupellation	Wood burning hearths, cupels of bone ashes, metallic lead.	*Aurarii* (?)	Dark workshops to control the process.
Gold parting by cementation	Furnaces with iron grills, crucibles or clay pots; clay, lute, sea salt, ochre, misy. Working benches with small anvils and hammers to flatten. Water containers for rinsing the gold foils.	*Aurarii* (?)	Light for the work at the benches and at the furnaces; ventilation, water supply available.
Gold assaying	Touch stone, small furnaces; punches.	*Probatores et signatores auri Aurifices*	Well-lit ateliers.
Gold melting and casting	Small furnaces, fire-resistant crucibles having a rounded bottom and a spout. Tongs with curved heads, spiral shaped small sticks, ingot moulds. Punches for ingots.	*Aurifices solidorum*	Dark workshops to allow the evaluation of the temperature of the metal.
Cutting and adjustment of blanks	Working benches (with drawers?). Hammers to flatten. Measuring instruments and compasses. Shears. Precision balances, weights, iron files and burnishing stones.	*Aurifices solidorum*	Well-lit workshops.
Recovery and recycling of gold scrap	Mortars with pestles, sieves, tweezers, water tanks.	*Aurifices solidorum*	Well-lit workshop, water supply available.

Minting

Facchinetti

As it is well known the *solidi* were minted coins: a blank was inserted between two dies, one of which rested on an anvil. The types and legends were struck by hitting the upper die with a hammer. In this way, thanks to the malleability of the metal, a superficial deformation of the blank was achieved, corresponding to the impressed parts of the die (Delamare, Montmitonnet and Morrisson, 1984).

Thus, coinage belongs to the final part of the coin production cycle, but before this it is necessary to prepare not only the blanks, but also the dies (Table 3). The body of the die was made of iron or of bronze (Malkmus, 2007). The body of the bronze dies was made by casting the molten metal into a cylindrical or truncated cone mould. Dies were subject to an ever-increasing wear during coinage that can be recognized by the loss of details up to their final breaking. Some of the *solidi* of the Treasure of Como show irregular lines that can be identified as the cracks formed in the dies (Facchinetti, 2020, p.177). In the *solidus* of Libius Severus depicted in Figure 12, for example, it is possible to see the imprint of the die fracture in the left-hand part of the field. In the Treasure of Como, this solidus belongs to a group of 35 coins produced with the same D/ die: their examination shows a deterioration of the die to the point of fracture.

After that the base of the die had been polished and quenched if it was made of iron, it was engraved using chisels and burins. Some repetitive details such as the pearls on the crowns of the emperors could have been made using small punches. A final polishing of the surface took away all the small irregularities that may have formed by the engraving or by the use of punches.

Figure 12. Solidus of Libius Severus (*Mediolanum*, 461-465; Facchinetti, 2022, cat. no.538) showing the imprints of the cracks of the die. Photo: L. Caldera. © MiC - SABAP-CO-LC.

Possibly engraving began with the subdivision of the surface into two concentric circles using a compass. They had the purpose of helping in the making of the beaded rim and of the legend inside it. No traces of the first circle remain because it was completely removed by the making of the edge, however, the second is still visible on some coins as a thin curved line in relief in the space between the letters (Figure 13).

The engravers could make also other reference lines to make the main design, but no trace of them is left because of the ensuing engraving. Changes in the spacing or in the dimensions of the letters in order to adapt them to the space left by the main design and sometimes the partial overlapping of legend and main design, show that the engravers after dividing the space and drawing the

Figure 13. Solidi of Leo I (a. *Mediolanum*, 461; Facchinetti, 2022, cat. no.120) and Maiorianus (b-c. *Mediolanum*, 457-461; Facchinetti, 2022, cat. nos.436 and 437) showing the lines made by the compass in order to arrange the letters. Photo: L. Caldera. © MiC - SABAP-CO-LC.

Figure 14. Solidi showing the superimposition of a letter to the figures: a. Anthemius (Roma, 467-472; Facchinetti, 2022, cat. no.775); b. Valentinian III (Ravenna, 426-430; Facchinetti, 2022, cat. no.237); c. Anthemius, (*Mediolanum*, 467-472; Facchinetti, 2022, cat. no.793). Photo: L. Caldera. © MiC - SABAP-CO-LC.

exergo line, made the images first and then the monetary legends (Facchinetti, 2022, p.175) (Figure 14).

It is interesting to observe that the letters were not made using punch marks, as it happened in the Middle Ages. The examination of the letters repeated on the same die shows differences in their shape and dimensions which show that each one was engraved individually.

As the production of gold coins (solidi) was discontinuous, in short periods of time and possibly without notice, and tied to the presence of the *comitatus*, the mints, especially those of the western Empire, had no way of planning their activities. Moreover, the existence of different styles in the various mints suggests that the engravers did not belong to the retinue of the *comitatus*. But in exceptional occasions, this meant that the dies could not be made ahead of their usage, but we do not know how long would it take to make the new dies. To shorten the time, the dies of earlier coinages, those from other mints and those of the R/, which had been produced for the coinages of various emperors, could be used. In Como Treasure there are *solidi* showing how two dies of reverse, one belonging to the mint of Milan, the other to that of Ravenna, were used for coinages in the name of different emperors: Leo I, Maiorianus and Libius Severus in Milan and Leo I and Maiorianus in Ravenna (Facchinetti, 2020, pp.172-173). Moreover, a die of Obverse of Anthemius made in Milan was used also in Rome (Facchinetti, 2020, p.171).

We must envisage that the mints had archives where the dies were safely kept both during times of daily interruptions in the production and in the periods of absence of the *comitatus*.

The study of the coins shows that the production sequence for the *solidi* could be simplified, possibly because of the need for minting large numbers of coins in a short time.

Numismatics are well aware of the practice of minting new coins using those belonging to previous monetary issues. In this way it was possible to shorten the time avoiding the production of new blanks. Although gold is quite malleable this second coinage does not always erase the traces of the previous one, since the degree of malleability decreases after the first coinage if the coins are not re-heated (Delamare, Montmitonnet and Morrisson, 1984, p.9). This allows us to recognize coins made in this way, as, for example, a *solidus* of Ariadne from the hoard of San Mamiliano at Sovana (Grosseto) (Longo, 2015) which shows traces of a previous coinage. Also, in the Treasure of Como there are overstuck coins, e.g a *solidus* of Leo I of the mint of Constantinople (Facchinetti, 2022, cat. no.74; Figure 15)

Not melting the coins meant that it was not possible to ascertain the purity of their gold and so risking the use of false coins with a gold purity below the standard.

It seems that a special method was used in order to avoid this problem, but as far as we know it was used in the mint of Constantinople only. Some *solidi* attributed to this mint show a quadrangular hole with inflexed edges possibly made with a chisel and then filled up with gold fragments (Figure 16).

Joan Fagerlie was the first person to systematically study these specimens starting with those in Scandinavia. She called these coins "mutilated", because this mutilation was always on the obverse carrying the emperor's face and she interpreted it as a form of test of the gold without ruling out that the defacement of the emperor had a political intent (Fagerlie, 1967, pp.145-147). The emperor's portrait was the legitimizing element of the monetary issue Fagerlie thought that the mutilation

Figure 15. Solidus of Leo I (Costantinople, 457-468; Facchinetti, 2022, cat. no. 74) reminted from a damaged coin. Photo: L. Caldera. © MiC - SABAP-CO-LC.

Figure 16. Solidus of Leo I (Costantinople, 457-468; Facchinetti, 2022, cat. no.76) with mutilation at its center. Photo: L. Caldera. © MiC - SABAP-CO-LC.

"were made by peoples living close to the empire and perhaps by those who were the intermediaries in the contact between Scandinavia and the South" (Fagerlie, 1967, p.146).

More recently Svante Fischer has suggested that the mutilation of the coins was made by tax collectors. Since taxes had to be paid in gold they checked and marked coins to be used for the production of new *solidi*. The reintegration of the weight of the coins may have had the purpose to place them in circulation. The mutilated coins in the hoard of San Mamiliano at Sovana (Grosseto) suggested an alternative hypothesis to Fischer. The mutilation may have been made in the Western Empire, possibly in Italy between the years 476 and 477, according to the latest coins from the Scandinavian hoards. Perhaps this was done with the aim of marking those coins destined to leave the boundaries of the empire for ever because of their use for the payment of the Scandinavian mercenaries. To them the mutilation may have represented some sort of quality mark and check on the gold they received (Fischer, 2019, pp.16-19).

A review of the literature and in light of the new data from the mutilated *solidi* of Como has allowed us to suggest a new interpretation (Facchinetti, 2022, pp.180-187). It is based on the fact that the traces of the mutilation are visible both on the Obverse and on the Reverse of the coins and that some of these coins were clearly overstruck after their weight was reinstated. In fact, details of the main design were impressed on the gold fragments used to fill the holes. This is clearly visible on some of the *solidi* in the above-mentioned hoard of San Mamiliano (Arslan, 2015, cat. nos.38, 69) and of the Treasure of Como (Facchinetti, 2022, cat. nos.44, 68, 86) (Figure 17).

Thus, we cannot rule out the possibility that all the mutilated coins were overstruck but that they were not recognized as such because of their poor conditions. We should remind that studies about this subject are based mainly on coins discovered in Scandinavia, which are often very worn. Even if the first mintings were not completely erased by overstamping, the resulting difficulty in identifying the main motifs makes it impossible to tell whether the mutilation was carried out in the imperial portrait or in the figures of the R/.

If we accept the hypothesis of a systematic overstriking of this type of coins, we may be reminded that as far as we know all of them are from the mint of Constantinople. Then their mutilation was done in the East and it was somehow connected to their method of production. We can think that it was a means to verify their alloy, a task of the *comes sacrarum largitionum* (*CTh* XII, 8, 1), according to the *constitutio* of Arcadius of 409, which was carried out in the mint itself. Since its purpose was to verify the alloy and it was made in a state atelier, if the sampling was made on the obverse, it does not seem that the damage of the imperial portrait would fall into the crime of *maiestas* (Carlà, 2016), most possibly the same can be said about the destruction of imperial portraits when old coins were melted down.

Sampling of a small specimen of metal from the coin was a method to quickly verify the alloy. If the specimen assayed by melting showed that it was gold, then the coin's weight was reinstated filling up its hole with gold fragments before overstriking.

The use of mutilations in coinages, as *RIC* 605 in the name of the emperor Leo I, produced in large quantities suggests that it was a strategy to shorten the production time in a period when huge amounts of gold coins were needed at short notice. Concerning *RIC* 605, coined be-

Figure 17. Solidus of Leo I (Costantinople, 457-468; Facchinetti, 2022, cat. no.86) with mutilation at its center. The gold used to fill up its hole is minted. Photo: L. Caldera. © MiC - SABAP-CO-LC.

Figure 18. Solidus of Libius Severus (*Mediolanum*, 461-465; Facchinetti, 2022, cat. no.620) with faulty coinage on the Obv. Photo: L. Caldera. © MiC - SABAP-CO-LC.

tween 462 and 466, it is possible to connect this intense production to the financial needs for preparing the military expedition against the Vandals in 468.

Even if Late Antiquity minting was standardized, it was possible to implement solutions aimed to optimize the production by skipping or shortening some of its stages.

The end of the production cycle must have included a control of the quality and of the weights of the coins and a registration of their quantity. The weights of the blanks and of the coins to be overstruck were verified before their coinage. We cannot rule out that they were weighed again before being put into the imperial coffers to make sure that the mint workers did not file or cut small bits of the blanks in order to steal precious metal. A visual inspection of each coin was necessary to check if legends and types were readable. The *solidi* of the Treasure of Como suggest a lowering of the quality standards during the 5th century mainly in the western mints. In fact, some of these coins show faults in their minting due to a bad positioning of the blank between the dies or to a rotation or slipping during repeated minting attempts or to the use of damaged blanks (Facchinetti, 2022, pp.177-180; Facchinetti and Cucini, in print) (Figures 15 and 18).

It is not by chance if the *solidus* at Figure 15 belongs to the above-mentioned series *RIC* 605 and can be connected to the financial needs for the war against the Vandals. But the greater percentage of clearly faulty western coins shows the possible deterioration of the technical level of the workers starting with the engravers themselves. In facts there is a clear tendency toward simplification in the representation of the main designs which is not due to their small size (Figure 19), as shown by the comparison with a *solidus* of Anthemius minted in Rome in 467-468 using dies made by an engraver possibly from the east (Figure 20). Only two specimens of this coin are known (Facchinetti, 2022, p.195).

It is easy to link this deterioration in quality to the political events of the last turbulent decades of the western empire. These must have had an impact on the staff of the *comes sacrarum largitionum*.

Table 3. From dies production to minting

Department	Gears and materials	Staff	Features of the workshops
Production of dies	Melting furnaces. Working benches, compasses, chisels, burins.	*Artifices* *Sculptores*	Very well-lit workshops.
Minting	Working benches with anvils. Dies, tongs, hammers, containers for coins.	Minters	Well-lit workshops.
Check	Scales, books.	Imperial officers	Well-lit workshops.
Archive	Safes to keep the dies.	Imperial officers	High security rooms.

Figure 19. Solidi of Libius Severus (a. Rome, 462; Facchinetti, 2022, cat. no.503) and Anthemius (b-c-d. Mediolanum, 467-472; Facchinetti, 2022, cat. nos.795, 794, 882). Photo: L. Caldera. © MiC - SABAP-CO-LC.

Figure 20. Solidus of Anthemius (Rome, 468; Facchinetti, 2022, cat. no.756). Photo: L. Caldera. © MiC - SABAP-CO-LC.

The *moneta comitatensis* of Milan

Cucini

The reconstruction of the operative chain of the *solidi* shows that various ateliers with their own features and staff with diversified specializations were necessary for their production.

As there have been no archaeological excavations of a late antique mint to date, the question remains as to how such a workshop should be imagined. In order to guarantee their safety, they must have been within strong buildings with few entrances that could be kept under control and in areas safely in the hands of the imperial power. They had to be close to the warehouses of precious metal and well connected to urban and suburban roads. Easy hauling of all supplies and of the product to be distributed, i.e. the coins, was essential for the mints as for any other large manufacturing enterprise.

It has been suggested identifying the mint of Milan's *comitatus* with the remains of strong buildings discovered during construction works between 1864 and 1904 and again in 1949 in the piazza Mentana, in the southernmost area of the imperial palace (C. Cucini in Facchinetti, 2022, p.259). This building was large at least 45 x 48 m, it had up to 6 m thick foundations made of pebbles and it was subdivided into large quadrangular rooms (Calderini and Gerra, 1951). The old excavations were limited to observing the position of the walls without investigating the areas inside the rooms. Because of this the little information gathered does not offer many clues for the identification of the purpose of this building which originally had been interpreted as thermal baths because it is near to via Bagnera (from *balnearia*) (Calderini and Gerra, 1951; Ceresa Mori, 2018, p.100). Its position inside the southern part of the imperial palace, possibly reserved for the service and the dwellings of the *potentiores* (Ceresa Mori, 2018, pp.111-112; Ceresa Mori and De Vanna, 2020, pp.27, 31-32), its proximity with the *cardo* (today Via Torino) and to the *porta Ticinensis* and last but not least its strong walls seem to correspond with the above-mentioned requirements for the mint of the *comitatus*. Because of the building's size we cannot rule out that it hosted not only the mint but also the *thesaurus*, known from the *Notitia dignitatum* (*Occ.* XI), where gold ingots and coins were kept. Until new archaeological investigations allow us to verify this hypothesis, we cannot rule out that the building in Piazza Mentana was really the seat of the *opulens moneta* cited by *Ausonius* (*Ordo Urbium Nobilium*, 7, 6).

Conclusions

Cucini and Facchinetti

The detailed study of the gold *solidi* from the Como hoard has led to far-reaching insights into the reconstruction of the production process. The results make it possible to propose a reconstruction of the *chaîne opératoire*, which was used in the mints of Late Antiquity for the production of gold coins. The detailed inspection and examination of these coins using XRF and SEM/EDS made it possible to reveal the technique used to produce the coin blanks. The iron filings visible to the naked eye in the body of about 62 coins lead us to reconsider the whole system of blank making.

The production process was fast and efficient, requiring far fewer workers (and potential thieves) and reduced the production process just to the essentials.

The process began with the preparation of the delivered gold in the late Roman Imperial mints. Here, gold came from different sources. Most of the gold was already processed into coins collected by taxes and levies: this gold had a high degree of purity. Possibly also scraps, semi-finished gold objects, broken jewels were reused in the mints and would have variable gold percentage. A smaller quantity of gold was mined from hard rock lodes and from gold placers. This "new" gold needed a preliminary smelting under oxidizing conditions and a further purification by cupellation.

The reforms of Valentinian I and Valens (366-367 AD) established that all the gold from any source reaching the state mints had to be purified and cast into ingots. Purification and melting of large quantities of gold in the late Roman mints were well organized. The sequence of operations was split into different departments.

The first phase was parting gold from silver and any other metals by the salt cementation process. Gold was beaten into foils and covered with a "cement" formed by a mixture of common salt, ochre and corrosive sulfates. These cemented foils were arranged in crucibles sealed with clay and put on a charcoal fire at low temperature. The chemical attack was repeated for days in well-ventilated rooms with many small furnaces. The purified metal was assayed before coinage by the method of fire assaying.

After the refining of the gold, it was poured into elongated moulds as wide as the diameter of the *solidi* to obtain narrow gold strips about 1 mm thick. After cooling, these were then cut into squares and then into a circular shape of the desired width using shears and their edges were adjusted with files *al pezzo*. During the adjustment of the shape and weight, small iron filings from the files and from the blades of the shears detached. All scrap and cut out of pure gold produced in this operation had to be recovered and recycled. In this way the iron filings ended up in the following melting process.

Given the effectiveness of the process and the professionalism of the minters, we surmise that the technology used for the *solidi* must have been the same as that used for the *tremissi* and their subunits. Moreover, numerous references to gold coins from the Republican and early Imperial periods published by authors (see p.13) indicate that the origin of this production technique predates the late Imperial period. The same production technique was also used later in the Middle Ages and into the Renaissance.

Our analysis has provided new results that support previous hypotheses and has made it possible to recognise that techniques such as the production of blanks from metal foils (which are better known in later periods) were already used by the 5th century. Observation of the presence of iron filings in the *solidi* from Milan, Rome and Ravenna shows that the same *chaîne opératoire* was most probably used in all these mints. At present, we know of no coins from eastern mints that show similar traces of iron filings, even if the coins were made using the same production methods. The absence of iron filings could be explained, among other things, by a more careful separation from the gold filings.

This technological uniformity of the production process is very understandable when one considers that some aspects of gold processing are simpler than those of other metals, making it more conservative. Once the production system was mastered, it was used by all imperial mints and continued to be used without significant changes until modern automation. The origin of the gold is still an open question. As a large part of the *solidi* was minted melting down old coins, it can be assumed that part of the gold did not return to the state treasury. It was set aside or used to pay barbarian mercenaries, tributes to the Germanic tribes or to make precious items (Facchinetti, 2022, pp.87-90). Therefore, it was necessary to have secure sources of raw materials. XRF analyses of 45 *solidi* have shown a gold content between 99.52 and 99.98 wt.%. Silver was not detected; copper and iron are present at very low percentages. So, the color and hardness of the coins did not change, and this was quite important for the Roman state. Only 4 *solidi*, all from the last period of activity of the imperial mint at Milan, have a low percentage of tin. Because gold from the Alpine Italian deposits is not associated with cassiterite, this gold with tin must have come from other geological regions. XRF analyses of 2 *solidi* attributed to non-official ateliers show an abnormal composition and also the semi-finished gold objects and broken jewels found in the Treasure of Como had variable gold percentages.

The Como Gold Treasure analysis project is currently ongoing. The aim is to identify the exact composition or classification within the treasure inventory and to begin identifying the gold sources by analysing gold samples from hard rock sources and placer deposits. Future analyses will examine gold deposits in the Italian Alps to determine the sources of the gold used in the mints.

Notes

1 Regarding the discussion about the number and the dating of the different coins, the value and comparison with other hoards as well as the discussion about the deposition: Facchinetti, 2022, pp.43-64, 127-212, 279-300 (with E. Possenti).

2 Such as the anthology of Greek-Roman texts of the manuscript *Parisinus Graecus* 2327 (Wolters, 2006) and the 12th century Schedula of Theophilus (Hawthorne and Smith, 1979).

3 ASN 1937.158.276, https://numismatics.org/collection/1937.158.276?lang=it.

4 MAN, Naples, inv.P.14273, https://www.medaglieri.numismaticadellostato.it/#/vetrine-virtuali/lista-espositori/3/visita-virtuale/elenco-moneta/560?nominale=aureo&idEspositore=3&online=true.

5 MAN, Naples, inv.P.145503/8, https://www.medaglieri.numismaticadellostato.it/#/vetrine-virtuali/ricerca-avanzata/elenco-moneta/553?nominale=aureo&online=true.

6 ANS 1980.109.166, https://numismatics.org/collection/1980.109.166?lang=it.

7 ANS 1967.153.81, https://numismatics.org/collection/1967.153.81?lang=it.

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