ARCHAEOMETALURGICAL AND MANUFACTURING PROCEDURES: STUDIES OF TWO ANCIENT COPPER COINS 1851 AND 1853

Fig. 1 The Soho Manufactory

Introduction

The coins presented in this study belong to the Republic of Chile, Independence stage, and their values are One cent (1851) and Half cent (1853). The 1851 coin belongs to a private collector and the 1853 coin was rescued from the archaeological site "Historical Fort May 25 Village" and is currently exhibited in the Narciso Sosa Morales Museum in front of the actual site. Numismatic studies support the observation of the relationship between money and nations. Coins are a material testimony of the identity of a people, of an era and of the monetary policies that have animated the economy. Engravers and craftsmen have shaped in metal many of the most significant characteristics of the history of a nation, as well as its artistic development. The rich iconographic heritage allows us to read the historical symbols of our societies and recognise the identity of young American nations following their Bicentennial celebration. The creation of these new nations required a new image, hence new symbols derived from the local nature such as erupting volcanoes; the Andes Mountain range; the sun; the eagle and the condor; the Andean camelids, are added to more historical or political symbols such as hands swearing on the constitution; the figures of the Republic and Minerva. These latter are representations of freedom and the education of the people through the school, amongst others. In the 18th century, the idea of the nation began to slowly form as a group made up of individuals who associated freely and with the fragmentation of the old Spanish empire in America, the new nations required symbols that would give a homogeneous identity to these new countries. In the country of Chile, through the enactment of the law of January 9, 1851, the Chilean monetary system was transformed, moving from Reales and Escudos to Pesos and Centavos, with the following equivalence 1 Peso = 8 Reales. The aforementioned law, in article 4, states: "There will be two kinds of copper coins, called cents and half a cent of refined copper without mixing any other metal." And the law of March 19, 1851, established that: "The copper coins will bear on the obverse the central star of the shield with the inscription: Republic of Chile and year of issue; and on the reverse, the expression of its value, a bouquet of circular laurel, and the motto: “Economy is wealth”. Throughout the numismatic history of Chile, different versions of the coat of arms have been used on the coins. Initially, when Chile was a Spanish colony, the coats of arms of Spain were used. Later on, when independence came, Chile’s coat of arms showed a shield that depicted the Earth on a pillar. There were more simplified versions of this coat, in which only the central flat star was shown like in the case of the 1851 coin, however, in the case of the 1853 coin, the same shield is represented but with a five-pointed star possessing additional relief. These precise details are observed in Fig. 7.

In order to comply with this law, copper was commissioned from the Carlos Lambert smelter in Coquimbo (Chile). The plates produced were taken to Santiago where they were minted at the Casa de Moneda. The defects in the plates resulted in the coins having high variability in weight, which ranged between 8.388g and 9.400g.

Fig. 2 Map location of Birmingham Mint, 71 Bath Street. ©Landmark Information Group Ltd. and Crown Copyright 2021. FOR EDUCATION USE ONLY.

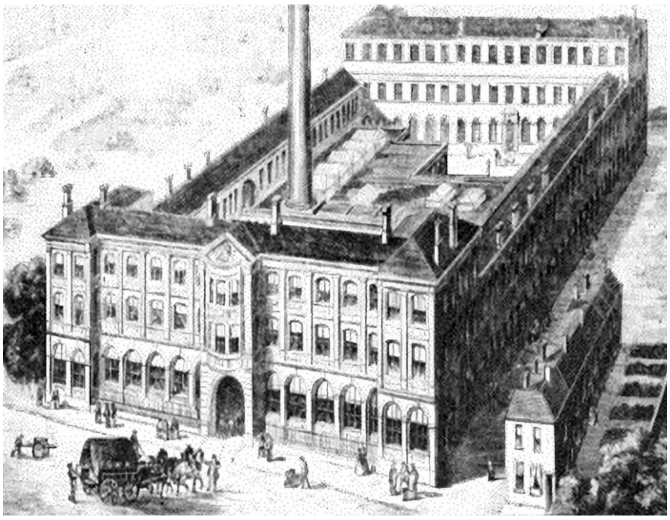

Fig. 3 Exterior view of Messes. Ralph Heaton and Son's Mint, Birmingham.

This added to the technical deficiencies of the mint for the minting of copper coins (it was the first time that such large quantities were produced), and it consequently led to halting the production of these coins in the country, and the production moved abroad. Except for the information presented below, there is no complete information on which variant was minted in which country. These historical coins have been catalogued as KM # 119.4 and KM # 126 and were minted by The Heaton & Sons' Mint, located in Birmingham, England.

Ralph Heaton II

Ralph Heaton II (1794 – October 1862) was the son of Ralph Heaton I, an engineer, inventor and businessman in Slaney Street, and later Shadwell Street in Birmingham. Ralph Heaton II was a die sinker operating in Shadwell Street independently of his father. On 2 December 1817, Ralph I conveyed to his son, land and buildings at 71 Bath Street (Fig. 1 and 2) to enable him to develop a separate company. Ralph II engaged in brass founding, stamping and piercing, examples of his products are brass chandeliers for the newly invented gas lighting and a patented "bats wing" burner.

Birmingham Mint

The Birmingham Mint, a coining mint, originally known as Heaton's Mint or Ralph Heaton & Son's Mint, in Birmingham, England, started producing tokens and coins in 1850 as a private enterprise, separate from, but in co-operation with the Royal Mint. On April 1, 1850, the auction of equipment from the defunct Soho Mint, created by Matthew Boulton around 1788, was announced. At the auction on April 29, Ralph Heaton II bought the four steam screw presses and the six plate presses for making blanks from metal strapping.

This information is very well described in a newspaper of the time, where it is reported that a complete set of presses, pneumatic pumps, and other machinery for minting, were acquired by Ralph Heaton and Son. In this news, it became obvious that Ralph Heaton & Son intended to move their attention to a long-term monopolized manufacturing branch of the Soho company (Heaton Mint 1850). The Ralph Heaton and Son's Manufactures were installed at the 71 Bath Street works (Fig. 2 and 3) and trade tokens were obtained that year for use in Australia. In 1851, coins were minted for Chile. The same year, copper plates were made for the Royal Mint to convert into pennies, halfpennies, farthings, half farthings, and quarter-farthings. In 1852, the Mint won a contract to produce a new series of coins for France. At this time, the Mint was a pioneer in the minting of bronze. In 1853, the Royal Mint was overwhelmed with the production of gold and silver coins. They even re-minted copper coins for Chile. The Birmingham Mint won its first contract to mint finished coins for Great Britain: 500 tons of copper, minted between August 1853 and August 1855, with another contract in 1856. During the peak of operation by their new owners in Birmingham, the four presses of the original Boulton screw and James Watt hit around 110,000 coins a day.

As overseas orders increased, particularly for Chile and India, the Mint added a new pressure lever and more equipment, filling the Bath Street facility. In 1860, the company purchased a 1-acre (0.40 ha) parcel on Icknield Street (the current site, since it was expanded) and built a three-story red brick factory, completed in 1862, where it employed 300 people. At that time, it was the largest private mint in the world. In 1861, a bronze coin contract was signed for the newly unified Italy, and the Mint sent blanks and equipment to Milan for its Milan staff to convert into finished coins.

Fig. 4 Birmingham Mint and its Façade on Icknield Street.

Experimental Cleaning method: Electrolytic Reduction

The coins under study were in good conditions and not only were their metallic cores well preserved, but the original surface was covered only with non-deforming corrosion products that could be easily reduced back to the metallic state via a simple cleaning procedure. It was decided to use electrochemical cleaning through electrolytic reduction (Aldaz et al 1986). This treatment consists in the creation of a galvanic reaction in which the metallic object to be treated acts as the cathode and a galvanized steel sheet (zinc) or an aluminium sheet act as the anode, with 1%M sodium hydroxide as the electrolyte. When the galvanic reaction takes place, the less noble metal (aluminium or zinc) loses electrons in favour of the more noble metal (copper), thus producing a reduction of some corrosion products back to the metallic state. At the same time, the reaction produces hydrogen, which when released forms bubbles that mechanically removed further corrosion products from the metal surface. The results obtained were very satisfactory: the treatment needed just a fraction of time (2 hours) usually required for metal cleaning; the degree of cleanliness achieved allowed the revelation of appreciable details on the copper coin surface. Different results can be obtained depending on the intensity of the applied current which affects the rate of reduction of the

Fig. 5 The before (5 a. and 5 b.) and after (5 c. and 5 d.) of the 1853 historical copper coin to electrolytic cleaning and macroscopic images.

Fig. 6 Inverse and reverse of 1851 historical copper coin after the electrolytic cleaning.

Table 1. 1853 Coin characteristics by Krause catalogue

Material	Copper
Weight	4.6-5.0 grams
KM#	126
Diameter	22mm
Edge	Smooth
Year	1853
Print	2.667.000
Coined	Heaton Mint, Birmingham, England

Table 2 1851 Coin characteristics by Krause catalogue

Material	Copper
Weight	10 grams
KM#	119
Diameter	30mm
Edge	Smooth
Year	1851
Print	no found data
Coined	Heaton Mint, Birmingham, England

Fig 7. Half a Cent Coin 1853 by Krause catalogue.

Fig. 8 One Cent Coin 1851 from Classical Numismatic Group.

corrosion products to the metallic state and mechanical cleaning by the action of bubbles of hydrogen on the surface. But in general, it is advisable not to work with very high currents, due to the complexity of the chemical reactions that could occur and affect the cleaning process sought (Birchenall 1977).

Figs. 5 a. and 5 b. show the state in which the 1853 copper coin was received and Figure 5c and 5d show the coin after cleaning. Figure 6 show the 1851 coin after cleaning. The clean and polished coins (Figs. 5c and 5d and 6) clearly show their origin, year of issue, monetary value, legend and two laurels.The material is primarily Copper (Cu), with alloying elements that do not play a major role in the chemical composition of this historical element.

Due to the calamine (green) patina formed on its surface, which behaves as a protective barrier over time and corrosion, the coins have maintained an almost perfect state of preservation. Coin minted in 1853, Republic of Chile, five-pointed star in relief, Value: Half a Cent, Legend: Economy is Wealth.

These coins (1851 and 1853), are mainly identified by:

Inverse: REPUBLICA DE CHILE, Star of five points and year of minting 1853 between two points. Numbers 1 of the date with straight top.

Reverse: ECONOMY IS WEALTH. Denomination in words surrounded by laurels. Four-pointed star on bottom. Letter ‘Q’ for “RIQUEZA” with short outer tilde for the 1853 coin. And for the 1851 coin the letter ‘Q’ with the

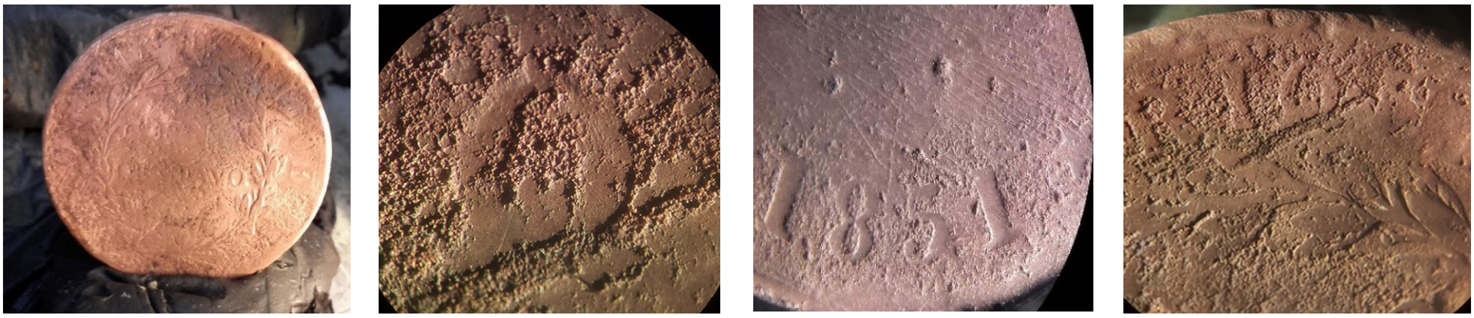

Fig 9. Historical coin macroscopy 1851; Value: One Cent.

Fig 10. Three images of the 1 Cent coins (1851) typified as (KM # 119.2; KM # 119.3 and KM # 119.4) on their back for the morphological comparison of the letter Q.

Table 3. Characteristics of the 1851 coins compared

Date	Mintage	Frequency	Characteristics
1851	100000	38%	**KM#119.1** (Pointed top-1 Single loop in wreath’s knot; leg of “Q” like ~) Santiago Mint; rare
1851		42%	**KM#119.3** (no mintmark on left star; double loop on wreath’s knot; short leg below “Q”) Heaton Mint
1851		9%	**KM#119.4** (no mintmark in left star; flat star; leg traversing “Q”) Heaton Mint; rare
1851 H	3300000	36%	**KM#119.2** (mintmark in left star; flat 5-pointed star; double loop on wreath’s knot) Heaton Mint

Chemical analyses

Table 4 1853 Coin Chemistry Composition

% Zn	% Ni	% Fe	% Mn	% Cu	% Pb	% Si	% As	% Bi
<0.076	0.099	<0.090	<0.015	96.2	<0.10	<0.26	0.091	0.11

Table 5 1851 Coin Chemistry Composition

% Zn	% Ni	% Fe	% Mn	% Cu	% Pb	% Si	% As	% Bi
<0.063	0.069	0.062	<0.016	80.0	<0,066	0.48	0.10	0.079

Comparison of chemical compositions with other coins also minted in England in the same period.

Table 6 Coin: HMS Investigator, Country: Great Britain, Analysis: R4887/Mean

Date	Fe	Co	Ni	Cu	Zn	As	Sb	Sn	Ag	Bi	Pb	Au	S
1848	0.01	0.01	0.05	99.29	0.01	0.32	0.03	0.00	0.07	0.10	0.04	0.03	0.00

Table 7 Coin: Caduceus (bolt), Country Great Britain, Analysis: R3915/Mean

Date	Fe	Co	Ni	Cu	Zn	As	Sb	Sn	Ag	Bi	Pb	Au	S
1857	0.00	0.00	0.10	99.48	0.01	0.17	0.02	0.00	0.05	0.02	0.09	0.03	0.01

Table 8 Coin: Islay locomotive (steam pipe), Country: Great Britain, Analysis: NRM4

Date	Fe	Co	Ni	Cu	Zn	As	Sb	Sn	Ag	Bi	Pb	Au	S
1857	0.00	0.00	0.04	99.48	0.00	0.17	0.01	0.01	0.07	0.05	0.12	0.03	0.00

Table 9 Coin: Islay locomotive (steam pipe), Country: Great Britain, Analysis: LCul

Date	Fe	Co	Ni	Cu	Zn	As	Sb	Sn	Ag	Bi	Pb	Au	S
1857	0.00	0.01	0.04	98.77	0.01	0.32	0.03	0.01	0.02	0.09	0.63	0.01	0.03

Mechanical Testing

Table 10 1853 Coin, Vickers Microhardness

1º	146 HV	138.7 HBr
2º	132 HV	125.4 HBr
3º	121 HV	115.0 HBr
AVERAGE	133 HV	126.36 HBr

Table 11 1851 Coin, Vickers Microhardness

1º	137 HV	130.15 HBr
2º	109 HV	103.55 HBr
3º	101 HV	95.95 HBr
AVERAGE	116 HV	109.88 HBr

Macroscopic Observations of the 1851 Historical Copper coin.

For the Chilean 1 Cent copper coin of 1851 (Figs. 9 and 10) there are variants regarding the shape of the letter Q in the word WEALTH (RIQUEZA in Spanish). The first type (KM # 119.2 and KM # 119.3) has the Q leg only outside the letter (common) and in the second type (KM # 119.4) the Q leg crosses the letter (rare).

There is another variant, even rarer, with the Q leg ~ like to the letter Ñ (from the Spanish Alphabet).

In this case, the 1 Cent copper coin from 1851, the letter Q for the word WEALTH, it is seen that the Q leg crosses towards the inside of the letter Q [4], (Table 3).

The investigation of the coin's microstructure was performed after etching. For etching, alcoholic solution of 2% ferric chloride ($FeCl_3$) was used.

The 1853 coin shows a grain structure typical of hot-working and consequent annealing with some visible twin grains, variable grain size, and some porosity seen as dark holes due to corrosion (Fig. 11). There is no evidence of second phases precipitation. Some intragranular fractures have also occurred due to copper corrosion.

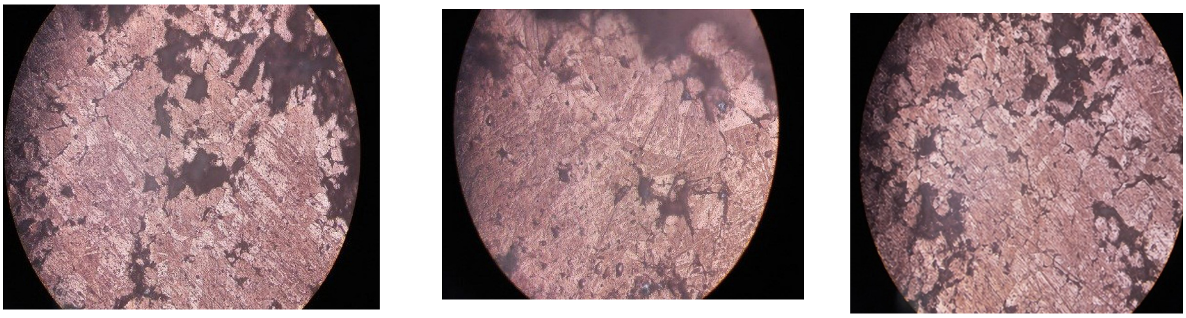

Fig. 11 Micrograph of the 1853 historical copper coin. Detail corrosion by pitting. Reagent: Alcoholic solution of 2% ferric chloride (FeCl3). Magnification: 100X

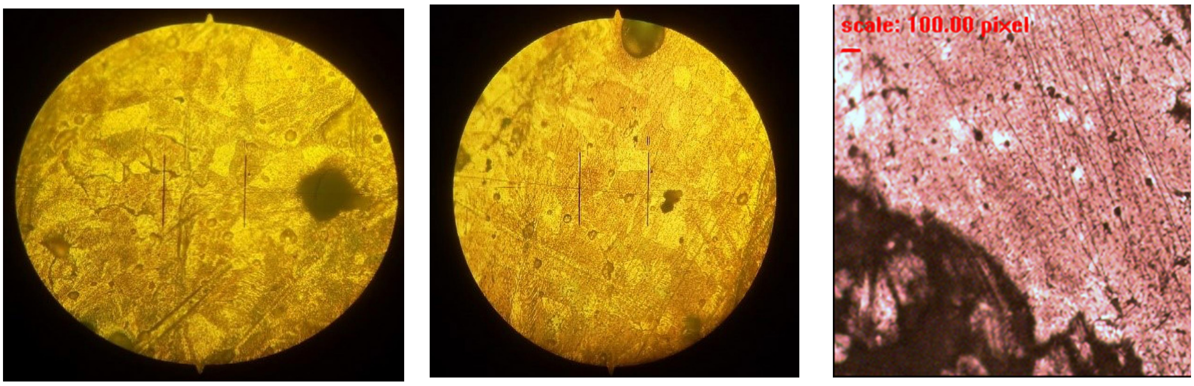

Fig. 12 Micrograph of the 1851 historical copper coin. Corrosion at the grain edge and detail of slight porosity. Reagent: Alcoholic solution of 2% ferric chloride (FeCl3). Magnification: 400X (a, b) and 100X (c).

The 1851 coin shows a structure with a well-formed recrystallized grain matrix, having straight twin lines and very little porosity present (Fig. 12). There is no evidence of a secondary phases. The X-ray fluorescence analysis for both coins confirms that only minor, trace-type alloy components are involved with Copper (Cu) being the majority component. The chemical data and the metallographic evidence both indicate that the alloy is of a single phase in line with the historical decree of January 9, 1851, when the Chilean monetary system was transformed from Reales and Escudos to Pesos and Cents, and this decree of law said: "There will be two kinds of copper coins, called cents and half a cent of refined copper without mixing any other metal."

According to the manufacturing method used at that time, a rail was prepared where the molten metal was poured, which was obtained from a coal furnace first and later with the passage of time, it was operated with gasoline, so the metal contained in the crucibles was melted and then it was moulded to obtain solid ingots, (Fig. 13).

Ingots that did not have the adequate thickness to obtain the blanks, needed to pass several times through the rolling mills, (two rollers that pressed the metal strip) to be stretched until it obtained the required thickness. When the rail hardened, it was necessary to anneal it to re-laminate it (Figs. 14 and 15). If the rail was too long, it would be cut into smaller pieces.

Once a thickness equal to the blanks was achieved, the rails were annealed to make it more workable. Since oxidation could be generated during annealing, the rails were put in the furnaces in sealed boxes to limit this effect.

In 1786/1788, the first automatic machinery appeared to drill the rail and obtain the blanks (Fig. 16). These machines were manually fed, and the operator had to move the metal strip forward following the rhythm of the machine. The freshly cut blanks then went through the press that created a pre-listel, which, amongst other things, favoured the minting of the listel into a coin avoiding wear. The press was formed by a conduit through which the flange passed and while the coin was pressed along its edge, the flange raised it creating the pre-listel and eliminating the burrs left by the cut of the coin. Afterwards the coin was annealed to soften it, eliminating internal tensions to facilitate its coinage. Rotary annealing furnaces for blanks appeared in the early twentieth century as seen in Fig. 17.The annealing of the blanks was followed by washing. Since rust forms on the blanks during the annealing, a cleaning procedure is required: first, a chemical solution and then a bath of soap and water resulted in a final shiny surface. The drying procedure used hot sawdust which eventually evolved into drying machines in later years (Muñiz García n.d.).

Fig. 13 The molten metal was poured into the rail, with moulds in the shape of ingots

Fig. 14 Rail laminators

Conclusion

The idea of a nation/territory meant the adoption of ones own emblems and symbols, this meant that new nations like Chile resorted to republican allegories: stars, tree of freedom, among others, which allowed the substitution of sovereign imagery by symbols that appealed to a new political order, thus becoming an effective vehicle for the visual construction of the nascent American republics. Not only were symbols required to identify themselves as a nation by referring to their former ruler. The symbols used were in line with the independence ideas, with clear inspiration from the French Revolution and the independence of the United States of America; for that reason, the inscriptions of freedom, union, force, and independence, represented the new order.

The result of the electrolytical cleaning using sodium hydroxide is highly recommended or suitable for cleaning pure copper coins, however the literature shows that for copper alloys and silver alloys, this method is not recommended. In this case, as the coins are virtually made of pure copper, all the products of corrosion (greenish layer of malachite) were separated in a time of around 60 minutes. After that, the entire surface could be seen in detail. In addition, the good state of preservation of these ancient coins was verified. Data from catalogues of coin collectors and numismatists were also used to verify the legitimacy of the currencies, numerical data of minting and the company in charge of manufacture were obtained. It was even verified that there are several models of coins of the same value. In this case, the half cent from 1853 can vary in the shape of the laurel loop that can be single or double ones, while other models of the one cent from 1851 differ in the form of the ‘Q’ of the word RIQUEZA (Wealth) in the Spanish language.

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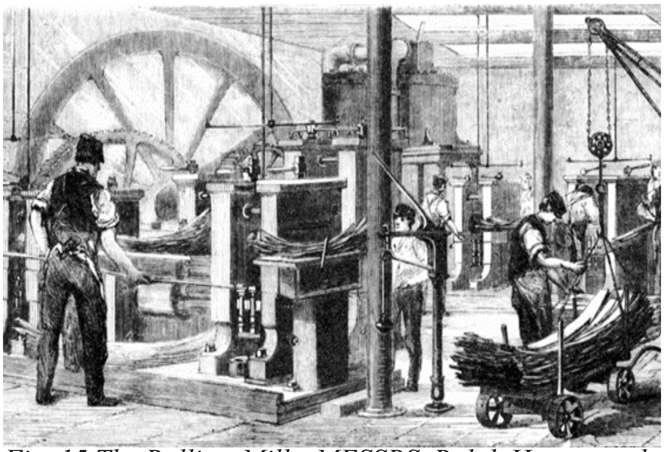

Fig. 15 The Rolling-Mills, MESSRS, Ralph Heaton and Sons’ Mint. Image ©The British Library Board, All Rights Reserved.

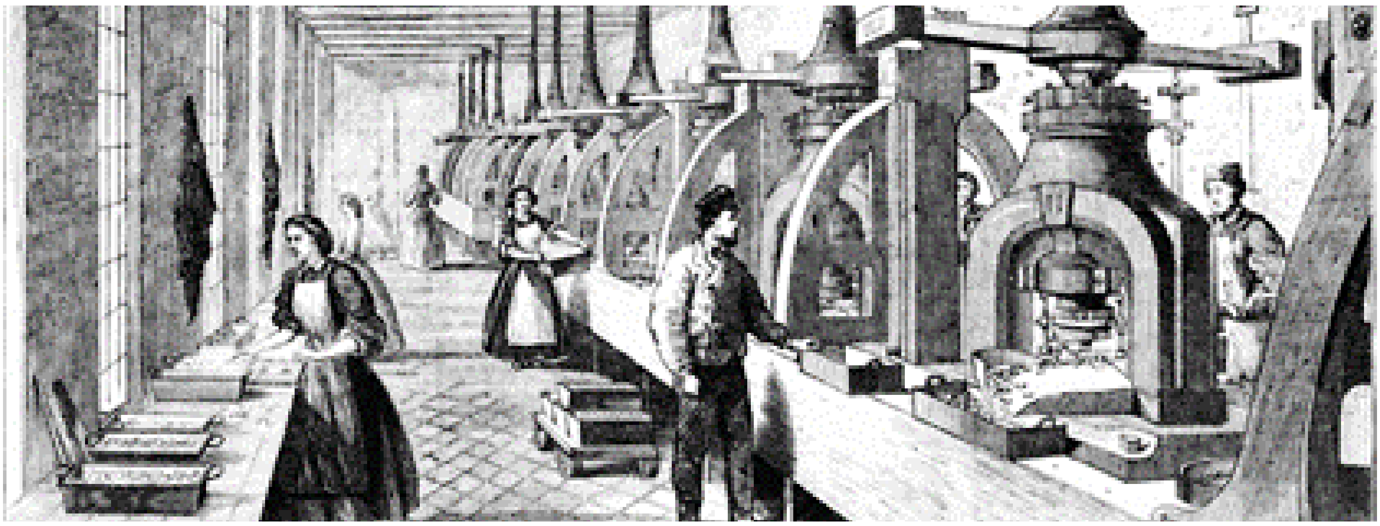

Fig. 16 The Coining - Presses, MESSRS, Ralph Heaton and Sons’ Mint. Image ©The British Library Board, All Rights Reserved.

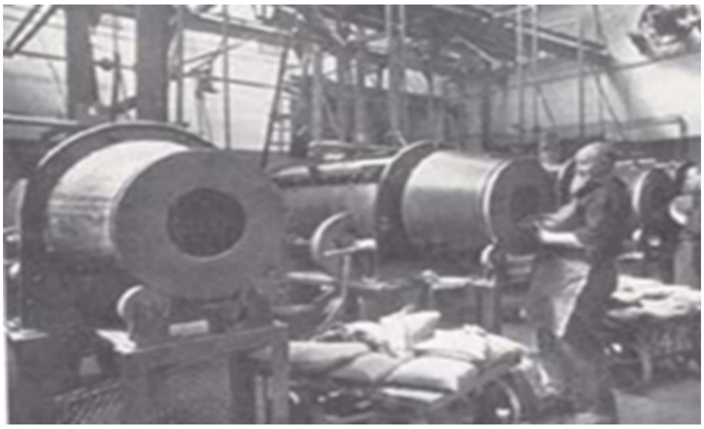

Fig. 17 Rotary annealing furnaces for blanks

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Birchenall, C. (1977) *Principles of gaseous reduction of corrosion products*. National Bureau of Standards special publication 479. 39-57.

Images used for comparison: First type: courtesy of Classical Numismatic Group St. James 'Auctions Ltd. and Second type: courtesy of Heritage Auctions (www.ha.com)

Muñiz García, B. (n.d.). Manufacture of the currency through the times, version October 2005-2008.

Fragments of Stone Washing Tables from Roman gold mine in Carinthia, Austria

The valley of the river Lavant (Lavanttal) in Carinthia is well known for its medieval and early modern gold-mining that is well documented in the contemporary written sources (Pichler 2003 and 2020). The remains from the mining of primary and secondary gold deposits are collapsed adits and shafts as well as pits. The only evidence of Roman settlements in the area are tombstones and spolia found near Bad St. Leonhard (Dolenz and Egger 1971, Piccottini 1973). There is also evidence of a Roman road in the valley of the river Lavant.

The Roman gold mine lies in a wooded area about 3 km to the northwest of Bad St. Leonhard (Roman province of Noricum). This is the only mine not mentioned in any of the medieval sources, which suggests that it dates to an earlier period. It is bisected by a modern road. The southern part (Area 1 on Fig. 1), where the actual mining took place, covers an area of about 0.18 km2 and the northern part (Area 2 on Fig. 1), an area of about 40,000 m2.

The deposit that the Romans mined is an alluvial cone consisting mainly of schist, pegmatite and quartz rock fragments (Pichler 2020, 253). The LIDAR scan shows features typical for Roman hydraulic mining (Fig. 1). The parallel channels are up to 8 m deep (Fig. 2). Large stones have been heaped onto the ridges between the channels. Water for ground-sluicing was supplied by the Mischlingbach, a brook to the north of the mine. No traces of the leat have survived. The reason for this could be agricultural activity or the fact that the leat consisted of a wooden channel supported by posts. Similar features are

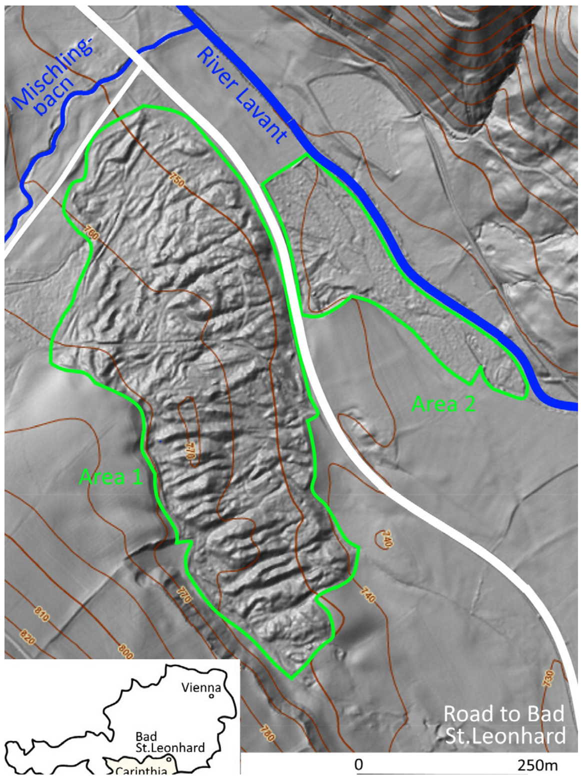

Fig. 1 LIDAR scan of the Roman gold mine near Bad St. Leonhard (LIDAR scan: Land Kärnten, mapping: B. Cech).

known from the Roman gold mine in the Karth, a landscape about 70 km to the south of Vienna. The latter mine is currently being researched in detail by the author and an interdisciplinary team of scientists (www.karthgold.com).