ARRC – Acculturation, Romanisation, Roman Culture: Processes of Integration Across the Roman Empire

Edited by László Borhy, Kata Dévai, Linda Dobosi, and Csilla Sáró

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László Borhy – Kata Dévai – Linda Dobosi – Csilla Sáró

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Copper alloys in Gaul under the Roman conquest

The *Celtic Brass Coins* project

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Abstract: The introduction of brass in Europe has long been considered as a marker of Roman influence. In Gaul the use of zinc as an alloy component, attested since the 1st century BCE, becomes frequent during the latter half of the same century. The *Celtic Brass Coins* project funded by the French National Research Agency intends to understand better the dynamics under which brass spread in Gaul through the lens of numismatics, using historical, archaeological, and elemental analytical approaches. In order to achieve this goal, portable X-Ray Fluorescence (pXRF) has been used extensively on coins from various museum coin collections in France, with additional pXRF analysis conducted on more than 1,400 copper-alloy samples from Bibracte (Mont Beuvray, Burgundy, eastern France), an *oppidum* which was the main urban centre of the Aedui people, a major political and economic partner of the Romans. When available, both typological and stratigraphic information are used, in addition to the compositional data, to date the appearance of brass more precisely in this context. The first results show that around a quarter of the copper-based samples from Bibracte (excluding the coins) were indeed made of brass, especially among the objects for personal adornment (with an almost exact correlation between the brooch types and the alloys used). More unexpected is the near total absence of obvious brass Mediterranean imports.

Keywords: Bibracte, brass, elemental analysis, Gaul, Romanisation

Brass and zinc in Gaul

Brass, the alloy of copper and zinc, requires specific metallurgic techniques during the production process: smelting covers only part of it. While bronze could be made by mixing its two base metals (copper and tin) together in liquid form, the use of zinc makes this operation more complicated because its melting and vaporisation temperatures are quite close to one another (420°C and 907°C): zinc vapour would begin escaping the crucible in large quantities even before all the solid zinc has melted down. Furthermore, copper would still be solid at this point (melting at 1085°C). Several methods have already been suggested for the copper-zinc alloying process, including the prior production of zinc oxides (ZnO).[1] These technical specificities explain the later development of brass metallurgy.

Known in ancient sources as *orichalcum*, brass became ubiquitous in the archaeological record of Temperate Europe in the Roman period. Two millennia after the appearance of bronze in this

1 Bourgarit – Thomas 2015.

✉ Corresponding author

region, this sudden shift raises a question: what dynamics were in action to enable the production and use of brass? Extensive archaeometric studies developed in the regions East of the Alps[2] have clarified the steps of its introduction starting as early as the middle of the 1st century BCE, but such systematic surveys are still missing for the territory of ancient Gaul. In this area, one of the open questions is the possible impact of Caesar's Gallic Wars on the introduction of the new alloy.

A few brass and zinc objects, undeniably of La Tène culture but from chronologically ambiguous contexts, bring forward this question. These include the boar standard from Soulac-sur-Mer (Charente-Maritime, western France),[3] the statue of the so-called 'God of Bouray' (Essonne, Parisian region)[4] or the zinc tablet dedicated to the metalsmith god, Gobanos found in Bern (western Switzerland).[5] In this context, a few coins bearing the name of Vercingetorix minted before or during the siege of Alesia in 52 BCE (Fig. 1), show that its use had undoubtedly begun by the end of the Gallic Wars.[6]



Fig. 1. Vercingetorix brass coin imitating gold types, found in Grésigny-Sainte-Reine, next to Alesia (Côte-d'Or), MAN 285, diameter: 19 mm (Musée d'Archéologie nationale).

The *Celtic Brass Coins* project in Bibracte

This paper is part of the five-year *Celtic Brass Coins* project which brings together six complementary French partners[7] and aims to better understand the introduction of brass in late Iron Age coinage in ancient Gaul in a multidisciplinary study with the aid of material studies, archaeometry, archaeology and digital humanities. The project revolves around the development of a large-scale pXRF (portable X-ray Fluorescence) analysis campaign on almost 4,000 coins from French national museum collections (Bibliothèque nationale de France, Musée d'Archéologie nationale and several museums in Normandy and Northern France), as well as on a collection of non-monetary objects from Bibracte representative of the material culture of the 1st century BCE.[8]

Oxidized or corroded brass is indistinguishable from other copper alloys to the naked eye. Only by using elemental analyses can the alloy be identified. In this paper, we present the first results of pXRF analysis conducted on monetary and non-monetary objects of Bibracte, and discuss the introduction of brass as an alloy for the production of objects in Gaul. Bibracte is an *oppidum* located on Mount Beuvray (Burgundy, eastern France) that was mainly active from the end of the 2nd and throughout the 1st centuries BCE. Capital city of the Aedui people and a major political and economic partner of the Romans in Gaul for the whole period, Bibracte was the site of several episodes of the Gallic Wars before being abandoned around the turn of the common era in favour of the newly created city of Augustodunum (Autun). The choice of Bibracte as a main case study in

2 Istenič – Šmit 2007; Bursák *et al.* 2022.

3 Dubos *et al.* 2017.

4 Pernot – Hurtel 1987.

5 Fellmann *et al.* 1999.

6 Nieto-Pelletier *et al.* 2024; Nieto-Pelletier *et al.* forthcoming.

7 The partners include the IRAMAT laboratory which coordinates the consortium, the CRAHAM laboratory, the Bibliothèque nationale de France, the Musée d'Archéologie nationale, the Maison des Sciences de l'Homme du Val de Loire and BIBRACTE EPCC. More information on the project can be found at its dedicated website: https://brasscoins.hypotheses.org (last access: 26 February 2026).

8 2449 coins analysed at the time of the presentation preceding this paper in May 2025.

this project stems from the fact that this *oppidum* is an archaeological reference site for the material culture from the 1st century BCE, nearly undisturbed by any posterior human activity. Its numerous metal crafts workshops and its overall material culture bear witness to the material culture of Central Gaul in the 1st century BCE and its evolutions shift all along this period. Thus, the analysis of objects found in known archaeological contexts at Bibracte should help identify the beginnings of the use of brass and its purposes.

Sample selection

The series of samples chosen for analysis were selected from the Bibracte storage rooms, where all the finds from excavations since 1984 are kept, and from display cases of the Bibracte Museum, which presents artefacts from 19th-century excavations on Mount Beuvray as well as from other sites.

This selection includes typologically identifiable copper-based artefacts, with a special attention to brooches and to objects of Roman typology. Pieces of metalworking waste material were also picked for analysis in order to observe how much brass was being used compared to other copper alloys. A few 'white metal' objects (i.e. with whitish altered surface) were selected as well, in case some were found to be made out of metallic zinc instead of the more common lead, tin or silver.

Artefacts measuring less than 3 mm were avoided (to match the chosen analytic window size of the pXRF), as were those that were extremely corroded. Conversely, artefacts presenting non-corroded, non-oxidized surfaces (found in anoxic contexts from the basins at Fontaine Saint-Pierre and the well at Theurot de la Roche) have been systematically included in the analysis.

The material in districts with strong evidence of metal-working (Porte du Rebout, Champlain, Côme Chaudron, Parc aux Chevaux 14/15, Domus PC2) was thoroughly studied, as well as the material from Domus PC1 and the Croix du Rebout cemetery due to the diversity of objects found there. The material from the Franciscan convent at Pâture du Couvent was excluded from the research in order to avoid accidentally analysing medieval and modern residue. Nearly every copper-base object displayed at the Bibracte Museum, 318 objects, were included in the study, thus encompassing artefacts found on Mount Beuvray during the 19th century (from Musée Rolin, Autun, 24 objects), others found in the larger territory of the Aedui (from Musée Denon, Chalon-sur-Saône, 3 objects; example of analysis on one of these objects illustrated in Fig. 2), and finally grave goods from the territory of the Ambiani (Somme, Northern France, from Musée Boucher-de-Perthes, Abbeville, 11 objects).[9]



Fig. 2. Analysis on one of the Celtic cauldrons from Lux (Saône-et-Loire), on loan from the Denon Museum to the Bibracte Museum (photo: P. Mazille).

Protocols

Portable XRF (pXRF) is a fast, non-destructive surface method analysis. The results obtained are thus highly impacted by corrosion. The portable device used was a Niton XL5+ from Fondis Elec-

9 The authors wish to renew their thanks to L. Ayache for enabling the study of the objects from the different museums cited here.

tronics, placed on a portable test bench with a cover or on a tripod for some museum objects (Fig. 3). Each analysis session started with the measuring of 5 certified materials, 3 from the CHARM set of reference materials[10] and two from the CTIF.[11] Each object was analysed at least twice or more depending on its nature (objects made up of different parts were analysed once on each part), using the main and low filters of the electronic metals mode (10 seconds main and 30 seconds low for a 40 seconds analysis)[12] and at a 3 mm window.[13] Analyses took place in October and November 2024.[14]

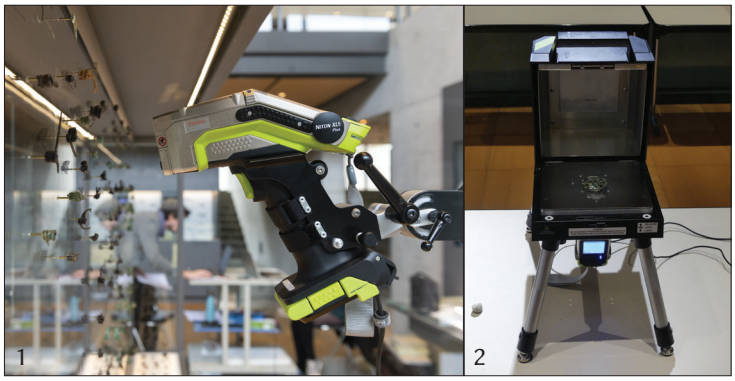


Fig. 3. 1 – freestanding analysis (Bibracte, A. Mailler), 2 – using a portable test bench (photos: P. Mazille).

The main limitation of this method is the influence of corrosion on the measured results. This problem proved to be significant when working with the objects found at Bibracte because most of them were deeply corroded. It has long been demonstrated that pXRF analyses led on corroded surfaces and uncorroded surfaces can yield vastly different results concerning zinc, tin, lead and iron contents (Fig. 4).[15] We were fortunate to be able to scrape the surface of 35 objects (mechanical cleaning made by P. Mazille) in order to perform tests on both the corroded surface and the scraped metal to assess the difference in chemical composition measured by surface analysis. This helped determine in the case of some objects if they were in the brass category or not. For example, the drip (Inv. no. B2021.41.827.1) (Fig. 5) has a heavily oxidised greenish porous surface and measurements made by pXRF on this surface yielded only 2% zinc, along with 2–3% of tin and lead. The artefact had previously been drilled to observe the core metal layer, and surface measurements on the drilled part yielded 17% zinc and less than 0,5% tin and lead, confirming the overestimation of lead, tin and iron by surface analysis and the underestimation of zinc content (due to the dezincification process which entails the preferential disappearance of zinc in the outer layers).

Based on the results obtained from the analysis of the scraped objects, on the previous research on the subject, and taking into account the important corrosion of most of the objects, it was established for this study that an object would be identified as brass if the surface measurements showed more than 1% zinc and less than 10% tin and 10% lead.

It might be argued that some materials are 'quaternary alloys' rather than binary brasses, which we are unable to confirm with a surface analysis (further study by a more in-depth analysis, LA-ICP-MS,

10 32XSN6A, 32XLB17A, 33XGM4AC; Hegingbotham *et al.* 2015.

11 Centre Technique des Industries et de la Fonderie, UZ50 and UZHR5.

12 Bliujienė *et al.* showed that with a Niton Xl3t the analysis results did not change after 35 s so it was deemed sufficient as a time of analysis, our reasoning is the same: Bliujienė *et al.* 2021, 41.

13 Studies have demonstrated that this protocol is sufficient to identify a brass alloy, see Nieto-Pelletier *et al.* forthcoming.

14 Short presentations of these sessions are available at https://brasscoins.hypotheses.org/1810 (last access: 26 February 2026), and at https://www.bibracte.fr/actualite/le-projet-celtic-brass-coins-passe-par-bibracte (last access: 26 February 2026).

15 The difference in tin and lead contents detected by pXRF between the corroded surface and etched sample has for example been demonstrated in Castelle *et al.* 2020. The works of Di Fazio are also important on the matter of surface corrosion of brass, see Di Fazio *et al.* 2019.

is needed to give more details on the alloys' nature).[16] Other copper alloys measured (such as leaded bronze for example) were also identified according to data from literature and taking the corrosion of the objects into consideration.

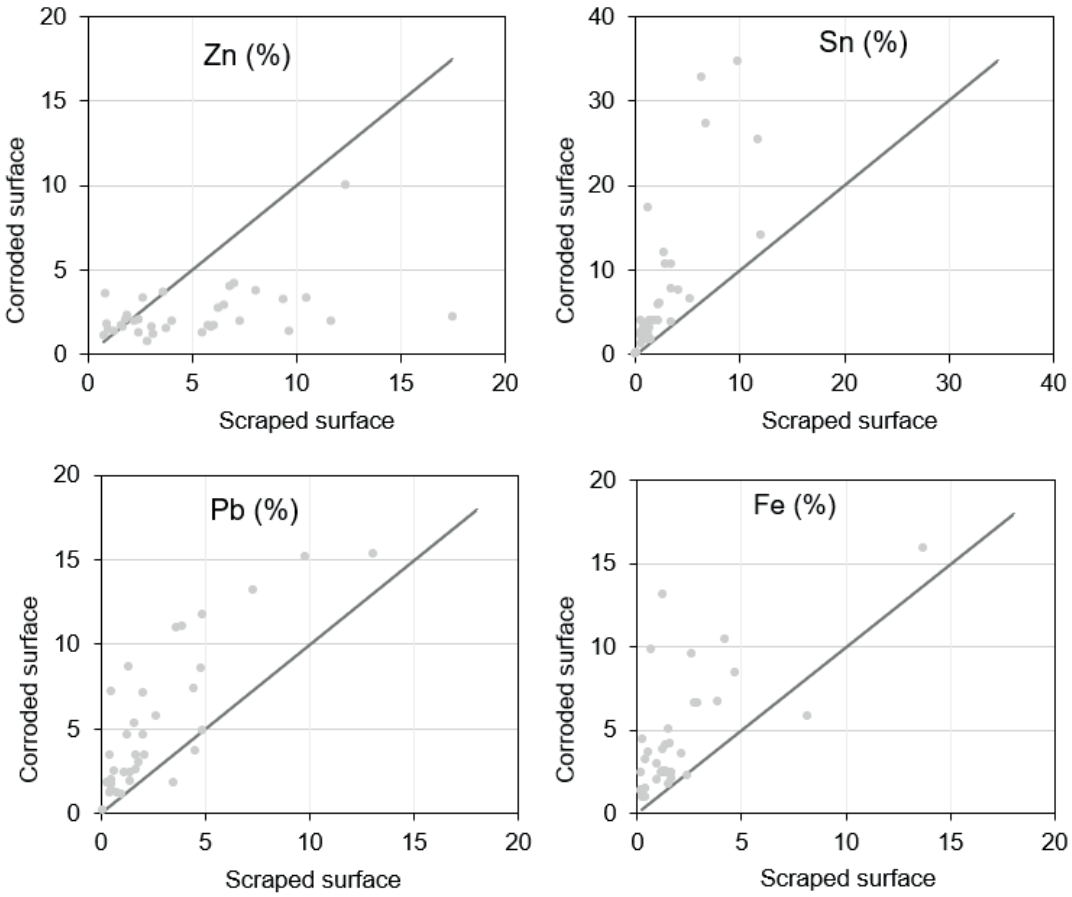


Fig. 4. Binary graphs showing the discrepancy of chemical contents between corroded surfaces and scraped surfaces (C. Bossavit).

Preliminary results and first observations

The analysis campaign indicated brass as the material for 334 objects out of 1,451 (23% of the selection) and 32 brass coins out of 57 coins. For the remaining 1117 objects, 1,069 proved to be copper-dominated alloys,[17] 933 of those are bronzes: 609 binary copper/tin alloys and 324 leaded bronze objects (bronzes with a composition of more than 15% detected lead on the surface). Sixty-four objects do not fall into the binary bronze category because of the high levels of antimony and arsenic they present (which were not detected in all other copper-alloy analysed objects), making these 'quaternary alloys'. The last categories of copper-based metals observed in Bibracte were copper with no tin (1% or less) but traces of arsenic, and lead-rich alloys (the latter sometimes up to 70%).

16 To find out more about the LA-ICP-MS technique and its uses to copper-alloys, see https://brasscoins.hypotheses.org/la-icp-ms (last access: 26 February 2026), and the presentation given at the GMPCA conference (in French): https://webtv.univ-rouen.fr/videos/communication-2-2-4 (last access: 26 February 2026).

17 We chose to exclude the silver-based objects from this paper, since the project deals with copper-alloys, but 15 such objects were analysed (two were previously identified as lead). Likewise, some elements were lead or tin residues, and are not considered in this paper.

While it appeared that brass was used in a limited range of object types, bronze and other copper-alloys tended to characterise many object categories (as well as production leftovers). One exception may be 'quaternary alloys', mostly used for the production of rings. Rings could also be made of leaded bronze, but the use of a mixed copper-alloy with very variable lead and antimony contents, is mainly seen in rings. This probably shows how those highly versatile objects produced in large numbers and with low aesthetical pursuit were last-stage productions of recasting processes, recycling various metallic residues whose content was unknown to the artisan.

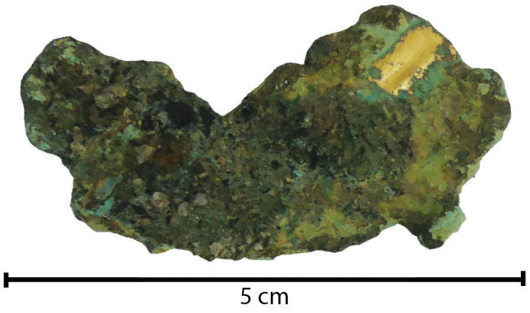


Fig. 5. A large drip, showing both an extremely oxidized outer layer and the inner gold colour of the original brass, Inv. no. B2021.41.827.1 (photo: P. Mazille).

Brass remained in the minority whatever the artefact category (metalworking residue, sheet and rod fragments, decorative objects, grooming objects, *militaria*, etc.), except for objects for personal adornment, brooches in particular. Some of those were evidently made locally in large quantities, being found in various stages of the production process. In our case, about 60% of the analysed pieces for personal adornment was brass. It is noteworthy that each basic brooch type measured in this study, considering either its general shape or spring technology, is almost always made of a single copper alloy. For example, brooches that have an external spring cord with fixing claw (e.g., *Kragenfibeln*, *Flügenfibeln*) are always made of brass and never of bronze. Thus, earlier brooch types appear not to have survived this metallic transition and are replaced by newer forms (Fig. 6). Among the selection of 137 properly dated brooches, only one measurement seemed to contradict this model for Bibracte at first sight: while 22 Nauheim specimens were found to be made of bronze (unsurprisingly for such a common type of early La Tène D adornment), the fragmentary brooch (Inv. no. B2005.39.31.1) proved to have been made out of brass. This brooch had been previously identified as a Nauheim type brooch, but it now seems more likely that it belonged to the later Jezerine type.

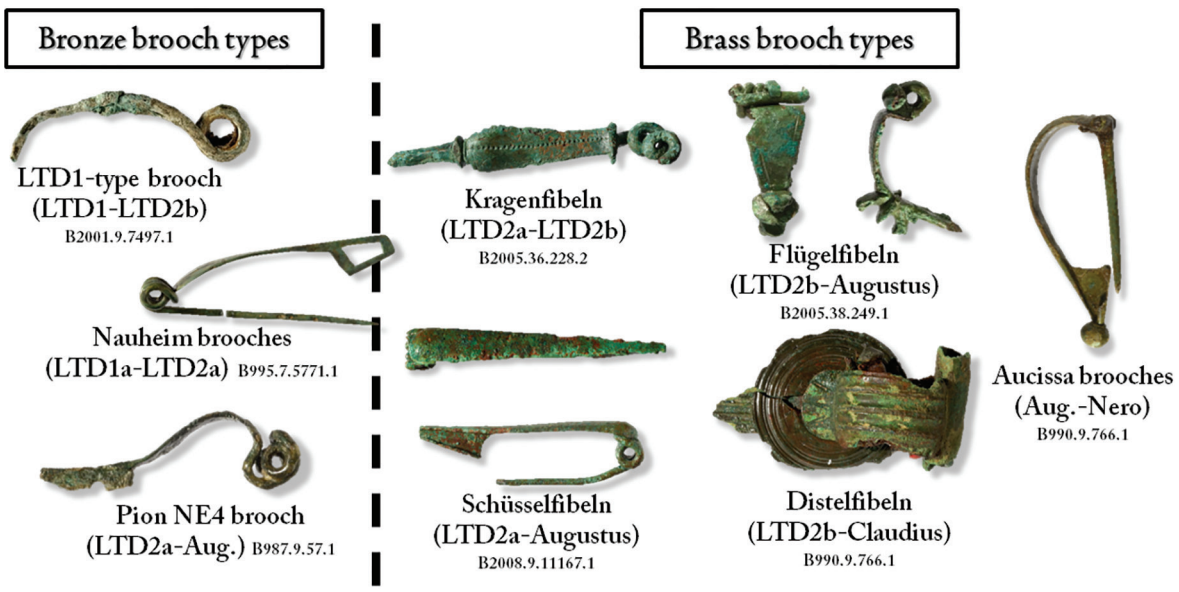


Fig. 6. A selection of basic brooch types spread between bronze and brass alloys (photos: Bibracte, Antoine Maillier).

It is interesting to compare this observation with a similar study undertaken by J. Istenič and Ž. Šmit on 77 brooches from the 1st century BCE from Slovenia.[18] These were analysed with both XRF and PIXE (Particle-Induced X-ray Emission) methods: J. Istenič and Ž. Šmit also found one main alloy pertaining to each brooch type, but with more instances of counterexamples (such as 4 non-brass out of 18 selected Alesia brooches, for example).

Although it has been suggested that early brass used in Temperate Europe was re-melted from Roman imports,[19] no domestic object originating from the Mediterranean and excavated in Bibracte has been evidenced to be cast out of brass. Among the numerous handles belonging to strainers, pans, *simpula* and Campanian metallic ware, spatulas and seal boxes, none show even the slightest traces of zinc. Almost all Roman military objects follow this trend, with two exceptions. The first one is a D-sectioned prism with two fixation bars adorned with a silver sheet (Inv. no. B2018.41.192.4), interpreted as decoration for a Roman soldier's *cingulum* (belt with straps). While made out of brass, its discovery in Domus PC2, a building still occupied in the later years of Bibracte, tends to make it evidence of the late 1st century BCE occupation of the site. The second one is a mesh mount from the top of a Roman scabbard found at Côme Chaudron (Inv. no. B2005.32.1985.4), which may date back to the Gallic Wars.[20]

Beside these observations 57 coins of different types have been tested as well to complete the existing analytic data. A new brass coinage was identified: the fairly rare SEGISV series (Fig. 7), traditionally attributed to the Segusiavii (Central Gaul) due to the legend probably referring to the tribe name, although its main findspot is actually Bibracte.[21] While not accurately dated, it is thought that this coinage starts in the 40s BCE.[22] It is not unreasonable to suggest that these coins, resembling or inspired by northern coinages of Gaul on the obverse,[23] and representing an eagle on the reverse (thus similar to some brass issues of southeastern Gaul such as the VOLC coinage), were issued in Central Eastern Gaul. Another rare brass coin was analysed during this campaign: a MAGVRIX type coin (Inv. no. B2007.9.10433.2), for which only two other coins have been identified and are kept at the Bibliothèque nationale (with unknown provenance).[24] Its estimated date of production is the same as that of the SEGISV coinage.



Fig. 7. 'SEGISV' type coin found in Bibracte, Inv. no. B991.8.165.2. Diameter: 10 mm (credits: Bibracte, Antoine Maillier).

18 Istenič – Šmit 2007.

19 Caley 1964, 3; Istenič – Šmit 2007, 146; Barbato 2015, 109.

20 Pernet *et al.* 2008, 130.

21 A total of 17 SEGISV coins have been analysed, 11 kept at Bibracte, 2 at the Musée d'Archéologie nationale (both were found at Bibracte) and 4 at the Bibliothèque nationale de France (with no indication of provenance). Other examples have been identified at Vendeuil-Caply, Mâlain, Lux, Lyon, Chassey-le-Camp, Nuits-Saint-Georges, Barry, Chambles and Alise-Sainte-Reine: Colbert de Beaulieu – Fischer 1998, 392–393.

22 Brenot – Scheers 1996, 62.

23 Scheers 1971, 38–75.

24 The similarities in iconography to the Carnutes' TVRONA/DRVCCA bronze coinage (no examples present at Bibracte) may indicate an attribution to the Carnutes tribe for the MAGVRIX: Troubady 2016, 170.

Perspectives

In a nutshell, this paper focused on the work led on monetary and non-monetary objects found in archaeological contexts at Bibracte, as part of the *Celtic Brass Coins* project investigating the introduction of brass in Gaul. We found no evidence of the use of brass objects at Bibracte before the middle of the 1st century BCE, and demonstrated the systematisation of the use of this alloy for brooches soon after this date. Only scarce evidence is available for brass artefacts imported from the Mediterranean region and, reversely, numerous residues show large-scale local production of brass objects, especially brooches.

It is to be noted that those results, currently still being processed, present two main limitations. The first one is the small size of sampling for some object types, especially some brooch types. Secondly, the fact that Bibracte is a distinct context, linked to Rome by long-standing commercial and political relations, and not necessarily representative of Gaul as a whole. Thus, further examinations will be required to decide this question: more detailed processing of the data acquired at Bibracte, including statistical analyses and chronological cross-referencing; but also, additional investigations on 1st century BCE non-monetary artefacts from all around the Gallic territories.

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