New Aspects of Celtic Gold Coinage Production in Europe

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New archaeological finds at the Celtic oppidum (site) of Tarodunum/Kirchzarten, near Freiburg (South-Germany, Black-Forest Region) and their analytical evaluation add another chapter to the still enigmatic Celtic metallurgy, especially in relation to the production of gold/silver/copper alloys for coinage.

ON CELTIC GOLD COINAGE IN GENERAL

The first and most ancient Celtic gold coins are imitations of Greek gold staters, minted under the reign of Philipp II of Macedonia (382-336 BC). The precious metal for this coinage probably came from mines in the Pangaion Mountains (1). The average weight of these Greek gold staters was about 8.6 grams and their fineness always came close to 990 (2). The dating of these so-called Philippou staters poses problems, because even posthumous issues bear the name of Philippou (3). The Philippou staters were much appreciated among Celtic tribes. Although the very beginning of an indigenous Celtic coinage in Central Europe can be dated from finds associated with Celtic burials, *ie* the 3rd century BC (4), many questions related to their introduction still remain unanswered. This is partly because early Celtic imitations of the Greek coins are rare.

Only about one hundred years later, *ie* in the middle of the 2nd century BC, the minting of Celtic gold coins increased considerably (5). These later issues differ in many respects not only from the Greek originals, but also from the earlier Celtic imitations. The 2nd century Celtic gold coinage occurs in several denominations, such as stater nominals down to fractions of quarter-staters. The new types are of significantly lower weight than the Greek prototypes: 7 grams for the stater pieces and about 1.8 grams for the quarter staters. Contrary to common opinion among numismatists, this should not be regarded as an intentional reduction in weight due to debasement. It is actually the result of maintaining the coins' volumes constant, though their fineness was reduced. Consequently, lower gold contents meant reduced weight (6). The gold content in these coins varies between 50 and 70 wt% (average 60 wt%), with increased silver percentages of 20 to 40 wt% (average 33 wt%) and only a residual copper content of around 10 wt% (average 7 wt%).

Specific to Celtic gold coins originating from the Upper Rhine Valley and manufactured from alloys of the ternary system Au-Ag-Cu, is an increasing silver content (7). With a gold content below 50 per cent, it is only justified to label these coins as gold staters of the Philippou type because of their iconographic and typological characteristics. At the end of this interesting monetary and numismatic development (around 100 to 80 BC), the former gold stater of extreme fineness had finally become a coin consisting of about 800 parts of silver and 200 parts of copper. Gold is completely absent. This was made convincingly evident by chemical analyses carried out on recent finds from Basel (8).

Celtic gold coins from Anglo-Saxon territories indicate a completely different development: Here, gold is alloyed with increasing amounts of copper. Thus, the final results are pure copper coins. In the Northern expanses of the Celtic sphere of influence, silver played a less important role as alloying constituent in local mints (9).

The regional and chronological variations associated with Celtic coinage have attracted attention from numismatists, archaeologists and scientists alike. Nearly all the metals known by the 3rd century BC were at one time or another used as coinage metals, mostly in the form of alloys, but frequently also in their pure state.

In the Upper Rhine Valley, the 2nd century BC proved to be a time of significant monetary transitions. Not only was gold replaced by silver, but alloying practices and technical aspects of coin production evidently underwent changes. Disc-shaped flans were replaced by globules of appropriate alloys which, after striking, resulted in coins of convex-concave shape.

THE SITE OF TARODUNUM AND ITS NUMISMATIC FINDS

Since the beginning of the 19th century, a large fortified area (approximately 200 hectares in size), a few kilometers to the East of the city of Freiburg/ Breisgau (Black Forest Region) was identified as the Celtic Oppidum *Tarodunum* (= *Zarten*). The name of this site was first mentioned by Claudius Ptolemaios (83-161 AD) in his 'Geographike Hyphegensis'. The modern villages of Kirch*zarten* and Hinter*zarten* still retain the roots of the original Celtic word in their names. Archaeological excavations at Tarodunum revealed a type of fortification corresponding to Caesar's *murus gallicu*s. Immediately in front of the hill-site oppidum is situated a late Celtic settlement, covering an area of about 16 hectares, occupied from the 2nd to the 1st centuries BC. Abundant finds of pottery, coloured glass and more than a hundred coins of precious and base metals are proof of extensive Celtic workshop activities, particularly in the realm of metals.

Among the spectacular artifacts excavated in the relatively small workshop area of the Celtic oppidum of

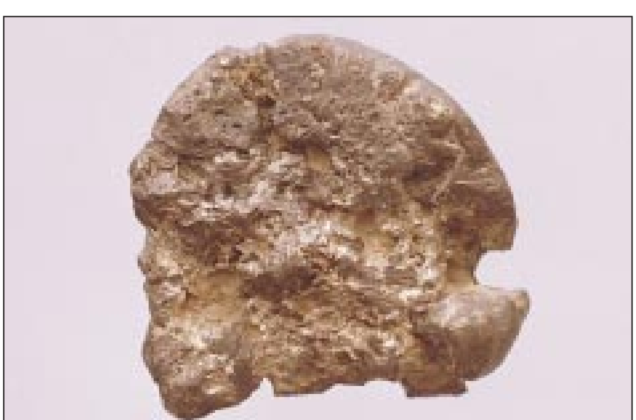

Figure 1 *E1290, piece of Au-Ag-Cu alloy, 25 g (melting residue), magnification 3.5*

Figure 2 *E1294, flan or blank prior to striking, magnification 3.5*

Figure 3 *E1292, obverse Philippou-type, magnification 3.5*

Tarodunum is an unprecedented assemblage of objects: runners of spilled metal, a flan or blank, lost prior to striking, and also a series of well preserved coins of the late Philippou type without the Greek inscriptions (10) (Figures 1-3). The brownish tarnish or surface colour of all these finds resembles that of bronze. Coins, blank and melting residues analysed by energy-dispersive XRF and TN-SPECTRACE 5000 (11), revealed the true nature of these metal objects: their average composition came close to 40 per cent of gold, 50 per cent of silver and 3 to 9 per cent of copper. Additionally, the objects in question were characterized by microprobe and/or scanning electron microscope investigations. The results are presented here for the first time, together with their metallurgical interpretation.

Table 1 *Results of XRF-Analyses Performed on Selected Areas (ca 5sq mm each) of Samples**

Inv-No.	Object	grams	g/cm^3	EDXRF wt-%	Ag %	Au %	As %	Bi %	Cu %	Fe %	Hg %	Ni %	Pb %	Sb %	Sn %
E1293	Philippou	5.50	9.4	OB1	58	38	0.02	0.01	4.0	0.01	0.27		0.21	0.01	0.03
				OB2	58	37	0.02	0.02	3.8	0.12	0.15	0.01	0.23	0.00	0.02
F12338	Philippou	4.19	7.9	OB	54	36	0.00	0.05	7.9	1.39		0.03	0.11	0.02	0.37
				RV	52	43	0.03	0.00	3.6	0.12	0.27		0.23	0.02	0.16
E1292	Philippou	5.14	8.2	OB	54	42	0.01	0.00	3.3	0.19	0.20	0.01	0.11	0.02	0.07
				RV	52	43	0.03	0.00	3.6	0.12	0.27		0.23	0.02	0.16
E1294	Blank/Flan	4.53	7.4	S1	52	42	0.03	0.05	3.7	0.77	0.35	0.02	0.33	0.10	0.11
				S2	51	43	0.02	0.01	4.3	0.35	0.23	0.02	0.33	0.08	0.09
E1290	Production	25.2	*	A1	54	41	0.00	0.04	3.9	0.58		0.00	0.19	0.02	0.00
				A2	53	37	0.03	0.03	6.5	2.25	0.15	0.00	0.23	0.02	0.00
				A3	60	32	0.04	0.06	6.4	0.68	0.18	0.06	0.33	0.07	0.44
				A4	55	37	0.01	0.04	4.7	1.01	0.29	0.55	0.20	0.15	0.20
F9722	Production	14.0	*	A1	45	51	0.01	0.02	3.2	0.08		0.02	0.22	0.04	0.04
				A2	50	46	0.04	0.04	3.3	0.15	0.08	0.01	0.17	0.05	0.05
F9723	Production	3.16	*	A1	49	40	0.03	0.11	8.8	0.86	0.09	0.63	0.08	0.25	0.07
				A2	48	42	0.01	0.06	9.3	0.21		0.68	0.05	0.15	
				AVG	**53.3**	**40.0**	**0.019**	**0.039**	**5.21**	**0.569**	**0.204**	**0.146**	**0.193**	**0.062**	**0.118**
				STD	**4.13**	**4.70**	**0.011**	**0.027**	**2.00**	**0.576**	**0.083**	**0.249**	**0.087**	**0.067**	**0.130**

* porosity of the object made determination of density difficult OB =Obverse RV = Reverse S1 = Side 1 S2 = Side 2 A1, 2, 3 = Analysis

The coins belong mostly to the Philippou-type staters with their characteristic iconographic and stylistic features but without the Greek eponym, *cf* Sample 3 (E1292), illustrated in Figure 3. This coin's diameter is 15 to 16 millimetres, with a weight of *ca* 5 grams, which is already well below the usual weight of staters. Sample 2 (E1294) has survived as blank in the shape of a flat, oval piece of metal, 13 to 14 millimetres in diameter (Figure 2), while sample 1 (E1290) is a melting residue of Au-Ag-Cu alloy, weighing 25 grams, with small pieces of adhering charcoal (Figure 1).

Results of XRF-analyses (simultaneous ED-XRF of 20 elements with ordering numbers 11 to 92 in the Periodic Table) performed on selected areas (about 5 square millimetres each) of these samples are summarized in Table 1.

Cd, Co, Cr, Mn, Ni, P, Pd, Pt, S, Te, Zn are absent, at least within the limits of detection (below 0.001 to 0.01 wt%). Only the inhomogeneous sample E1290 has a significant nickel content of up to 0.5 % – see below.

The similarity in chemical composition of all the finds analysed (coins, blank, production residues) is remarkable – see 'Average contents of elements and standard deviations' (bottom lines on Table 1). The variable iron contents are probably due to soil contamination and/or – as for instance in sample E1290 – to slag inclusions.

However, contrary to other Celtic sites from which coin production is known, *eg* Manching, near Ingolstadt in Bavaria, no coin moulds were discovered among the many pottery sherds at Tarodunum (12). Thus, it is not devious to propose an alternative mode of manufacturing blanks, *ie* melting the proportional mixture of starting materials (pure metals, scrap, master alloys etc.) in crucibles. The liquid coin metal would subsequently be cast into temporary moulds to make spherical blanks. Under the SEM the surviving blank shows a porous surface (Figure 5), while the surface of a coin is relatively dense and smooth (Figure 4), due to the impact of the striking blow. The blank could have been cleaned prior to striking by 'pickling' in organic acids. Such a process would partly dissolve base metals or oxides from the surface of the ternary

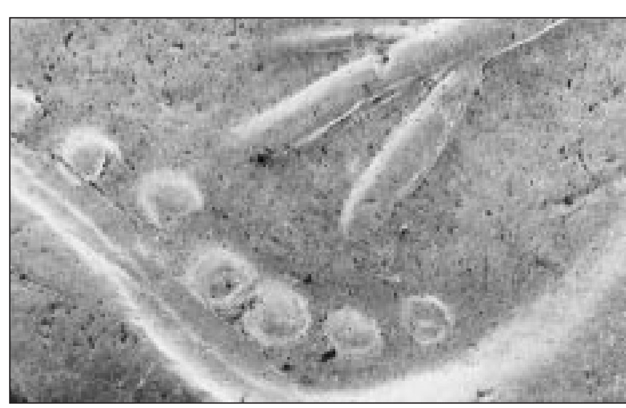

Figure 4 *E1292, SEM, reverse of the Philippou-imitation, magnification 40*

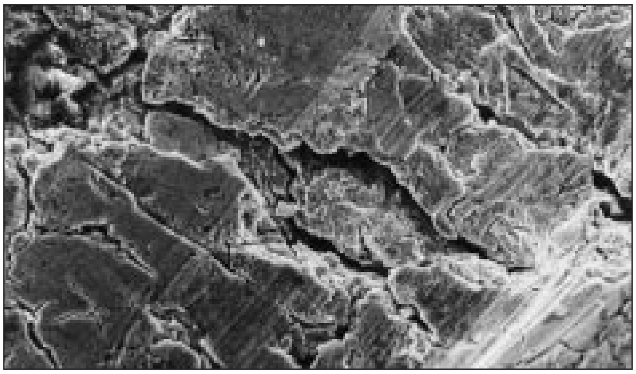

Figure 5 *E1294, SEM of the porous flan/blank, magnification 1,000*

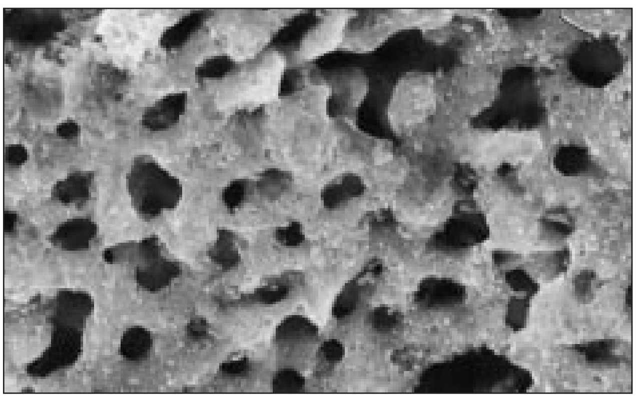

Figure 6 *F9722, SEM of channels and holes, magnification 1,000*

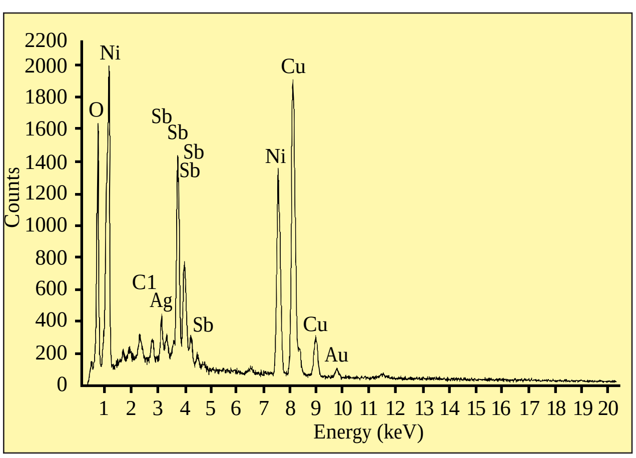

Figure 7 *F9723, SEM qualitative analysis using Philips (TRACOR) instrument*

alloy. This surface depletion of base metals and enrichment of noble metals was already common practice in early mints. However, we have no proof that in the case of Tarodunum finds this technique was applied to claim a higher gold fineness for the coin than actually corresponds to the alloy matrix. The colours of coins and blank are alike as are the compositions. A pronounced intentional surface enrichment would have shown immediately in the results of the ED-XRF analyses with their lower power of penetration.

The change in density from blank to coin becomes obvious when comparing calculated with measured densities (13). The mandatory request to restrict the investigations to non-destructive methods, prohibited the preparation of polished sections for metallographic examinations. Only micrographs would have revealed whether cold or hot striking was practised at Tarodunum.

Scanning electron microscopy (SEM) (14), combined with quantitative XRF-surface analyses, was employed to investigate two additional metallic finds from the same site: Samples F9722 (14 grams) and F 9723 (*ca* 3 grams). According to their composition, these specimens were also part of the mint's metallic relics. They too belong to the ternary system Au-Ag-Cu with an average ratio of these main elements of Ag:Au:Cu = 5:4:1.

Analyses of the cavernous, porous surface of sample F9722 gave chlorine (3 to 8 per cent) as additional main constituent. The presence of chlorides in this material is thus obvious. Under high magnification, the specimen's surface (Figure 6) shows an interesting, strikingly regular pattern of channels and holes, explaining the porosity mentioned.

The smaller metallic fragment F9723 is very similar in composition to F9722, with gold, silver, copper and chlorine present and with the same spongy, porous channel-perforated surface. However, in selected areas of this sample antimony, nickel and copper are surprisingly the dominating elements (Figure 7). These areas are hexagonal mica-like platelets (Figure 8), completely different in their morphology from the porous matrix. The mean values of several

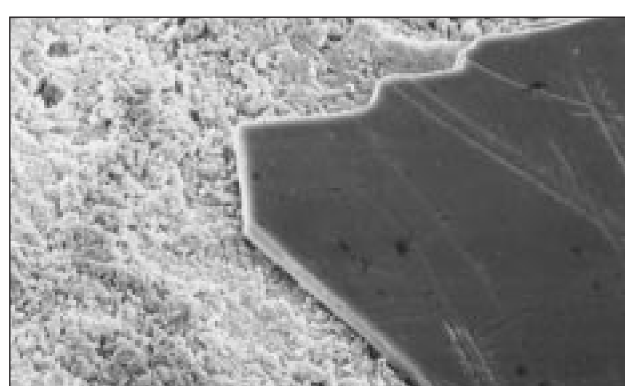

Figure 8 *F9723, SEM of one mica platelet (Cu-Ni-Sb), magnification 100*

Table 2 *Mean values of point analyses on the mica-like platelets on Sample F9723, shown in Figure 8*

Element	wt%	at%	Ratio with reference to Sb = 1
Sb	23.223	8.165	1.00
Ni	21.200	15.457	1.89
Cu	36.123	24.336	2.98
O	19.452	52.041	6.37

point analyses on these crystals are given in Table 2. These values correspond to a substance of the following formula $Cu_3Ni_{1.9}\ SbO_{6.4}$.

This is reasonably close to the composition of a compound known among extractive metallurgists as 'Kupferglimmer' (copper mica). It was (and still is) observed occasionally in copper metal. 'Kupferglimmer' is stable even during the most rigorous refining processes, like poling, and cannot be removed by oxidation (15). The most recent and detailed characterization of this mixed oxide was published by Chen and Dutriac (16). These authors give $Cu_3\ Ni_{2-x}\ SbO_{6-x}$ (with x = 0.1 to 0.2) as the composition range for 'Kupferglimmer'.

Partial substitution of copper by nickel (and *vice versa*) is possible, but the antimony level always remains constant. There is no doubt that the complex Celtic metal prill contains exactly this compound as hard to remove impurity, probably introduced in the course of the extraction of copper from local polymetallic ores containing Sb and Ni (17).

CONCLUSIONS

Finds from excavations of the Celtic site at Tarodunum near Freiburg have been investigated by non-destructive methods (XRF, microprobe, SEM). The results are interpreted as one more contribution towards understanding Celtic coin production methods. The various steps from metal to coin are represented by coins, a corresponding blank and melting residues apparently all from the same ternary gold/silver/copper alloy with a ratio of Au:Ag:Cu = 40:55:5. In the course of these investigations an interesting metallurgical detail was discovered *ie* the inclusion of crystals of copper-mica, a complex oxide of copper, nickel and antimony. The results presented here anticipate the final excavation report, still in preparation. They add to our knowledge in understanding minting techniques at the Celtic site of Tarodunum during the 2^{nd} century BC, a settlement situated in a region which was rich in mineral deposits and had abundant occurrences of placer gold in the river Rhine; ideal prerequisites for metal and alloy production.

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