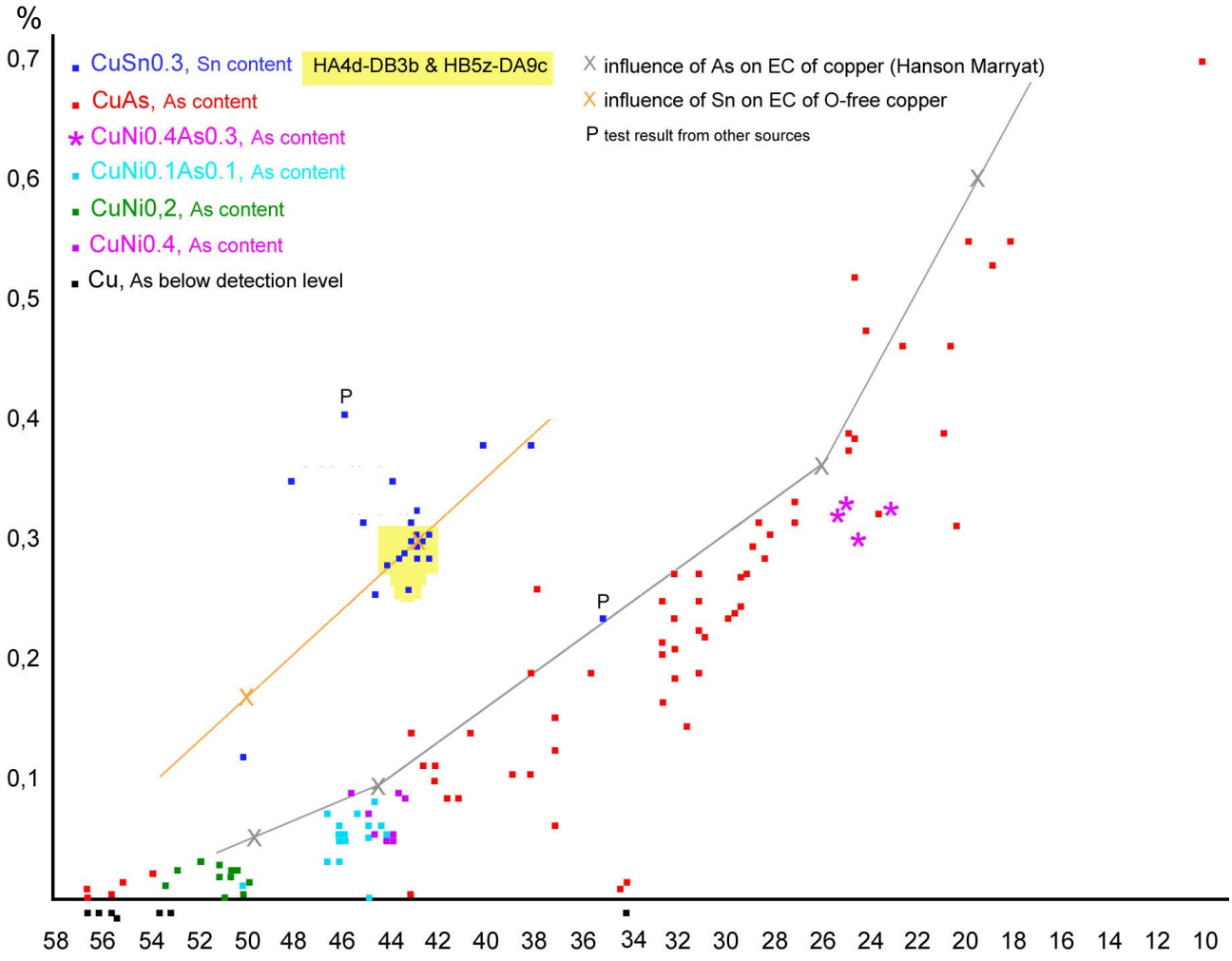
DOA 1916 T, 20 heller part H-y, copper alloys January 2018

A long standing riddle in German East African numismatics has been how to reconcile the X-ray fluorescence analysis results, presented by Balke in *Die Notmünzen von Deutsch-Ostafrika* in *MoneyTrend nr 3 / 1988,* with the results of electrical conductivity measurements, presented in *Kupfer und Kupferlegierungen bei 20-Heller-Münzen von Deutsch-Ostafrika* in *Münzen und Papiergeld nr 10 / 2004* by Peter Hammer and Guy Franquinet.
Where Balke analysed seven copper coins and found none of these to contain less then 99% copper or more then 0.1% zinc, Hammer and Franquinet came to the conclusion that of their sample of non-brass coins the material of 13 coins ought to be considered to be bronze and that only two coins did classify as pure copper. The question was how it was possible that all Balke's coins were copper, whereas 13 out of 15 'copper' coins would be bronze. Statistically his chances would have been 0.000075%.
Below it is shown that the conclusions of both articles don't contradict each other. Probably only one or two of Balke's coins might have been pure copper according to the Hammer and Franquinet definition, that is that it should have an electrical conductivity of 50 MS/m or more, and almost certainly none of their copper and bronze coins did contain less then 99% copper.
So in the end the whole problem has been caused by different definitions of copper.



Correlation between copper alloy and electrical conductivity

In the graph are presented the combined results of X-ray fluorescence analysis (XRF) analysis and electrical conductivity (EC) measurements of some copper 20-Heller coins, performed since 2012 on the premises the Dutch branch of Helmut Fischer in Eindhoven.

Along the vertical axis is given the percentage in weight of either tin (Sn) or arsenic (As), along the horizontal axis the EC in MS/m. Only one coin contained on one side less then 99% copper (98.5-98.7. The other side 99.05-99.3%. Two measurements each side). Seven different types of alloy are distinguished:
– CuSn0.3 (dark blue): copper with +/- 0.3% tin as main alloying element. This aloy is extremely pure, content of lead, nickel and arsenic in the order of 0.02% each.
– CuAs (red): copper with arsenic (As) as main alloying element. Three of these coins might also have been classified as CuNi0.1As0.1 as they contain around 0.08% nickel and respectively 0.11, 0.15 and 0.19% arsenic.
– CuNi0.1As0.1 (light blue): This notation indicates copper containing +/- 0.1% nickel (Ni) and +/- 0.1% arsenic. As a rule nickel content is about 0.07 to 0.10% and somewhat less arsenic. One coin did not render any arsenic.
– CuNi0.2 (green): copper containing around 0.15 to 0.2% of nickel. Arsenic content is low.
– CuNi0.4 (lilac): copper containing over 0.35% of nickel. Arsenic content is 0.05 to 0.09%
– CuNi0.4As0,3 (lilac star): a small group of four early HB5g-DB3i copper coins containing around 0.35% of nickel and 0.30 to 0.35% arsenic.
– Cu (black, below the horizontal line): very pure copper, no results for arsenic found. As the report of one of the test series also rendered results as – (lowest result in digits 0.007%), there might still be a minimal arsenic content.
There is no indication in the XRF results what might the cause the low EC of the five coins with little of no arsenic content but EC way below 50 MS/m. Possibly they contain a deoxidizing agent that could not be dectected.
Most copper HA4d-DB3b (10 out of 13) and HB5z-DA9c (3 out of 4) are CuSn0,3 coins. Their position in the graph is highlighted by a yellow background. Their clustering together makes it seem probable they stem from the same batch of material. The other CuSn coins are more an exception among the other copper coins struck by their die-combination, except perhaps two out of two HB5o-DB3o.

Meyers Großes Konversations-Lexikon, 1905, shows under copper a list of the composition of coppers produced at some different places. This list shows that 0.3% nickel or 0.13% arsenic was to be found in copper produced in Germany.

Erzeugungsort	Gehalt in Prozenten										Bemerkungen
	Kupfer	Silber	Blei	Arsen	Antimon	Nickel	Eisen	Wismut	Sauerstoff	Schwefel	
Garkupfer, rohgares Kupfer, Rosettenkupfer.											
Mansfeld	98,370	0,020	0,600	—	—	0,360	0,050	—	0,580	0,070	—
Schweden	99,170	—	0,470	—	—	—	0,050	—	—	0,110	0,5 Proz. Mangan
Südaustralien	99,480	—	0,360	—	—	—	—	0,048	—	—	—
Hammergares, raffiniertes Kupfer.											
Oker (Hampe)	99,325	0,072	0,061	0,130	0,095	0,064	0,063	0,052	0,117	0,001	0,012 Proz. Kobalt
	99,357	0,072	—	0,104	0,067	0,079	0,065	0,051	0,157	0,001	0,010 " "
Mansfeld (Hampe, Seigerhütte bei Hettstedt)	99,612	0,029	0,020	0,017	0,002	0,211	0,004	—	0,075	0,002	—
Riechelsdorf	99,311	—	0,210	—	—	0,280	0,020	—	—	—	0,08 Proz. Alkalimetalle
Mansfeld, diverse Sorten	99,400 bis 99,550	0,028 bis 0,030	0,043 bis 0,103	—	—	0,239 bis 0,275	0,025 bis 0,132	—	nicht angegeben	—	—
Chile	99,721	0,030	0,204	—	—	—	0,045	—	—	—	—
	99,742	0,016	0,132	—	—	—	0,110	—	—	—	—
Oberer See (Nordamerika)	99,920	0,030	—	—	—	—	—	—	0,280	—	Kein Arsen, Antimon und Wismut enthaltend
	99,890	0,030	—	—	—	0,003	0,005	—	0,190	—	
	99,830	0,030	—	—	—	0,030	—	—	0,220	—	
Arizona (Nordamerika)	99,990	0,008	—	—	—	—	0,021	—	—	—	besgl.
	99,990	0,008	—	—	—	—	0,014	—	—	—	
Übergares und überpoltes Kupfer.											
Oker (Hampe)	98,806	0,069	0,035	0,102	0,064	0,064	0,056	0,048	0,806	0,002	0,007 Proz. Kobalt (übergar)
Mansfeld (Hampe)	98,905	0,029	0,021	0,022	0,006	0,220	0,003	—	0,746	0,004	besgl.
	99,658	0,031	0,020	0,018	0,004	0,210	0,003	—	0,046	0,002	überpolt

CuNi0.2, CuNi0.1As0.1 and possibly even CuNi0.4 could thus very well be “natural” products of the copper smelting process.
For CuSn0.3 and CuNi0.4As0.3 this seems less likely. Either alloying elements were added on purpose or they might have entered the alloy by chance in a copper recycling prosess.
Some British Standard Regulations requested copper to contain more then 0.25% arsenic. To meet this request arsenic would have to be added after the “natural” base copper had been produced.

The XRF results, presented in *DOA 1916 T, 20 heller part H-x. X-ray fluorescence test results (2017)*, show also result for zinc, which are hard to interpret. Comparison of test results for three CuSn0.3 coins, used here, with reliable tests for the same coins from other sources, shows that where these first tests suggest around 0.2% zinc, in reality there is less than 0,01%.
For other coins the results for zinc seem rather random and might well be the result of noise in the measured X-ray signal or exteral pollution of the coins.

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