Analysis of Dubious Silver Tetradrachms by Specific Gravity Methods [1]

Applicability, Limitations and Critique

Dr. W.R. Vezin 18-2-2026

The Archimedean method of determining the volume, hence specific gravity of a coin or ingot, and under certain circumstances alloy formulation by measuring its buoyancy or upward force upon it when totally immersed in a fluid has a long history. This along with the science and technology was the subject of a review by W.A. Oddy [2]. Sources of error, both random i.e. instrumental limits of precision, and systematic, i.e. limits to accuracy, e.g. contamination, internal and external cavitations, surface tension, bubbles, corrosion and especially errors in the assumption of the density of debasing alloys, that they can be made up of a number of metals in any proportion, of different densities.

The view is generally held that the method is unsuitable for silver due to the close approximation of its SG (specific gravity equals density at 3.8°C) to copper, its most frequent debasing agent along with tin lead and zinc, in large silvers like tetradrachms, although with such coins, with educated guesses, quite accurate determinations can be made with Ag contents above about 85% but below which large errors rapidly develop.

Water is generally assumed to be unsuitable as its surface tension, 72 dynes/cm. causes bubbles but again with large coins briefly boiling the coin and its holder in a solution of sodium lauryl sulphate, DAZ etc. briefly (ST about 31) helps. 10 cu.mm air bubbles on a tetradrachm reduces Ag estimates by about 2%.

Fig 1.

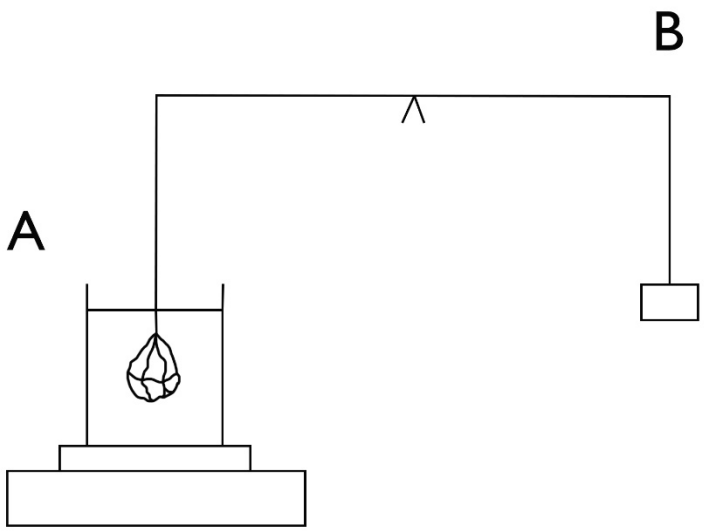


Fig. 1 shows two configurations of SG balances. **B** is Oddy's (ibid p.157) with its coin grab replaced by a small net of flexible plastic coated SWG 32 wire. The force measured is the weight of the coin plus the wire holder plus surface tension effects at the air/wire/liquid surface interface minus the upward force equal to the weight of the volume of liquid equal to the total volume of the coin and the submerged part of the coin holder and support wire. Configuration **A** is with a common type of 2 or 3 place small digital balance. This registers the total weight of the liquid plus 50ml polythene etc. container plus the downward force equal and opposite to the upward force on the coin plus holder less the surface tension effect as **B** above. As with **B** repeat the weighing without the coin to subtract the holder effects. **A** is less suitable as the weight of the liquid has to be kept constant. However a 2 – place can be good enough to estimate Ag levels $\geq$ 90% accurate to +/- 3% or so to be reassuring enough.

<u>Calibration Curves:</u> Oddy (again, loc. cit.) makes a most curious assertion (page 149) that a plot of SG/density vs. percentage of lower density diluent (e.g. Cu) in an alloy with higher density precious metal, would be a straight line and that the curves found (e.g. p.155) arise from alloy shrinking e.g. by formation of eutectics

etc. on cooling. Accordingly an empirical Au/Ag calibration curve was made up from specially made alloy samples from which interpolations were made. His results show that the deviations are not large ones from a straight line but are minute ones from a theoretical reciprocal curve, as follows:

A mass **A**, e.g. **A** = 100 is made up of **x** of lower density **c** base diluent (e.g. Cu in the case of Ag) or Ag/Cu with Au, plus **A** - **x** of higher density **b** precious metal:-

$$SG = \frac{A}{\frac{x}{c} + \frac{(A-x)}{b}}$$

$$SG = \frac{A}{x\left[\frac{1}{c} - \frac{1}{b}\right] + \frac{A}{b}}$$

$$\text{with gradient } d(SG)/dx = \frac{-A\left(\frac{1}{c} - \frac{1}{b}\right)}{\left\{x\left(\frac{1}{c} - \frac{1}{b}\right) + \frac{A}{b}\right\}^2}$$

Fig 2.

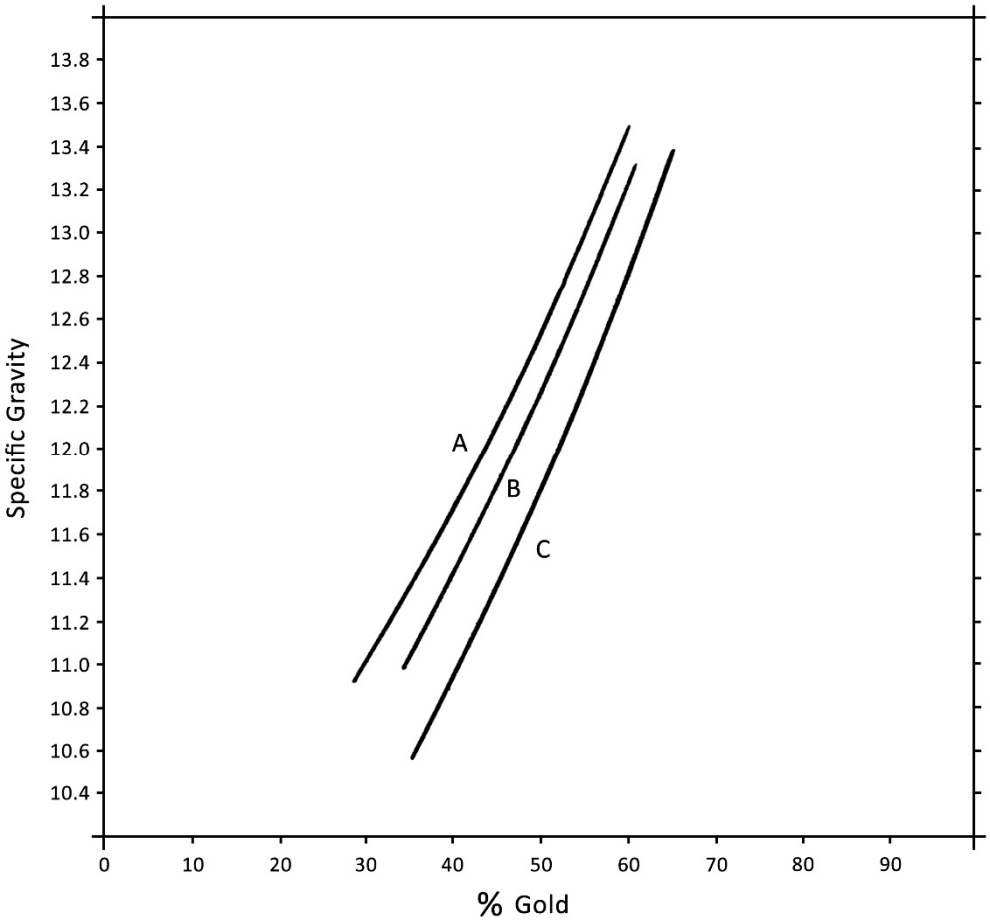
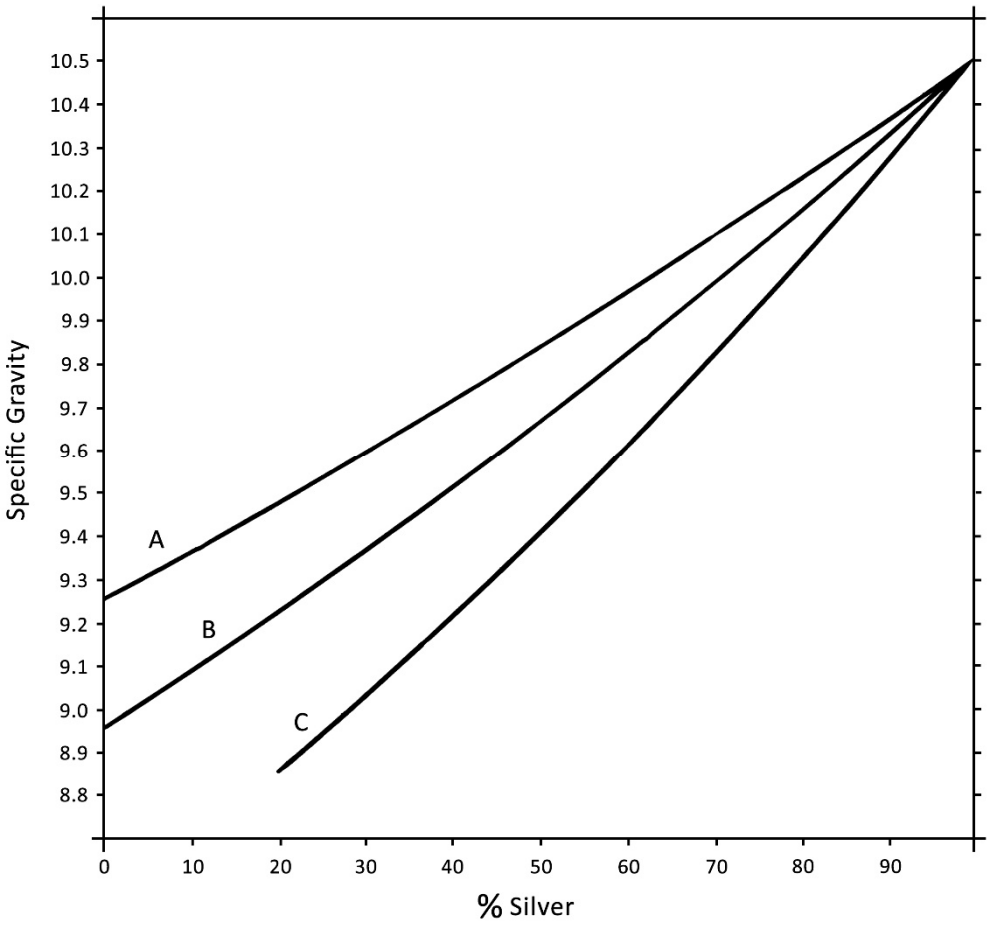


Fig 3.



Assuming zero total volume change figs. 2 & 3 are a family of reciprocal curves where right to left from the origin SG = **b**, right hand vertical axis **x** = 0 the gradients, the curvatures and the rate of the decrease of the slopes all depend upon 1/**c** – 1/**b**, and the smaller this is, the smaller these parameters, the flatter the curve and the less accurate, becoming a straight horizontal line SG = **c** = **b**. Oddy's empirical data, (ibid. p.155) seem to show that the effects of shrinkage are tiny, equivalent to about 2%, or about 20% of the determined amount amount of Au in a debased tremissis containing 10%. Theoretical SG curves of Ag and Au alloys with three debasing metals: **A** = leaded bronze SG = 9.26, Cu80, Sn4, Pb15 + 1% assorted impurities of assumed SG 9.26, average for Rome, Gordian III to Philip I, **B** = Cu100, copper, pure, SG 8.96 and **C** = Roman orichalcum Cu80, Zn20, SG 8.52. All curves coverage to a point SG = **b**, **x** = 0, with the systematic errors vanishing, but with the curves rapidly separating at high **x** values. Diluents of unknown make-up in silver will probably follow a curve somewhere between **A** and **B**. Tin may push a little to the right of **A**. Au/Ag alloys follow a curve far to the left of **A**, fig. 2. A low **c** yellow metal additive, e.g. Sn, Zn may move the curve to the right as far as **A** or **B**. This probably led to the general consensus that SG determined Au contents of early medieval Au is generally ~ 3% too low, suggesting use of the wrong curve.

SG	**Au/Ag**	**Au/Cu**
13.61	50%	64
12.90	40%	56.5
12.20	30%	49.5
11.56	20%	41
10.99	10%	34.5
10.60	2.1%	30.0

Column 1 & 2 list some data from Oddy's empirical curve on Au/Ag alloys, which seems to show that using the theoretical curve generally overestimates; 0.3% at 90% Au, 0.4% at 80, 0.7 – 0.8% at 50 – 40, increasing to 1.1 – 1.6% at 30 – 20%. These errors are near the limit of random error detectability.

Column 3, Au values using Fig. 2, **B**. Hence routine BM quotes of both Ag and Cu curves is limited to Au levels above c. 83%.

REFERENCES

1. Vezin, W.R. 2026 Numismatic Oddities Number 12. Ipswich Numismatic Society. (in press)
2. Oddy, A., The analysis of coins by the specific gravity method in Oddy, W.A. & Cowell, M.R., 1998: Metallurgy in Numismatics 4. 147 – 157. R.N.S. London.