Impurity Ferromagnetism in Roman & Chinese AE Coins: Observations & Limitations

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Several publications exist on the analysis of the formulation and impurity constituents of old and ancient copper-based coins. Of impurities, iron is ubiquitous, often predominant, but very variable, without apparently affecting contemporary quality assurance. On Roman AE Carter & King (1) – plus several references therein also consulted, show variations of a factor of a thousand or more (<0.001 to 1%) among a population of a few hundredths to a few tenths of one percent. Cowell et al (2) also report huge variations in iron content of Chinese cash, usually in the region of a few tenths of a percent in the early empire but increasing with the use of zinc during the late Qing Dynasty to nearly 1% with fliers of 3 – 11%. Seemingly unnoticed are apparent variations of ferromagnetism within individual coins. Thus ferromagnetism alone would appear to lack applicability to questions of authenticity, but sometimes in combination with other features can be useful.

Inconsistencies in iron content arise from batch to batch variable incompletion of reaction of FeO with added silica sand carried out during the smelting process of copper pyrites, $CuFeS_2$. B/H plots by Goulpeau (3) in a study of remnant ferromagnetism in coins of known Fe content appear to show that magnetic responses derive from metallic Fe rather than from ferromagnetic oxides such as Fe_3O_4, Fe_2O_3 & FeO.OH. Other impurities would not contribute: Paramagnetics of which magnetic responses are indistinguishable from very dilute ferromagnetism in the setup are present at insufficient concentrations. Ferromagnetism of any nickel would be abolished by dissolving in copper. Chinese coins contain small amounts of cobalt, however. Iron has temperature dependent low solubility in copper and precipitates on cooling.

Fig. 01: Elagabalus, Berytus, Phoenicia. AE 26-7, 14.4g. Rev: Silenus in arched tetrastyle gateway; BMC Greek 26, 81, 192 et seq. Awful, genuine coin but interesting. Struck on very highly refined metal with a tiny Fe content, just a few parts per million, the resulting diluted ferromagnetism just annulling the diamagnetism of the flan, amounting to virtually zero force resultant. Were this an EF coin one would initially suspect it to be fake, before realising that it is possibly genuine, though most unusual, and that a counterfeiter using either their own formulation, or stock of old metal, would end up with an object of higher ferromagnetism. A type one error is declaring a genuine article fake. The type two, the opposite.

Fig. 02: Trajan, AE34, 28.6g sestertius. Rev: Trajan's Column, S-C SENATVS POPVLI SQVE ROMANVS – very rare; RIC II p.292, 680. Again, produced from very pure metal with ferromagnetic response similar

to that of a George VI penny. It also has an unusually smooth or rounded edge together originally suggesting it to be a more recent forgery. The surface however has a thin film covering of crystalline malachite, which cannot be counterfeited and would take millennia to form. The flan seems carefully produced, and rounded in the mint carefully, but somewhat more roughly than would be the case by a modern forger. Was it a special commemorative issue? Were there coin collectors in Rome? There appear to have been amongst the continental Celts. Of this more later.

Fig. 03: China, Ch'ing Dynasty. AE 53, 53.6g 500 Cash, Hsien Feng 1855 AD, Board of Public Works Mint: KM C#2 – 9.1 copper, forgery. A numismatist would cite indistinctness of certain characters. The metal is of a later diamagnetic extreme high purity unavailable for the time, despite its aged appearance. The magnet described is often able to physically pick up multiple cash pieces of this weight and period.

Fig. 04: China, Republic 20th C. An uncatalogued decoration, medal or amulet, AE 77, 84.1g, based on a Wang Mang Interregnum Zhuang Quan Si Shi (40 unit) 23mm AE piece, Harthill 9.18, a prohibitively rare (£20,000+) item. Catalogued amulets or charms based on old coins nearly always exhibit additional embellishments, or invocations or symbols on the reverse. The obverse rim malachite patination appears painted and enamelled on, ditto the reverse mediaeval colouration, which is in slight relief. The metal is significantly ferromagnetic but not as to allow itself to be 'picked up' as above. This is evidence that manufacturers were aware of mediaeval metallurgy. A K – alpha SEM

electron microprobe on exposed metal on the rim would determine whether melted down ancient cash, or a recent imitative formulation was used.

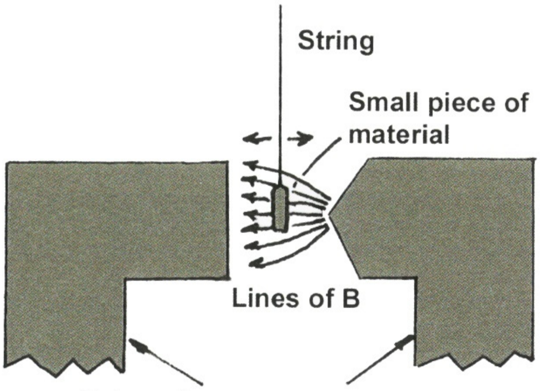

Fig. 05: A semiquantitative estimate of ferromagnetism in a coin may be obtained from a modification of the setup shown here (4), a demonstration of diamagnetism – the default state in all matter that is not ferromagnetic or paramagnetic (this latter characteristic of unpaired electrons). There is an error in the figure: Diamagnetics move from a strong to a weak field irrespective of whether the 'sharp' pole is N or S, or away from any isolated 'blunt' ditto, which will also give a field gradient. Paramagnetics, like aluminium or air, attract. The coinage metals generally, and e.g. water, repel, like most matter. These forces are minute, about a millionth of ferromagnetism, which is confined to three elements at the middle top of the D-block series, because of their (and certain specific alloys) unique external field amplification properties of their electronic structures. As described as follows, paramagnetics behave as very diluted ferro, high levels requiring modifications:

A) The two electromagnetic poles replace by a single flat squared off pole of a small strong permanent magnet, e.g. a 2X1 cm pole of an Eclipse Alcomax 0.2 Tesla type or small neodymium.
B) Attach a length of fine thread to the edge of the test coin via a 10mm~ length of cocktail stick and a minimal amount of Blu Tack, etc.
C) Suspend the coin in an area free of air currents, allow to settle down and equilibrate (giving a few judicial spins to help it along).
D) Arrange things such as to allow the magnetic pole to be moved at right angles to the surface (obv. or rev.). A 1987 Standing Liberty silver dollar, a diamagnetic, will rotate away from a magnet applied off-centre.

Obviously significantly ferromagnetic coins require different approaches.

References

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For details on para-dia and ferromagnetism see Feynman ibid section II, 34-37.