A Study of some Forged Silver Coins recovered from 17th C and 19th C Shipwrecks

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Introduction

This paper describes the characterization of two debased* silver coins which have been recovered from shipwreck sites off the coast of Western Australia. One coin came from the wreck of the Dutch East Indiaman 'Batavia' (1629) and the other from the American China Trader 'Rapid' (1811).

The central core of both debased coins was principally copper but the method of fabrication was apparently different.

Although the scanning electron microscope has been used extensively in examination of works of art and other material objects we report on the less-used back scattered-electron/low vacuum mode[1] which requires no sample preparation and gives more readily interpretable information.

Description of coins

The fragment of the Rijksdaalder, a coin from the United Netherlands Province of Overyssel c. 1620, was recovered from the wreck of the 'Batavia' after 340 years in the sea and had been treated in the Conservation Laboratories of the WA Museum prior to the present examination. The fragment had metal corrosion products partly filling the inner void, (see Fig. 1), and had external wall thickness of 0.9 mm with a gap between the obverse and reverse sides of 1.3 mm. The thickness of the top and bottom layers ranged from 0.7 mm to 0.3 mm in moving from the edge towards the centre of the coin. The apparent diameter of the coin, 42 mm, is typical of a genuine coin of that period. The thickness along the rim varies from 2.4 to 2.7 mm compared with 2.5 mm for a genuine coin.

Examination of the edge of the coin under a binocular microscope (x40) showed areas of overlap between the layers of silver used to form the obverse/reverse sides and additionally revealed a characteristic stress corrosion pattern along the lines of cold working around the circumference. This evidence indicates that the solid edge of the coin was formed around the central metal core by burnishing[2].

The second coin was a piece-of-eight dated 1796 with the marks of the Mexico mint and the assayer's initials F.M. When raised from the wreck (1811) of the 'Rapid' after nearly 170 years in the sea, its surface was covered with a layer of coralline algae and metal corrosion products. The concretion was removed by soaking the coin in 1M hydrochloric acid; the coin was subsequently stabilized by chemical reduction with sodium dithionite in a 1M sodium hydroxide solution[3]. After polishing and manually removing some corrosion products around the coin's edge its laminated construction was discovered (see Fig. 2). The silver layers were quite thin, 0.25 mm, and both obverse and reverse surfaces had an irregular series of blisters which apparently were sufficiently severe to fracture the silver laminate. The inner metal core was corroded up to a depth of 7.5 mm from the outer edge. The overall dimensions of the debased coin were not significantly different from genuine coins of that date and mint.

Corrosion potentials

The use of corrosion potential measurements for the detection of debasement in silver coins has recently been reported[4] and has been used in the study of these two forged coins. When a metal is placed in an aerated electrolyte, such as sea water, a measurable electrode potential is developed as a result of the combined oxygen reduction and metal oxidation. In the case of silver the oxidation reaction results in the formation of a thin film of silver chloride. The presence of a metal less noble than silver, i.e. one with a lower redox potential, will result in a depression of the corrosion potential.

The corrosion potential of individual coins was measured against a Titron

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*"debase   depreciate (coin) by alloying etc" (OED).

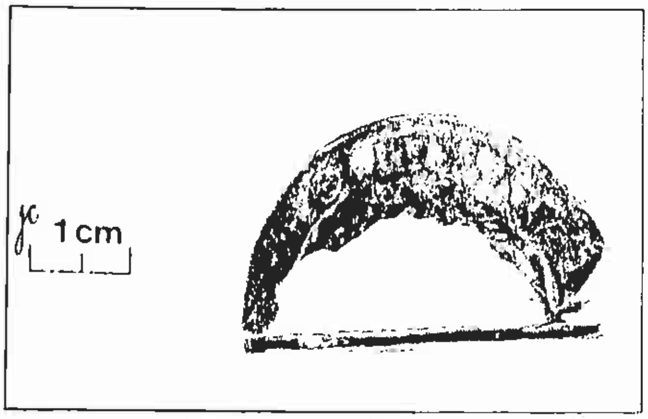


Figure 1 Part of a Rijksdaalder of the United Netherlands Province of Overyssel c. 1620 from the 'Batavia' (1629). The coin was angled on a mirror surface to provide a full edge profile in the reflection

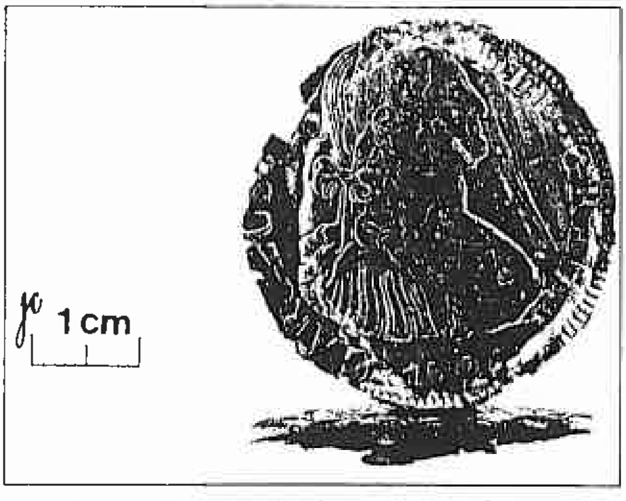


Figure 2 The Spanish Silver dollar (8 real) dated 1796 with mint mark of Mexico and assayers initials F.M. Recovered from the wreck of the 'Rapid' (1811); the coin was photographed using the same technique as Figure 1

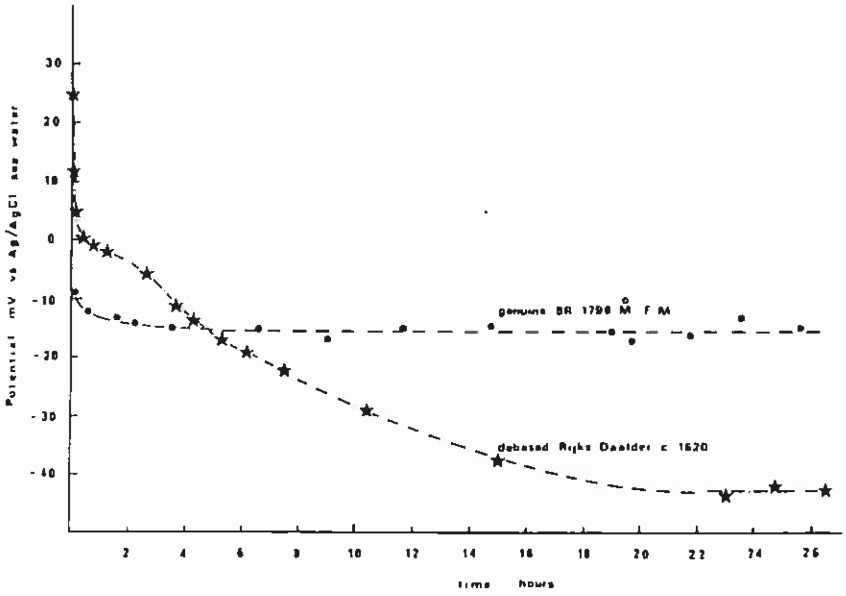


Figure 3. Corrosion potential of the Rijksdaalder fragment in sea water as a function of time. The reference coin was a genuine 945 silver dollar.

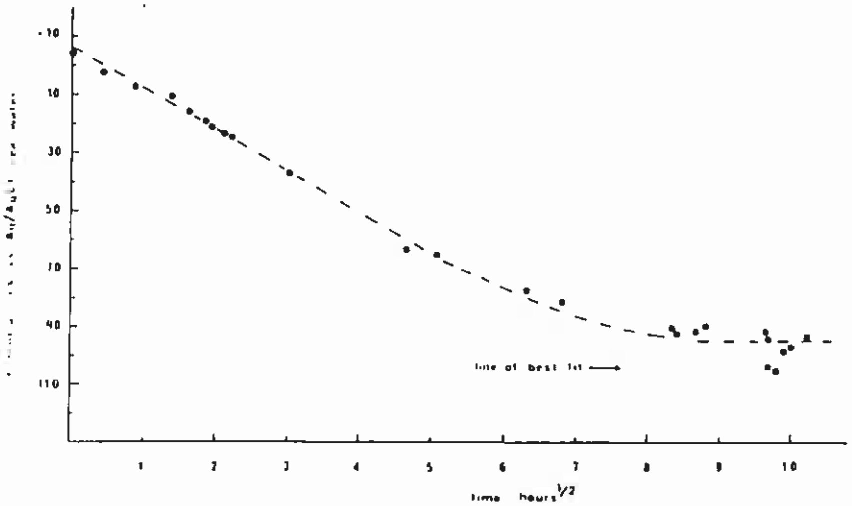


Figure 4 Plot of the corrosion potential of the forged 1796 Mexico mint piece-of-eight against the square root of time. The line of best fit was obtained using a least squares linear regression, the correlation factor was 0.993.

silver, silver chloride reference electrode in seawater (35.6% salinity) using a high impedance mV meter (FLUKE model 8010A multimeter) and was monitored for the specified times.

The Rijksdaalder initially registered a more positive voltage than the reference electrode which was immersed in the same sea-water solution. The potential rapidly fell to that of the reference and then continued to slowly decrease until it reached a steady value of -42 mV after 24 hours (see Fig. 3). The data for a genuine silver (94.5% Ag, 5.5% Cu) coin are included for comparison. The initial potential of the fragment reflects the potential of the metallic silver surface which was rapidly covered by a thin film of silver chloride. As the salt solution penetrated the corrosion product film inside the coin, the potential change indicated the presence of the base metal.

The corrosion potential for the 1796 piece-of-eight forgery showed similar behaviour to that of the Rijksdaalder. The potential decreased for more than 60 hours to a final value of -95±5 mV. It was found that the corrosion potential was linearly dependent on the square root of time for 25 hours after which the rate of change decreased until the steady value was reached (see Fig. 4). The coin had been only partly immersed in the sea water and the time dependence of the corrosion potential may well be a reflection of the diffusion of the electrolyte through the corrosion product layer surrounding the metal core.

A similar dependence of the corrosion potential, E corr, on time was observed for the Rijksdaalder fragment for $2 < \text{time} < 16$ hours. In both cases the slope of E corr vs $t^{1/2}$ was -14.5 ± 0.2 m V.hr$^{-1/2}$.

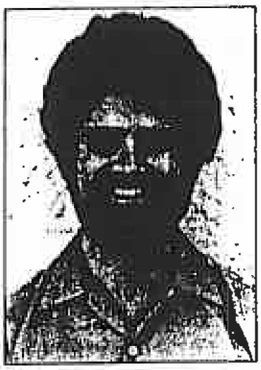
Surface and core analyses

A 1 mm diameter dental drill was used to take a sample from the metal core of the 1796 forgery. A 24 mg sample was dissolved using 10% nitric and tartaric acid and analysed using atomic absorption spectroscopy with the following results: Silver 2.18%, Copper 94.5%, Tin 1.01%, Lead 0.67%, Zinc 0.73% and Nickel 0.35%. The composition of the metal core of the Rijksdaalder fragment could not be quantitatively determined since there was not sufficient solid metal left in the core. However, there was some residual elemental copper found along with the principal corrosion product, cuprite (Cu_2O) and so it seems likely that the central layer was composed principally of copper.

The corrosion products from the centre of the Rijksdaalder were analysed using the SEM energy dispersive X-ray analyser. Since no traces of tin or lead were found it is unlikely that these elements formed a major part of the base metal core component. The sample preparation consisted of placing the corrosion products on a piece of double sided sticky tape, which was attached to the sample stage and placed in the specimen chamber. The whole operation took only a few minutes. Similar procedures were used to prepare the coins for examination under the SEM. For details of the modified SEM the paper by Robinson and Nickel[1] should be consulted. The surfaces of the two debased coins were analysed for copper and silver and both coins appeared to have higher copper-to-silver ratios than genuine coins obtained from the parent wreck sites. When the surface analyses were compared with a standard Sterling Silver (Perth Mint assay) the apparently anomalous values were found to correspond very closely to a 92.5% silver alloy.

Because of the differences in redox potential of copper and silver in chloride-containing media there was preferential corrosion of the copper-

Ian MacLeod obtained his PhD from the University of Melbourne in 1974 after working for three years on the electrochemistry of metal fluorides in anhydrous hydrogen fluoride. The next two years were spent at the University of Glasgow preparing organophosphorus metal complexes with Professor David Sharp. In 1976 he joined Professor A. J. Parker's group at Murdoch University where he investigated the electrochemical behaviour of copper in aqueous acetonitrile. For the past three years he has been a research officer at the conservation laboratories of the WA Museum in Fremantle studying the corrosion of non-ferrous metals on shipwrecks. In that time he has developed several new techniques for stabilizing corroded metal artefacts.



rich areas of the alloy. This frequently results in extensive intergranular corrosion. As the coin corrodes copper corrosion products will normally move towards the metal-sea water interface where they will be precipitated as Cu_2O or $Cu(OH)_3Cl$ whereas the silver corrosion products are more uniformly distributed in the matrix. During the conservation treatment these surface copper minerals are removed leaving behind a 'silver-rich' surface.

Although both forgeries had been cleverly fabricated their ultimate detection was largely a result of the differences in the corrosion rates of silver and copper in sea water. It seems likely that the 1796-dated coin was made by attaching the 0.25 mm thick silver-rich laminates to the core by use of a silver solder (72% Ag 28% Cu) prior to rolling and stamping. The cracks in the laminate and the surface blisters (Fig. 5) may have been caused by localized under-film corrosion with subsequent delamination being caused by the volume expansion as the metal was converted to corrosion products. After stamping, the edges of such forgeries would probably have shown the 'pink' colour of the copper core. Immediate detection of the forgery may have been prevented by dipping the coin in a silvering solution. Silvering of bronze coins was practiced in the third century and although the durability of such coatings is uncertain[5] these procedures would have enabled the forgers to successfully pass the coins.

Penalties for debasement of coinage were severe. In 1124 Henry I of England suspected debasement of his money so all the moneyers were mutilated by depriving them of their right hands and their testicles[6]."

Since the Rijksdaalder fragment had a 'thick' layer of silver surrounding the metal core its detection was fortuitous, being primarily due to the fracture of the coin in the wreck, which subsequently exposed the core to corrosion. A scanning electron micrograph of the fractured edge of the coin is seen in Figure 6. The coin surface has not had any sample preparation and the photograph from the video monitor clearly shows the transgranular cracking mode of failure[7].

With both forgeries the exposed copper-rich metal core acted as the major site for the anodic (metal dissolution) reaction while the more noble (silver) surface layers acted as the negative electrode where the major reaction was reduction of oxygen. In the case of the 1796 coin any etching of the milled edge would have served to provide a reactive surface for subsequent corrosion.

Density measurements

Traditionally, debasement of silver coins has been detected by density measurements. Measurements made on some coins from the 'Batavia' described in numismatic terms as "fine to very fine" showed apparent specific gravities that were significantly lower than those anticipated for silver coins of better than or equal to 92.5% silver (see Table 1). The densities of 130 coins from the 'Rapid' which had been treated in the same way as the forgery showed a range of values, 9.8 ±0.2 $g.cm^{-3}$, which were all

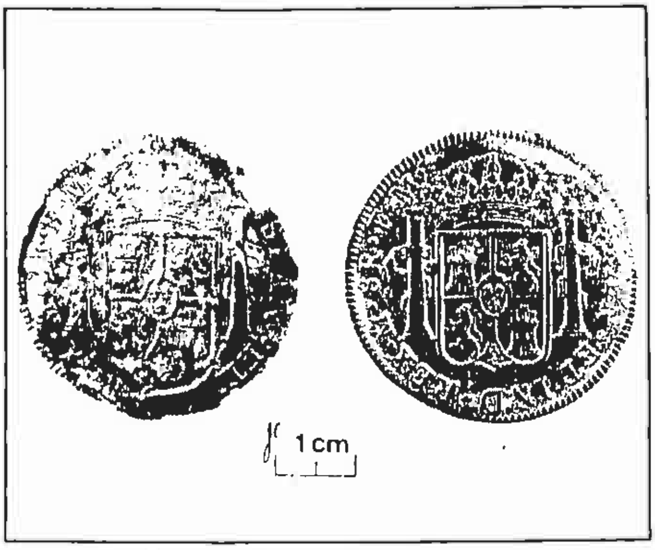


Figure 5. Debased 1796 laminated coin on the left showing blisters on the surface, genuine coin of same date and shipwreck on the right

Figure 6. A scanning electron micrograph from the SEM TV screen showing the fractured edge of the Rijksdaalder fragment. Full width of image is approximately 80μm (x3000).

significantly lower than the standard sterling silver disc. Frequently, the densities of coins recovered from shipwrecks are anomalous, because of their porosity.

Microscopic examination of polished cross-sections of the silver coins recovered from Dutch shipwrecks off the Western Australian coast showed up extensive intergranular corrosion. The removal of copper corrosion products by outward diffusion of the soluble complexes will ultimately produce a microporous sample. Although some of the voids may be filled with silver corrosion products it is extremely difficult to find a suitable liquid which can 'wet' these microscopic voids. Despite these problems the densities of the two copper-based forgeries were clearly significantly lower than the genuine coins. In the absence of other techniques density measurements can be used in an initial assessment of suspect coins.

The origins of the forged Rijksdaalder and the piece-of-eight remain unknown. In the light of the above observations it may be prudent to re-examine the collections of specie in other museums and private collections.

Table 1

Densities of silver coins recovered from the wrecks of 'Batavia' (1629) and the 'Rapid' (1811).

Coin	Mint	Date	Density $g.cm^{-3}$
Sterling silver (92.5% Ag, 7.5% Cu)	Perth, W.A.	1980	10.35
genuine Rijksdaalder	Overyssel	1622	9.75
forged Rijksdaalder	Overyssel	c. 1620	8.40
genuine piece-of-eight	Mexico	1796	10.06
130 pieces-of-eight	Mexico	1759-1809	9.8±0.2
forged piece-of-eight	Mexico	1796	8.60

Acknowledgements

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APCC 1982 National Workshop & World Bank Briefing Session & Annual Dinner

For international projects in many areas to proceed, there is a growing dependence on both financing and feasibility. Unless Australia's exporting consultants have a clear understanding of the background of these subjects they will be likely to miss out on key opportunities through a failure to understand the latter's needs. This one-day Workshop - 8.30 am-5.00 pm on Friday 24 September, Lakeside Hotel, Canberra - will assist in preparing Australian consultants to grasp the benefits of such an approach which has yet to become established in Australia.

Consultant Services Officer at the World Bank, Mr Maurice Dickerson, is leading the team of speakers who have accepted invitations to address the Workshop. These include: Mr P. D. Isaacs (Macdonald Wagner & Priddle Pty Ltd) - "The Professional Consultant and Financing"; Mr G. H. Thompson (Senior Vice-President, Bank of America) - "The Role of Private Banks in International Development Projects"; Mr A. Hislop, (General Manager, Export Finance and Insurance Corporation (EFIC)) - "An Export Credit Agency's View"; Ms R. McGovern (First Assistant Secretary, Bilateral Programs Division, Australian Development Assistance Bureau (ADAB)) - "Shaping New Aid Projects"; Dr G. N. T. Lack (W. D. Scott & Company Pty Ltd) - "Economic Feasibility and Practicality".

Mr Dickerson will also lead a Briefing Session on the use of consultants by the World Bank which will be held from 2.30 pm-4.30 pm on Thursday 23 September, immediately preceding the Council's Annual Dinner scheduled to commence at 5.30 pm. The Deputy Prime Minister and Minister for Trade and Resources, the Rt Hon. J. D. Anthony, CH, MP, will be Guest Speaker for the Dinner.

Registration for the National Workshop, World Bank Briefing Session and Annual Dinner will be open to non-members as well as members of APCC. Non-members wishing to receive a copy of the registration brochure to be distributed in August, should contact the APCC Secretariat - PO Box 1156, North Sydney, 2060, Telephone (02) 982 9083, 929 5566, Telex APCC AA73621 - to ensure that their practice is on the distribution list.