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Analytical study of an 1899 Peruvian dinero: unveiling the mystery of a coin that wasn't officially minted

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Abstract

The present paper presents the analytical study of an unusual Peruvian 1899 *dinero* coin whose authenticity has been questioned since the 1970's. This coin, which is present in some numismatic collections although there is no record of having been minted officially, has been characterized using non-destructive techniques such as X-ray fluorescence (XRF), scanning electron microscopy coupled with energy dispersive spectroscopy (SEM–EDS), and X-ray diffraction (XRD). Results are consistent with a cast counterfeit coin made at the turn of the 19th and 20th using a copper base alloy that was silver-platted to pass unnoticed among the public. The alloy used, generally known as *german silver,* was common for counterfeits in North America and Europe in that period. The historical reasons for the appearance of this unexpected coin in Peru during a time of economic difficulties, where the public experienced a shortage of small-change coins, are briefly outlined.

Keywords Coin, Counterfeit, XRF, SEM–EDS, XRD, German-silver, Nickel-silver

Introduction

One of the primary concerns faced by currency users, collectors, and museums is coin falsification. This practice can be grouped into two general categories: on the one hand, there is the counterfeiting of current money made to pass as legal currency, affecting all users. On the other hand, there are copies made to deceive coin collectors or museums, usually known as forgeries [1, 2]. The first group exists since the invention of currency. The second, however, began during the Renaissance, when collecting became more common and has never stopped since [3].

Coin counterfeiting has always been illegal, but the study of surviving counterfeits made to circulate in ancient times is of high historical value and allows us to understand complicated economic situations [4]. In many cases, it also allows us to understand the falsification techniques used in the past and reveals data on the technological development of those times. [5, 6]

The detection and identification of counterfeit coins is a time-consuming task to which numismatists and law enforcement dedicate much time, especially when it pertains to high-value coins. There are specialized Journals such as *The Numismatist* that, for decades, in almost all of their issues, have shown how to identify specific characteristics on high-valued pieces that are typical diagnostics of counterfeits. There have also been publications especially dedicated to counterfeiting (*Counterfeit Coin Bulletin* and the *Bulletin of Counterfeits*, for example) and books explaining the processes used [2]. The involvement of scientists who try to contribute to these issues through techniques such as X-ray fluorescence, electron

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microscopy, or diffraction techniques is getting increasingly common [7–10].

The present study has been focused on a Peruvian *dinero* bearing the 1899 minting year. This coin belongs to the 1863–1917 period when the monetary unit of Peru was the "sol". A one-sol coin was a silver piece of 25 g, with a nominal composition of 90% silver, the remaining being copper. Lower denominations minted in silver included the half of sol (50 cents), the fifth of sol (20 cents, "*quintos*"), the tenth of sol (10 cents, "*dinero*") and the twentieth of sol (5 cents, *"medio dinero*"). Higher denominations were minted in gold, and the lower ones in copper-based alloys. Not all the coins were minted every year, so collectors must be cautious and rely on numismatic catalogs and publications in order to complete their collections.

Counterfeiting of coins during the use of this monetary unit has been noted in some sources [11–13], but data is very scarce and no compositional analysis has been published. It is well known that most counterfeiters, in order to be successful, reproduce highly circulated coins that they expect to pass unnoticed [4]. The case of the 1899 *dinero* presented in this paper is thus worth noting: according to the official Lima Mint figures [11], which have been cited in most international catalogs [14, 15], 1899 was a year for which no *dineros* were minted. However, a thorough search of the literature located at the Peruvian Numismatic Society Library showed the presence of three old catalogues that included the 1899 dinero coin, the oldest being from 1978. One of them listed this coin as extremely rare [16] and the other two as "Possibly fake" [13, 17]. Horace Flatt, a well-known North American historian of Peruvian numismatics and coin collector also listed a specimen of this coin in his collection, mentioning that it was most likely a counterfeit [11].

One of such coins surfaced from a group of *dinero* coins used during a MSc thesis [18] that was carried out by a student under the supervision of one of the present paper's authors. Given that there was no public information on this coin it was an excellent opportunity to carry out a thorough analytical study of the coin following the simple sequence outlined by Al-Saad [19] using all available techniques to the authors. In this work the chemical composition of the coin is studied by XRF and SEM coupled with EDS, and the alloy has also been characterized by XRD. A metrological characterization of the coin (width, size and weight) was also carried out and compared with a corpus of 80 similar circulated coins of the time.

It is important to highlight that the objective this paper is not to determine if the coin is false (as reasonable doubts of its legitimacy have always existed) but to characterize it in order to know (and make available) its chemical composition and possible ways of manufacturing. In addition, it is also expected to understand why a coin that was not officially minted could end up being counterfeited, and how this can be connected to the coin counterfeiting in the Americas during the nineteenth century.

Experimental

The 1899 dinero coin belongs to a group of more than four hundred 1863–1917 silver coins that were acquired from local numismatic dealers in Lima from 2014 to 2018 for their study by postgraduate students and are now kept at the chemistry laboratory of the University of the authors. The 1899 coin was purchased inadvertently. The different objects and counterfeit coins used for comparisons during the research (listed in the supplementary section) belong to private collections from either members of the Peruvian Numismatic Society or the San Pedro Church in Lima.

An Ohaus Pioneer Analytical balance (with a sensitivity of 0.1 mg) was employed to measure the weight of all coins. A Mitutoyo CD-6″CX digital caliper was used to measure the coins' diameters and widths (sensitivity 0.01 mm). The XRF analyses were carried out using a portable Bruker AXS Tracer III-SD instrument equipped with a rhodium X-ray tube and a Si-PIN detector with a resolution of 150 eV at FWHM. The instrument's voltage and current were set to 40 kV and 1.3 µA, as recommended by the instrument's manufacturers for metallic samples. No radiation filters were used. Measuring time was set to 120 s given that longer times did not improve the signal quality. Data were collected on both sides (obverse and reverse) of the four coins shown in Fig. 1. The approximate beam size is drawn to scale in Fig. 1a. XRF spectra were analyzed using the software Spectra 7.4.0 from Bruker AXS, specially to determine the peak area of elements that were in very low concentration. The elemental composition of the 1899 *dinero* was calculated constructing a calibration curve with the aid of the 10 certified standards shown in the Additional file 1: Table S1. The curve and the quantification were carried out using the online application Cloud Cal v3.0 [20] which has been proved as a powerful application for quantification of XRF data [21] and is based on the Lucas-Tooth and Price algorithm that accounts interelement effects in the absorption and emission of X-rays. The coin's alloy was also compared with other contemporary and modern objects with similar compositions, the list of which is in the supplementary information (Additional file 1: Tables S3, S4).

Elemental maps were constructed using the energy-dispersive *X-ray microfluorescence* (ED-XRF) *spectrometer* MIDEX SD from Spectro. The instrument is equipped

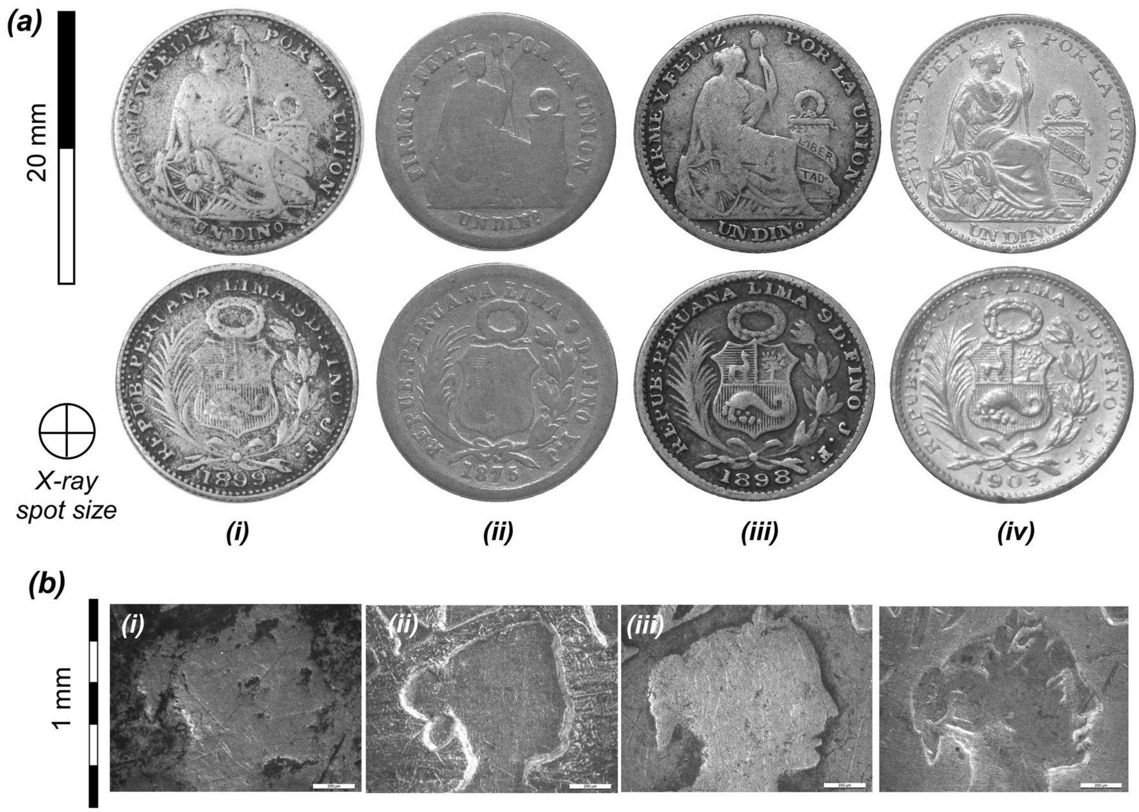

Fig. 1 Photographs and micrographs of selected circulated one dinero coins. **a** photograph of (i) the 1899 dinero under study, (ii) a highly worn 1875 specimen (where most of the raised details in the devices –seated Liberty Lady and coat of arms- are lost), (iii) a contemporary 1898 example and (iv) a well preserved 1903 specimen in a very fine state. The approximate X-ray spot size has been drawn to scale. **b** Wear patterns (surface pits and scratches) observed on the seated Liberty Lady's face on the reverse of each coin

with a silicon drift detector (SDD) with 30mm^2 area and a Mo X-ray tube operated at maximum power of 40W and a voltage of 48kV. An automatic XYZ tray was used to collect the elemental maps. Each map comprised of a 60×60 grid of points over a 2 cm×2 cm square. Each point was measured for 15 s for a total of nearly 31 h per map. Elemental data for each map was extracted using internal calibration using the fundamental parameters software FP Plus.

X-ray diffraction (XRD) analysis were performed using a Bruker D8 Discover DAVINCI instrument equipped with a Lynxeye detector and a Cu Kα X-ray tube. The XRD data were collected for 2θ angles between 20° and 80°, with a 0.02° step and an integration time of 0.5 s. Crystalline phases were identified from PDF-2 database using Bruker AXS Software Difracc.EVA 5.

Microscopical examination was carried out using a Leica DM1000 LED microscope equipped with a DFC 3000 G camera. Images were processed with the Leica Application Suite v4.8 software. SEM analysis was carried out using a FEI Quanta 650 scanning electron microscope equipped with a tungsten filament and a concentric backscattered electron detector for energy dispersive x-ray spectroscopy (EDX). Accelerating voltages of 20 kV and working distance of 10.6 mm were used for images and EDX analysis.

Results

Macroscopic and metrological description of the coin

The coin under study is the 1899 *dinero* coin shown in Fig. 1a(i). As observed, it is a coin with high degree of wear, where the devices and lettering are not very clear, in strong contrast with the slightly circulated contemporary coin shown in Fig. 1a(iv). The wear patterns (surface pits and scratches, Fig. 1b) are consistent with a coin that circulated more than 100 years ago. At first glance, this coin cannot be distinguished from a dirty and/or a highly worn coin of the time (Fig. 1a (ii) and (iii), respectively).

The diameter of the coin, 17.95(2) mm, is within the official specifications [22] and is similar to the averages observed in contemporary coins from the same period (1863 to 1917), as seen in Fig. 2a. Its thickness, although not officially specified, is also within that observed in contemporary coins (Fig. 2b). The

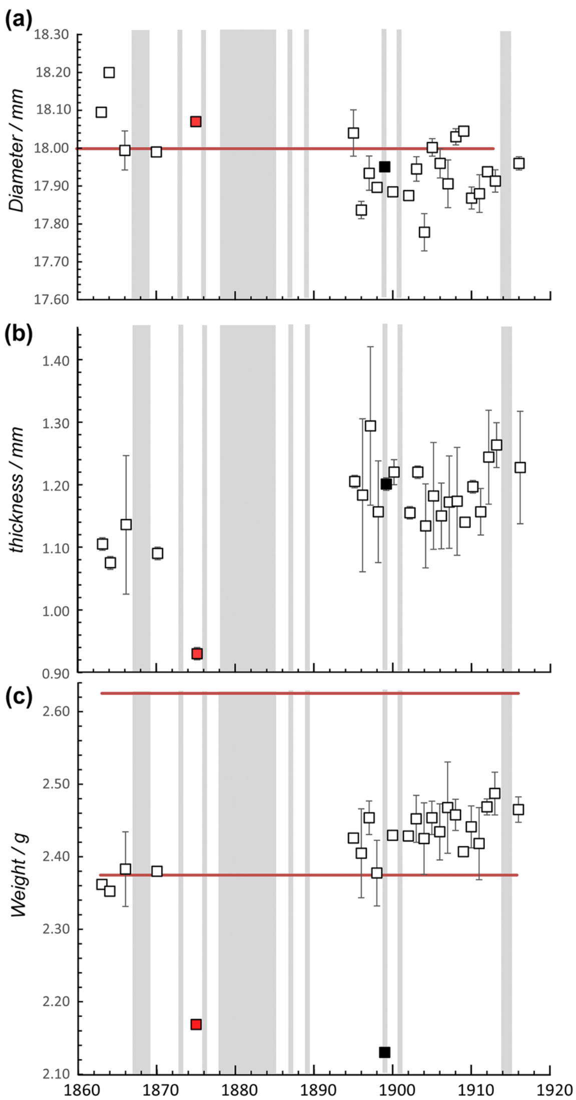

Fig. 2 Metrological study of the 1899 *dinero* coin (black squares) in the context of other contemporary *dinero* coins from the 1863–1917 period. **a** Yearly mean diameter, **b** mean thickness, and **c** mean weight. Standard deviation is included when three or more coins from the same year were available. Red square is the highly worn 1875 dinero coin from Fig. 1b. Grey areas cover the years when no dinero coins were minted (according to official figures). The horizontal line in **a** indicates the official diameter. Horizontal lines in **c** are the maximum and minimum legally accepted weights

main difference relies in the coin weight: it is nearly 13% below the mean values observed for contemporary coins, as shown in Fig. 2c. This low weight is similar to the highly-worn 1875 genuine coin shown in Fig. 1b(ii). This is important because, in such a small coin, most users would probably be unable to tell this weight difference from other used coins, making it easy to pass the coin unnoticed.

Analytical study of the coin

Figure 3 shows an example of an XRF spectrum of the 1899 *dinero* together with the spectrum of the other three *dineros* depicted in Fig. 1a. As observed, the main metals in the genuine circulated coins are silver and copper (as expected), whereas in the 1899 coin the main peaks correspond to copper, nickel and zinc. Minor peaks of potassium, calcium, iron, cobalt and lead (almost imperceptible) were also observed in the 1899 *dinero*. Calcium, potassium and iron are usually associated with surface dirt but the iron peak area is above the quantification limits so it is probably part of the coin's alloy (partly could be dirt). The presence of iron and nickel in silver coins is associated to the instrument background (their area under the peaks are nearly identical to those observed in the BNF-C30.10.2 standard, Additional file 1: Table S1, with less than 50 ppm of Fe and 100 ppm of Ni). The presence of cobalt and lead can be associated with the coin's alloy. When measured near the rim (or coin border), some XRF spectra of the 1899 coin showed the presence of silver traces (Fig. 3b, inset) so its chemical composition was calculated from XRF data collected on three different points as close to the center as possible, to avoid silver peaks. In this regard, cobalt could not be precisely determined and is expected to be around 500 ppm as the peak area analysis of the two available standards containing cobalt (36X-CN23, with 500 ppm and 31X-B8-J2, having 75 ppm) resulted in statistically identical results, very similar with the data of the coin.

The calculations using CloudCal gave the following elemental composition in w/w percentages (mean of three points, with the parenthesis indicating the error percentage): Ni = 12.5(4), Cu = 67.8(6), Zn = 19.4(4), Fe = 0.19(9) and Pb = 0.07(6). Peak area analysis of lead in the 1899 coin is slightly above the limit of detection and very close to the limit of quantification so its values must be interpreted with care.

The resulting composition, usually known as nickel silver, was compared with known Cu/Zn/Ni standard alloys since de 1970's [23] and no close match was observed, which could indicate and older origin. To delve deeper into this aspect, the spectrum obtained for the dinero coin was compared with that obtained for different nickel-silver objects, including some counterfeit and genuine coins.These objects (see Additional file 1: Tables S3, S4) cover a time span from the middle of the nineteenth century to the end of the twentieth century. The spectra are shown in Fig. 4. As can be seen, the central part of the spectra (Ni/Cu/Zn signals) is very similar in all cases but differs on the sides. There are no lead signals at the higher energy end of the spectra in the most recent objects (upper half of the figure) but are common in older objects. On the lower

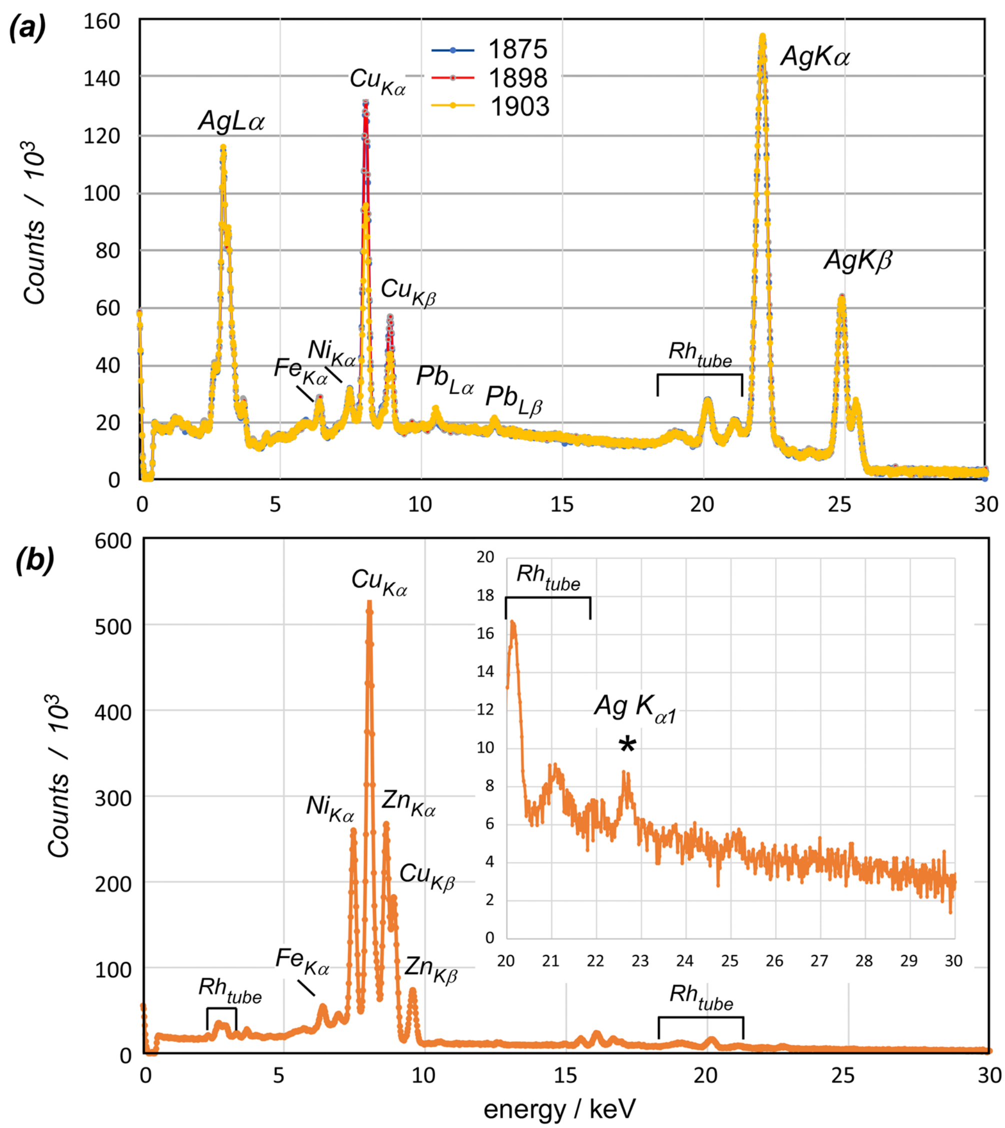

Fig. 3 Comparative X-ray fluorescence spectra of the four coins depicted in Fig. 1. **a** silver coins, **b** 1899 dinero coin measured closer to the rim. The inset of the XRF spectra selected in **b** shows the presence of a very small silver peak

energy region, iron peaks are usually more intense in old objects, in which cobalt and manganese metals are also more common. These observations reduce the possibility of a recent manufacture of the coin and are consistent with an alloy prepared in the nineteenth century. The composition of the contemporary genuine silver coins was not calculated in this research but their spectra are consistent with that expected for a 90% (or higher) silver content as officially specified [18]. The great similarity in their spectra (which are almost superimposed) is an indication that their composition was kept nearly constant within all the years this monetary unit existed (1863–1917).

The observation of blackening in most of the lettering sections of the coin (Fig. 1a(i)), together with the presence of silver in some spectra, were considered strong indications that the coin could have been once silver-plated (the formation of silver sulfides or silver oxides gradually blackens the silver [24, 25]). The possibility of silvering was initially explored using SEM EDX. The SEM EDX study focused on the obverse (the side of the coat of arms) given that it was the most blackened side. Consequently, if the coin had been silvered, this side would be the most plausible place for finding this metal. Figure 5 shows two micrographs obtained in backscattered mode, one taken in an area near the rim, next to the inscription

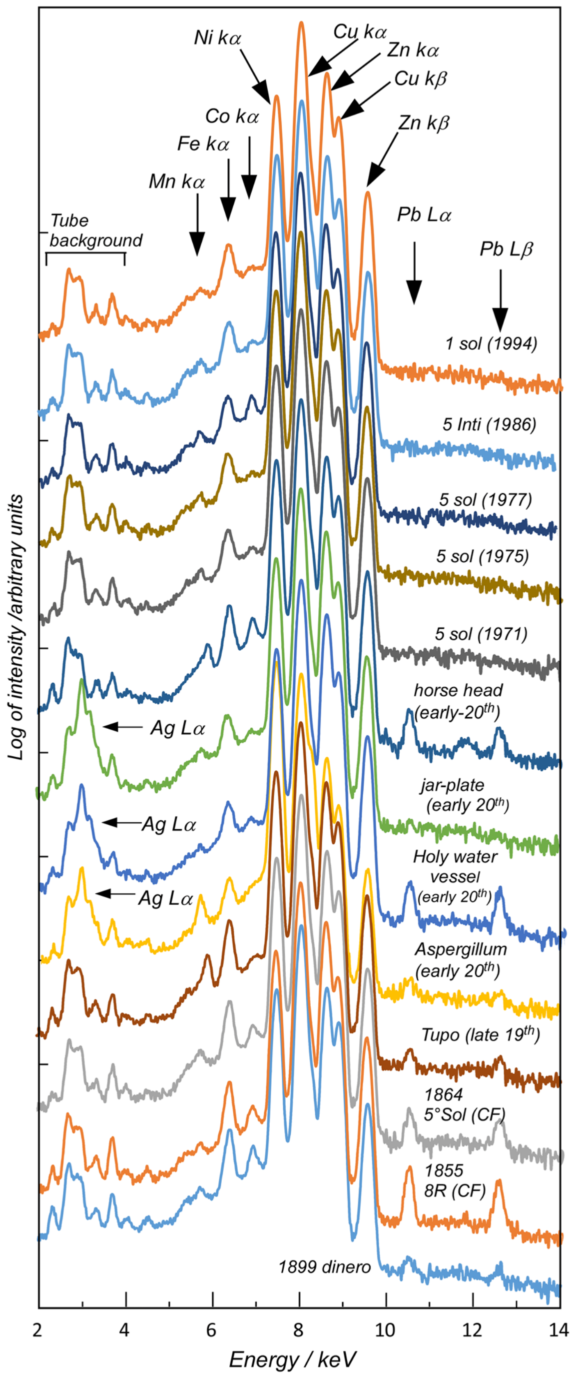

Fig. 4 Comparative X-ray fluorescence spectra of the different objects described in Additional file 1: Tables S3, S4 made from similar alloys than the 1899 dinero coin (shown in the bottom). Full description of each object and corresponding photographs are in the supplementary information. *CF* counterfeit

"FINO", and the other taken over the cornucopia. While the cornucopia area shows a "clean" surface, the border area contains surface deposits between the letters of the legend. The EDX analysis shown in Fig. 4d, clearly indicates the presence of silver in the deposit zone and its absence in the letter N and in the cornucopia. The fact that the area with silver is also the blackened area of the coin (Fig. 4a) confirms the previous supposition of an old (now missing) silver plated layer. The presence of Al, Si, O, Ca, and Mg elements can be associated with accumulated dirt or Impurities associated with silver ores, as observed in ancient or reasonably old coins [9, 26].

Detailed elemental maps of the coin's surface using the X-ray fluorescence instrument described earlier were carried out to gain knowledge of the silver distribution on the coin's surface. Figure 6 shows that the silver is concentrated on the beaded border, while copper, nickel and zinc are evenly distributed. This observation is consistent with a previous presence of a silver coating that has been progressively worn off as a result of usage. As expected, the center shows no silver which is consistent with this being the part of the coin most eroded due to the rubbing of the fingers during manipulation. The region between the letters and the beaded border is especially suited for retaining dirt and the silver cover, as observed in the SEM–EDX measurements. The past existence of an upper layer covering the coin was also observed by microscopic examination: Fig. 7a shows some remains of what once seemed to have been the silver coating, clearly visible around some beads.

The plating method used for the coin is not known but mercury amalgamation, which was used for plating forged coins in the nineteenth century [27], can be discarded given that no mercury has been detected on the surface. Although there are other silvering methods, electroplating seems a plausible option. This latter method had been invented at the beginning of the nineteenth century and gained momentum with *german silver* and similar alloys which were easily silver-plated and profusely used as cheap household silverware substitutes with similar performance (high corrosion resistance and durability) [28].

The manufacturing process of the coin requires more work to establish. Genuine coins at the Lima Mint were always struck, but some images of Fig. 6b show typical characteristics of cast coins, such as remains of what appear to be air bubbles trapped in a casting mold, the absence of sharp edges in the legend's letters and the grainy surface. Nevertheless, there is an intriguing absence of many of the typical cast characteristics: the coin's diameter and width are well within the observed in contemporary genuine coins, and the reeded edge shows no cast line.

The alloy used in the coin was finally analyzed using X-ray diffraction. Figure 8a shows the diffraction patterns taken on both sides of the *dinero* coin. It can be observed

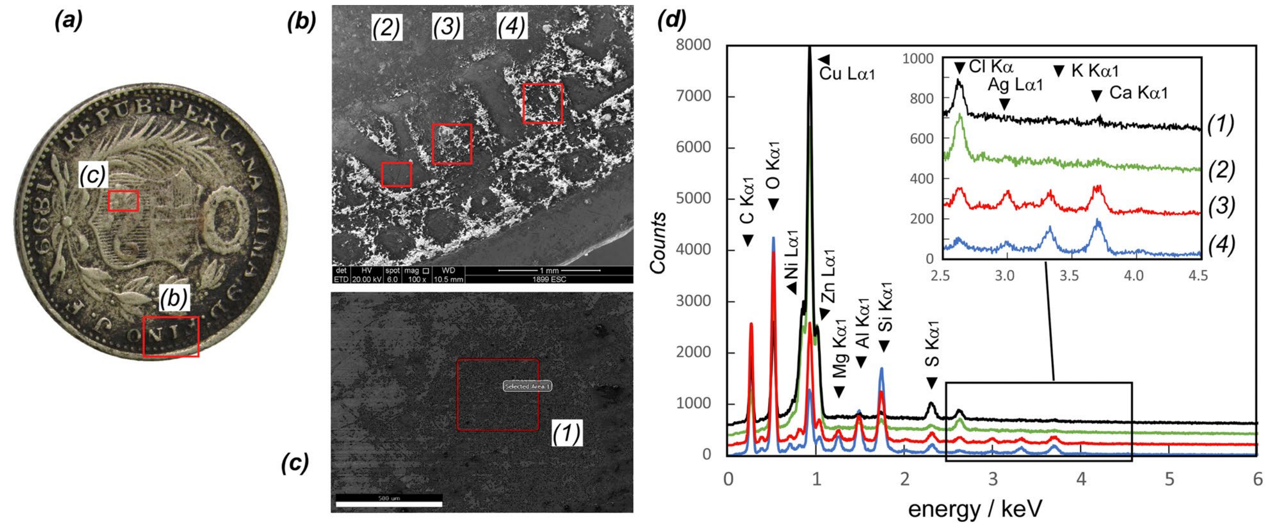

Fig. 5 SEM micrographs of selected obverse regions of the 1899 dinero **b**–**c** and the corresponding EDX spectra for the selected points on the images **d**. The red squares in **a** show the regions of the coin measured in the SEM–EDS instrument

that both sides show the same simple pattern from which the main peaks were indexed considering a single phase with a cubic face-centered crystal structure (space group $Fm\overline{3}m$). This observation is consistent with the cubic α-phase of the copper-rich region in the ternary Cu-Ni-Zn phase diagram [29]. A simple XRD pattern fit resulted in a unit cell of 3.645 Å, slightly larger than copper's. This unit cell is consistent with a substitutional alloy containing a higher amount of zinc than nickel, as observed from the X-ray fluorescence compositional analysis [30]. Very small silver peaks are also observed, especially the (111) plane reflection of its face-centered cubic unit cell in the obverse side (the most blackened one). Again, this is consistent with a silver-plated core from which most of the silver has been washed away.

Figure 8b shows the XRD pattern of the 1899 dinero coin, the patterns of two genuine modern coins made with nickel silver, and the simulated data of a non-textured nickel silver pattern (GSAS-II software was used in the simulation [31]). All patterns have been aligned and normalized to the intensity of the (111) diffraction plane in order to show the intensity difference with the other planes (the simulated pattern is offset on 2θ for comparison purposes). It is clearly seen from the different intensity relation of the diffracted planes that the modern struck coins show a preferred orientation that favors the (200) and, more prominently, the (220) planes. The 1899 coin shows minimal or negligible preferred orientation in the (111) planes. These differences are consistent with published reports of textured cubic FCC alloys that have been uniaxially compressed, like struck coins, which tend to favor (200) and (220) crystallographic planes at the surface [32–34]. Cast FCC alloys, on the contrary, tend to show no texture (or one favoring (111) planes due to the solidification process [35]). Without a proper texture study with appropriate equipment (which is not the focus of this work), it is not possible to establish the exact growth directions in order to get more precise information on the coining methods. However, data agree with a cast coining method for the 1899 *dinero* coin.

Discussion

The present study has shown that the analyzed 1899 *dinero* was made using a ternary Cu/Ni/Zn alloy, nowadays known as nickel silver ("german silver" was a more common name in the nineteenth century). The absence of a ternary Cu/Ni/Zn standard alloy since the 1970s with a similar composition, together with the presence of iron, cobalt, and lead in the alloy (elements which have also been observed in objects and counterfeit coins made with this alloy in the nineteenth century) make it reasonable to consider that this coin was made around the turn from the 19th to the twentieth century. In the nineteenth century the composition of this alloy was difficult to standardize and their small compositional differences were known with different names (*german silver*, paktong, pakfong, Maillechort, Argentan, neusilver, etc.). German silver alloys enjoyed ample use for ornamental objects and silverware substitutes despite not containing silver in its composition. It is interesting to note that, during the first half of the nineteenth century, this alloy was widely used in the United States and Mexico to counterfeit dollars and half dollars [36, 37], and by Canadian and US counterfeiters to forge Spanish colonial coins

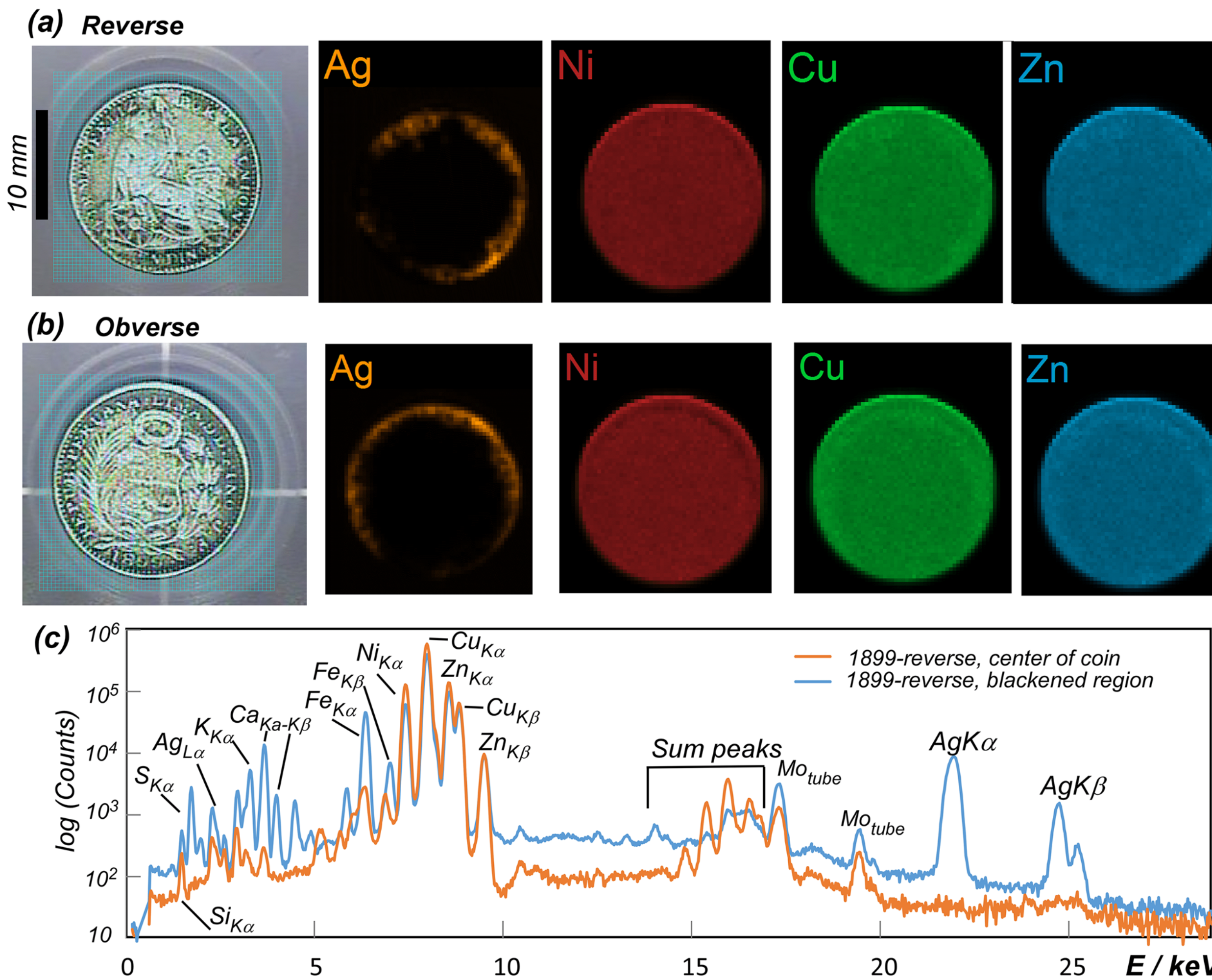

Fig. 6 XRF compositional maps of both sides of the 1899 dinero coin. **a** reverse, **b** obverse. Each side contains elemental maps of the 4 main elements detected, and includes the grid of the measurement points. The compositional maps are self-consistent: the color intensity for each element is proportional to its concentration in the different locations of the coin's surface. The intensity between elements, however, cannot be considered proportional to their relative concentration. An example of two XRF spectra, one taken on the blackened border, and the other in the center of the reverse side, are shown in **c**

[38]. Different compositions of the alloy were also used for forging coins in Europe during the time mentioned. In fact, the chemical treaties published in the mid-nineteenth century included special chapters devoted to the detection of counterfeit objects (specially coins) that imitated silver but were made using cheaper alloys such as *german silver* [39, 40].

When *german silver* was proposed to the US Mint in 1837 for its use in small coins, it was immediately rejected because it presented a fabrication problem: its exact composition was difficult to maintain due to the volatilization of zinc in the melting furnaces of that time. Moreover, since the properties of the resulting alloys were very similar regardless of the exact concentration, the counterfeiting of coins might be facilitated, resulting in a bigger problem [41]. Consequently, this alloy was not used for regular coinage in any country at the time. However, it was a common alloy used for token coinage (low-value money emitted by private land owners, plantation owners, etc.) in the Danish West Indies (now Virgin Islands) from 1887 to 1892 [42], and in many other Central American and Caribbean countries such as Cuba, Jamaica, Puerto Rico, Costa Rica, El Salvador, and Guatemala during the second half of the 19th century [43].

The X-ray fluorescence data also indicates that the coin was once silver plated. This was also part of counterfeiting practices. In fact, counterfeit silver-plated *german silver* coins were also observed in the United States in the nineteenth century [44]. The use of silver-plated alloy was as elegant as pernicious choice from counterfeiters

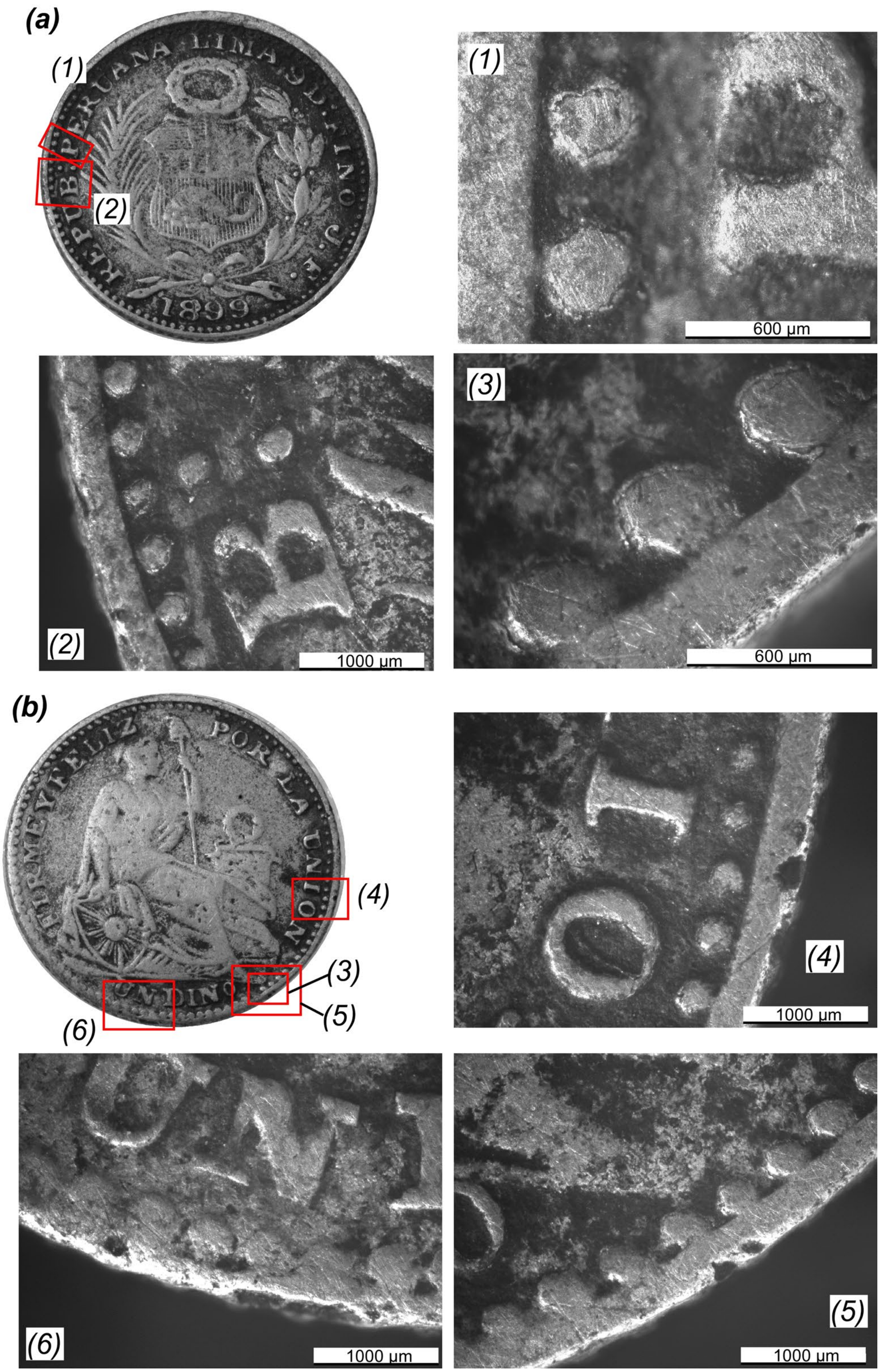

Fig. 7 Detailed images of selected sections of the 1899 coin. **a** obverse and **b** reverse. The remnants of an old silver-plated layer are clearly seen in images (1), (2) and (3). Surface roughness and what appear to be cast bubbles are shown on (4), (5) and (6)

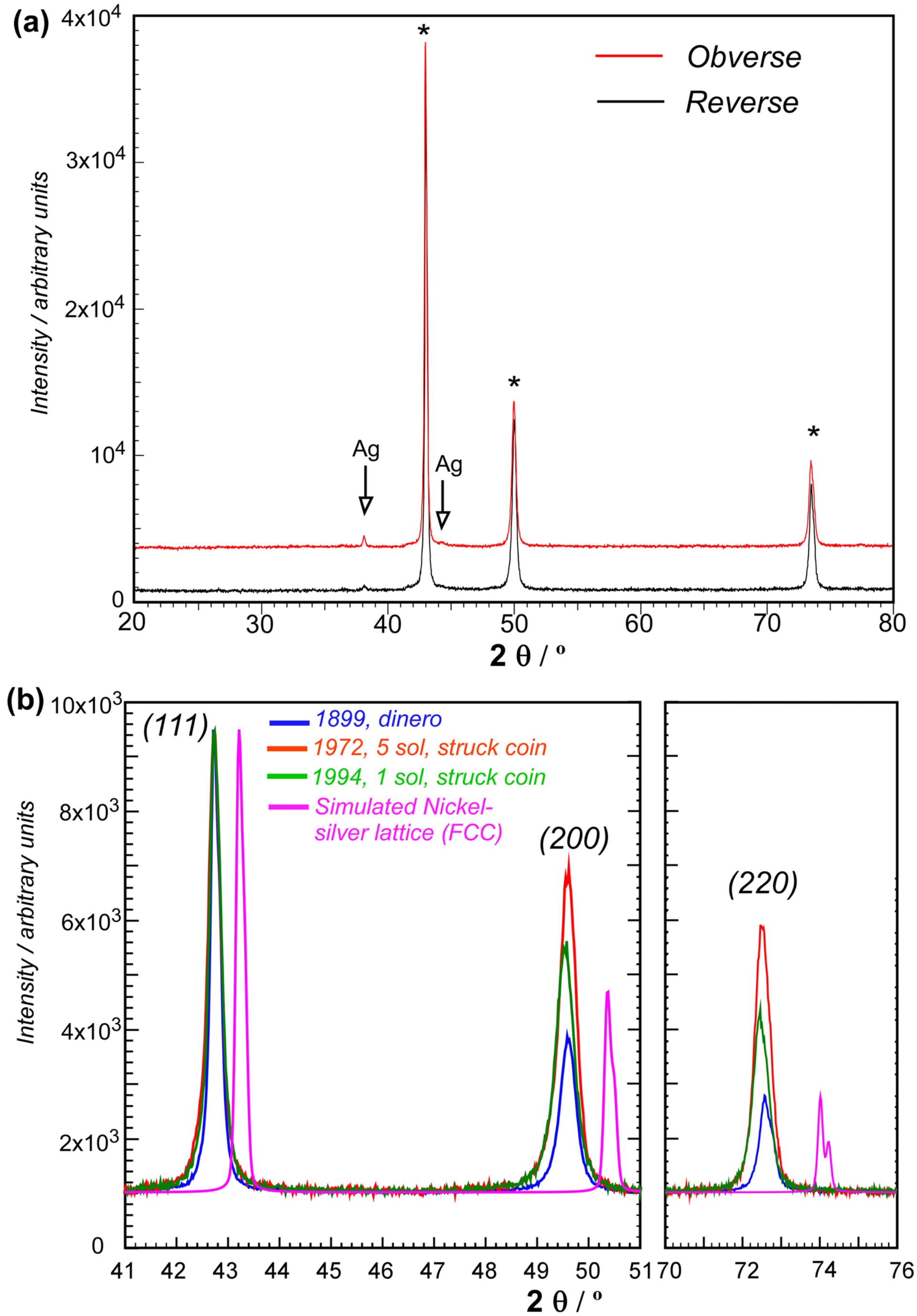

Fig. 8 **a** X-ray diffraction patterns taken on the reverse and obverse sides of the un dinero coin. Asterisks indicate the single face-centered cubic phase indexed with a 3.645 Å unit cell. Arrows indicate the small peaks of the silver used for plating. **b** XRD patterns of the 1899 *dinero* compared with two modern Peruvian struck coins and the simulated pattern of an ideal non-textured nickel silver alloy. The peak position and intensity of the (111) plane have been normalized whereas the simulated data has been shifted for ease of comparison

because it was an inexpensive process (used for cheap household silverware substitutes) and ordinary currency users were not accustomed to differentiating silver-made from silver-plated objects, especially if they were as small as the present coin (of just ~ 2,5 g). If we consider that both silver and silver-plated coins tarnished similarly upon use, discrimination between counterfeit and legal coins must had been very difficult for the general public.

The presence of what appear to be remnants of bubbles, the observation of blurred or not well-formed lettering, the grainy surface shown in most of the images of Fig. 7, and the XRD data indicate that the coin was probably made by casting, which was the simplest and cheapest process used by counterfeiters of coins intended for the general public [45, 46]. It is to note, however, that the width and diameter of the coin fit perfectly with the genuine coins. Since nickel silver can experience up to 2% contraction upon cooling from the melt (on the basis of its thermal expansion coefficient [47]), the forgers must have had excellent metallurgical knowledge to create an appropriate mold that would compensate for such effects.

The last question to be answered is why was a coin that was never minted counterfeited? It is our belief that this counterfeit coin was not made as a numismatic rarity to deceive modern collectors (it had already been dubbed as "probable" counterfeit in all catalogs) but rather to be used as current money (its worn state indicates ample use). As indicated before, counterfeiters usually make common coins that do not draw attention expecting them to pass unnoticed [4]. This is why an 1899 *dinero* coin is surprising for modern collectors and numismatist but probably not for its users in the past. In 1899 other fractional Sol coins used for small commerce (such as the *quintos* and *medio dineros*), had been coined at the Lima Mint so there was no reason to doubt the 1899 *dinero*. The logic behind the existence of this counterfeit coin must then rely on the critical situation of Peruvian small commerce. The need for fractional coins of low denomination for daily commerce was so high during the nineteenth century [11, 12, 48], that probably this extra currency was passed inadvertently and could have even been welcome by users. This is not a bold supposition, as the same reason has been used to explain the great number of counterfeited small-value coins that circulated in the United States during the eighteenth century [49], and also in Canada and Mexico in the eighteenth and nineteenth century [50].

There are still two open questions, however: given that no dinero coins were struck in 1899, the coin from which this copy was made, and where it came from, remains a mystery. The coin's letterings are slightly misaligned with contemporary coins but not the "seated Liberty" image or the coat of arms so this coin might have been an ad hoc creation by the counterfeiters inspired in the design of previous year's coins. But why using a year in which no dinero coin were minted? The explanation might be related with a foreign origin of the coin: given that *german silver* alloy was almost absent in coins and tokens of Peru at the time, counterfeiters might have been located abroad (where the alloy was more widespread). This would explain the coining date: they might have been unaware of the inexistence of the 1899 *dinero*. Desperate users in need of small change coins probably overlooked the detail. Nevertheless, local origin of the coin cannot be discarded: *german silver* objects (as those shown in Additional file 1: Tables S3, S4) were not uncommon at the time. Moreover, preliminary data compiled in Additional file 1: Table S5 show that few *german silver* counterfeit coins had already circulated in the middle of the nineteenth century.

These unanswered questions pave the way for future historical and scientific studies on coin counterfeiting in Peru from the late nineteenth century to the early twentieth century and its connection to similar regional practices.

Conclusions

The present study has been focused on unveiling the chemical composition and coining characteristics of an 1899 dinero coin whose authenticity was doubtful since there was no official record of its minting. The combined use of different analytical techniques has made it possible to verify that neither the manufacturing methods nor the composition of the coin are those observed in the original coins of the time (late nineteenth century). The alloy used and the fabrication method, together with the remnants of al old silver layer and the high wear observed, are consistent with a coin made at the turn of the nineteenth and twentieth centuries that circulated for a long period of time. The use of *german silver* indicates that counterfeiters of coins shared their knowledge all through the Americas and with the Old World. The source of the coin might have been a North or Central American country, as this alloy was uncommon in Peru (at least for coinage purposes) at that time. Nevertheless, local origin cannot be discarded as other *german silver* counterfeit coins and objects existed during that period. Although it is difficult to be certain, this counterfeited coin could have passed unnoticed due to the vital need for small change for daily commerce. Together, these data fill an existing gap in Peruvian numismatics regarding the composition of this unofficial coin whose existence, known to the international numismatic community at least sin 1978, stands as a reminder of a troubled historical period when counterfeiting, despite being an illegal activity, provided the necessary means to sustain commerce.

Abbreviations

SEM–EDS	Scanning electron microscopy-energy dispersive X-ray spectroscopy
XRF	X-ray fluorescence spectroscopy
XRD	X-ray diffraction
SDD	Silicon drift detector

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40494-023-01092-2.

Additional file 1. The additional file material contains 5 tables with information of the XRF standards used for the chemical analysis, metrological data of the coins, compositional analysis of several objects from the late 19th and early 20th century and their photographs and, finally, preliminary data on the alloys used in some Peruvian counterfeit coins.

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Author contributions

LOSM designed the study, performed the XRF and XRD measurements and wrote the paper. FB carried out and interpreted SEM measurements and wrote the paper.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article and its Additional file information files.

Declarations

Competing interests

The authors declare that they have no competing interests.

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