

# X-ray Fluorescence Spectrometry and a Range of Medieval Coinage: Insights and Surprises<sup>1</sup>

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## Introduction

In a Princeton Numismatic Workshop, on March 15, 2009, Alan M. Stahl, Curator of Numismatics at Princeton, provided a handout summary of the technical issues facing numismatic investigations. The basic questions to be asked, he posed, concern five main areas: 1) The “Fineness” of a coin, the proportionate composition of a piece, represented as a percentage (as in 92.5% fine), or as a fraction of 1000 (as “a fineness of 925/1000”); 2) The Origin of metal, a significant contribution to a general understanding of regional wealth (as Bede’s statement that gold deposits were to be found in Ireland and Britain), commercial exploitation (as the Roman Imperial organization of Iberian gold mines), and the nature and frequency of trade routes; 3) The Manufacturing process, a critical issue, specifically in determining the procedures needed to establish, maintain or manipulate the nature of a particular issue; 4) The Authenticity of a coin, particularly in regards to rare pieces that may have a tremendous historical importance; and, finally, 5) The Age of a coin, a complex subject the determination of which depends on often scarce, incomplete, or imprecise documentation, as well as the difficulty of establishing the chronology

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<sup>1</sup> The author would like the anonymous collector in Davis who volunteered access to his coins for the purpose of this analysis.

of a particular find or hoard (one, hopefully, that has been fully recorded as to nature, quantity, site and stratum before it has been dispersed—all of this is constrained in dating to after the last firmly datable piece in the hoard).<sup>2</sup>

To this list must be added an even more fundamental question of the perceived or actual value of a specific coin. At the heart of this problem is what might seem like a very non-economical principle: the value of money is an act of faith (*credere*=credit). Gold and silver are traditionally esteemed because of their beauty, but as Thomas More indicated in his *Utopia*, relative rarity can be a deciding factor: if gold were more plentiful than iron, perhaps indeed society might well make its chains and chamber-pots out of it. Since coins in the Middle Ages were hand-stamped on somewhat irregular disks, called “blanks,” (after striking, the disk is called a “flan”), slight, scarcely detectibly shaving or clipping of a coin would allow a dual benefit of obtaining, in transaction, the accepted value of the coin and at the same time retaining a measure of precious metal. The integrity of the coin was so critical to insuring smooth commercial transactions that clipping and counterfeiting were often legislated in the same statutes.<sup>3</sup> Another problem relating to value was “debasement,” the official use of cheaper metals, combined with the more precious metal or metals in a coin, in order to retain the assigned value and simultaneously increase the issuing polity’s profit. In numismatic history, pure silver coins are out of the ordinary, since silver wears quickly in circulation; an alloy of copper was and still is

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<sup>2</sup> Document made available by Dr. Stahl, October 12, 2011.

<sup>3</sup> See, for example, Visigothic Law, c. 681, in Roy C. Cave & Herbert H. Coulson, *A Source Book for Medieval Economic History* (Milwaukee: The Bruce Publishing Co., 1936; reprint ed., New York: Biblo & Tannen, 1965), pp. 128-129, as reproduced in the Medieval Sourcebook, <http://www.fordham.edu/halsall/source/631visigothic-coins.asp>.

introduced into the manufacturing process, both to harden the coin and to produce the desired profit, the right in general to which was called or seignorage or seigniorage. In a time of economic distress, as for example had occurred in the Byzantine Empire during the twelfth century and following, an important issue, the aspron trachy, was debased from its original issue in an alloy called "electrum" at 30% gold, 60% silver, and 10% copper to a lower and lower percentage of gold, and finally to an eventual loss of gold content altogether. The Empire over time recalculated the declining value of the aspron trachy against the higher denomination, the gold hyperpyron, so that outright fraud was not the object; nevertheless the sole reason for debasement was entirely a matter of circumstantial economic pressure.

While the psychological consequence of no longer having faith in a debased currency is often described as "Gresham's Law," the concept was first seriously explored by the fourteenth-century scholastic philosopher and theologian Nicholas Oresme, whose work, the *De origine, natura, jure et mutationibus monetarum*, he himself translated into French for King Charles V as the *Traictié de la premiere invention des monnoies*.<sup>4</sup> The law, too often crudely stated in the maxim, "Bad money drives out good," meaning that when both less trustworthy money and more trustworthy money are at hand, the purchaser will attempt to cast off the bad and retain the good; what is not usually indicated but is the critical circumstance is that the "bad" money has been alleged by the minting authority to have the same value as the "good."

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<sup>4</sup> Charles Johnson, ed. and trans., *The De Moneta of Nicholas Oresme and English Mint Documents* (London: Thomas Nelson and Sons Ltd., 1956).

For an example from the Renaissance and the coinage of Henry VIII, a debased silver shilling of his third coinage was still officially trafficked as the equivalent of twelve sterling silver pennies, as his father's "good" shilling had been. As described by C.E. Challis, the fraudulent "Great Debasement," as it is called, began in 1544: to compensate for the king's profligacy, the Tower Mint reduced the fineness of his silver coins from sterling at 925/1000 to a fineness of 500/1000 and eventually to 333/1000.<sup>5</sup> Similarly, the two later shilling issues of Henry's son, Edward VI (1547-1553), were also debased, down to a fineness of 157/1000; the situation was addressed by a royal commission in 1551, and in the short reign of Queen Mary (1553-1558); and it was finally resolved by Queen Elizabeth I, who, in 1559, reissued the untrustworthy pieces, especially marked, at either fourpence-halfpenny or twopence-halfpenny, an official reduction in value of 62.5% and 87.5% respectively.<sup>6</sup> An insight into the effect of sixteenth-century debasement can be found dramatized in Ben Jonson's play "The Alchemist" (written by 1610) in which Alchemist's housekeeper, Face, questions a lawyer's clerk, Dapper, about how much money might be available to bribe his intended beloved's servants:

**Dapper.** Yes, here are six score Edward shillings.

**Face.** Good !

**Dapper.** And an old Harry's sovereign.

**Face.** Very good !

**Dapper.** And three James shillings, and an Elizabeth groat,  
Just twenty nobles.

**Face.** O, you are too just.

I would you had had the other noble in Maries.

**Dapper.** I have some Philip and Maries.

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<sup>5</sup> C.E. Challis, ed., *A New History of the Royal Mint* (Cambridge, England: Cambridge Univ. Press, 1992), pp. 228-244.

<sup>6</sup> C.H.V. Sutherland, *English Coinage, 600-1900* (London: B.T. Batsford, 1973), p. 152.

**Face.** Ay, those same  
Are best of all: where are they? (Act III, Scene 1)<sup>7</sup>

Here the discriminating Face states that he would have preferred the sounder money of Queen Mary, or, even better, the shillings and sixpences of King Philip of Spain and Mary, apparently ignoring the opprobrium that the two monarchs might have engendered in the late Tudor and early Stuart eras. Furthermore, the “old” in “an old Harry's sovereign” might refer both to the monarch himself and to the earlier gold coinage of Henry VIII, as opposed to later issues that had been debased, just as the silver had been.

The technique for this sort of debasement, as used by Henry's mint and others, was to sandwich a sheet of base copper between two thin sheets of silver, and anneal them, so as to retain the appearance of a silver coin but not its real value; this practice dates back to the Classical era. Unfortunately, in Henry VIII's case, his frontal portrait on the obverse meant that the silver wore off his protruding nose first, earning him the sobriquet “Old Copper Nose.”

The example, below, demonstrates a medieval plated coin, in this case a denarius (“penny”) from Milan, probably minted under the Emperors Henry IV or Henry V (the inner circle on the obverse is read, simply, H [E] R I C N, with [I]MPERA[TOR] as the surrounding legend), and thus putatively from 1056-1125:

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<sup>7</sup> *Three Plays*, eds. Brinsley Nicholson and C.H. Herford (New York: Hill and Wang, 1957), p. 275.



The arrow on the reverse points to visible copper and copper oxide protruding from the layer underneath; copper can also be detected on the obverse, on the lower right edge (at about 5:30). Such debased denarii were widely minted in the cities of Northern Italy throughout the Middle Ages; their common ancestor, the denarius of Carolingian rulers, measured (with the usual caveat for variation) 1.65-1.7 grams, 20 mm, and 90% or so fine silver. The Milan denarius, above, in contrast, weighs .648 grams, is 16 mm, and probably contains a silver component of below 25%.<sup>8</sup> Such coins represent a challenge for the technique of analysis that was employed in this investigation, x-ray fluorescence (see **Appendix 3**, below), as will be clear in the section on Crusader denarii (“deniers”), below: since the x-rays collide almost entirely with the surface, base metals below may escape detection.

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<sup>8</sup> See Philip Grierson, *The Coins of Medieval Europe* (London: Seaby, 1991), pp. 34 and 40 on Carolingian coinage, and pp. 93-94 for Italian denarii of the twelfth century.

Another usual means of debasement was to alloy together a larger percentage of copper, melting it in with the precious metal, which was most often silver, and then to hammer out the alloy into sheets of the desired thickness, to cut the roughly round pieces and to strike them as if they were pure silver. The alloyed metal might range from 70% to 20% silver, and coins minted in this metal are traditionally called “billon,” after the French “bille,” meaning “log” or “ingot.” Somewhat confusingly, pure precious metal, in bars for instance, is called “bullion,” perhaps from the French bouillir, to boil, possibly referring to the refining process. Billon coins, even those at 700/1000 fine, begin to show their base metal coloring, which of course darkens as more copper is added; as Stahl indicates, this is called, in Venetian mint records and elsewhere, “black money.”<sup>9</sup> The following two French denarii, roughly contemporary, vividly demonstrate the difference. The first, minted in Dijon under a “VGO” of Burgundy (perhaps Hugh IV [1218-72]), contains almost no silver.

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<sup>9</sup> Alan Stahl, *Zecca : the mint of Venice in the Middle Ages* (Baltimore : Johns Hopkins University Press in association with the American Numismatic Society, New York, 2000), 21. Nicholas of Oresme uses the term “nigra mixta” in Chapter III: “De diuersitate materie monetarum et mixtione,” in Johnson, p. 7.



The second of Champagne, under a Count Henry (Henry I [1152-1180] or the II [1180-1197]), has a surface fineness, as established by x-ray fluorescence, of 90.2%. And to show that even the designers of dies in the Middle Ages had a sense of humor, on the reverse the arrow points to a comb, a pun on "Champaign" ("peigne").

Stahl highlights the difficulty for the Venetian mint authorities that their own debased coinage created, as opposed to a newly-introduced purer issue, to be described later, in this way: “The Venetian minting authorities would then have faced a problem that would plague all medieval minters who tried to keep coinages in ‘white’ money and ‘black’ money circulating side by side in a fixed relationship. The differential utility value of the two coinages could cause higher demand on one or the other, which would cause hoarding and strain the market relationship.”<sup>10</sup> This seems a little counter-intuitive, especially given that our various modern denominations of currency do not “float” against each other; for us, it would never be necessary at one point in time to use eleven dimes to obtain a dollar, or at another point, a dollar could be purchased for nine. So a brief illustration is in order: when going abroad, we need to purchase British pounds or European Community euros; if we feel that the euro is undervalued (as it once was, down to \$.85), we might buy a large number of euros and hoard them as much as possible, trusting in the day when the euro would rise and its purchasing power, as against the dollar, would increase, so that a book costing 100 euros, rather than the \$130 that is now the exchange rate, would actually cost us \$85, by using our hoarded euros. Since we would be interested in getting rid of dollars when they were, relative to the euro, expensive, this might eventually be a rebalance, but this would take time. In the Middle Ages, such fluctuating rates were somewhat exacerbated by the fact that the coinage most typically used some proportion of bullion, so that the value of the metal itself, over and above the assigned value as in exchange rates, became a factor. This imbalance can be

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<sup>10</sup> *Zecca*, p. 21.

seen in the English King Henry III's experiment with a gold penny (1257), which was issued as worth twenty silver pennies. The intention was to compete with Italian and French gold, encouraging large purchases conveniently, without the additional cost levied in an exchange. As it happened, the coin was vastly undervalued—that is, it was in terms of the market value of gold worth more than that much silver, and it quickly was hoarded out of circulation and most likely melted down, so that very few specimens survive.<sup>11</sup> Interestingly, throughout the Middle Ages it was more often foreign exchanges that supported or undermined trust in a currency, rather than domestic economic environments.

In the relationship between 'black' and 'white' money there are still other factors as well, as Stahl indicates: minting a single coin of higher value is less costly in terms of production than minting the monetary equivalent, many coins, that is, of lower value, since those costs are established on a unit basis: once the metal has been obtained, it is equally expensive or cheap to strike a dollar or a penny. Stahl goes on to point out that in such cases of disparity, the lower-cost coin would be further devalued, to make the additional expenditure less onerous and, hopefully, more profitable, thus further driving down the relative value between the related currencies.<sup>12</sup> The minting institution, of course, could, as Elizabeth did, recalculate the relative value; it could increase, for instance, the number of silver pennies needed to purchase a gold one. But the complexity of exchange, in which, as in "The Alchemist," various issues connoted various values, coupled with the difficulty of officially setting and communicating such measures, made

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<sup>11</sup> Sutherland, *English Coinage*, pp. 64-65.

<sup>12</sup> *Zecca*, pp. 21-22.

this no easy task. Even today, there are episodes of confusion and even panic concerning the relative value of money.

The lesson in both Oresme and Gresham is that debasement is to be avoided, as corrosive to public trust. But, as if any further complexity were needed, there are two factors that almost make debasement desirable: 1) convenience and 2) economic (as opposed to political) inevitability. The first can be quickly dealt with, the fact that small change is very much a practical necessity. In colonial America, as in the Caribbean, the large Spanish milled dollar was often cut up into eight wedges to facilitate minor purchases, a custom commemorated in the phrase “two bits” for a quarter-dollar. In medieval England, pennies were often halved and even quartered to make small change, and in 1279, under King Edward I (1272-1307) sterling half-pennies and farthings were first minted. The latter, small from the outset, became over time, under inflationary pressure, so small that by the mid-sixteenth century it could no longer be minted; but still in the reign of Queen Elizabeth I a sterling three-farthing piece was issued so that a penny would receive the correct change for a farthing purchase.<sup>13</sup> The solution, though the English were long in adopting it, was to produce a copper or bronze coin with no precious metal at all, in effect a debased equivalent of sterling, hence the name “token.” Even so, under George III, there was an attempt to produce both copper tuppenny and penny pieces at their metallic value, pieces so large they were called “cartwheels.” But convenience triumphed, and now all modern coinage is token.

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<sup>13</sup> Sutherland, *English Coinage*, p. 153.

The apparent economic inevitability of debasement relates to a larger, more complicated situation, that of inflation; as many economists have demonstrated, and certainly as the fate of the farthing has proven, in a healthy, prosperous system a certain degree of inflation—classically defined as too much money chasing after too few goods—is to be expected. If a penny can no longer purchase what it once did, a perfectly logical response might be to opt for debasement, or, as in the case of English coinage, for a reduction in the weight of the issue. In the Middle Ages, this process was slow and, given such factors of revolts, wars, plagues, vulnerability to environmental change, it was uneven. Nevertheless, over the centuries, as with the English silver farthing, a gradual inflation can be charted, which could well result in the official distribution of debased coin as a compensatory measure.

As having been said, debasement was seen by Oresme and others as an unmitigated evil, just as many might view inflation today; it was viewed as a betrayal of the belief that citizens, especially the poor, placed in their money, and in the governing entity that was to have earned that trust. When there was an opportunity to mint more pure precious-metal coinage, as was true in seventeenth- and eighteenth-century Germany, the intention was to inspire pride in the city, religious institution, province, state, kingdom or empire that had issued it; if there was to be debasement, it was often viewed as an expedient, and a temporary one at that, necessitated by intense pressure. The considerable liabilities to issuing potentially overvalued coinage might be obvious, and possibly overwhelmingly so, but ambition, a yearning for prestige, and a

demand for a venerable presence far more often carried the day; beyond this ambition, the moral stance explicit in Oresme seems to figure in the conversation as well.

### **Comparison One: Byzantine solidus/nomisma and the Abbasid dinar**

This discussion leads easily into the first comparison undertaken in our analysis, that between a Byzantine gold solidus (“nomisma” in Greek), and an Abbasid dinar. While there is a considerable gap in time between the two issues, the solidus stemming from the reign of Justin II (565-578), the nephew and successor emperor to Justinian, and the dinar from the reign of Timed al-Mansur (754-775), the comparison serves because of the universal value and longevity of the solidus. From early on, the various Muslim dynasties strove to create an alternative gold coinage to the solidus, and their success was decidedly mixed. The solidus, originally introduced during the Roman Tetrarchy as a reformed, 100% pure gold piece, at a stable weight of about 4.4 grams, retained that weight and purity into the eleventh century, dominating trade throughout the Middle Eastern and Western world as the “bezant.”<sup>14</sup> The quality of the gold has meant that very little chemical deterioration occurs in many surviving specimens of the solidus, as the piece, below, demonstrates; but the customary absence of wear as well, in this particular example as in many others, might seem at first to be remarkable, since pure gold is almost as soft as lead. But it is not in fact unusual, as it is not unusual with similar highly-valued gold pieces of Medieval Europe, including, for example, surviving Florentine florins and Venetian ducats. My

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<sup>14</sup> See Grierson, *The Coins*, pp. x, 1.

theory is that the economy of the West was such, in the pre-modern era, that in general transactions in gold were either made in massive quantities, and therefore the coins were not handled at all, or they were hoarded and therefore not passed from hand to hand on a frequent basis. This is partly supported by the appearance in "The Alchemist," above, of a single gold coin, the surviving nearly hundred-year-old sovereign of Henry VIII, among the more recent silver pieces in Dapper's purse. In contrast, the dinar, below, shows considerable wear, as well as a black substance very much resembling bitumen; on the basis of a single piece, it is of course impossible to speculate with confidence, but the wear may well be a sign, perhaps, of a much more vibrant local economy in the Arabic Middle East than in the Empire, in that there might have been more occasion for ordinary, relatively large purchases in which a gold piece would be required. In terms of x-ray fluorescence, the solidus, as expected, registered at a superior fineness of 995.7/1000, in contrast to the Abbasid dinar, at a lower but still respectable 972.4/1000. In weight, this solidus conforms faithfully to the standard 4.473 grams; the dinar, reduced as it might be through wear, registered at 3.897 grams. Though, as explained, above, the flans of medieval coins were irregular hammered pieces, a measurement of diameter is often useful: solidus is 22mm in diameter, while the dinar is 19mm.



Below is a more complete comparison of the two pieces. In the table, the number of seconds, "600," indicates the time during which the coin was subjected to the beam. The longer the exposure, the more accurate the results can be assumed to be.

Identification of the coin	% Copper	% Silver	% Gold	Weight
Byzantine Solidus, 600 seconds	0.22	0.2	99.57	4.473
Abbasid Dinar, 600 seconds	0.13	2.6	97.24	3.897

## Comparison Two: The Venetian grosso and its derivatives

Dr. Stahl has over the past two decades almost singlehandedly uncovered many of the mysteries concerning one of the most important economic developments of the Middle Ages: the minting and dissemination of a most significant coin, quickly to be called the “*grosso*,” in Venice at the end of the twelfth century. Dr. Stahl has provided extensive surveys of the origin and nature of the *grosso*, most notably in his book on the mint in medieval Venice, the *Zecca*, as well as in antecedent publications.<sup>15</sup> Briefly stated, by the end of the twelfth century, the increased prosperity of the Republic of Venice had been demanding an expansion of available and trustworthy coinage for commercial interactions. At the same time, the three most reliable sources of such coinage, the silver Veronese penny (or “*denarius*”), the gold dinar of the Crusader States, and, as mentioned earlier, the electrum aspron trachy of the Byzantine Empire, had all recently undergone debasement. This last coin, the trachy, figures prominently in the history of Venetian culture as well as its economy. For seven hundred years, starting the early fourth century, the standard gold coin for the Empire, depicted above, the solidus, had been reliably fixed at 24 carats, that is, pure gold or 1000 fine, and at 72 to the Roman pound, or about 4.40 grams. The coin became an international standard, and remained so even after it was reduced, during the reign of Michael the Paphlagonian (1034-1041) to 20 carats, approximately 833/1000 fine, while still retaining its customary weight. Over

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<sup>15</sup> See, for example, “The Grosso of Enrico Dandolo,” in *Mélanges Tony Hackens, Revue Belge de Numismatique*, 145 (1999), 261-68; and “The coinage of Venice in the age of Enrico Dandolo,” in *Medieval and Renaissance Venice*, edited by Ellen E. Kittell and Thomas F. Madden ([Urbana : University of Illinois Press, 1999), 124-140.

the next sixty years, a time of intense pressure on the Empire, the coin began to be minted either in electrum or simply in silver. A coinage reform of 1092 developed a new piece, the gold hyperpyron, at about 21 carats, essentially .875 fine, and another coin, representing a third of the hyperpyron, the aspron trachy, consisting of electrum at, as has been mentioned, 30% gold, 60% silver, and 10% copper. This latter coin circulated widely throughout the Eastern Mediterranean in the twelfth century, and was far more useful and therefore recognizable for ordinary, mid-level commerce, as differentiated from what might be more infrequent transfers of quantities of gold coin, on one hand, or decidedly local uses of smaller denominations in copper.

Throughout the twelfth century, the Venetians, in addition to relying on Byzantine issues, also depended commercially on gold coins minted by the Latin Kingdom of Jerusalem, imitations of Middle Eastern dinars; and when smaller value coins were needed for more modest purchases, Venetians depended as well on the penny of Verona. In fact, the dependence was sufficiently adequate to allow the Venetians to cease minting their own penny, which had customarily been worth half that of Verona, from about 1140 to a little before 1172; at that point the Doge Vitale Michiel II (1156-1172) began issuing it again. The Veronese pennies had been accepted throughout Northern Italy, all the way through the Alps, and so it behooved Venice to adopt, even when she recommenced minting, what was called, "the Standard of Verona."<sup>16</sup> As an indication at this time of how rapidly Venice began to come into its own, however, with the advent of the

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<sup>16</sup> *Zetta*, 13.

succeeding Doge, Sebastiano Ziani (1172-78), a new Venetian penny, modeled on and established as a parity to that of Verona, appeared, and it quickly found adoption in Northern Italy and the Alpine regions as well. Then, at some point in the 1180's, the Veronese penny became debased, and while parity seems to have been maintained, the Venetians must have seen at this juncture an opportunity to strike out on their own. They were aided in this decision by a nearly simultaneous debasement and devaluation of the asperon trachy, whose gold fineness fell from 30% to less than 28.5% under Emperor Isaac II (1185-95), and by the debasement and eventual collapse of the crusader dinar, beginning in the mid-twelfth century, especially after 1187, and, as Stahl indicates, references to that coinage "rarely appeared in Venetian documents thereafter."<sup>17</sup>

It is easy to imagine the ambitious Doge Enrico Dandolo (in office, 1192-1205) and his fellow Venetians seeing a perfect opportunity, in view of the increasing unreliability of these standards, to not only establish a leadership in stabilizing commerce, but also in the process to create a coin that would play a revolutionary role in the medieval economy. Most probably in 1194, the Venetian mint began striking a coin of about 2.18 grams, characterized by as pure a silver as was at the time metallurgically possible, at, it has been traditionally estimated, 985/1000 fine (as opposed to the penny, at perhaps 200/1000).<sup>18</sup> While only the size of a modern dime, the new issue acquired its name, the *grosso*, in comparison to the penny's one-third of a gram.

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<sup>17</sup> Ibid., 15.

<sup>18</sup> Stahl, "Grosso," p. 125.

Venice had the means to purchase the silver, mines in the north and west, the Carinthian Alps perhaps providing a greater share,<sup>19</sup> and while there were other, previous issues of fine-silver coinages, mainly English sterling pennies (introduced by Henry II beginning in 1180, at 925/1000 fine and 1.38 grams) and coins from Cologne and other German cities, and even coins from other polities in Italy, the higher purity of the *grosso*, along with Venice's commercial sophistication, eventually made the coin preferential and universal throughout the Eastern Mediterranean and into Northern Italy, the Alps, and the Balkans.

But while the coin itself represented a new era in Venetian pride and prosperity, it also provides a fascinating glimpse on how something novel might be introduced and eventually accepted in the Middle Ages. The Venetians had long utilized a traditional, widespread imagery for their minor coin issues, with crosses at the center and appropriate legends; but with the introduction of the *grosso* the Republic decided to adopt, and as it were displace, the iconography of the aspron trachy, superseding the Byzantine coin that had been a standard for a century. As introduced by Alexis I, the trachy's reverse displayed a saint, in this case, Saint Demetrius, handing a labarum or a cross to the Emperor, with both standing; and the obverse depicted Christ. The Romans had begun using Christian symbols on their coinage in the fourth century, but it was not until the late eighth that portraits of Christ or the Virgin appear, and it is only with the trachy that this specific combination of images can be found. Below is a trachy of

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<sup>19</sup> For a discussion on this, see Wolfgang von Stromer, *Bernardus Teotonicus e I rapporti commerciali tra la Germania Meridionale e Venezia prima della istituzione del Fondaco dei Tedeschi*, Centro Tedesco di studi Veneziani, Quaderni 8 (Venice, 1978).

John II (1118-43), depicting Christ enthroned on the obverse, and the Emperor on the reverse, accompanied by Saint George <sup>20</sup>:



**Lot 573**

**John II, 1118-1143. Electrum Aspron Trachy (4.42 g) minted at Constantinople.** Christ seated on throne, raising right hand in benediction; in left, book of Gospels. *Reverse:* John and St. George standing, holding patriarchal cross. Hendy plate 10, 3-4; R. 2098; S. 1942. **Extremely Fine.**

The Venetians, while choosing a flat, smaller, thick fabric of metal, as opposed to the thin, cup-shape of the aspron trachy, otherwise closely imitated the Byzantine coin, with an identical enthroned Christ, with identical titles accompanying that image, and with Saint Mark taking the place of the various saints in handing the standard of Venice, rather than the labarum or cross, to an identified Enrico Dandolo.

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<sup>20</sup> Michael Hendy, *Coinage and Money in the Byzantine Empire, 1081-1261* (Washington, Dumbarton Oaks Center for Byzantine Studies, trustees for Harvard University; [distributed by J. J. Augustin, Locust Valley, N.Y.] 1969), p. 104, plate 10, 1-6. The image is taken from an on-line sale catalogue.



The Venetians were not the first to copy the trachy: some decades earlier, King Roger II of Sicily (1130-1154) had struck a ducat that closely mirrored the Byzantine coin, even to its cup-shape:



This coin,<sup>21</sup> following the iconography of Alexis I, that is, with a bust of Christ, facing, rather than Christ enthroned, demonstrates the wide sway of Byzantine economic influence in the Mediterranean throughout the twelfth century; its original fineness was 500/1000, however, and by the conclusion of the century it had fallen to less than 33%.<sup>22</sup> For this reason, perhaps, among others, it simply cannot be said to have the impact that the *grosso* commanded.

A remarkable fact about the subsequent issues of the *grosso* was the extent to which the coin's design, originally drawn as it was from a Byzantine prototype, never varied throughout the next hundred and fifty years, so much so that the punches used to create new dies for the original coins were carried on from Dandolo to the next doge, Piero Ziani. This can be dramatically illustrated in Ziani's *grosso* (1205-1229), set alongside that of Pietro Gradonigo (1289-1311):



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<sup>21</sup> From the Harvard Art Museum's online catalogue (<http://www.harvardartmuseums.org/art/182640>)

<sup>22</sup> Stahl, *Zecca*, 20.



That this iconographic, conservative imitation is entirely purposeful can be proven by the revived later *grosso* issue of Andrea Contarini (1368-82), of 1379-82, the only change in the intervening hundred and eighty years being a more naturalistic portrait of the Doge; in contrast, Saint Mark and Christ are presented in precisely the traditional way:



Given this obvious preference for what is familiar in coinage, and given the enormous success of the issue, it should not be surprising that a number of other medieval polities imitated the grosso, even to its name and naturally its iconography. The following, a “groš” from Serbia, issued by Stefan Uroš I (1243-76), circulated alongside the grosso; as such, it represented a difficult dilemma for the Venetians, in that during the time when the Serbian coin contained reliably fine silver, it could be accepted by the Republic on the basis of weight; but as that fineness decayed, various exchange rates were set, and a Venetian department called the *Office of Serbian Grossi* was established in 1296.<sup>23</sup> The image of Christ is exactly the same, the position of the figures nearly identical, the only differences being that Stefan, in royal robes, is identified as “REX” and Saint Mark has been replaced by Saint Stephen. The Venetians, it would seem, were indeed disturbed by an obvious imitation, but perhaps pragmatically accommodated themselves as long as its value could be determined precisely.



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<sup>23</sup> Stahl, *Zetta*, p. 37.

King Stefan Uroš' ambitions for his Serbian realm, as well as his newly exploited silver deposits in Bosnia, made it perhaps inevitable that would duplicate the Venetian *grosso*, and gain some prominence doing so. While the Serbian coin is first documented right at the end of King Stefan's reign, in 1276,<sup>24</sup> it is probable that the *groš* had appear many years earlier. According to Metcalf, by 1294 the weight of the *groš* was considerably diminished, making this analyzed exemplar, above, at 2.104 grams, in some likelihood a representative of an earlier issue.

In one of those ironies common to numismatic history, the Byzantine Empire under Andronicus II (1282-1328) began minting a fine silver coin, called the *basilikon*,<sup>25</sup> that was very much in the style of the *grosso*, and consciously so:

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<sup>24</sup> David Michael Metcalf, *Coinage in the Balkans, 820-1355* (Thessaloniki: Institute for Balkan Studies, 1965), 203-210.

<sup>25</sup> S. Bendal and P.J. Donald, *The later Palaeologan coinage, 1282-1453* (London: A. H. Baldwin and Sons Ltd., 1979), pp. 64-69. The image, below, is taken from an on-line sale catalogue.



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**ANDRONICUS II W/ MICHAEL IX. AR BASILIKON. CONSTANTINOPLE. VF**

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Byzantine Empire, Andronicus II Palaeologus, with his son, Michael IX. Joint reign, AD 1295 - 1320. AR Basilikon Constantinople. 1.89g. 19.5mm. Christ enthroned facing, wearing nimbus cruciger, pallium and colobium, raising rt. hand in benediction, and holding the book of Gospels. / Andronicus and Michael standing facing, holding a labarum between them, both wearing crown and loros. SB. 2402. VF, good details and attractive toning.

These coins were issued in fairly large quantities well until the mid-fourteenth century. Another coin added to the list is a Bulgarian groš of Tsar Ivan Alexander and Michael Aser (1331-55); the issue is in fact an imitation, not of the grosso, but of the grosso's imitation, Andronicus II's basilikon: the two figures on the obverse are Tsar Ivan Alexander and Michael Aser, like the coin of Andronicus, depicting the Bulgarian Emperor and his son, Michael IX.<sup>26</sup>

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<sup>26</sup> Philip Grierson, *Byzantine coins* (London : Methuen ; Berkeley : University of California Press, 1982) p. 273. The image is from an online sale catalogue.



The next table represents a refined version of the raw data that was first obtained on the two *grossi* depicted thus far, as well as the two *groš*, along with grossi of the doge immediately following Dandolo, Pietro Zani (1205-1229) and of Pietro Gradonigo (1289-1311),

Identification of the coin	% Copper	% Silver	% Gold	Weight
Venetian grosso Dandolo, 900 seconds	2.60	97.4	0.04	1.939
Venetian grosso Ziani, 600 seconds	3.55	96.1	0.37	1.933
Venetian grosso Gradonigo, 600 seconds	1.89	97.8	0.31	1.997
Venetian grosso Contarini, 600 seconds	5.43	94.3	0.24	1.924
Serbian groš, 600 seconds	5.44	94.5	0.02	2.104
Bulgarian groš, 100 seconds	0.44	98.9	0.64	1.483
Bulgarian groš, 600 seconds	0.43	98.9	0.64	"

This data offers some important preliminary results. Most significantly for our purposes, it indicates a very high percentage of silver for Dandolo's grosso, in the 900-second run; at 97.5%, it is very close to Stahl's estimate of 98.4%.<sup>27</sup> The readings also suggest a slight but discernable loss in fineness in the grosso issues

<sup>27</sup> "The Grosso," p. 264.

of subsequent doges, which matches Stahl's own discussion,<sup>28</sup> though throughout the time span of the grosso's mintage there was considerable flux and variation, as the Gradonigo grosso and Stahl himself both indicate.

There was a much smaller detected percentage of silver on the 600-second run for the Dandolo grosso (not recorded here); this may represent a misreading, in that it indicated a dominant presence of cadmium, which immediately follows silver on the periodic table; such anomalies represent another one of the potential weaknesses of this form of analysis. The high quality of Sefan Uroš's groš matches the Venetian grosso in terms of parity, which, as has been said, that coin enjoyed for a while.<sup>29</sup> The high silver content of the Bulgarian groš might not be unusual, given its lighter weight.

The appearance of the *grosso*, according to Stahl, represented a difficulty mentioned earlier, of the relationship between debased, lower-value, "black" issues and ones with superior quality. In other words, the *grosso* might well have anticipated the fate of the gold penny of Henry III, through undervaluation failing to reach its intended extent of circulation and facilitation of commerce. Stahl has estimated the mintage of this new coin, based on a careful census of dies used for Dandolo's *grossi*, at over 450,000 pieces;<sup>30</sup> if the coin was indeed introduced in 1196, this would have meant a somewhat meager output per year, though no mint records survive to indicate whether or not production increased

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<sup>28</sup> *Zecca*, p.359.

<sup>29</sup> *Ibid.* p. 37.

<sup>30</sup> "Grosso," p. 266.

with preparations for the Fourth Crusade. One scholar has called this mintage “anemic,”<sup>31</sup> but it is not necessarily so, given the coin’s subsequent success, one that eclipsed all other fine silver coins of the era.

To be specific, while the *grosso* was, apparently, established as worth twenty-four pennies (two shillings), the survival into modern times of only thirty-one of these coins almost certainly indicates that they were undervalued, and apparently melted down for their pure metal. Since one of the strategies available to counter undervaluation is an official re-calculation of the *grosso*, it is not surprising to find a *grosso* pegged at 26.11 pennies by mid-thirteenth century, rising to 28 in 1269 and 32 in 1282.<sup>32</sup> Stahl even proposes, credibly, that Venetian pennies were no longer issued by 1205, in order to forestall more extensive hoarding and melting of the more valuable coin. The half- and quarter-penny were continued for the purposes of small change, it being inconvenient and unlikely that 48 of the former and 96 of the latter would be collected in order simply to obtain a *grosso*. The quarter-penny, in fact, was for all intents and purposes a “token,” containing almost no silver, the first such in Europe since the Western Roman Empire.<sup>33</sup>

If the introduction of Dandolo’s *grosso* was indeed not immediately propitious, The modest mintage could be seen as a somewhat careful (and even cautious) hedge, as a counterbalance to the flagrant, and perhaps risky, appearance of the

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<sup>31</sup> Thomas F. Madden, *Enrico Dandolo and the Rise of Venice* (Baltimore : Johns Hopkins University Press, 2003), 110

<sup>32</sup> *Zecca*, 26.

<sup>33</sup> Stahl, “The Coinage,” 126.

remarkably pure coin. But for whatever reason, Venetian pride or the Fourth Crusade, Pietro Ziani continued the pure silver issue, at irrefutably greater numbers, as did subsequent doges, as indicated by the high quality of Gradonigo's *grossi* of many decades later. For the next hundred and more years, the *grosso* retained an immense trustworthiness and consequent popularity, with some 5,000,000 of them, for example, struck in 1319 alone;<sup>34</sup> in 1356, mintage of the *grosso* ceased, for a variety of reasons,<sup>35</sup> but in 1379 it was re-introduced by the Venetian Senate, at again a high quality of silver, set at 960/1000 fine (for an approximation of which, see the table, above), under Doge Andrea Contarini (1368-1382). And, though subject the usual vagaries of intervening fortune, the Venetian *grosso* survived impressively into the mid-fifteenth century.

### **Comparison Three: Crusader coinage and interactions with Arabic Issues**

This section is divided into three parts: in the first, two small, thin nearly identical Crusader denarii/deniers will be discussed as one pair; in the second, a Frankish Crusader coin will be compared to contemporary French issue; and the third part focuses on a Crusader imitation of an Islamic dirhem. The Crusader coins of the first part can be taken as fair representations of minor coinage in Christian holdings in the Eastern Mediterranean: the two were minted in Antioch, under either Bohemond III (1149-1201) or Bohemund IV (1201-1232), and dated between circa 1163 and circa 1220 (with a suspension between 1216-1219). In the second part, a denier from Achaea, of Philip of Taranto (1307-1313),

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<sup>34</sup> Stahl, *Zecca*, p. 405.

<sup>35</sup> *Ibid*, p. 65.

minted in the small town of Clarentza or Glarenza (now a site near Port Killini in the northeastern Peloponnesus), has been paired with a denarius from contemporary France, indicating a continuity in design. Importantly, these two parts function here to delineate the limits to x-ray fluorescence as an analytical tool. As implied above, such small silver coins were common in Europe and the Middle East, and they served a useful purpose in everyday exchanges.

The first pair, from Antioch, can be considered standard for the type:



Though it is difficult to make out, even in magnification, the figure at the center of the coins' obverse is a helmeted profile bust (hence the common name, "helmet" deniers), in chain mail, with a cross on the helmet, a crescent on the left of the figure, and a five-pointed star on the right. On the reverse, a crescent appears in the upper-right quadrant that has been demarked by the cross. In diameter they are both roughly 19 mm. The top coin, though it looks "black," has about the same surface silver composition as the lower, which demonstrates the weakness of judging by color alone. In David Metcalf's schema, these coins can be classified as Class "E," one of the more plentiful issues from the duchy.<sup>36</sup> As was mentioned above, it is with coins such as these that our x-ray analysis is most likely to provide inadequate readings. As Metcalf warns, "Metal analyses of billon coins are liable to give an exaggerated figure for silver contents because of the problems of 'surface enrichment'." Contrary, then, to the high percentages of the coins' silver in the table, given, below, Metcalf reports that the "intrinsic value of the 'helmet' coins, at about 0.2g of pure silver," or "about a quarter" of the weight (125).

The second pair of this first set, one from Frankish Greece, of Philip of Taranto (1307-1313),<sup>37</sup> and, for purposes of comparison, one French contemporary, possibly from Troyes, differ little from the above in appearance, though they have the more common cross on the obverse, and an abstract image on the reverse, in the case of the Greek coin, the common French rendition of a castle:

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<sup>36</sup> David Metcalf, *Coinage of the Crusades and the Latin East in the Ashmolean Museum Oxford*, 2<sup>nd</sup> ed. (London: Royal Numismatic Society, 1995), pp. 125-132.

<sup>37</sup> For a full description, see *ibid*, p. 265.



As was mentioned above, this general series of Crusader pieces is often denigrated as “billon,” though to someone using the coin, especially when it had been freshly minted, it would seem to have a silver content closely approaching, and in this case actually exceeding, a fineness of 900/1000. In contrast, the French coin, since it is obviously plated, and shows considerable deterioration, provides a more accurate reading for its composition, though this in turn may be usually high, and probably exaggerated, because the underlying copper is so much in evidence. In other words, no matter how little silver “surface enrichment” remains, it still must be more than a bit greater than .01%.



Identification of the coin (all 600 seconds)	% Copper	% Silver	% Gold	Weight
Antioch, Bohemund IV (top)	10.36	89.6	< 0.01	.899
Antioch, Bohemund IV (bottom)	8.21	91.8	0.01	.949
Achaea, Clarentza, Philip of Taranto	11.75	88.3	< 0.01	.806
France, Troyes? "Count Henry"	99.91	< 0.01	0.09	

To repeat, even though debased, the Crusader pieces, as *A History of the Crusades* remarks, filled an important gap in the Middle East, between the variety of gold available, in the one hand, and the copper used for very minor purchases on the other.<sup>38</sup>

The third set of coins represents something of a puzzle. It concerns a dirhem from the Artuqid emirate, centered on the city of Mardin in modern southeastern Turkey. In the time relevant to this study, approximately 1186-1259, it was under the suzerainty of the Ayyubid dynasty to the south, but for the most part, its coinage followed an independent course, closely imitating in many of its issues

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<sup>38</sup> J. Poteous, "Crusader Coinage with Greek or Latin Inscriptions," in *A History of the Crusades*, gen.ed. K.M. Sutton (Madison: Univ. of Wisconsin Press: 1989), Vol. 6, Pp. 369-377.

Byzantine, Roman, and even Greek coins of a thousand years earlier. However, under the rule of Nasir al-Din Artuq Arslan bin Il-Ghazi (597-637 AH, 1201-1239 CE), the coin types began to imitate distinctly Ayyubid styles, specifically that of Aleppo coinage, from 634 AH that of al-Nasir al-Din Yusuf II ibn Al-'Aziz Muhammad (Prince of Aleppo, 634-658 AH, 1236-1259 CE; Sultan in Damascus, 648-658 AH, 1250-1259 CE).<sup>39</sup> The succeeding emir, Najm al-Din Ghazi I, al-Sa'id, bin Artuq Arslan (637-658 AH, 1239-1260 CE), followed his predecessor, and for the Artuqids, the new type continues for the next sixty years or so, and then disappears. Here is the analyzed al-Din Ghazi's Artuqid piece:



Wear and off-center striking make such coins difficult to decipher. Fortunately, however, there is a useful web site, generated by a Mr. Anadolu Sikkeleri (<http://mehmeteti.150m.com/index.htm>), that depicts a close relative of this coin, and I have reproduced this information on the page following.

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<sup>39</sup> Paul Balog, *The Coinage of the Ayyubids* (London: Royal Numismatic Society, 1980), pp. 225-229, plate XXXV.



Artuqids, Najm al-Din Ghazi I, al-Sa'id, silver dirham

Mint	Date	Diameter	Weight	ID
Mardin	643 AH	21 mm	2.79 gm	UE-1466
<b>Obverse</b>	"El-imam el-Musta'sum billah emir'ül müminin. La ilahe illallah Muhammed resulullah"			
	<p>نننموملارنما تقلاب مصعتملا ماملا مللالوسر دمحم مللالاملالا</p>			
<b>Reverse</b>	"El Melik el-Salih Eyub el-Melik es-Said Gazi. Duribe bi-Mardin sene 643"			
	<p>ىذاغديسلالكلملا بوبوا حلاصلا اكلملا تنامتسو نيعبر او ثلث تفس نيدر امد ببر ضد</p>			

This description matches the two center inscriptions of the analyzed dirhem, though the marginal arrangements are slightly different, and the date may be, from the partial inscription, only somewhere in the 640's. The issue is historically important, because it records on the obverse the name of the very last Caliph (here "Imam"), al-Musta'sim-billah (640-656 AH, 1242-1258 CE), executed by the Mongols, as well as on the reverse that of the last Ayyubid king ("Melik"), al-Salih Ayyub (636, 643-647 AH; 1240, 1245-1249 CE), overthrown by the Mamluks. The dirhem also, and more importantly, brings us to a curious situation, involving Crusader counterfeiting of Arabic coins, which had been occurring from the time of the First Crusade.<sup>40</sup> The Crusader copies, duplicate down to the Islamic legend (which, in the spring of 1250, Pope Innocent IV forbade), were widely traded; and, though typically they contained less silver, if only slightly, they are nonetheless in recovered hoards not distinguished from the authentic dirhems with better silver, an example perhaps in which convenience and calculated risk trump Oresme's dicta.

When the Crusader-era coin, below, was purchased in 1976, via an ad in a coin publication, it was advertised as a Crusader imitation, and indeed analysis shows it to have a number of features, the lower weight, the lower silver composition, the blurred Arabic, as would fit the pattern. But it is not an imitation of the commonly exchanged Ayyubid dirhem, but rather one of the Artuqid coin described above:

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<sup>40</sup> See Paul Balog and Jaques Yvon, "Monnaies a legends arabes de l'orient latin," *Revue numismatique* 6(I) (Paris:1958), 133-168.



The legend is almost identical to that of the imitated coin, with a slight error, indicated by the arrow, of a blundered alef. Here are the results of analysis:

Identification of the coin (all 600 seconds)	% Copper	% Silver	% Gold	Weight
Artuqid Dirhem	7.78	92.0	0.27	2.895
Crusader copy of Artuqid Dirhem	19.29	80.5	0.20	2.745

The much higher percentage of copper in the Crusader coin is apparent in its slightly yellow cast, but again it is extremely likely that the coin would have, if its wear is any indication, been broadly accepted. M.L. Bates and D.M. Metcalf report that Artuqid dirhems seem to have “circulated indiscriminately together” with those of the Ayyubids,; and they continue, stating, “Since any dirham with one of the few Aiyubid designs seems to be accepted at parity, it was rational for the crusaders also to issue their version of this standard coinage.”<sup>41</sup> A Crusader imitation of an Artuqid coin, then, is not surprising. Bates and Metcalf, in outlining the fortunes of Crusader imitations, do not mention Artuqid copies

<sup>41</sup> “Crusader Coinage with Arabic Inscriptions,” in *A History of the Crusades*, Vol. 6, p. 458.

again, but if they parallel those of the Ayyubid issues, then the fineness of the first imitated Islamic dirhems (from 613-630 AH, 1216-1233 CE) measures from 96.5%-84.9%, while the Crusader copies of them range from 94.2%-79.6%; by 650 AH (1252/3 CE), however, dirhems from the last remaining Ayyubid territory, the Principality of Aleppo, fell to 83.2%-74.4% fine. If our Artuqid dirhem is indeed of the 640's, its 92% fineness fits well within the range of its Ayyubid counterparts, and the Crusader copy under study would fall at the lower end of that spectrum.

There is one interesting feature to the Crusader copy that might figure in dating the coin; even before Pope Innocent IV's prohibition against retaining Muslim inscriptions on Christian coins in 1250, Crusader engravers may have disliked such absolutely literal imitations, and seem to have subtly changed the name of Mohammed in the pious formula to Michael ("Mikha'il"), so that, perhaps, the Archangel becomes "the messenger of God."<sup>42</sup> Though the inscription is indistinct, the word does appear in the 7:00 legend to contain a kaf, and so this coin may be part of a larger series of imitated Ayyubid dirhems of that sort, dated to 643 (1246). It may represent, then, a curiosity with a fascinating history.

#### **Comparison Four: English Sterling**

Unlike many other polities, the English traditionally held to the silver standard that had been established by Henry II (1154-1189) in 1180, that is, sterling at 92.5% silver. The English had begun minting pennies, and with a few exceptions

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<sup>42</sup> Ibid., 467-468.

(as, for example, Henry III's ill-fated gold penny mentioned above) this was the only denomination issued between the late eighth century, when it was introduced in Kent, Mercia and at Canterbury under the influence of the Frankish denarius, until the fractional silver of Edward I (1227-1307) and the gold coinage of Edward III (1327-1377). However, in the reign of Henry I (1100-1135), and particularly in the time of civil war and chaos under Stephen (1135-1154), the penny had become suspect, partly due to widespread plating, partly because of unofficial "irregular" coins, issued by the nobility, but most as a result of clipping. The accession of Henry II brought a measure of stability that allowed the establishment of a standard that was to continue, again with occasional exceptions, until 1920. This penny is classified as "short cross" coinage because the reverse depicts a cross running only to the inner boundary of the legend. By the time of Richard's nephew, Henry III (1216-72), the practice of clipping had become widespread on these pennies, necessitating a redesign, so that the cross would discourage such practice by continuing to the edges, thus creating the "long cross" series that continued from 1247 through the next two hundred years and more.<sup>43</sup> The "short cross" issue, because of its reliability, was immensely successful, as indicated by a reference to sterling that occurs in Venetian records in 1202.<sup>44</sup> Needless to say, there were soon imitations of English sterling appearing all over Northern Europe, and extensively in Flanders.

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<sup>43</sup> Challis, *A New History*, 107-114. For the following, see pp. 108-109.

<sup>44</sup> Stahl, "The Coinage," p. 128 and note 30.

The first penny in this series to be analyzed through x-ray fluorescence is that of Richard the Lionhearted (1189-1199), which, either out of respect for or fear of his father, the dead king Henry II, retained his legend and every other appearance pertaining to the original penny, including its characteristic short cross<sup>45</sup>:



The readings, below, for Richard's penny may seem to represent an aberration, at 96.5% silver, since Richard is reputed to have retained the sterling standard re-introduced by his father, at 92.5%. In fact, a claim was made in 1247 that the short cross pennies of Henry II, Richard I, John, and the early pennies of Henry III were in reality substandard; assays of the "short cross" coins, it was alleged, showed a purity of 95.833%, not 97.5%, as had been contended (in the specifications of the time, an actual ten pennyweights [dwt] of copper per troy pound of silver, as opposed to the alleged six).<sup>46</sup> According to Challis, recent analyses show that any difference between the older and newer coins can be accounted for by wear, and the results of these tests consistently register sterling,

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<sup>45</sup> J.J. North, *English Hammered Coinage*, I, 164. Sutherland, *English Coinage*, pp. 60-61.

<sup>46</sup> A pennyweight=.776 grams. 240 pennyweights make a troy pound of twelve ounces. If it helps, 12 grains make a pennyweight.

that is, 18 dwt or 92.5% silver in fineness. The implication is that Henry III was opting for the profitable provision—one might say, “ruse” —of “recoinage,” which has its own long history, in that old coins were to be brought in to a mint, weighed, and exchanged for their silver equivalent in new ones, for a fee; after a certain date, the old pieces would no longer be considered legal tender. Our x-ray tests show indeed that there is very little change in the ratio of silver in both the short and long cross pennies, belying Henry III’s accusation, and that the difference in weight can well be explained by detectable wear on the former; nevertheless our readings do, perhaps provocatively, indicate a high proportion of silver in the short cross issues, one that approaches the original presumption of 6 dwt fine.

The case of the last coin to be tested, that of Henry VI (1422-1461, 1470-1471), also shows an usually high silver content, but in this case the Chi-square reading for silver was an unacceptable 5.2 (any calculation over 5 is taken as suspect); a more important indication of the progress of the sterling penny, and English coinage in general, is the significantly reduced weight of the coin. This had begun during the reign of Henry IV (1399-1413), who, faced with shortages of bullion, in 1412 reduced the weight of a penny from the established (since 1351) 1.5 dwt (18 grains, or 1.164 grams), down to 1.25 dwt (15 grains, or .970 grams).<sup>47</sup>

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<sup>47</sup> Challis, *A New History*, p. 172.

Identification of the coin (all 600 seconds)	% Copper	% Silver	% Gold	Weight
England Penny Richard I	3.53	96.5	< 0.01	1.3717
England Penny Henry III	3.23	96.8	< 0.01	1.42
England Penny Henry VI	1.82	97.7	0.52	.89199

The English resisted a token coinage for far longer than the rest of Europe, still minting almost sequin-like pennies through the reign of George III; after that, for all practical purposes the silver coin ceases existence as currency.<sup>48</sup>

### Conclusion

The use of a non-destructive x-ray fluorescent analysis on this range of medieval coins has for the most part confirmed earlier studies in the field of numismatics, the most notable being a validation of the fine silver *grossi* of Enrico Dandolo and his successors in Venice in late twelfth-, thirteenth- and fourteenth-centuries. While the analytical approach that we utilized is far from definitive, it neatly complements other methods, dependent not only on physical and chemical investigations, but also on traditional sources, documentary evidence where it exists, archeological discoveries, which are ongoing, and the application of informed and plausible speculation.

In the future, there will be continued scholarly activity concerning the metallic content of coins, leading to further insight. For example, of profound interest is the matter of locating the origin of the metals to be struck, since that work will

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<sup>48</sup> Sutherland, *English Coinage*, p. 181.

illuminate such critical issues as trade routes and consequent economic development. The work of Anne-Marie Desaulty and Francis Albarede at the Ecole Normale Supérieure in Lyon has shown that English coins, beginning with the reign of Mary in 1553, evinced a shift to minting with new-world silver, away from the silver that had been mined in central Europe, the tradition; this trend might be thought natural enough considering Mary's marriage to Philip II, but it is one that continued surprisingly well into the reigns of later English monarchs.<sup>49</sup> Alan Stahl has reported similar analytical efforts occurring the world over. Interestingly, the Desaulty project measured not silver as a marker, but trace elements of lead isotopes, which in this case was much more indicative of provenance.

In a similar fashion, the BACH project will in the future concentrate on trace elements, in quantities so miniscule as to have been impossible to measure before. As Professor Cahill writes,

In addition to the major elements seen in the coins, the S-XRF analysis sees essentially all elements from about silicon to uranium. These are all in only trace amounts, but offer the opportunity of identify the source of the silver ores.

As an example, while most of the trace elements in the Dandolo and Contarini are similar, within a factor of 2, there are differences. The Dandolo, for example, is much richer in selenium, tin, antimony, tellurium, and mercury than the Contarini, while the latter is much richer in cobalt, nickel, and indium. In future work, we propose to exploit these differences as a way to identify both primary ore sources and metallurgical processing.<sup>50</sup>

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<sup>49</sup> Anne-Marie Desaulty and Francis Albarede (corresponding), "Copper, lead, and silver isotopes solve a major economic conundrum of Tudor and early Stuart Europe," *Laboratoire de Géologie de Lyon, Ecole Normale Supérieure, Université de Lyon 1, and CNRS, 69007 Lyon, France; and Dept. of Earth Science, Rice University, Houston, Texas 77030, USA. Geology*, November 6, 2012, posted online 6 November 2012; doi: 10.1130/G33555.1.

<sup>50</sup> Email correspondence, March 5, 2013.

These differences, when further analyzed and compared with coins from the traditional sources of medieval silver throughout the Middle Ages, will enable us to fix more exactly what connections existed, and what might be drawn from that evidence.

### **Appendix 1: Coins Analyzed**

DX1 a Venice Grosso Enrico Dandolo (1192-1205) 1196-1204  
Obv: Enrico Dandolo, receiving standard from Saint Mark:  
HDANDOLDVXSMVENETI  
Rev: Christ enthroned: IC XC

DX1 b Venice Grosso Pietro Zani (1205-1229) 1205-1229  
Obv: Pietro Zani, receiving standard from Saint Mark: PIANIDVXSMVENETI  
Rev: Christ enthroned: IC XC

DX1 c Venice Grosso Pietro Gradonigo (1289-1311) 1289-1311  
Obv: Pietro Gradonigo, receiving standard from Saint Mark:  
PEGRADONIGODVXSMVENETI  
Rev: Christ enthroned: IC XC

DX1 d Venice. Grosso, reintroduced 1379. Andrea Contarini (1368-1382) 1379-1382  
Obv: Andrea Contarini, receiving standard from Saint Mark:  
ANDR[CON]TARENOSMVENETI  
Rev: Christ enthroned: IC XC

DX1 e Serbia. Groš. Stefan Uroš I (1243-1276) after 1243-1276  
Obv: Tsar Stefan, receiving standard from Saint Stephen  
Rev: Christ enthroned: IC XC

DX1 f Bulgaria. Grosh. Ivan Alexander and Michael Aser (1331-1355) 1331-1355  
Obv: Tsar Ivan in armor and Michael Aser  
Rev: Christ enthroned

DX2 g Byzantine. Solidus. Justin II (565-578) 565-578  
Obv: Justin II: DNIVSTINVSPPAVG  
Rev: Victory enthroned: VICTORIAAVGGCS/CONOB

DX2 h Abbasid. Dinar. Timed al-Mansur (754-775) 754-775

Obv: Scarcely legible: Timed al-Mansur  
Rev: Not legible. No mint

DX2 i Crusader. Denier. Antioch. Bohemond III (1149-1201) or Bohemund IV (1201-1232), c. 1163 and c. 1220  
Obv: Cross: ANTIOCHIA  
Rev: Duke in armor: BOANVNDVS

DX2 j Crusader. Denier. Antioch. Bohemond III (1149-1201) or Bohemund IV (1201-1232), c. 1163 and c. 1220  
Obv: Cross: ANTIOCHIA  
Rev: Duke in armor: BOHEMVNDVS

DX2 k France Denier Possibly Troyes "Count Henry" (12<sup>th</sup> century?)  
Obv: Cross: HENRICICOMIS  
Rev: Cross: Little legible: TR?

DX2 l Crusader Denier. Achaea. Glarentza Philip of Taranto (1307-1313) 1307-1317  
Obv: Cross: PhSPACHTARDR  
Rev: Cross: DECLARENCIA (Clarentia= Glarentza, Peloponnesus)

DX3 m Artuqid. Dirhem. Mardin Najm al-Din Ghazi I al-Sa'id (637-658 AH, 1239-1260 CE)  
Obv: Star: El-imam el-Musta'sim  
Rev: Star: El Melik el-Salih Eyub el-Said Gazi

DX3 n Crusader. Dirhem. Copy of DX3 m Artuqid Dirhem Mardin Najm al-Din Ghazi I al-Sa'id  
Obv: Star: El-imam el-Musta'sim  
Rev: Star: El Melik el-Salih Eyub el-Said Gazi

DX3 o Champagne. Denier. Count Henry I (1152-1189) or Henry II (1180-1197) 1152-1197  
Obv: Cross: HENRICOMES  
Rev: Arms: CASTRIPROVINS ("The Castle / City of Provence)

DX3 p England Penny Richard I (1189-1199) 1189-1199  
Obv: King: HENRICUSREX  
Rev: Cross: CANTVIARD (Canterbury, Viard the Minter)

DX3 q England Penny Henry III (1216-1272) 1247-1272  
Obv: King: HENRICUSREXIII  
Rev: Cross: CANTERIOHANES (Canterbury, John the Minter)

DX3 r England Penny Henry VI (1422-61; 1470-1471) 1423-1427  
Obv: King: HENRICUSREXANGLIE  
Rev: Cross: CALIS (Calais)

## Appendix 2: The BACH Collaborative Team

This project was carried out with the cooperation of the DELTA Group, headed by Thomas Cahill, at the University of California, Davis, whose primary mission is the analysis of aerosols in the environment. Through the late 1980's and beyond Professor Cahill was prominent in proton bombardment of humanities materials at the Crocker Nuclear Laboratory under the auspices of CHAPs (Crocker Historical and Archaeological Projects); this became one of the most successful Humanities-Technology cooperative projects in the UC System, and quite possibly in the nation. Thanks to the volunteer work of Professors Cahill and Richard Schwab (History), major breakthroughs were made in the understanding of the processes by which Diderot's *Encyclopedia* was published, by which Gutenberg produced his Bibles, by which the Dead Sea Scrolls actually changed provenance, by which marbles used in Greek statuary could be identified, and, most controversially, by which the authenticity of Yale's Vinland Map could be imagined. In identifying the secret formula for Gutenberg's ink alone, in detecting high concentrations of cadmium and lead, they established a foolproof method for detecting forgeries. Based on a comparison of ink (which was mixed fresh each morning, they have proposed that Gutenberg had six presses in operation simultaneously. The current incarnation of CHAPs has been rechristened BACH, Beam Analysis of Culture in the Humanities.

## Appendix 3: Description of x-ray Fluorescence

By Sean Barberie and Thomas Cahill, of the DELTA (Detection and Evaluation of Long-range Transport of Aerosols) Group, UCD

The ability to find out what rare and exotic materials may have been used to craft historical artifacts without damaging the object is a major benefit to investigations of the artifact. The specific technique utilized in this study was x-ray fluorescence spectrometry (XRF), a process by which elements from sodium up through the Periodic Table to uranium can be detected in however a minute a quantity. Basically, the analysis depends on the fact that different elements in an alloy emit x-rays of different wave-lengths when the surface is excited by x-rays, gamma-rays, or particles. To identify those elements, and thus "fingerprint" the object, a beam of high-energy photons from a synchrotron light source, in this case the Stanford Synchrotron Radiation Lightsource (SSRL) at SLAC (Stanford Linear Accelerator Center), is trained on a clean part of the artifact's surface, and electrons were expelled from the inner shells of the struck atoms, causing a cascade to occur. The electrons then relax, emitting x-rays unique for each element. Since these x-rays are characteristic of the type of atom from which they were emitted, they are known as *characteristic x-rays*. Sensitive equipment detects these characteristic x-rays and by their energies identifies the elements of origin. The resultant spectrograph of the reflected beam is then compared with samples of known composition. This method produces both qualitative and quantitative results, in that it detects trace as well as major components. When well calibrated, it is accurate and precise. Since it measures surfaces, its results

are somewhat aided by cleaning, polishing, or air-blasting, but otherwise it is entirely non-destructive.

#### Appendix 4: Example of Raw Data for Dandolo Grosso

WinAxil 4.0.1 Spectrum Evaluation Short Report: 5/6/2012 8:57:15 PM

DX1.a.Venice.Grosso.Dandolo

Spectrum: C:\Program Files\SIINT USA\PiSpec-nt\DX1a900.wax

Sample: Fitting region: 1 - 1769(ch) 0.01 - 36.28(keV)

Continuum: Smooth Filter using 24 iterations

Chi-square: 204.086 2 iterations Last change: 0.091

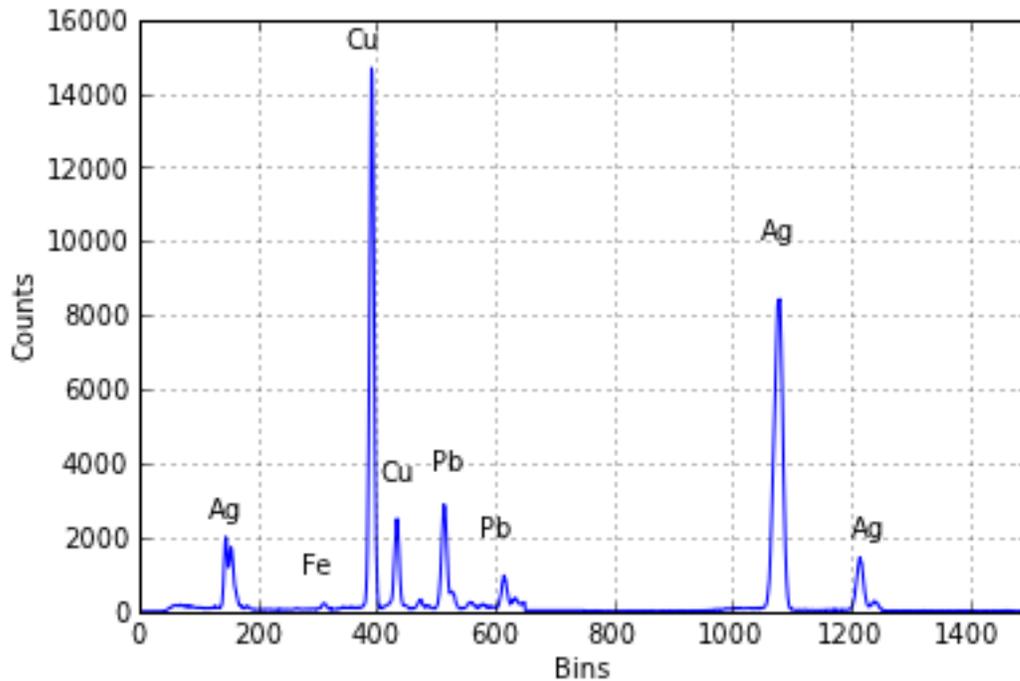
El Line*	E(keV)	Area $\pm$ StdDev**	Chi- Square***
Si Ka	1.74	898 $\pm$ 38	19.7
P Ka	2.013	512 $\pm$ 35	7.6
S Ka	2.307	313 $\pm$ 35	3.5
Cl Ka	2.622	632 $\pm$ 41	1.7
K Ka	3.313	5480 $\pm$ 81	373.5
Ca Ka	3.691	314 $\pm$ 41	19.9
Ti Ka	4.509	93 $\pm$ 32	0.4
V Ka	4.95	41 $\pm$ 32	0.9
Cr Ka	5.412	214 $\pm$ 36	0.7
Mn Ka	5.895	56 $\pm$ 36	0.7
Fe Ka	6.399	1391 $\pm$ 53	0.7
Co Ka	6.925	184 $\pm$ 41	1.8
Ni Ka	7.472	378 $\pm$ 45	7.8
Cu Ka	8.041	134681 $\pm$ 351	39
Zn Ka	8.631	1331 $\pm$ 61	6.8
Ga Ka	9.243	-28 $\pm$ 55	3.1
Ge Ka	9.875	217 $\pm$ 74	5.7
As Ka	10.532	11398 $\pm$ 200	45.8
Se Ka	11.208	-233 $\pm$ 58	1.4
Br Ka	11.908	-41 $\pm$ 78	72.8
Pd Ka	21.123	455 $\pm$ 55	2.7
Ag Ka	22.103	143229 $\pm$ 360	10.1
Cd Ka	23.108	85 $\pm$ 40	0.9
In Ka	24.137	117 $\pm$ 42	2.3
Sn Ka	25.191	-136 $\pm$ 75	29
Sb Ka	26.272	132 $\pm$ 31	1.4
Pt La	9.434	-172 $\pm$ 53	0.6
Au La	9.707	1934 $\pm$ 64	1.8
Hg La	9.98	413 $\pm$ 69	1.9
Pb La	10.542	14958 $\pm$ 139	20.1
Bi La	10.828	3565 $\pm$ 71	17.9

\*Ka/La refers to electron shell excited

\*\*The most meaningful measurement, a count of x-rays in each peak, but not to be taken in direct comparison with other readings

\*\*\*A Chi-square of less than 5 is acceptable

**S-XRF spectrum of the Dandolo grosso: The Right-Hand Peak has been Reduced by Approximately a Factor of 50**



To the right of this spectrum, the scale has been reduced by almost a factor of 50 to keep the silver (Ag) peak in perspective. There are numerous other elements near the copper (Cu) and lead (Pb) peaks that are too small to see here.